THE MOSQUITOES OF NORTH AND CENTRAL AMERICA AND THE WEST INDIES

BY

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VOLUME ONE

A GENERAL CONSIDERATION OF MOSQUITOES, THEIR HABITS, AND THEIR RELATIONS TO THE HUMAN SPECIES

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INTRODUCTION.

The discovery that mosquitoes are agents in the transmission of certain diseases, and especially the discovery by Sir Ronald Ross, in 1898, that mosquitoes are the agents in the transmission of malaria, aroused a widespread interest in these insects. Hitherto the Culicidæ had been treated by entomologists with the other flies, and, being regarded as unimportant members of the order Diptera, were not especially studied and only such species as happened to find their way into entomological collections were described by systematists.

In the year 1902, when the Carnegie Institution of Washington began its important work in aid of scientific research, the systematic and biological knowledge of American mosquitoes was slight. A bulletin published by the U. S. Department of Agriculture in 1900 embodies our knowledge of the North American mosquitoes at that time. Twenty-three species were distinguished in this bulletin, while a number of the descriptions by early writers remained unrecognized. For the first time, the full life-histories of two widely different species were given. In the same year Major George M. Giles, formerly naturalist of the Indian Marine Survey, published in London the first edition of his "Handbook of the Gnats or Mosquitoes," which was the first attempt to bring together and coördinate the knowledge of the mosquitoes of the world. This work includes 48 species from North America and, although many of these were unknown to the author, the original descriptions were made available for students.

In 1901 the British Museum of Natural History published the first two volumes of "A Monograph of the Culicidæ of the World," by F. V. Theobald. In this work, 69 species were treated as North American and West Indian, but a number of these had not been studied by the author. At about the same time a volume entitled "Mosquitoes; How they Live; How they Carry Disease; How they are Classified; How they may be Destroyed," by L. O. Howard, was published. In this book 25 species were recognized and classified in synoptic tables by D. W. Coquillett. Considerable space was given to discussions of the habits of mosquitoes, their function in the carriage of disease and to the subject of remedies.

While considerable knowledge had accumulated about the habits of mosquitoes in general, it became evident that the different species diverged widely in habits and detailed information on these points was needed. It is necessary to distinguish carefully in this respect. Only those species that are harmful to man, either as agents in the carriage of disease or as annoying by their bites, need to be considered in economic work. Much useless labor and expense can be avoided by an accurate knowledge of the habits of the species. For instance, Boyce (Mosquito or Man?, p. 96, 1909) refers to the mosquitoes living in crabholes as "the chief nuisance in those houses which are situated near the sea," and figures a tent for capturing these mosquitoes. Our observations prove that the crab-hole mosquitoes do not bite nor annoy man, and no consideration need therefore be given to their destruction. Again, the commonest mosquito during the summer months in the Northern States is undoubtedly *Culex territans*, which is the only species breeding abundantly in a certain class of fresh-water marshes and pools at that season. We now know that this species does not annoy man (in spite of its name), and are enabled to state that such fresh-water marshes and ponds are not breeding-places of noxious mosquitoes.

Therefore, realizing the imperfect character of our knowledge and especially the very great need of a competent monograph of the species of Culicidæ of North and Central America and the West Indies, both from the biological and the sanitary points of view, application was made, in April, 1902, to the Carnegie Institution of Washington, for a grant which should enable the preparation of a monograph to include all possible information concerning all mosquitoes of the geographical regions just mentioned.

The grant requested was made by the Trustees of the Institution in January, 1903, and organization work was at once begun. It was at first expected that the monograph could be completed in three years, and the grants made hy the Institution covered that period. At the expiration of the third year, however, it was found that the material was by no means complete. Too much reliance had been placed upon the promises of volunteer observers, and important regions were, for this reason, not properly covered. The workers engaged in the preparation of the monograph were not content to publish the material accumulated, since it was their earnest desire to make the work as complete as possible and as valuable as possible to biologists and to sanitarians. The investigations were, therefore, continued during 1906, 1907, and 1908, partly by the help of funds appropriated to the U. S. Department of Agriculture by Congress for the investigation of insects affecting the health of man and animals, partly by the assistance of the Isthmian Canal Commission, partly hy the help of volunteer observers in the West Indies and Central America, and partly at the expense of two of the authors (Dr. Dyar and Mr. Knab). While it is realized that the present work is incomplete, the additions gained by the work of the last few years has surely more than doubled its value.

In planning the work in the early months of 1903, it was decided to secure local observers advantageously situated in the different faunal areas of the United States, and to compensate them for observations during the summer months, in the course of which each should make as complete a collection as possible of the mosquitoes of the region in which he was located, should rear each species in all its different stages, and should submit all specimens and complete notes, with sketches, at the completion of the season. During the first year there were employed for this purpose Miss Isabel McCracken, of Stanford University, a graduate student and assistant of Prof. V. L. Kellogg; Mr. Frederick Knab, of Chicopee, Massachusetts (one of the present authors); Mr. O. A. Johannsen, of Cornell University, Ithaca, New York; Mrs. E. G. Hinds, at Victoria, Texas; Mr. John R. Taylor, of Las Animas Hospital, Havana, Cuba; Dr. H. G. Dyar, of the U. S. National Museum (one of the present authors), at Kaslo, British Columbia; Mr. T. H. Coffin, of the Johns Hopkins Medical School, in the Bahama Islands; and Mr. Kenneth Taylor, at Minneapolis, Minnesota.

In addition to these observers, the following individuals made volunteer collections and observations which were transmitted to Washington: Mr. G. G. Coghill, of Pacific University, Forest Grove, Oregon; Major William M. Black, U. S. Army, Panama; Mr. H. C. Weeks, Bayside, Long Island, New York; Dr. J. B. Smith, State Entomologist of New Jersey, New Brunswick; New Jersey; Dr. Alfredo Dugès, of Guanajuato, Mexico; Dr. J. W. Dupree and Prof. H. A. Morgan, of Baton Rouge, Louisiana; Dr. José H. Pazos, of San Antonio de los Baños, Cuba; Dr. W. E. Britton, State Entomologist, New Haven, Connecticut.

The material brought together during 1903 was very encouraging, and many of the reports of the paid observers were full and contained many new contributions to the knowledge of the early stages of mosquitoes.

With the opening of the season 1904 it was thought best to limit the number of paid observers working in the manner described above, and only two were so employed, namely, Mrs. Maurice F. Ricker, of Big Fork, Montana, the wife of Professor Ricker, the head of the summer biological station at that point, and Mrs. Hinds, of Victoria, Texas. Dr. A. Siegrist, of Puerto Angel, Pochutla, Oaxaca, Mexico, was also tentatively engaged. The sanitary officials of the Panama Canal Commission promised assistance, and two of them were promised compensation for expenses incurred in collections and observations. The results from Panama and from Puerto Angel were, however, *nil*.

The extreme importance of a most thorough knowledge of everything connected with the yellow-fever mosquito (*Aëdes calopus*) induced the grantee of the research fund during the spring and summer of 1904 to make an especial effort to determine its geographical distribution, and to learn as much as possible about its habits. In the course of another investigation he went to south Mexico in the spring, going as far south as Oaxaca, and studied the effect of altitude upon the distribution of the species from the seaboard at Vera Cruz up to Orizaba. The Mexican sanitary authorities were consulted, and his efforts were very intelligently seconded through the great courtesy especially of Dr. Eduardo Liceaga, the president of the Superior Board of Health of the Republic of Mexico.

Beginning with the middle of June, Mr. Herbert Barber, of Washington, was sent upon a trip to determine, if possible, the line of northward distribution of the yellow-fever mosquito in the United States. He began at Brownsville, Texas, and followed approximately the line of distinction between the upper and lower austral life zones as laid down by Merriam. He proceeded gradually as far as Louisville, Kentucky, where the work was taken up September 1 by Mr. T. H. Coffin, who followed it through to the Atlantic seaboard.

By the operations just described the main portion of the mosquito fauna of the principal inhabited regions of the United States was rather fully worked up, and during 1905 an especial effort was made to secure material representing the mosquito fauna of southern Mexico, Central America, the West Indies, and Alaska. The Canal Zone was again left to volunteer observers. One of the authors, Mr. Knab, left Washington the end of May, visited Key West and Havana, then Vera Cruz, Córdoba, Orizaba, Santa Lucrecia, Rincon Antonio, Almoloya, Tehuantepec, Salina Cruz, and Acapulco in Mexico; Acajutla, San

Salvador, Sonsonate, and Izalco in the Republic of Salvador; Champerico and San José in Guatemala; Puntarenas, Santo Domingo, San José and Port Limon in Costa Rica; and Corinto, Nicaragua. Mr. Knab collected a large amount of valuable material, and one important result of this work was to show that the yellow-fever mosquito occurs at every point visited on the Pacific coast. While it could be assumed that this would be the case, there had, up to that time, been no authentic record of the fact.

At the same time that Mr. Knab started for Central America, Mr. August Busck, of the Department of Agriculture, was sent to the West Indies, sailing from New York on June 1. He visited Grenada, Trinidad, Tobago Island, St. Vincent, Barbados, Martinique, Dominica, Guadeloupe, St. Thomas, Santo Domingo (Santo Domingo City, San Francisco Mountains and Samara Bay), returning to Washington early in October, having collected and bred a very extensive series of mosquitoes and having aroused the interest of a number of local observers, who subsequently were of much assistance in the investigation.

Early in the summer Mr. A. N. Caudell was sent to Florida to work out the life history of a species not yet fully known, and in the spring Dr. Dyar and Mr. Knab went to western New England to study carefully the as yet little understood spring and early summer mosquitoes of that region. During midsummer Dr. Dyar visited the Adirondacks to work out some hitherto unknown points in the life histories of certain species inhabiting that region.

Early in June, while engaged upon another investigation, the grantee visited the Natural History Museum in Vienna to study the mosquito types of Wiedemann, in the Wiedemann and Winthem collections. He took with him from the United States determined material of several species about which there existed some doubt as to their identity with the Wiedemann types, and cleared up several points of systematic importance. Returning to this country in the early autumn he was able to give many points of value in quarantine measures to the Public Health and Marine-Hospital Service, and in late October visited New Orleans and observed the operations of the closing days of the campaign against the yellow fever, which proved so successful, making notes on the methods used against the yellow-fever mosquito and taking photographs.

During 1906 Dr. Dyar made extensive observations upon the Pacific coast of the United States, stopping first at Bright Angel Camp in Arizona, and then proceeding gradually from San Diego northward through California, Oregon, and Washington into British Columbia, stopping a sufficient length of time at favorable localities to make the requisite observations and rearings. The trip was begun in April and the final observations were made August 26.

Considerable additional material was received from volunteer assistants during the year, and especially from Mr. F. W. Urich, of Trinidad, British West Indies. The main portion of the year was devoted to preparation of descriptions and illustrations and general work on the monograph. The intended expedition for the study of the mosquitoes of Alaska was, however, not made.

In 1907 the paucity of material from the Panama Canal Zone was very obvious as contrasted with the abundant material from other regions, and, although liberal promises had been made by persons stationed in the Zone, practically no material had been received during the four years already spent upon the monograph. An arrangement, therefore, was made with the Isthmian Canal Commission by which the expenses of a trained observer were met by the Commission during a period covering the end of the dry season and practically all of the rainy season, the time occupied in a visit to the Zone and a careful study of its mosquito fauna. Mr. August Busck was selected for the purpose. He left New York April 12, arrived at Colon April 19, and from April 19 to July 30 worked the Zone from Panama to Colon, though mainly the region around Tabernilla, and also made two trips into Panama, on the Upper Chagres River, from May 18 to 28, and to Taboga Island, from June 30 to July 7. The amount of information gained by this expedition was extraordinary. Previously only 7 species of mosquitoes were known from the Canal Zone, but Mr. Busck returned with more than 90 species, of which 30 were new to science. His visit also interested certain persons, resident there, in the more careful study and rearing of mosquitoes, and a great deal of additional valuable material has been received since his return, especially from Mr. A. H. Jennings of the Sanitary Department. The expedition resulted in benefit to the Sanitary Department of the Isthmian Canal Commission, since Mr. Busck was able to give some important points on the habits of certain species concerned in the transmission of disease. At the same time he learned much concerning the practical work carried on under the Sanitary Department and returned filled with admiration for the enlightened efforts which had accomplished such admirable results in the practical elimination of the disease-carrying mosquitoes from the Zone.

Mr. Knab undertook an expedition to Saskatchewan to work out the life histories of the mosquitoes of the northern prairies, until then unknown. He left Washington early in April and returned the latter part of June. Dr. Dyar later visited a new locality in Maine.

The work during 1908 was mainly devoted to the continuance of the preparation of the monograph. Dr. Dyar did some field work in Maine and New Hampshire in midsummer. Mr. Knab in the winter of 1907–1908 visited Mexico, remaining during the early months of 1908 in the vicinity of Vera Cruz, Córdoba, Orizaba and Omealca, engaged partly upon another investigation, but also collecting and rearing mosquito material.

During the entire period of the preparation of the monograph the grantee and his fellow authors have met with the heartiest cooperation on all sides. While it is true that many promises have been made which have not been fulfilled, and while it is true that the completion of the work has been delayed through a too great reliance upon certain of these promises, and while through such a reliance the mosquitoes of certain regions have not been studied with the necessary care to properly round out the work, it is well understood by the authors that by no means all of the good intentions of a busy man can be fulfilled, and they are grateful for the intention itself and for the cordial promises. They realize also that while it seems easy to collect and rear mosquitoes, it is really a rather difficult thing to do properly, and only when properly done are the results of value.

It has been found necessary to omit the group Corethrinæ, which should be included to properly round out the family Culicidæ, and restrict ourselves to the Culicinæ—the forms with the long proboscis.

It seems advisable to call attention at the outset to changes in the scientific names of those species which are most important from the economic standpoint. These changes have become necessary, partly through the strict application of the laws of priority, partly through generic revision, and also from a more exact knowledge of the specific limitations of the species concerned. The reasons for these changes will appear in the systematic part of the work.

Most important is the change in the name of the yellow-fever mosquito from the generally adopted *Stegomyia fasciata* and *Stegomyia calopus* to *Aëdes calopus* as a result of the untenability of the generic concept "*Stegomyia.*" What was known in this country as *Anopheles maculipennis* is now *Anopheles quadrimaculatus* and *A. occidentalis*, the first-named species being distinct and confined to the Old World. Through priority *Culex fatigans* or *Culex cubensis* becomes *Culex quinquefasciatus*. *Culex pungens* appears to have been used in the earlier writings on North American mosquitoes as a concept to include *Culex pipiens*, *Culex restuans*, and *Culex quinquefasciatus* (and perhaps others) before these species had been differentiated.

While it is expected that this work will be of assistance to medical and sanitary men, as well to others, it must be distinctly understood that it is an entomological monograph and not a medical monograph. The writers are entomologists and not physicians or medical investigators. Thus, while necessarily in the first volume some space is given to the history of the discoveries of the relation of mosquitoes to disease, and to the diseases themselves in a broad way, as well as some consideration of the life histories of their causative organisms, these portions are not the result of original investigation, but have been compiled from reliable sources.

We are under great obligations to Dr. Arthur Neiva, of the Instituto Oswaldo Cruz in Rio de Janeiro, who, during a visit in Washington, gave us liberal help and advice in the preparation of the parts on mosquito-borne diseases. The part on the malarial organisms is from his pen and presents the modern views in succinct form.

Especial thanks are also dne to Mr. Louis H. Aymé, United States Consul-General at Lisbon, Portugal, who, while in the States on a vacation from his former Brazilian post, spent many hours of his leisure time in translating for the writers, from the Portuguese into English, the more important portions of Goeldi's large work on the mosquitoes of Pará. To the following the hearty thanks of the authors are due for material or for assistance in one way or another. In this list are not mentioned the writers' colleagues in the Division of Insects, U. S. National Museum, or in the Bureau of Entomology of the U. S. Department of Agriculture, although many of them have been of assistance. Individual species or small lots of mosquitoes have been received from many correspondents, but these are mentioned in the text in the consideration of the individual species.

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EARLY ACCOUNTS OF MOSQUITOES.

MOSQUITOES AS PESTS.

The old writer, Thomas Moufet, collected from early writings accounts of mosquito abundance, from which it appears that Herodotus noted that these insects swarmed in prodigious numbers in old Egypt and that the natives of marshy regions built towers on which to sleep, since the mosquitoes did not fly high. Mosquito nets and canopies were in use in those early days. The army of Julian the Apostate on one occasion was so fiercely attacked by mosquitoes as to be driven back. In ancient Greece, according to Pausanias, the inhabitants of cities were sometimes forced to abandon their homes on account of mosquitoes making it impossible for them to remain. Mionte, a rich city of Ionia, was abandoned by its inhabitants on account of mosquitoes which forced them to flee to Mileta. The same thing happened with Pergamo, a beautiful city in Asia. Sapor, King of Persia, according to Theodoritus, was compelled to raise the siege of Nisibis by a plague of gnats which attacked his elephants and beasts of burden and so caused the rout of his army.

Ammianus Marcellinus, in his Roman History, in discussing the wild beasts of Mesopotamia, gives the following paragraph on lions *versus* mosquitoes (quoted from Cowan):

"The lions wander in countless droves among the beds of rushes on the banks of the rivers of Mesopotamia and in the jungles, and lie quiet all the winter, which is very mild in that country. But when the warm weather returns, as these regions are exposed to great heat, they are forced out by the vapours, and by the size of the Gnats, with swarms of which every part of that country is filled. And these winged insects attack the eyes, as being both moist and sparkling, sitting on and biting the eyelids; the lions, unable to bear the torture, are either drowned in the rivers, to which they flee for refuge, or else, by frequent scratchings, tear their eyes out themselves with their claws, and then become mad. And if this did not happen, the whole of the East would be overrun with beasts of this kind."

Pliny, in his natural history, speaks of mosquitoes and in referring to their humming noise says (freely translated): "Who gave the mosquito so terrifying a voice, infinitely greater than it should be in comparison to the size of its body?" He distinguished the Hymenoptera from the Diptera by stating that the former have the sting in the tail and the latter in the mouth, and that to the one it is given as an instrument of vengeance and to the other of avidity.

About 1736 *Culex pipiens* became so numerous in England that, as described by John Swinton, vast columns of them were seen to rise in the air from the steeple of the cathedral at Salisbury, which, at a little distance, resembled columns of smoke and caused many people to think that the cathedral was on fire. In the same account it is stated that in the year 1766, in the month of August, they appeared in such incredible numbers at Oxford as to resemble a black cloud darkening the air and almost intercepting the rays of the sun. On the evening of August 20, Sir John Swinton, in the garden of Wadham College, about half an hour before sunset, saw six columns of these insects ascending from the tops of six boughs of an apple tree—two in a perpendicular, three in an oblique direction, and one in a pyramidal form—to the height of 50 or 60 feet. During that season mosquitoes were particularly troublesome by their bites.

Such swarms as these were evidently rather commonly seen in the marshy parts of old England, as indicated by the following lines from Spenser's Faerie Queene:

> As when a swarme of gnats at eventide
> Out of the fennes of Allan doe arise,
> Their murmuring small trumpets sownden wide,
> Whiles in the air their clust'ring army flies,
> That as a cloud doth seem to dim the skies;
> Ne man nor beast may rest or take repast,
> For their sharp wounds and noyous injuries,
> Till the fierce northern wind with blust'ring blast
> Doth blow them quite away, and in the ocean cast.

Spenser, in his "View of Ireland" (1633), has the following on the subject of the Irish mosquitoes:

"They goe all naked except a mantle, which is a fit house for an outlaw—a meet bed for a rebel—and an apt cloak for a thiefe. It coucheth him strongly against the Gnats, which, in that country, doe more to annoy the naked rebels, and doe more sharply wound them, than all their enemies' swords and speares, which can seldom come nigh them."

Kirby and Spence have brought together several instances of remarkable stories from the older travels, such as the following:

"In the neighborhood of the Crimea the Russian soldiers are obliged to sleep in sacks to defend themselves from the mosquitos; and even this is not a sufficient security, for several of them die in consequence of mortification produced by the bites of these furious blood-suckers. This fact is related by Dr. Clarke, and to its probability his own painful experience enabled him to speak. He informs us that the bodies of himself and his companions, in spite of gloves, clothes, and handkerchiefs, were rendered one entire wound, and the consequent excessive irritation and swelling excited a considerable degree of fever. In a most sultry night, when not a breath of air was stirring, exhausted by fatigue, pain and heat, he sought shelter in his carriage; and, though almost suffocated, could not venture to open a window for fear of the mosquitoes. Swarms nevertheless found their way into his hiding-place; and, in spite of the handkerchiefs with which he had bound up his head, filled his mouth, nostrils, and ears. In the midst of his torment he succeeded in lighting a lamp, which was extinguished in a moment by such a prodigious number of these insects, that their carcasses actually filled the glass chimney, and formed a large conical heap over the burner. The noise they make in flying can not be conceived by persons who have only heard gnats in England. It is to all that hear it a most fearful sound. Travellers and mariners who have visited warmer climates give a similar account of the torments there inflicted by these little demons. One traveller in Africa complains that after a fifty miles journey they would not suffer him to rest, and that his face and hands appeared, from their bites, as if he was infected with the small-pox in its worst stage. In the East, at Batavia, Dr. Arnold, a most attentive and accurate observer, relates that their bite is the most venomous he ever felt, occasioning a most intolerable itching, which lasts several days. The sight or sound of a single one either prevented him from going to bed for a whole night, or obliged him to rise many times. The species, which I have examined, is distinct from the common gnat, and appears to be nondescript. It approaches nearest to *C. annulatus,* but the wings are black and not spotted. And Captain Stedman in America, as a proof of the dreadful state to which he and his soldiers were reduced by them, mentions that they were forced to sleep with their heads thrust into holes made in the earth with their bayonets, and their necks wrapped round with their hammocks."

Quite the most interesting and really important of the observations upon mosquitoes by the older travellers, however, are those of Humboldt. The account is of general interest as indicating the conditions of life in the regions of the upper Orinoco and Magdalena rivers, and the hardships endured by the missionaries who early visited those regions and who passed their lives there. It is also of special interest as a record of the observations of a very acute observer and reasoner. The observations were all original, and most of them were in direct contradiction to the views of former travellers and of the writers on natural history. The differentiation between the different species of biting flies, including mosquitoes, the discovery that different species inhabit different regions and bite at different times of the day and of the night, the fact that with certain of the residents of the upper Orinoco the existing fevers and other maladies were attributed to mosquitoes, the curious reasoning of the author on the possible carriage of disease by blood-sucking insects and the origin of fevers, and many other points in this chapter combine to make it one of very great interest in the light of present knowledge of the Culicidæ of tropical regions. Parts of it, therefore, in free translation, are here presented. It must be kept in mind that Humboldt's account deals with biting flies belonging to different families, and, in speaking of the separate forms, he uses the terminology customary in the Spanish-American countries. By the term *"mosquitos"* he does not mean Culicidæ, but Simuliidæ; the mosquitoes in our sense are called *"zancudos"* and *"tempraneros"*; the *"jéjen"* are minute Chironomidæ, now assigned to the genus *Culicoides.* In speaking of these forms collectively, Humboldt uses the term *"tipulaires,"* which roughly corresponds to the group Nemocera, as now understood. In order to avoid confusion we have translated the French word "cousin," which corresponds to our word "mosquito," by the word "gnat."

"After having spent two days at the cataract of Atures we were glad to be able to leave a place where the temperature of the air was generally 29° C. in the day and 26° C. at night. This temperature seemed still warmer than it really was. The lack of concurrence between the thermometer and our feelings should be attributed to the continuous irritation of the skin by the mosquitoes. An atmosphere filled with venomous insects always appears hotter than it really is. A Saussure hygrometer indicated in the shade (as usual) at the minimum in the day time (3 hours after noon) 78° 2″, at night at the maximum 81° 5″. . . . We were horribly tormented by the *mosquitos* and by the *jéjen,* venomous little flies or *simuliums;* at night by the *zancudos,* a species of large gnat or mosquito which is feared even by the natives. We began to have badly swollen hands and faces, and the inflammation increased from day to day until our arrival on the banks of the Temi. The means by which they try to escape from these little animals are very extraordinary. The good missionary, Bernardo Zea, who passes his life under the torments of mosquitoes, has constructed himself, near his church, upon a scaffolding of palm trunks, a little room in which he can breathe more freely. We mounted there in the evening by the help of a ladder, to dry our plants and to write up our journey. The missionary had noticed with exactness that the insects abound most in the lower layer of the atmosphere, that which is near the soil, up to 12 to 15 feet in height. At Maypures the indians leave their village in the night in order to go to sleep on the little islands in the middle of the cataract. They get some sleep there; the mosquitoes appear to avoid the air surcharged with vapors. Everywhere we found them less abundant in the middle of the river than on the banks; in descending the Orinoco one suffers only when getting into the boat.

"Persons who have not sailed upon the great rivers of equinoctial America, the Orinoco for example, or the Magdalena, can not conceive that at every moment, without interruption, one can be tormented by the insects swarming in the air, and how the number of these little animals can render vast regions almost uninhabitable. One can never become accustomed there to stand the bites without complaint. However lively may be one's interest in the objects of his search, it is impossible that one should not be constantly distracted by the *mosquitos*, the *zancudos*, the *jéjen*, and *tempraneros*, which cover the hands and face, which pierce the clothing with their spear-like suckers, and which, getting into the nostrils and into the mouth, make you cough and sneeze. Thus . . . in the missions of the Orinoco, in these villages placed on the banks of the river, surrounded by immense forests, the plague of flies affords a constant topic for conversation. When two persons meet in the morning the first question asked is, 'How have you found the *zancudos* during the night?'

"This is the place to mention the geographic distribution of these insects which shows quite remarkable phenomena. It does not appear to depend solely upon the heat of the climate, upon the excess of humidity, or the thickness of the forests, but upon the local conditions difficult to characterize. It can be said, for example, that the torment of *mosquitos* and *zancudos*, is not as general in the torrid zone as is commonly believed. Upon plateaux more than 400 fathoms higher than the ocean level, on very dry plains distant from the banks of great rivers, for example at Cumaná and at Calabozo, there are not obviously more *mosquitos* than in the most civilized part of Europe. Their number becomes enormously increased in Neuva Barcelona, and, more to the west, upon the coast which extends towards Cape Codera. Between the little port of Higuerote and to the mouth of the River Unare the unfortunate inhabitants have the custom of stretching themselves upon the ground and passing the night covered with earth 3 or 4 inches thick, leaving out only the head, which they cover with a handkerchief. One still suffers from the bite of the insects, but in so much less degree that it can be easily borne, in descending the Orinoco from Cabruta towards Angostura, and in going up from Cabruta towards Uruana, between the 7th and 8th degree of latitude. But beyond the mouth of the Arauca River, after the Straight of Baraguan is passed, the scene changes constantly. Beyond this point there is no longer any repose for the traveller. If one remembers his Dante he believes that he has entered the *città dolente*, and he will believe he can read upon the granite rocks of Baraguan the memorable lines of the third canto:

Noi sem venuti al luogo, ov'i' t'ho detto
Che tu vedrai le genti dolorose.

"The lower layers of the air, from the earth up to 15 to 20 feet in height, are filled with venomous insects like a condensed vapor. If one places himself in an obscure place, as, for example, in the grottos of the cataracts formed by blocks of granite, and directs his eyes towards the opening, one sees clouds of *mosquitos* which are thicker or thinner according as these little animals in their movements come together or disperse. At the mission of San Borja they suffer even more from *mosquitos* than at Carichana, but at Aturés, and above all at Maypurés, this suffering reaches its maximum. I doubt whether there is any part of the earth where man can be exposed to more cruel torments during the rainy season. In passing the fifth degree of latitude one is somewhat less bitten, but on the upper Orinoco the bites are more painful because of the heat and the absolute lack of wind.

"'One should be in the moon,' said a Saliva indian to Father Gumilla, 'for in its beautiful and clear light one would be free from mosquitoes.' These words coming from a savage are very remarkable. Everywhere this satellite of the earth is for the American savage the habitation of happiness, the country of abundance. The Eskimo who counts among his riches a plank or tree trunk thrown by the waves upon a coast deprived of vegetation, sees in the moon plains covered with forests. The indians of the forests of the Orinoco see bare fields in which the inhabitants are never bitten by mosquitoes.

"Going further towards the South where the system of brownish yellow river waters begins, which are generally called black waters, upon the banks of the Atabapo, of the Temi, of the Tuamini, and of the Rio Negro, we enjoyed a repose, *I had almost said an unexpected happiness. These rivers run through thick* forests like the Orinoco, but the Nemocera and gnats, and the crocodiles as well, avoid the neighborhood of the black waters. Are these waters, a little colder and chemically different from the white, unsuitable for the larvæ and nymphs of the Nemocera which must be considered as true aquatic animals? Some small rivers, which are dark blue or yellowish brown, like the Toparo, the Mateveni, and the Zama, are exceptions to the general rule of the absence of *mosquitos* near black waters. These three rivers swarm with them, and even the indians discuss the problematical causes of this phenomenon. In descending the Rio Negro we breathed freely at Maroa, at Vavipe, and at San Carlos, villages situated on the borders of Brazil. But this amelioration of our condition was very short, for our sufferings recommenced when we entered the Cassiquiare. At Esmeralda, at the eastern extremity of the upper Orinoco, where the country known to the Spaniards ends, the clouds of *mosquitos* are almost as thick as in the Grand Cataracts. At Mandavaca we found an old missionary who told us with an air of sadness that he had passed *his twenty years of mosquitos* in America. He told us to look at his legs in order that we might be able to tell the people some day across the sea what the poor monks suffer in the forests of the Cassiquiare. As each bite leaves a little brownish black spot, his legs were so speckled that one could with difficulty see the whiteness of his skin between the spots of coagulated blood. While the insects of the genus *Simulium* abound on the Cassiquiare, which has white waters, the *Culex* or *zancudos* are proportionately rare; one hardly encounters them, whereas on the rivers which have black waters, on the Atabapo and the Rio Negro, there are generally many *zancudos* and no *mosquitos*. . . .

"I have just shown according to my own observations that the geographic distribution of venomous insects varies according to whether the water is white or black, and it is much to be desired that a learned entomologist should study upon the spot the specific differences between these criminal insects which play in the torrid zone, in spite of their minute size, a very important part in the economy of nature. What appears to us very remarkable, and it is a fact known to all the missionaries, is that the different species do not associate, and that at different hours of the day one is bitten by distinct species. Each time the scene changes, and when, according to the naïve expression of the missionaries, other insects mount guard, one has some moments, even a quarter of an hour, of rest. The insects which disappear are not immediately replaced in the same number by those that succeed them. From half past six in the morning until five o'clock in the evening the air is filled with *mosquitos,* which are not, as has been stated in some travellers' stories, of the shape of our European gnats, but of that of a little fly. These are the *Simuliums.* . . . Their bite is as painful as that of *Stomoxys.* It leaves a little reddish brown spot which is very excruciating and is the extravasated and coagulated blood where the beak has pierced the skin. An hour before the sun sets these creatures are replaced by a species of small gnat called *tempraneros* (one which shows itself early) because they appear also at sunrise; their presence lasts one hour and a half; they disappear between six and seven o'clock, or, as they say here, after the Angelus. After some minutes of sleep one is bitten by the *zancudos,* another species of gnat with very long legs. The *zancudos,* whose beak forms a piercing sucker, causes the sharpest pain and an inflammation which lasts several weeks. Its song is like that of our European gnat, but it is stronger and more prolonged. The indians claim to recognize the *zancudos* and the *tempraneros* by their song; these latter are true twilight insects, while the *zancudos* are nocturnal and disappear towards sunrise.

"In the journey from Carthagena to Santa Fé de Bogota we have observed between Mompox and Honda, in the valley of the Rio Grande de la Magdalena, *zancudos* filling the air from eight o'clock in the evening until midnight, diminishing about midnight and hiding themselves three or four hours, and returning in clouds with a devouring appetite about four o'clock in the morning. What is the cause of these alternations of movement and repose? Are these animals tired by a long flight? On the Orinoco it is very rare to see true day gnats, while on the Magdalena one is bitten day and night except for about two hours at midday. The *zancudos* of the two rivers are without doubt of different species. Are the eyes of one of these species affected by the light of the sun more than the eyes of the other species? . . .

"At a time when they had not yet studied the geography of animals and plants they often confounded the analogous species of different climates. They thought that in Japan, in the Andes and at the Strait of Magellan the pines, the *Ranunculus,* the deers, rats, and the Nemocera were the same as those of Europe. Celebrated naturalists have thought that the gnat of the torrid zone was the same as the gnat of the European marshes, only more vigorous, more ferocious, and more dangerous under the influence of a burning climate. This opinion is very erroneous. I have examined and described with care upon the spot the *zancudos* with which one is most tormented. On the rivers of Magdalena and Guayaquil there are five very distinct species. Latreille, the foremost entomologist of the century, has been good enough to revise the detailed description of these little animals, which I will give in a note.

[Here follow the Latin descriptions of the following new species: *Culex cyanopennis, C. lineatus, C. ferox, C. chloropterus,* and *C. maculatus.*]

"The species of *Culex* of South America generally have the wings, the thorax and the feet bluish and striped, giving a metallic effect from the mingling of spots. Here, as in Europe, the males, which are distinguished by their plumose antennæ, are extremely rare, and one is never pierced except by the females. The preponderance of this sex explains the immense increase in numbers of individuals, each female laying several hundred eggs. In traveling up one of the great rivers of America, one notices that the appearance of a new species of *Culex* announces the proximity of a new tributary. To cite an example of this curious phenomenon, *Culex lineatus,* which belongs to the Cañon of Tamalaméque, is noticed in the valley of the Rio Grande de la Magdalena only at a spot north of the juncture of the two rivers. It extends up but not down the Rio Grande. It is in the same way that upon a principal vein the appearance of a new substance in the vein rock indicates to the miner the neighborhood of a secondary vein joining the first.

"In recapitulating the observations just indicated, we see that in the tropics these insects do not extend upon the slope of the Cordilleras toward the temperate region where the mean heat is below 19 to 20 degrees C.; that with only a few exceptions they avoid rivers with black waters, and dry and deforested localities. On the upper Orinoco the atmosphere swarms with them much more than on the lower Orinoco, because in the first region the river is bordered by thick forests and because the borders of the forest are not separated from the river by extensive arid plains. With the diminution of water and the destruction of the woods the *mosquitos* will diminish in the new world; but the effects of these changes are as slow as the progress of agriculture. The towns of Angostura, of Nueva Barcelona, and of Mompox, where, by a lack of police supervision, the streets, the squares, and the interior of the courts are covered with brush, are sadly celebrated for their abundance of *zancudos*.

"The people born in the country, whether they are whites, mulattoes, negroes, or indians, all suffer from the bite of these insects; but, just as the extreme cold does not render the north of Europe uninhabitable, the *mosquitos* do not deter men from establishing themselves in countries where they abound if these countries, by their situation and their government, offer resources to agriculture and to industry. The inhabitants pass their lives complaining of the plague, of the insufferable torment of flies; but, in spite of these continual complaints, they none the less seek by preference the commercial cities of Mompox, of Santa Marta, and of Rio la Hacha. Such is the power of adaptation to evils continually suffered, that the three missions of San Borja, of Aturés, and of Esmeralda, where, to use the hyperbolical expression of the friars, there is less air than mosquitoes, would become, without doubt, flourishing cities if the Orinoco offered to the colonists the same advantages for exchange of productions as the Ohio and the lower Mississippi. The abundance of venomous insects retards but does not entirely stop the progress of population; it does not prevent the whites from establishing themselves there where the commercial and political condition of the country promises real advantage. . . ."

[Here follows an account of the chigoe (*Sarcopsylla penetrans*)]:

"One of the most barbarous of the tribes of the Orinoco, the Otomaques, know the use of mosquito bars made of palm fibers. We have seen that at Higuerote the people of color sleep covered with earth. In the villages of the River Magdalena the indians often invited us to lie down with them under the skins of cattle, near the church, in the middle of the plaza, where they brought together all the cows of the vicinity. The proximity of the cattle gave some repose to the men. The indians of the upper Orinoco and of the Cassiquiare, seeing that Monsieur Bonpland could not prepare his plants on account of the continual torment of *mosquitos*, made him enter their ovens or *hornitos*. Thus they call their little rooms without doors or windows, which they enter on their bellies through a very low opening; then by a fire of damp brush which produces much smoke they succeed in driving out the insects through the opening. The absence of *mosquitos* is purchased very dearly by the excessive heat of the stagnant air and by the smoke of the torch of copal which lights the oven while one remains in it. Monsieur Bonpland dried, with a courage and a patience worthy of eulogy, hundreds of plants, shut up in these bake-houses of the indians.

"The pains which the natives take in order to lessen the annoyance by insects sufficiently proves that, in spite of the different organization of the dermal system, the copper-colored man is as susceptible to the bites of mosquitoes as the white man, but, as we have elsewhere stated, the pain appears less great and the bite is not followed by the swelling which follows without interruption for several weeks, and which increases the irritability of the skin, and which throws persons with delicate complexion into that feverish condition which always accompanies eruptive maladies. Whites born in equinoctial America, and Europeans who have lived a long time in the missions on the borders of the forests and of the great rivers, suffer much more than indians, but infinitely less than Europeans recently landed. It is not, then, as some travelers say, the thickness of the skin which renders the bite more or less painful at the moment it is experienced; it is not on account of the particular character of the skin that the swellings and the inflammatory symptoms are less with the indians; it is upon the nervous irritability of the dermal system that the degree and the duration of the trouble depends. This irritability is increased by very warm clothes, by the use of alcoholic liquors, and by the habit of scratching the wound; finally, and this physiological observation is the result of my own experience, by baths taken at too short intervals. In places where the absence of crocodiles allows one to enter the river we have observed that the immoderate use of baths, while allaying the pain of old *zancudo* bites, rendered us much more sensitive to new bites. If one bathes more than twice a day one gets his skin into a state of nervous irritability of which no one in Europe can form any idea. One would say that all of his sensitiveness was in his skin.

"As the gnats pass two-thirds of their life in the water, it is not surprising that in forests traversed by great rivers these injurious insects become more rare in proportion as one leaves the river. They seem to prefer to remain near places where they have bred and where they are to lay their eggs. As a matter of fact the savage indians become accustomed to mission life with greater difficulty since in the Christian villages they find a torment which they did not know in their own homes in the interior. We have seen at Maypurés, at Aturés, and at Esmeralda that the indians fled to the forests solely from fear of mosquitoes. Unfortunately all the missions of the Orinoco, from their very beginning, have been too near the banks of the river. At Esmeralda the inhabitants assured us that if the village had been placed in one of the beautiful plains which surround the high mountains of Duida and of Maraguaca, they would have breathed freely and would have enjoyed some sleep. The 'great cloud of mosquitos' (this is the expression of the friars) is found only upon the Orinoco and its tributaries. This cloud grows less in proportion as one leaves the rivers. . . .

"I have learned that these little insects make migrations from time to time, like the monkeys that live gregariously. At the beginning of the rainy season certain species, by which we have not yet been bitten, are found in certain places. We have been informed that on the Rio de la Magdalena, at Simití, they know no other *Culex* than the *jejen*. One can pass the night there peacefully, for the *jejen* is not a nocturnal insect. Since 1801 the large gnat with blue wings (*Culex cyanopterus*) has become so abundant that the poor inhabitants of Simití do not know how to obtain a peaceable nap. On the swampy canals of the island of Baru, near Carthagéna des Indes, there is a little whitish fly known as the *cafafi*.* It is scarcely visible to the naked eye, and causes very painful swellings. It is necessary to wet the mosquito bars in order to prevent the *cafafi* from working through them. This insect, fortunately rare elsewhere, comes up in January by the canal to Morales. When we were in this village in the month of May we found *Simulium* and *zancudos*, but more of the *jejen*.

"Slight changes in nourishment and in climate appear to change the activity of the poison in the same species of gnats or mosquitoes. On the Orinoco the most voracious insects are those of the Grand Cataracts, of Esmeralda and of Mandavaca. On the Rio de la Magdalena *Culex cyanopterus* is the one feared

* "Perhaps a Culicid." [This is very probably a *Culicoides*, H., D. & K.]

above all at Mompox, at Chilloa, and at Tamalaméque. It is here that it is the largest and strongest, and here its legs are blacker. One can hardly help laughing when one hears the missionaries dispute about the size and ferocity of the *mosquitos* on different parts of the same river. In the midst of a country where they are ignorant of what is going on in the rest of the world this is the favorite subject for conversation. 'How sorry I am for you!' the missionary of the Raudales on our departure said to the missionary of the Cassiquiare. 'You are alone just as I am in this country of tigers and of apes; fishes where I live are rarer than here; the heat there is greater, but as to the flies, I can boast that with one of mine I can beat three of yours.'

"This voracity of insects in certain places, this avidity with which they attack man,* this activity of the venom, variable in the same species, are remarkable facts, but they find their analogy with some of the larger animals. The crocodile of Angostura pursues man, while one can bathe peacefully at Nueva Barcelona in the Nevari River in the midst of these carnivorous reptiles. The jaguars of Maturin, of Cumanacoa, and of the Isthmus of Panama are cowardly compared with those of the upper Orinoco. The indians know very well that the monkeys of such and such a valley are easily domesticated, while others of the same species, caught elsewhere, will die of hunger rather than submit to slavery.

"The people in America form ideas concerning the health of climates and concerning pathological phenomena, just as the savants of Europe do, and these ideas, just as with us, are diametrically opposed to one another according to the provinces into which the new continent is divided. On the Rio de la Magdalena the abundance of *mosquitos* is regarded as a nuisance, but very healthy. 'These animals,' say the inhabitants, 'bleed us slightly, and in an excessively warm country, preserve us from the *tabardillo*, from scarlet fever, and other inflammatory maladies.' On the Orinoco, the banks of which are very dangerous to health, the sick people accuse the *mosquitos* of all the diseases that they have. 'These insects are born in corruption and increase it; they inflame the blood.' It is useless to deny this popular belief which considers *mosquitos* as acting in a salutary way by local bleeding. Even in Europe the inhabitants of swampy countries do not ignore the fact that insects irritate the dermal system. Far from diminishing the inflammatory condition of the skin, the bites increase it.

"The abundance of gnats and *mosquitos* characterizes unhealthy countries only when the development and multiplication of these insects depends upon the same causes which give birth to miasmas. These injurious animals love a fertile soil covered with vegetation, with stagnant pools, and moist air which is never agitated by the wind. They prefer, in place of bare spots, shade, that degree of light, of heat, and of humidity, which all favor the action of chemical affinities and accelerate the putrefaction of organic substances. Do the *mosquitos* themselves add to the unhealthiness of the atmosphere? When one thinks that, at an elevation of three or four fathoms, a cubic foot of air is often peopled by a million winged insects and that these have within them a caustic and poisonous liquid—when one remembers that several species of *Culex* are from the head to the end of the body (without counting the legs) 1-4/5 lines long—when one considers finally that in this swarm of gnats and mosquitoes, spread like a cloud in the air, there are a great number of dead insects carried by the force of the ascending current and by the side currents which are caused by the unequal heat of the soil—one asks if the presence of so much animal matter in the air does not give birth to certain miasmas. I think that these substances

* "How surprising is this voracity, this appetite for blood on the part of little insects which feed normally upon plant juices, which live in an almost uninhabited country! 'What would these animals eat if we did not go through here,' the creoles often say in passing places where there are only crocodiles covered with scaly skin and hairy monkeys."

act differently upon the atmosphere than soil and dust; but it will be prudent to make no definite assertions upon this subject. Chemistry has not yet solved any of the numerous mysteries of the unhealthiness of the air. It has taught us only that we are ignorant of many things which we thought we knew fifteen years ago, thanks to the ingenious dreams of the ancient eudiometry.

"What is less uncertain, and confirmed, so to speak, by daily experiences, is that on the Orinoco, the Cassiquiare, the Rio Caura, and everywhere where the air is very unhealthy, the bite of the *mosquitos* increases the disposition of the organs to receive miasmatic impression. When during whole months one is exposed night and day to the torment of insects, the continual irritation of the skin causes febrile movements and depresses the functions of the stomach by the effect of the antagonism, so long known, between the dermal system and the gastric system. One begins to digest with difficulty; the inflammation of the skin brings about abundant perspiration; one can not quench his thirst; and to his always increasing impatience follows, with persons of weak constitution, a condition of low spirits during which all the pathogenic causes act with force. Today it is not the dangers of navigation in little canoes, it is not the savage indians, or the serpents, the crocodiles, or the jaguars, which makes Spaniards fear the voyage up the Orinoco; it is, as they say naïvely, 'the sweats and the flies.' Let us hope that man, in changing the surface of the earth, will little by little bring about a change in the constitution of the atmosphere. The insects will diminish when the old trees of the forest will have disappeared, and one will see in these desert countries the rivers bordered with villages, the plains covered with pastures and cultivated fields.

"Whoever has lived a long time in countries infested by *mosquitos* will have proven, as we have, that there is no radical remedy against the torment of insects. Indians covered with onoto, with bolary earth, or with turtle oil, are every instant slapping their shoulders, their sides, their legs, almost as though the body had not been painted. It is doubtful in general whether painting is a relief—certainly no great relief. Europeans recently arrived on the Orinoco, on the Rio de la Magdalena, on the Guayaquil or the Chagres rivers (I mention the four rivers where the insects are the most numerous) at first cover the face and the hands. They soon find the heat too great, and they are tired of being completely inactive, and end by uncovering. Persons who do not wish to do any kind of work during the navigation of the rivers can bring from Europe an especial kind of clothing in the form of a sack under which they can rest hidden, opening it only every half hour. This sack should be held open by whalebone hoops, for a simple mask and gloves would be hardly bearable. Sleeping upon the earth, upon skins or in hammocks, we have not been able in the Orinoco region to use mosquito bars. A mosquito bar is useful only when it forms about the bed a tent so well closed that there is not the least opening by which a mosquito can enter. This condition is very difficult to bring about, and often one is forced (for example when going up the Rio de la Magdalena, where they travel with these mosquito bars), in order not to suffocate with heat, to get out from under his bar and to walk in the open air. A mild wind, smoke, and strong odors afford almost no relief in the places where these insects are very numerous and very voracious. It is wrongly stated that these little insects avoid the odor of the crocodile. We were horribly bitten at Bataillez on the road from Carthagéna des Indes to Honda, while we were dissecting a crocodile eleven feet long and which infected the whole atmosphere of the neighborhood. The indians recommend the exhalation of burnt cowdung. When the wind is very strong and accompanied by rain the *mosquitos* disappear for some time. They bite the most cruelly on the approach of a storm, and especially when the thunder is not followed by showers.

"Everything which moves about the head or the hands helps to chase the insects away. 'The more you move, the less you are bitten,' say the missionaries. The *zancudo* buzzes a long time before alighting, but when it has gained confidence and has once commenced to insert its sucker and to suck blood one can touch its wings without frightening it. At this time it holds its two hind legs in the air, and if, without bothering it, one lets it suck its fill there is no swelling and no pain. We have often tried this experiment upon ourselves in the valley of the Rio de la Magdalena on the advice of the natives. One asks oneself whether the insect only injects the poison at the moment when it is frightened away, or if it sucks back the poison when it is allowed to suck as much as it will. I am inclined to the latter opinion, for, in allowing *Culex cyanopterus* to peaceably bite the back of my hand, I noticed that the pain, very strong in the beginning, diminished as the insect continued to pump up the blood. It ceased absolutely at the moment when the sucking was finished. I tried also the experiment of wounding my skin with a pin and of rubbing the puncture with crushed gnats, but no inflammation followed. The irritating liquid of the nemocerous insects, in which chemists have not yet recognized any acid property, is contained, as with the ants and other hymenopterous insects, in special glands, and it is probably too dilute and in consequence too weak if one rubs the skin with all of the crushed insect."

If, in the above account, one has kept in mind that by the word "mosquito" Humboldt designated *Simulium*, it will be seen that he clearly distinguished between the blood-sucking flies belonging to different families.

In the account which follows, of the abundance of mosquitoes in southern Russia, by Jaeger, the Culicidæ and Simuliidæ were evidently not differentiated. Thus the statement of the mosquitoes entering the noses, mouths and ears of cattle and of causing the death of many of these animals, clearly applies to the Simuliidæ, the ravages of which, in that country, are well known. The account is nevertheless of interest.

"When traveling some years ago in the country of the Czernomorzi, or Cossacks of the Black Sea, we observed before each house of the different *slanitzas* or villages, of the Cossacks, large heaps of half dried manure ignited and smoking, which our driver informed us was for the purpose of keeping off the mosquitoes. Toward evening, on a very hot June day, we ascended the right bank of the muddy and slowly-running River Kuban, on the left bank of which the independent Circassia stretched out before us, when suddenly swarms of small mosquitoes covered us, our servant, and driver, and horses, lighting upon us in lumps an inch thick, and, in spite of all the covering we could hastily throw over us, tormenting us excessively with their bites.

"On the road, at a distance of every four or five versts (three or four English miles), we found a military post of about a dozen Cossacks, keeping themselves and their horses under ground, except one sentinel, who was standing upon a scaffold twelve feet high, in order to watch any inimical movements of the Circassians, to repulse their attacks, and, in case of one, to give notice of it to the two nearest posts by means of the ancient Persian telegraph, viz.: by igniting a bundle of straw, which was then fastened to the top of a high pole and elevated. At midnight our misery reached its climax. Though covered with a wide cloak, the mosquitoes entered every opening, and inflicted upon us such painful wounds that our faces were so swollen we could scarcely recognize one another. To our joy a large camp-fire was seen at some distance, which, according to the driver's assurance, was the post-station, where fresh horses could be had. We arrived at the spot, and with great precipitation left the carriage, running in haste to the fire, near which a large dog was howling and running as if mad; the horses, as soon as they were unharnessed, sprang into the fire to get rid of the mosquitoes, and only with difficulty could they be removed to the subterranean stable, where the postmaster, a half-invalid officer of the army, with some men and a number of imperial horses, resided. The officer immediately ordered fresh horses for us, and, looking from under a very heavy covering at our pitiful condition, told us to hurry on, and by daybreak we should arrive at the next station, where we could find comfortable houses and be relieved from the attacks of mosquitoes. In less than five minutes the horses were harnessed, and the Russian word *Boshoal,* 'Go on,' from the commander to the new driver, was music to our ears. When we arrived at the next station we stopped at the first house, the owner of which was a captain of the Cossacks, who received us with the usual hospitality, inborn in the Russians of all grades, and entirely unknown in any part of Europe or America, Poland and Hungary excepted. The captain conducted us into a well-furnished, comfortable room, assisted us to undress and get to bed, and from time to time applied wet cloths to our swollen face and body, until a profound sleep temporarily relieved our excruciating pains. The same care was taken of our servant, who, in the madness caused by his sufferings, attempted to shoot himself that he might be out of misery, but was prevented by two athletic Cossacks, and watched and nursed until he, too, was relieved by sleep. It was not until after a week of suffering that the fever and inflammation subsided so that we could open our eyes. . . .

"As the Cossacks of the Black Sea are no agriculturists, but derive their subsistence from their numerous herds of horses, oxen, sheep, goats, and hogs, they suffer immensely at times from the ravages of the mosquitoes. Although they are fortunately not seen every year, these blood-suckers may be considered a real Egyptian plague among the herds of these Cossacks; for they soon transform the most delightful plains into a mournful, solitary desert, killing all the beasts, and completely stripping the fields of every animated creature. One can not look upon the spectacle without pity when he sees the poor cattle exhibiting so much terror at the approach of these innumerable swarms of mosquitoes, whole herds hurrying home for shelter, running as if mad, and often, in their fright, plunging into the river and being drowned. Thousands of these insatiate tormentors enter the nostrils, ears, eyes, and mouth of the cattle, who shortly after die in convulsions, or from secondary inflammation, or from absolute suffocation. In the small town of Elizabethpol alone, during the month of June, thirty horses, forty foals, seventy oxen, ninety calves, a hundred and fifty hogs, and four hundred sheep, were killed by these flies."

EARLY ACCOUNTS OF THE BIOLOGY AND STRUCTURE OF MOSQUITOES.

Although simple lenses were known in very ancient times, and although many interesting and important observations were made with these simple lenses, it was not until the invention of the compound microscope, at the end of the sixteenth century and its development during the seventeenth century, that competent observations began to be made upon the very small animals. In that century, and especially towards its close, a number of patient workers examined with these new instruments the small, common forms of life about them and discovered many most interesting and, to them, almost miraculous facts concerning their microscopic appearance and concerning their habits and methods of life.

The organization of the proboscis of the mosquito and its manner of functioning were the objects of especial interest to the early investigators with lens and microscope. The work of some of these anatomists, when we consider the instruments at their command, was most remarkable, and while faulty in the light of our present knowledge, gives testimony to the enthusiasm and devotion of these men. It would lead too far to enter into a discussion of the early investigators. A brief account of them, and their relation, to the facts as found by modern workers, is given by Dimmock, while Meinert, in his "Fluernes Munddele," gives a very complete account of these early researches on the composition of the mosquito's proboscis. There were naturally enough discrepancies as to the component parts of the proboscis, but Swammerdamm, in his work of 1669, had already determined them correctly.

Many of the earlier works, like Barth's "De Culice dissertatio," contain little that is original, but quote, as was then the fashion, at great length from the writings of ancient authors.

Robert Hooke, in his "Micrographia, or Some Physiological Descriptions of Minute Bodies made by Magnifying Glasses, with Observations and Inquiries thereupon," published in 1665, treats so interestingly of the life-history of the mosquito that we quote from it at some length. He calls the larva

". . . a small scaled or crusted animal which I have often observed to be generated in Rain water. . . . It is supposed by some, to deduce its first original from the putrifaction of Rain-water, in which, if it have stood any time open to the air you shall seldom miss, all the Summer long, of store of them striking to and fro."

A description of the larva follows, with constant reference to the plate, with its crude but characteristic figures, and observations on the internal structure and the circulation of the "bloud." Its mouth was "pretty large" and "contrived like those of Crabs and Lobsters, by which, I have often observed them to feed on the water, or upon some imperceptible nutritive substance in it. . . ."

"Both its motion and rest is very strange and pleasant . . . for, where it ceases from moving its body, the tail of it seeming much lighter then the rest of its body, and a little lighter then the water it swims in, presently boys it up to the top . . . where it hangs suspended with the head always downward. . . . the hanging of these in this posture, put me in mind of a certain creature I have seen in *London* that was brought out of America, which would very firmly suspend it self by the tail . . . and was said to sleep in that posture, with her young ones in her false belly. . . ."

He kept some in a glass of rain-water and observed their transformation to pupa and adult and described the pupa, and also, very accurately, the emergence of the adult. He philosophizes:

"I have been the more particular, and large in the relation of the transformation of divers of these little Animals which I observed, because I have not found that any Authour has observ'd the like; and because the thing it self is so strange and heterogeneous from the usual progress of other Animals, that I judge it may not onely be pleasant, but very usefull and necessary toward the completing of Natural History."

He speculates upon what he has seen, and wonders if, after all, the varied organisms supposed to come from putrefaction may not develop from eggs dropped in the water by the parent. He had an idea that the gnat's eggs might possibly be ejected in the air—". . . for it seems not very improbable, but that those small seeds of Gnats may (being, perhaps, of so light a nature and having so great a proportion of surface to so small a bulk of body) be ejected into the Air, and so, perhaps, carried for a good while too and fro in it, till by the drops of Rain it be washed out of it." He believes, speaking of metamorphoses of insects, that were men "diligent observers, they might meet with multitudes" of instances.

He describes, in another place, a female mosquito, and speaks of letting it bite his hand, and of watching its body swell with the blood,

"making it appear very red and transparent, and this without further pain than whilst it was sinking in its *proboscis* . . . a good argument that these creatures do not wound the skin and suck the blood out of enmity and revenge, but for meer necessity and to satisfy their hunger."

The copper plates of Hooke's work were republished with new text by an anonymous writer in 1745, under the title "Micrographia Restaurata." The self-satisfied complacency of this edition is in sharp contrast to the intimate style of the original work. It alternately apologizes for Hooke's short-comings and exalts the present-day perfection of scientific knowledge, brevity and directness of speech. Under our treatment of the mosquito larva the accounts of Swammerdamm, Réaumur and Hooke are mentioned. The unknown commentator, however, draws upon the paper by J. J. Wagner, "De Generatione Culicum" (Ephem. Acad. Nat. Curios., 1684), for his description of the life-history. This account, which in reality treats of one of the Chironomidæ, states that the female gnat dips its tail into the water and lays a gelatinous mass of eggs attached to a water weed—that they hatch into small reddish maggots which sink to the bottom of the water, where they form cases in which they live for a time and later come forth and become pupæ and mosquitoes.

John Swammerdamm, in his Historia Insectorum Generalis, Utrecht, 1669 (in English in Book of Nature, London, 1758, pp. 153–159), shows plainly that he had carefully studied mosquitoes with the microscope, and describes the larva very carefully (complimenting Robert Hooke's admirable figures in his Micrographia) and stating that the mosquito larva holds its position at the surface of the water because its tail never becomes wet, supposing it to be oily. He describes the transformation to the pupa stage, carefully describes the pupa stage and the transformation to adult, and gives a long description of the adult, including the mouthparts, determining correctly the number of setæ in the proboscis. He thought, however, erroneously, that in biting the mosquito was able to protrude the setæ from the end of the sheath, without flexion of the latter.

P. Bonanni, in a curious work entitled "Observationes Circa Viventia," etc., Rome, 1691, in which he considers the methods of reproduction of many different kinds of lower animals with especial reference to spontaneous generation, gives very good figures of the larva, pupa, and adult, and of the wing-scales, of a *Culex*. The drawing of the adult is obviously traced from Swammerdam and printed reversed. The larva and the pupa are different from the Swammerdam drawings, and may have been drawn originally from specimens under observation.

P. P. San Gallo, "Esperienze intorno alla generazione dele zanzare" (Ephem. Acad. nat. Curios., 1712, cent. 1 and 2, pp. 220–223, Tab. 1), gives some attention to the writings of earlier authors, and quotes Pliny, Ammianus Marcellinus, the Arabian doctor Zacharias Ben Muahammed Ibn Mahmud, and Francisco Redi. He gives an account of observations made by himself in June, 1679, upon mosquitoes in breeding-jars. He describes the larva, figures the male and female adults, and also a larva which is very poorly done.

D. Reviglias, in an article entitled "De Culicum Generatione," in the Acta Acad. Nat. Curios., 1737, T, 4, Obs. 3, p. 420, gives a study of the mosquito's beak, and figures very poorly the adults. He gives an illustration of a larva which is obviously not a mosquito larva, but that of a dermestid beetle which had found its way under the glass in which the female mosquito had been confined.

In 1734 Réaumur began the publication of his "Mémoires pour servir à l'Histoire des Insectes," and in his fourth volume (1738), has, as his thirteenth memoir (pp. 573–636), his famous "Histoire des Cousins" in which he describes the entire life-history and structure of *Culex pipiens* with a wealth of detail that is almost the despair of modern naturalists—in fact, few modern works even approach it, if we except Lownes's classical study of the anatomy of the blow-fly. The observations of Réaumur were so full, and his authority was accepted as so all-satisfying, that the publication of this memoir practically put a stop, for a hundred and fifty years, to all further studies of the aspects of mosquito life. The general works published in that period derived their information concerning mosquitoes from the standard observations of Réaumur, and this, it may parenthetically be stated, holds for a number of the other studies made of common species of insects by the famous French author. And this confidence in him has in the main been fully justified, although here and there a different interpretation is possible in the light of later knowledge, especially in physics and in microscopic interpretation. While it is not strange that his accurate observations on the transformations and structure should have been followed by later writers, frequently without credit, it is a curious fact that the duration of the different stages as ascertained by him in Paris prior to 1738 should have been slavishly quoted in standard works as the duration of the stages of practically all mosquitoes. Down to the publication of the life-history of *Culex pipiens* in America by one of us in 1896, the data established by Réaumur in a different part of the world have been considered as applicable to all mosquitoes. The frequent references to Réaumur by Miall in his admirable book entitled "The Natural History of Aquatic Insects," published in London in 1895, shows that even at the present time, and with the latest instruments and methods of research, the French author practically remains standard.

Most of the accounts of the early writers are based on material obtained from rain-water barrels or like receptacles and consequently treat of the same species of mosquito, the common *Culex pipiens,* or at most closely related forms. As we have already mentioned, the transformation so faithfully described by Wagner was not that of a mosquito but a *Chironomus,* a midge quite similar in general appearance. A Parisian naturalist, Joblot, in 1754, was the first to describe the larva of *Anopheles* in "Observations d'histoire naturelle, faites avec le microscope, sur un grand nombre d'Insectes." We have not seen this work.

The Swedish naturalist, De Geer, in the sixth volume of his "Mémoires," published in 1776, gives a chapter on mosquitoes with many interesting original observations. He had already determined that the adults are by no means restricted to a blood diet. He states that they visit various flowers to suck honey and that he had found them particularly abundant on the blooms or catkins of the willow. He gives an excellent description of the mating habits and of the swarms of dancing males. He appears to have been the first to observe the larvæ of the species of *Aëdes* which develop in the snow-water of early spring and which are the predominating mosquitoes in northern countries. "It is in the stagnant waters of ponds and swamps that the larvæ of mosquitoes live, and which swarm with them in the spring and summer; but it is principally during the first season, and in those in which the ice has melted, that one finds them in abundance." Very naturally De Geer confused the species of *Culex* and *Aëdes,* and to complete his description of the life-history he drew upon Réaumur, repeating his statements for *Culex pipiens* regarding the eggs, the succession of generations and the mode of hibernation. The *Aëdes* he appears principally to have had under observation have but one brood and lay their eggs singly, facts which have only been determined within the present century and which will be found discussed in our general account of the habits of mosquitoes.

The German miniature painter Kleemann published, in continuation of Rösel's "Insecten-Belustigungen" a remarkable work under the title "Beyträge zur Natur- und Insecten-Geschichte." The work in some respects even exceeds that of the famous Réaumur. Thus we find in the chapter on mosquitoes (vol. 1, 1792, pp. 125–148, plates 15 and 16) that, while he gives the observations of Réaumur and others, he has verified them by observation, adding to them, and in some cases criticizing them. His plates, particularly the one illustrating the life-history of *Culex pipiens*, are wonderfully characteristic, exquisite in execution, and stand unsurpassed to this day. Like De Geer, he found the *Aëdes* larvæ which appear in the early spring in snow-water, although, like that author, he failed to realize that they were different from the rain-barrel mosquitoes, assuming that they were the first of a series of generations produced through the warmer months. He is quite pardonable in this, as the error persists with many even to this day.

Kleemann calculated that there could be three generations of mosquitoes during a season. After speaking of the retarded development of the larvæ, when confined in a small receptacle, he says (free translation):

"However, *in this year 1762, with long-continued warm spring weather*, I found this out in the following manner: I had already found these worms, full grown, in a wooden vat in which rain-water had been caught, at the beginning of June, and soon brought some of them to transformation. On this account I emptied it out and left it standing for some days without water. Towards the end of the month, however, I had it again filled with clean water and at the beginning of July found very many mosquito eggs therein, which brood then came to completion at the beginning of August. Thereupon I emptied the vat once more and again filled it with clean water, and also found in this, after some days, mosquito eggs which hatched in the middle of September. Even in October of this year I have still found mosquito eggs, the worms of which, however, at present (towards the end of this month) do not incline to transform: therefore I believe that they will hibernate without food and only transform in the spring; as I have also found the like full-grown worms already in April and May in the *swamps of the forests*; yes, even *in March of this year*, on a *bright day, I have* caught a male mosquito which I could not take for a hibernated one but for one freshly issued."

As above stated, the other general accounts of the last century followed Réaumur, and the life-history of *Culex pipiens* was not restudied until 1896, and of other mosquitoes not until several years after this. Since 1900 the whole civilized world has been turning out mosquito literature, good, bad, and indifferent; papers descriptive of new species have multiplied, many accounts of habits have been published, and much space has been devoted to the subject of internal anatomy, so that since that date the bibliography of mosquito literature has run into many thousands of titles.

STRUCTURE OF THE ADULT MOSQUITO.

THE HEAD.

The head is more or less globose, inserted upon a slender, flexible neck, a large part of its surface occupied by the eyes; there is a prominent clypeus, the antennæ are long, and the mouthparts consist of a long sucking proboscis and a pair of palpi, usually considered maxillary, inserted at its base. There are no ocelli.

THE EYES.

The many-faceted compound eyes are large, in most species almost or quite contiguous above and beneath. In front the eyes are deeply emarginate to make place for the insertions of the antennæ and the depth of the emarginations varies with the size and place of insertion of these organs according to the species or the sex. As the basal joint of the antennæ is often much larger in the male than in the female, in accordance with this the emargination of the eyes is deeper in that sex.

Aside from the emargination the eyes of the two sexes usually differ somewhat in shape and those of the female may be somewhat larger than those of the male. In the culicine tribe the eyes are markedly broadest at the sides and are much narrowed above the antennæ, particularly in the male; beneath they are broad and may be contiguous in their whole width. In the Sabethini the eyes are nearly as broad behind the antennæ as at the sides and the sexual differences are less marked. In certain genera of this tribe the eyes are broadly contiguous behind the antennæ; in other forms a chitinous wedge is inserted between the eyes *in such a manner that the eyes touch at their hindermost angles and diverge* towards the front. In a curious sabethid from the Philippine Islands, ***Heizmannia scintillans,*** the eyes are separated above by a broad strip of chitin, almost a third the entire width of the head. In the Culicini the eyes, when contiguous above, are never contiguous along the entire margin. The chitin of the occipital region is produced wedge-shaped between the eyes; when this wedge is small the eyes are contiguous, when large they are separated, the separation being usually greatest at the broadly rounded hind angles. In this tribe the median suture of the occiput may be seen continuing forward between the eyes thus clearly indicating that the intra-ocular wedge belongs to the occiput. In the Sabethini, as already mentioned, a wedge is inserted anteriorly and the eyes are approximated at their hind angles.

In addition to the compound eyes there are present a pair of rudimentary or vestigial eyes. These are situated laterally, close to the hind margin of the compound eyes. They are covered by the scale vestiture of the cheeks and are therefore not visible; however, they become plainly visible in a balsam preparation in which the pigment of the eyes has not been destroyed. These vestigial eyes consist, in fact, wholly of groups of pigment cells; there does not appear to be any modification of the chitin overlying them, and of course there is no trace of the "rod and cone" structure of the compound eyes. We shall revert to these vestigial eyes again in our discussion of the eyes of the larva.

THE ANTENNÆ.

The antennæ are composed of fifteen segments. The basal segment is greatly reduced and not distinctly visible, and therefore in descriptive work the antennæ are considered as fourteen-jointed.

Child, who demonstrated the presence of the basal rudimentary segment, states that the antenna is made up of sixteen elements, but he was in error with the number of joints in the shaft. In all Culicidæ examined by us the number of antennal joints, both in the male and female, have been found the same, fifteen, if one counts the basal reduced joint. The second joint differs from all the others; it is large, globose, with a cup-shaped hollow on top, and upon the floor of this hollow the third joint is inserted. In descriptive work this joint is usually termed the torus. This joint constitutes a highly specialized sense-organ, generally accepted to be an organ for the perception of sound waves. Farther on we will give the details of structure of this organ and a discussion of its functions. The joint differs considerably in size in different species and in the two sexes. The torus is largest in the male and this sexual difference is most marked in those species in which the male antennæ are strongly plumose. The tori are usually naked and smooth; often they are pruinose and sometimes more or less densely clothed with scales; there may be small scattered hairs present upon the surface.

The outer thirteen joints constitute the shaft and are slender, more or less elongate, and cylindrical; they are more or less pubescent and each bears a whorl of hairs. The appearance of the shaft, and the details of structure of the component joints, differ considerably with the species and groups of species and particularly in the two sexes.

The simplest form, perhaps, is that which obtains in the females of *Culex, Aëdes, Anopheles*, and related forms. In these the joints are elongate, cylindrical, subequal, with a whorl of long hairs at the base; the fourth joint (the second of the shaft) is the shortest, each succeeding joint progressively longer. The first and the last joints of the shaft differ most from the others. The first joint of the shaft is longer than the succeeding ones and usually more or less swollen; it also differs from the others in lacking the basal whorl of hairs and bears instead some irregularly inserted hairs near its middle. The terminal joint is the longest of the series and has a pointed apex; besides the basal whorl it has a whorl of sparse hairs just below the tip.

In some forms there is an apical whorl of smaller hairs upon all the joints of the shaft, but these do not show the regularity of insertion of the basal whorl of hairs. Besides these coarse hairs of the whorls there are many fine hairs, inserted in sensory pits, scattered irregularly over the surface of the joints; they vary in coarseness and abundance with the species. In addition scales may be present on some of the joints—particularly the first joint of the shaft is sometimes densely clothed with scales, as in *Megarhinus* and *Aëdeomyia*. The shape and proportion of the joints differs considerably in different genera. Thus in *Aëdeomyia* the joints are very short and stout, the second joint of the shaft hardly longer than broad; the succeeding ten joints are subequal, hardly twice as long as thick. The opposite extreme is reached in *Deinocerites*, where the joints of the shaft are slender and very long.

In a majority of the species the antennæ of the male are plumose; that is, the joints of the shaft are shortened, bringing the whorls of hairs close together, and the whorls themselves are composed of longer and much more numerous hairs. The torus, as already mentioned, is larger in the male, and this contrast is greatest in the forms in which the male antennæ are differentiated most. In the typical plumose antenna the whorls of the first eleven segments of the shaft are subapical, the basal one bearing a whorl as well as the others. The last two joints are very long and slender and bear basal whorls of hairs. On all but the last the slender segment is greatly expanded at the insertion of the whorl in order to accommodate the numerous, closely crowded hairs; the whorl does not form a complete circle, but there is a very slight interruption on the outer side. The first joint of the shaft is much longer than the succeeding ones and it bears coarse hairs upon the part below the whorl. The short segments, aside from the whorl, are smooth or nearly so; sometimes very small hairs are present upon the very short chitinous ring just above the whorl. The two last very long joints are densely hairy beyond the whorl, the hairs of the penultimate joint are particularly long and thus complete the plumose effect. The last joint is pointed at the tip, its whorl contains fewer hairs and they are inserted as in the female.

Raphaël Blanchard, in *Les Moustiques*, pages 45 and 47, states that the *antenna of the female has fourteen joints, that of the male fifteen, following* Ficalbi in this respect. In fact, the number of segments is the same in both sexes. Ficalbi's error occurs, as one can readily see by his figure, with the first joint of the shaft of the male antenna; the parts above and below the whorl are regarded as separate segments. This was done, apparently, in the attempt to homologize the antennæ of the two sexes and, as the third antennal joint of the female bears no whorl, it was natural to consider the basal part of the same segment of the male as a unit, and the part beyond, with the whorl at its base, as a separate segment.

Many modifications occur in the different genera and species. In the male of *Megarhinus* the antenna is remarkably stout and rigid; the first joint of the shaft is unusually long and very stout, clothed with numerous coarse hairs and a dense covering of scales; the whorl is apical. In the succeeding ten joints the whorls are much nearer base than apex, and the apical part of the joints is distinctly hairy.

In *Culex latisquama* the antennæ of the male are remarkably long, nearly equaling the considerably lengthened antennæ of the female. They are of the usual plumose plan but there is a lengthening of all the joints; even the two terminal joints are longer than in the ordinary type and the last joint is the longest; the ten shorter subequal joints are from three to four times as long as broad and bear the whorl slightly below the middle, the part above the whorl being pubescent. The hairs of the whorls are unusually long.

In *Culiseta* the antennæ of the males are usually as in the typical *Culex* males; in *Culiseta inornatus*, however, the male antennæ approach in character those of *Culex latisquama*, just described. The subequal joints of the shaft have the part above the whorls lengthened and the hairs of the whorls are less numerous, so the antennæ do not present the usual plumose appearance. Thus it will be seen that considerable differences in the character of the male antennæ may occur within a genus.

Another striking example of such difference occurs in the genus *Uranotænia*, where they are usually distinctly plumose in the male. In *U. lowii*, however, the male antennæ closely resemble those of the female. In the males of *U. sapphirina* and *U. geometrica*, with distinctly plumose antennæ, the joints of the shaft are long and slender; the whorls are basal and consist of numerous very long hairs and the part beyond the whorl bears many, irregularly inserted, long hairs which give the effect of a secondary whorl; the last two joints are lengthened, but not to the same degree as in the forms first described; these joints are coarsely hairy and the whorl on the last one is represented by a few hairs, inconspicuous among the general pubescence. Thus, in these forms, the antennæ, while distinctly plumose, approach in structure those of the female. In *U. lowii* the male antennæ are like those of the female. The joints of the shaft are long, cylindrical, and very coarsely hairy; the whorls are basal and consist of a few coarse, moderately long bristles; the two last joints are not modified in the manner of the plumose type and only the last joint is somewhat lengthened.

The mosquitoes of the genera *Deinocerites* and *Dinomimetes* are remarkable for the very great length of their antennæ, those of the male even exceeding those of the female. The joints of the shaft are cylindrical, long and slender, coarsely hairy, with a basal whorl of but few hairs. The first joint of the shaft is always very long and differs from the other joints by lacking the whorl-hairs. In the female of *Deinocerites* the first joint is three or three and a half times as long as the one following it and at least fourteen times as long as its own diameter. The other joints are subequal, each successive one becoming slightly shorter. The antenna of the male *Deinocerites* closely resembles in character that of the female but is still longer and more slender. The second joint of the shaft is nearly as long as the first and the joints beyond shorter slightly in succession; the last five to seven joints, however, are about equal. The relative proportions of the joints differ with the species. There may be a slight thickening of these last joints, most pronounced in the terminal one, the species differing in this respect. Thus in *Deinocerites troglodytus* the last seven joints show a thickening, while in *D. cancer* the last joint only is distinctly swollen.

In *Dinomimetes* the female antenna approaches very closely in character that of the male *Deinocerites*. The first four joints of the shaft are greatly elongated, the second nearly as long as the first, the next two somewhat shorter. The antennæ of the male *Dinomimetes* are very similar but lengthened still more. In both these genera the whorls are inconspicuous and consist of few and rather short hairs and they are further obscured by the presence of scattered equally coarse hairs among the general pubescence of the shaft.

The antennæ of *Dinanamesus* are intermediate in character between the forms just discussed and the ordinary culicine type, both as regards length and the nature of the hairs.

In the Sabethini the antennæ of the two sexes are usually similar and those of the female may in many cases be characterized as sparsely plumose. In the genus *Joblotia*, however, the antennæ approach closely the culicine type. In the female the hairs of the whorls are longer than in the culicines and there is a crowding of cilia towards the tip of the joints, giving the effect of a small apical whorl. In the male *Joblotia* the antennæ are densely plumose but differ from the common type by having the whorls basal and by having the penultimate joint densely clothed with long hairs. In the common type of sabethine antenna the joints of the shaft are slender, cylindrical, with a basal whorl of long hairs and an apical whorl of short hairs. The apical whorl is a modification of the general pubescence of the joint and is variously developed according to the species. The shaft of the male antenna is often longer and more slender than in the female. When the hairs of the whorls are sufficiently abundant the female antennæ appear sparsely plumose, like those of the male. The last two joints of the male antenna are somewhat longer than the preceding ones, but these differences are less marked than in the culicine forms. This lengthening of the last two joints also occurs in the females of some species, but usually it is only the last joint that is longer in this sex.

The globose second antennal segment, as we have already mentioned, is a highly developed organ of sense. Child has investigated this organ anatomically and histologically in the most careful manner, not only in a number of Nemocera, including *Culex*, but in insects of other orders. He succeeded in tracing the organ, variously modified, in nine different orders of insects. The organ reaches its highest development in the Nemocera, and, as it was first recognized as a sense-organ by Johnston, Child has named it Johnston's organ. The function of this organ has been frequently discussed. As our present knowledge of mosquito habits tends to modify the generally accepted ideas regarding its function, a description of the organ itself is essential. We translate this, as far as seems necessary, from Child's classic paper, and adhere to his procedure in first describing the organ in *Corethra* (*Mochlonyx* auct.), a non-biting culicid, and following with a comparative description in *Culex*. The conditions in the male of *Corethra culiciformis* are as follows:

"The cup-shaped second segment is 0.15 mm. in length and 0.25 mm. broad. The hollow of the cup, in which the shaft is attached, measures 0.08 mm. in diameter and is 0.05 mm. in depth. The outer surface of the segment is densely clothed with very small setæ and in addition with a few larger ones. This segment rests upon the annulate segment which is hidden in the anterior surface of the head, so that the movement of the entire antenna is brought about by the muscles attached here.

"It is this second segment which contains the sense-organ in question, Johnston's organ, an organ of great development and very complicated structure (pl. I,

Explanation of Plate I.

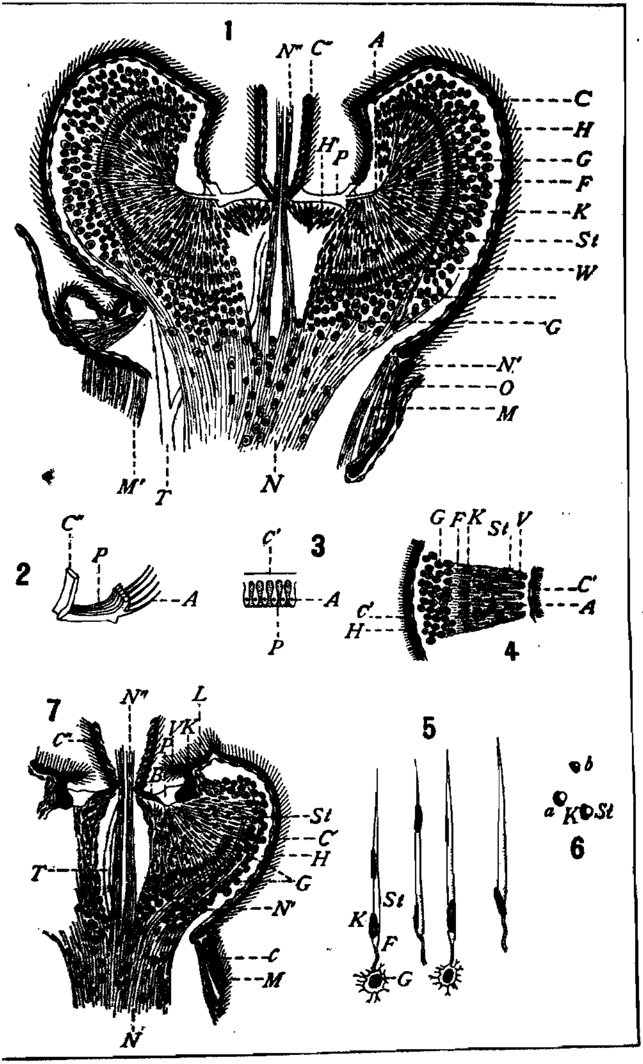
ANTENNAL SENSE-ORGAN OF CULICIDÆ.

Figs. 1-6. *Corethra culiciformis* Degeer.

1. First and second antennal segments of mature male; longitudinal section.
   N, main antennal nerve.
   M, antennal muscles within first segment.
   O, anterior head-integument.
   C, chitinous covering of first segment.
   G', posterior portion of layer of ganglion cells.
   N', nervecord which passes through layer of ganglion cells.
   W, transition stages between rods and hypodermal cells.
   St, layer of rods.
   K, basal nuclei of the rods.
   F, fibrous layer.
   G, layer of ganglion cells.
   H, single layer of hypodermis.
   C', *chitinous covering of the second segment.*
   A, chitinous process of plate.
   P, the plate.
   H', mass of hypodermis behind plate.
   C", chitinous covering of first segment of shaft (third antennal segment).
   N", nervecords of antennal shaft.
   M', muscles of head.
   T, trachea.
2. Part of plate with processes drawn in perspective.
   A, chitinous processes.
   P, plate with radial thickenings.
   C", chitinous covering of first segment of shaft.
3. Section through periphery of plate showing bases of processes.
   A, transverse section of a process.
   C', chitinous covering of second antennal segment.
   P, peripheral part of plate.
4. Sector at about point *A* of fig. 1 of transverse section of second antennal segment of male.
   A, chitinous process seen in transverse section.
   C', chitinous covering of second segment.
   V, radiate spaces between groups of rods.
   St, rods.
   K, basal nuclei of rods.
   F, fibrous layer.
   G, layer of ganglion cells.
   H, hypodermis of second segment.
5. Rods.
   G, ganglion cells of rods.
   F, fiber.
   K, basal nucleus.
   St, body of rod.
6. *Transverse sections of rods; a, through base of a rod; b, through upper nucleus.*
   St, body of rod.
   K, nucleus of rod.

Fig. 7. *Culex*. First and second antennal segments of female; longitudinal section.

N, main antennal nerve.
M, muscles of first segment.
C, chitinous covering of first segment.
N', nervecord which supplies second segment.
G, outer and inner layers of ganglion cells.
H, hypodermis.
C', chitinous covering of second segment.
St, rods.
L, *K*, *V*, thickened parts of chitinous covering of second segment.
P, plate.
B, base of shaft.
C", chitinous covering of first segment of shaft.
N", nervecords of shaft.
T, trachea.



After C. M. Child.

Antennal sense-organ of Culicidæ.

fig. 1), especially in the male. As mentioned above, the shaft of the antenna (pl. I, fig. 1, C''') is inserted in the center of a plate which is striped with radial thickenings of the cuticula (fig. 1, P; fig. 2, P) and which forms the floor of the cup-shaped depression upon the distal surface of the segment. Through an opening in its center the tracheal trunk and the nerves (fig. 1, N'', T) penetrate into the shaft of the antenna. Around the base of the shaft the plate is 0.01 mm. in thickness, however, towards the periphery it becomes somewhat thinner, then again thicker. At the same time it bends forward and joins the chitin covering the sides of the cup-shaped depression. This plate therefore, when seen from in front, has the form of a radially striped saucer with an opening in the center. From the periphery of this plate, in its entire circumference, there arise in a lateral direction 70 to 90 fine chitinous processes, 0.03–0.05 mm. in length, which gradually bend forward (fig. 1, A, 2, A) and which serve as points of attachment to the nervous end-organs in the manner to be described later. The processes do not take their origin from the surface of the plate but from deep within its substance. This is proved by the fact that in a section through this part of the plate from front to back the transverse sections of the processes can be recognized as small, more strongly light difracting circles (fig. 3, A) within the surrounding mass of the plate substance. The plate is composed of cuticular substance and its posterior surface is covered by a layer of hypodermal cells (fig. 1, H'). The plate is affected by different coloring substances in entirely the same manner as the connecting membrane between the antennal segments; for this reason and others to be mentioned below, it is not to be looked upon as a separate segment of the antenna but simply as connecting membrane.

The outer surface of the segment, as well as the sides of the cup-shaped depression up to the margin of the plate, which also belong to the surface, is formed by a layer of chitin, 0.005–0.008 mm. in thickness (fig. 1, C'). At the anterior margin of the cup its hollow is somewhat narrowed by the thickening of the chitin (fig. 1). At the base also, which serves as point of insertion for the muscles moving the antenna, the chitin is somewhat thickened. Under the chitinous layer there lies the hypodermal layer which in the imago generally consists of very small cells (fig. 1, H).

"Separated from the chitinous covering by a narrow space there is a layer of ganglion cells, 0.02–0.04 mm. in thickness (fig. 1, G),* consisting of nearly round, indistinctly defined ganglion cells of about 0.005 mm., which possess comparatively large nuclei. In preparations by maceration one sees that from the cells fine protoplasmic processes proceed (fig. 5, G). Owing to these fine threads, which are probably connected with each other, this layer has the appearance, under low magnification, of a nearly homogeneous mass densely filled with nuclei.

"Still farther inward, between the ganglion cells and the end-organs, there lies a layer, 0.005–0.007 mm. in thickness, of fibres running in two directions (fig. 1, F; 4, F). One set of these connects the ganglion cells, with the end organs, the others cross these at right angles from behind forward; these are fibres originating from the large antennal nerve and which connect with the ganglion cells. On the posterior portion of the ganglion layer the place can be detected where this nerve fiber passes through the cell layer (fig. 1, N'). It is noteworthy in this connection that the nerve fibres, which supply the larger part of the cell layer, lie between these and the end-organs instead of on the outer side of the layer, as in the posterior section. The smaller portion of the ganglion cells lying within the posterior half of the organ (fig. 1, G') connect mostly with fibres emanating directly from the nerve.

* "With reference to the cells my drawings are diagrammatic. I have not attempted to draw in the fine processes."

"This part of the organ contains only such cells and nerve-fibers as are found in the ganglion of every sense-organ composed of several elements, and in this case they are, moreover, very similar to the elements of the optic ganglion of the same animal. Its cells show the same size and also appear to stand in connection with each other by a net-work of protoplasmic fibers.

"More differentiated are the end-organs proper which form the remainder of the nerve-elements filling the interior of the chitinous capsule (fig. 1, *St*; 4, *St*). These lie inward from the layer of fibers and consist of a great number of small, thin, rod-like structures which can only be distinguished clearly in an isolated state, after maceration. Such a rod (fig. 5) is 0.04 to 0.05 mm. long, 0.002 to 0.003 mm. in diameter at its base, and represents a very pointed cone on the sides of which are generally found two oval nuclei, 0.005 to 0.008 mm. long and rich in chromatin, of which one is situated basally and the other towards the apex. In transverse section (fig. 6) the nucleus lies, perhaps covered by a thin layer of protoplasm, upon the surface of the rod, which is clasped more or less by it. At its base the rod gradually passes over into a fiber which proceeds through the fibrous layer to the ganglion cells (fig. 5, *F*). The body of the rod itself behaves towards stains like a cell-body but appears to be of more solid consistence and in preparations by maceration often shows an inclination to split from the apex into two or three fibres. Ontogeny proves that the rods are formed from the cell bodies. The rods are attached or hang by their apices from the chitinous processes of the above described central plate (fig. 1, *A*), and mostly upon their posterior surface. As is proved by maceration, this connection is a very firm one, for sometimes the apices of the rods may still be seen upon the processes while the larger part of them is already torn away. Through their slender form and close disposition the radiate arrangement is brought about. In longitudinal section (fig. 1, *St*) they correspond approximately with the radii of a circle the center of which is situated somewhat before the chitinous process. In a transverse section through the anterior end of the processes one sees that the rods (fig. 4, *St*) are divided into groups corresponding with them; between these groups there are narrow spaces, through about half their length (fig. 4, *V*), which are probably filled with blood during life. In each group the rods lie close together, and each, in transverse section, possesses several rods. Upon the rods lying next to the interspaces the nuclei are nearer to the apices of the rods than in the others; these nuclei lie upon the surface of the group and bound the interspaces, so, that, in a transverse section through the groups striking the rods at about their middle, one sees the rods and their nuclei as alternating layers; a double layer of nuclei separated by a narrow interspace and a multiple layer of rod-bodies, etc. In their basal portion the groups can no longer be distinguished (fig. 4).

"The antennal nerve arises on both sides from the anterior ventral part of the cerebral ganglion as a large nerve trunk containing ganglion cells. At the point of entrance into the antenna the nerve is nearly 0.1 mm. in diameter (fig. 1, *N*). After its entrance into the second segment the nerve spreads out in all directions and gives off fibers (fig. 1, *N'*) to the ganglion layer in the entire circumference of the organ, and these form a funnel, as it were, upon which the nervous parts of the sense organ are attached. These fibers pass through the layer of ganglion cells and continne into the fibrous layer (fig. 1, *F*), which in the anterior part of the organ separates the ganglion cells from the rods. This funnel is incompletely separated into bundles of fibres by interspersed ganglion cells. Other fibers go directly towards the posterior part of the layer of ganglion cells and from the center of the funnel there arise two thin threads of fibers which pass anteriorly through the opening in the central plate into the shaft of the antenna (fig. 1, *N"*).

"The tracheal system is somewhat complicated and very variable. In general the antenna is supplied by a large tracheal trunk which is present upon both sides of the head. This generally throws off a branch, which, passing towards the median side of the antennal nerve, enters the antenna and in its course sends out a number of branches to the large nerve. Another somewhat larger trunk passes along the lateral side of the nerve-trunk as continuation of the main trunk, probably also throws off branches to the antennal nerve and can also be traced into the antenna. At the base of the second segment both trunks divide into several branches; some of them pass between the ganglionic layer and the hypodermis and divide further, while others penetrate the 'nerve-funnel' and supply the central parts of the organ. At least one of these continues through the opening in the central plate into the shaft of the antenna.

"Beneath the central plate there is a space through which the tracheæ and the nerve cords pass. This space is enclosed at the sides by the 'nerve-funnel,' the layer of ganglion cells and the rods, as well as by some less differentiated cells (fig. 1, *W*) which represent transition states between the rod-cells and hypodermis (*H'*) lying beneath the plate; anteriorly the hollow space is limited by the plate and the hypodermal layer pertaining to it. It is connected, through the opening in the plate, with the interior space of the shaft as well as with the radial spaces between the groups of rods and in consequence it is also connected with the outer space between the hypodermis and the layer of ganglionic cells; during life it is filled with blood fluid.

"The essential among the elements of this highly developed sense-organ are then the rods, which are, as will be shown in the following, modified hypodermal cells. The remarkable size of the organ and the great number of sensory terminal elements, as well as the large nerve-trunk in immediate connection with the cerebral ganglion, point to a function of great importance in the life of the insect or the preservation of the species."

In the female the antenna is more simple and the sensory organ is much smaller and less complicated.

"The part corresponding to the plate of the male consists of a circular plate of cuticular substance surrounding the base of the shaft. Here it is clearly apparent that the plate is nothing but the connecting membrane, and the plate of the male is without doubt homologous with that of the female, only developed to a much higher degree. . . . The rods are in every respect similar to those of the male, of the same size, and also connected with the ganglion cells by fine fibers. Their mode of termination is, however, a different one than in the male. The plate in this case does not possess any processes but the rods terminate with their apices in the substance of the plate itself, and, to be more exact, between the chitinous ring and the base of the shaft. Upon the median and lateral surfaces of the rod-layer lie elongate, less differentiated cells representing intermediate stages between the rods and the ordinary hypodermal cells."

Child gives the following comparison of *Culex pipiens* with *Corethra:*

1. Male:

"The antenna of the *Culex* male shows great similarity with that of *Mochlonyx*. . . . The basal segment is here also rudimentary, somewhat sunken into the head and serves as point of attachment for the antennal muscles.

"The second segment is a comparatively large, cup-shaped organ, the relation of which to the other segments, and its structure, are in general the same as in *Mochlonyx*, so that I do not need to give a separate figure; I only wish to mention a few points in which the two forms differ from each other. The entire segment measures 0.17 mm. in length and 0.12 mm. in breadth, therefore is smaller than in *Mochlonyx*. The hollow of the cup is proportionally somewhat deeper and larger. The ganglion cells, instead of lying in one, lie in two layers separated from each other by nerve-fibres. Accordingly the nerve, which corresponds to the nerve N' (fig. 1), divides into two parts, of which one passes between the two layers of ganglion cells, and the other between the inner layer and the rods.* The rods are somewhat shorter and more slender than in *Mochlonyx*. Their length fluctuates from 0.02 to 0.025 mm. They appear shorter in the anterior part of the organ than in the posterior. Their nuclei are richer in chromatin than the ganglion cells."

2. Female: The following gives the essential parts relating to the organ:

"It departs in its structure from that of the female *Mochlonyx* and forms, to a degree, a transition between this and that of the male.

"The form of the entire segment is that of a very thick-walled cup provided with a very shallow hollow (pl. I, fig. 7); in this hollow the shaft is placed, the base of which is formed by a disk perforated by a central opening (fig. 7, *B*). In connection with this disk and covering its peripheral part, is the connecting membrane (*P*), which, as in the male, is furnished with radial thickenings and corresponds to the plate. The noteworthy thing is that here the base of the shaft forms a part of the floor of the depression. I consider this part *B* as belonging to the shaft because it is in direct connection without interruption with the lower part of the shaft and no difference can be detected from the chitinous covering of this. At the same time the demarkation between it and the connecting membrane or plate (*P*) is very distinct. The latter is nearly transparent, like the plate of the male, and appears to possess a consistency different from that of the common chitin. The outer wall of the depression is formed by a thickened portion (fig. 7, *K*) of the chitinous covering of the second segment with an annulate projecting margin (fig. 7, *V*) which projects towards the shaft and reduces the opening of the hollow. Outwardly from this excrescence the chitinous covering forms a zone covered with blunt elevations which carry fine bristles (fig. 7, *L*). The remainder of the surface of the segment is also covered with short, fine bristles.

"Close below the chitinous covering lies, as usual, the hypodermis of one layer; these are succeeded inwardly by the ganglion cells, which here, as in the male, are arranged in two layers, incompletely divided by nerve fibres. Separated from the inner layer of ganglion cells by a layer of fibres lie the rods, which are directly connected at least with the inner layer of cells by fine fibres. The rods are somewhat longer than in the *Culex* male, about 0.03 mm., but agreeing with them in form. In longitudinal section they lie in radiate arrangement, radiating from the connecting membrane or plate. In transverse section it is seen that, similarly to the male of *Mochlonyx*, the rods form groups (compare pl. I, fig. 4), separated by very narrow interspaces, throughout the circumference of the organ and corresponding to the thickenings of the connecting membrane. On the median and lateral margins of the rod-layer more or less modified hypodermal cells represent the transition stage between rods and ordinary hypodermal cells. Two nerve cords and a tracheal trunk pass through the central hollow space into the shaft of the antenna."

This organ, in conjunction with the antennal shaft and its whorls of hairs, has been generally looked upon as an organ of hearing. The long hairs of the whorls vibrate in response to sound waves of a certain pitch and react upon the sensory organ of the globose second segment. Johnston, in a paper published in 1855, was the first to describe the antenna as a complex sense-organ, and he

* In fig. 7, plate I, belonging to the female of *Culex*, this arrangement is likewise present.

confidently termed the second joint the "auditory capsule." His studies were evidently influenced by his knowledge of the structure of the vertebrate ear, not only in the interpretation of the anatomical structure of the organ, but, in consequence, also of its functions. Probably inadequate microscopes and methods contributed in large part to his errors. He described what he found as follows:

"The auditory capsule is filled with a fluid of moderate consistency, opalescent, and containing minute spherical corpuscles, and which probably bears the same relation to the nerve as does the lymph in the scalæ of the cochlea of higher animals. The nerve itself of the antenna proceeds from the first or cerebral ganglion, advances towards the pedicle of the capsule in company with the large trachea which sends its ramifications throughout the entire apparatus, and, penetrating the pedicle its filaments divide into two portions. The central threads continue forward into the antenna and are lost there; the peripheral ones, on the contrary, radiate outwards in every direction, enter the capsule space, and are lodged for more than half their length in sulci wrought in the inner wall or cup of capsule.

"In the female the disposition of the parts is observed to be nearly the same, excepting that the capsule is smaller."

Assuming the conditions to be such as described it was very natural to attribute to the organ complex functions. Johnston sums up his reasons for believing the antenna an auditory organ of high perfection as follows:

"The position of the capsules strikes us as extremely favourable for the performance of the function which we assign to them; besides which there present themselves in the same light the anatomical arrangement of the capsules, the disposition and lodgment of the nerves, the fitness of the expanded whorls for receiving, and of the jointed antennæ fixed by the immovable basal joint for transmitting vibrations created by the sonorous modulations. The intra-capsular fluid is impressed by the shock, the expanded nerve appreciates the effect of the sound, and the animal may judge of the *intensity*, or *distance*, of the source of the sound, by the *quantity* of the impression: of the *pitch*, or *quality*, by the consonance of particular whorls of the stiff hairs, according to their lengths; and of the *direction* in which the undulations travel, by the manner in which they strike upon the *antennæ*, or may be made to meet either *antenna*, in consequence of an opposite movement of that part."

A. M. Mayer, in the course of his researches in acoustics, made most interesting experiments with the supposed auditory function of the antennal hairs of the male mosquito. With tuning-forks, he showed that some of the hairs are of such a structure that they vibrate in response to sound-waves numbering 512 per second. Other hairs vibrated to other notes, showing altogether a considerable range. He says:

"I infer from my experiments on about a dozen mosquitoes that their fibrils are tuned to sounds extending through the middle and next higher octave of the piano."

Mayer carried his experiments farther, and, taking accurate measurements of the thickness and length of two hairs which vibrated in response to the tuning-forks Ut 3 and Ut 4, made large wooden models of them. The model of the hair vibrating to the Ut 3 tuning-fork was a meter in length. These models responded to vibrations of approximately the same number as the hairs themselves.

Perhaps the most interesting result of his experiments was the discovery of the fact that the antennal hairs enable the mosqnito to determine the direction from which the sound-waves proceed. He experimented with the song of the female and found that the hairs of the male antennæ vibrate when the song of the female comes more or less at right angles to them, while those which point to or from the source of sound are not affected. If the song is directly in front of the head it will be most fully received by the antennal hairs. If the song of the female affects one antenna more than the other, the male, by turning until both antennæ are equally affected, could thus determine the direction of the female.

"The song of the female vibrates the fibrillæ of one of the antennæ more forcibly than those of the other. The insect spreads the angle between his antennæ, and thus, as I have observed, brings the fibrillæ, situate within the angle formed by the antennæ, in a direction approximately parallel to the axis of the body. The mosquito now turns his body in the direction of that antenna whose *fibrils are most affected, and thus gives greater intensity to the vibrations* of the fibrils of the other antenna. When he has thus brought the vibrations of the antennæ to equality of intensity, he has placed his body in the direction of the radiation of the sound, and he directs his flight accordingly; and from my experiments it would appear that he can thus guide himself to within 5° of the direction of the female."

While Mayer accepted the function of the antennæ as auditory, he clearly perceived that no comparison could be made with the sense of hearing in the higher vertebrates, and expresses his conclusions in these terms:

"Some may assume from the fact of the co-vibration of these fibrils to sounds of *different pitch, that the mosquito has the power of decomposing the sensation* of a composite sound into its simple components, as is done by the higher vertebrates; *but I do not hold this view, but believe that the range of co-vibration of* the fibrils of the mosquito is to enable it to apprehend the varying pitch of the sounds of the female. In other words, the want of definite and fixed pitch to the female's song demands for the receiving apparatus of her sounds a corresponding range of the co-vibration, so that instead of indicating a high order of auditory development it is really the lowest, except in its power of determining the direction of a sonorous centre, in which respect it surpasses by far our own ear."

Our own observations of the habits of mosquitoes lead us to doubt that the antennæ, if auditory at all, are so in their primary function. The foregoing hypotheses are founded upon the assumption that the male seeks the female and is attracted by her song. In fact such is not the case. At least in those forms in which the antennæ of the male are most highly specialized the males "swarm" and the female seeks the male. In our experience the song of the female does not attract the male. Mayer appears to have come very near the truth when he found that the antennæ served for orientation. One of us (Knab) has observed that the males in a swarm always dance facing the breeze or air-current, no matter how slight this may be, and adjust themselves instantly to any shifting of the breeze. Why this is done would be difficult to explain, but that the antennæ make this possible is clearly apparent from Mayer's observations. Of course it can not be denied that the antennæ are perhaps also, in a very rudimentary way, auditory in function. Child already observed the great sensitiveness of the swarms of dancing males to sound vibrations,

"moreover not alone to the higher, but also to deeper tones. If one sings a deep note in the vicinity of a swarm, the entire swarm is immediately thrown into confusion which lasts several seconds. . . . Faint noises have the same effect, naturally in a lesser degree. I have observed the same from the whistle of a locomotive, even when this was one or two kilometers away. If one approaches a swarm of gnats in a boat, upon some sudden noise, such as a stroke of the oars, the entire swarm is thrown into a wild dance and frequently flies away or dissolves. As, however, with great care, even with fairly rapid movements, one can get close to the swarm without the gnats reacting in any way, it follows that the disturbance is caused by the sound and not by a visual impression. From these observations of course nothing can be concluded regarding the location of the organs of hearing; it is only proved thereby that the gnats are very sensitive to sound. But because it is in these insects that an organ occurs which appears especially equipped for the reception of air-vibrations, the probability of a connection with that behavior is very great."

While it is evident from the foregoing that mosquitoes react to sound-waves, it is by no means clear that they can perceive them as such. If the sound-impressions are received through the antennæ, as the organization of these appendages seems to indicate, it is still to be doubted that there is a differentiation of the impressions produced by sound-waves and other stimuli, such as a current of air, or between sounds of different pitch. Child's conclusion was that the function of Johnston's organ was originally the perception of tactile stimuli, and that when it became more highly developed it also served for the perception of sound-waves. "The resulting 'auditory impression' is a modified tactile impression." It is worthy of note, in this connection, that the male mosquitoes emit a very high-keyed song while swarming; in fact, this sound is so high that it is probably beyond the range of many human ears.

The part of the head inclosed by the eyes and bearing the antennæ shows little specialization, is partly membranous, and in large part hidden by the globose second antennal joints. Medianly, above the antennæ, and resting against the front margin of the eyes, is a small chitinous piece. In the Culicini this is usually rather poorly defined, subquadrate or more or less triangular, with its base resting against the margin of the eyes and the apex projecting forward between the antennæ. In the Sabethini it is conspicuous, although small, in those forms in which the eyes are separated above by a narrow wedge. This wedge, in fact, is a backward extension of the chitinous piece in question; the portion projecting forward beyond the margin of the eyes is prominent and may be either pointed or truncate in front. That part of the front below the antennæ and above the clypeus usually shows no structural peculiarities. In one sabethid genus, *Rhunchomyia*, however, this portion is produced into a tubercle which projects just above the clypeus.

CLYPEUS.

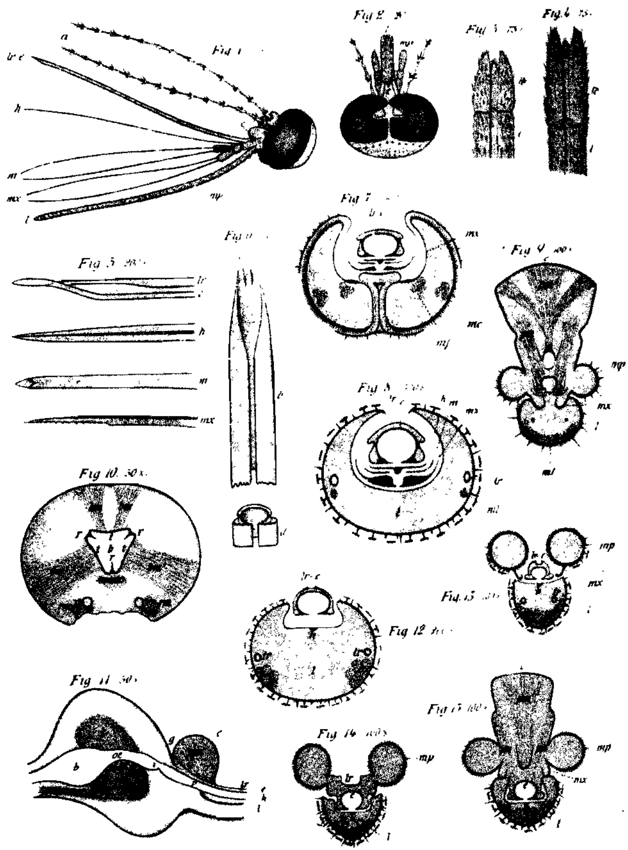
The clypeus is large and prominent, chitinous, and projects above the insertion of the proboscis. Its development is unusual, and this is to furnish a place of attachment, on its inner walls, for the powerful muscles of the epipharynx. It is strongly chitinized above and its shape is roughly globose, or roundedly

Explanation of Plate II.

1. Side view of head of *Culex*, with extended mouth-parts; *a*, antennæ.
2. Same from above with mouth-parts partly cut away.
3. Tip of labium of female *Culex*.
4. Tip of labium of male *Culex*.
5. Tips of separated setæ of mouth-parts of *Culex*.
6. Tip of labrum-epipharynx seen from beneath and in section.
7. Cross-section through labellæ and tip of labium of female *Culex*.
8. Cross-section near middle of the proboscis of female *Culex*.
9. Cross-section through pharyngeal region of forward part of head of female *Culex*.
10. Cross-section through posterior part of head of female *Culex*, to show the sucking bulb of the œsophagus. *b*, lumen of œsophageal bulb; *bm* and *bm'*, muscles to dilate the bulb; *r*, chitinous rods which support the œsophageal bulb; *rm*, retractor muscles of maxillæ, at their point of origin; *t*, elastic plates of sides of bulb.
11. Longitudinal section of head of a female *Culex*. *b*, œsophageal bulb; *g*, point where the clypeus appears cut off from rest of head; *v*, valve between pharynx and œsophagus.
12. Cross-section near middle of the proboscis of a male *Culex*.
13. Cross-section at base of the proboscis of a male *Culex*.
14. Cross-section further into the base of the proboscis of a male *Culex*.
15. Cross-section through pharyngeal region of head of a male *Culex*.

The following letters have the same signification throughout:

c, clypeus.
e, epipharynx.
h, hypopharynx.
i, infraœsophageal ganglion.
l, labium.
lb, labellæ.
lr, labrum.
lr-e, labrum-epipharynx.
m, mandibles.
mp, maxillary palpi.
mx, maxillæ.
oe, œsophagus.
p, pharynx.
pm, *pm'*, pharyngeal muscles.
s, supraœsophageal ganglion.
tr, tracheal stem.



After Dimmock.

Mouth-parts of Culex.

conical more or less constricted at base. It presents no noteworthy modifications. Its surface is usually naked and smooth, or, due to the presence of very fine hairs, pruinose. In some cases it is densely clothed with scales, and in one genus, *Joblotia,* it bears many scattered coarse hairs, particularly towards the margin.

THE PROBOSCIS.

All true mosquitoes have a long proboscis of complex structure; it is used as a sucking-organ, and in the females of many species as a piercing organ as well. It is most highly organized in the females with blood-sucking habits. The organ was already carefully studied by the early workers with the microscope, among whom may be particularly mentioned Leeuwenhoek, Swammerdamm, Barth, and Réaumur. These early investigators only studied the mouthparts *per se,* without thought of their relations to the mouthparts of other insects. It was not until after the study of entomology had been put on a firm footing by systematists, and the significance of the mouth-parts of insects in classification had been pointed out by Fabricius, that attempts were made to homologize the mouthparts of the different orders of insects. Savigny, in 1816, already developed the idea that the mouthparts of all insects were reducible to the same general plan of those of the chewing insects, and that these mouthparts were the serial homologues of locomotory appendages. The belief that the mouthparts of the mosquito (and of the Diptera in general) are homologous with those of mandibulate insects has been very generally accepted by modern entomologists. It was not, however, until about 30 years ago that any exact knowledge of the organization of the proboscis of the mosquito was reached, the previous analyses having been unsatisfactory from the scientific point of view, and conflicting. In 1880 two careful studies of the mouthparts of the mosquito and of other Diptera, carried out independently with strictly modern methods, were published by Dimmock and by Meinert. Both these works describe very completely the anatomy of the proboscis and related parts; the interpretation of the mouthparts by the two authors, however, is quite different. Dimmock followed the generally accepted idea and homologized the components of the proboscis with the mouth-organs of mandibulate insects. Meinert, on the other hand, concluded that no such homology exists and presented an entirely different interpretation. The studies of Kellogg, of the development of the mouthparts of the dipterous imago within the larva, show conclusively that the generally accepted view is correct and essentially as presented by Dimmock. It seems desirable, however, to present briefly Meinert's views, and also those of other authors when at variance with the accepted interpretation of the facts. Additions to our knowledge of the mouthparts made since by different workers will be also considered. Dimmock's description of the mouthparts of the female and male *Culex* is so clear and full that we reproduce it herewith, together with the excellent plate elucidating the structures (pl. II, opposite page 36).

In the female:

"The mouth-parts which form the proboscis of the female *Culex,* as I have found them by study of *C. rufus, C. ciliatus,* and *C. pipiens,* consist of a labrum (pl. II, fig. 1, *lr*), an epipharynx (*e*), a hypopharynx (*h*), two mandibles (*m*), and two maxillæ (*mx*), all sheathed, when in repose, in the labium (*l*), which receives them into a groove on its upper side. Each maxilla has a maxillary palpus (*mp*), which lies outside the labium; the latter has no palpi. The labium and maxillary palpi are covered with hair and scales; the other mouth-parts are naked, light brown, setiform, and transparent; they all originate at the anterior basal portion of the head, and are, with the exception of the maxillary palpi, of about equal length, that is, about three to four times the length of the head. The maxillary palpi, in the females of *Culex* proper, are about the length of the head. The scaleless mouth-parts are not jointed, and are the ones which penetrate the skin in biting. The labrum and epipharynx are united in their whole length, forming a piece which is shown in section in fig. 6, *d*. The other mouth-parts are free to the base. A pumping organ, trianguloid in cross-section (fig. 10, *b*), is formed by a dilation of the œsophagus behind the œsophageal nerve-ring. Each of the above-mentioned parts will be described more in detail later. In comparative size and strength the mouth-parts would be arranged as follows, the largest and stoutest first: labium, labrum-epipharynx (the name by which I designated this compound piece in diptera), hypopharynx, maxillæ, and mandibles.

"The general arrangement of the mouth-parts, relative to each other, is shown best in fig. 8, which is a figure of a cross-section through the middle of the proboscis of a female *Culex rufus*, while in repose, with the setæ sheathed in the labium. The labium (*l*), clothed on the outer side with its scales and hairs, is wrapped nearly around the other mouth-parts. In it lie the two maxillæ (*mx*), partly enclosing the parts above them, and thus helping to bind the parts together; above the maxillæ are the two mandibles (*m*), and immediately above the mandibles, in the median line, is the hypopharynx (*h*), with a thickened middle portion. Resting on the hypopharynx is the labrum-epipharynx; the epipharynx (*e*) is omega-form in section, and above it, delicately attached, is the labrum (*lr*). The changes in relative position which the mouth-parts of *Culex* undergo as they approach the head can be best described in the subsequent description, in detail, of each separate part.

"The labrum-epipharynx (fig. 1, 5, 6, 7–8; *lr* and *e*) of *Culex* consists of the thin labrum resting upon and fastened to the epipharynx; it tapers gradually from base to apex. The epipharynx is omega-form in cross-section, being a channel rather than a tube, a tube being formed by the pressing of the hypopharynx upon its under side. The tube thus formed is the channel through which the blood, which *Culex* sucks, passes into the pharynx. At its base or proximal end the epipharynx is supported and moved by strong muscles having their insertions on the upper side of its wings or lateral portions, and upon the upper side of its tube. These muscles extend upward and posteriorly, and have their origin on the inner surface of the clypeus. (See figs. 9 and 11.) These muscles (*pm*), by their contraction, elevate, and perhaps slightly retract, the epipharynx and the labrum to which they are attached. These muscles probably *aid* in suction for when the setæ are all stuck firmly in the skin, the contraction of these muscles would only serve to raise the base of the epipharynx from that of the hypopharynx; this action would tend to produce a vacuum between the two (see fig. 9), and thus cause the blood to be drawn up in the tube of the epipharynx. The probability that these muscles aid in suction is augmented by the fact, the explanation of which I have more fully developed in the part of my dissertation devoted to a comparison of the mouth-parts and suctorial apparatus in the different families of diptera upon which I have worked, that the corresponding muscles are devoted to suction in other flies, which cannot raise their epipharynx from their other mouth-parts so freely as is seen in fig. 1, and further, that in the male *Culex*, which does not possess—as does the female— a pumping apparatus behind the œsophageal nerve-ring, these muscles are the ones that must serve for suction. The section represented in fig. 9 was taken near the base of the clypeus; a few sections further on, posteriorly, the channel for the passage of food turns upward and then backward again, passing in its course a place (fig. 11, *v*) where its walls approximate dorsally and ventrally. This narrowing of the walls is probably a valve to prevent the return of fluids to the mouth during the pumping process. The pharynx with its surrounding muscles in *Culex* is the equivalent of what has been termed the fulcrum in *Musca*. Macloskie * writes of the fulcrum, 'It seems to be general in diptera; even the mosquito possesses it,' but he does not further describe it, in other diptera than *Musca*.

"The tip of the labrum-epipharynx seems to turn upward (fig. 1, *lr-e*), although the opening is upon the ventral surface, as may be seen in fig. 6, *b*, which represents the ventral view of the tip of this part. The tip of the labrum-epipharynx is comparable to a quill-pen with three tips near each other, the middle one of these three tips being slightly shorter than the other two. The two lateral portions of the epipharynx, as seen in section, when they near the tip, lay themselves closely upon the sides of the tubular portion, passing upward upon it, as seen in fig. 5, *lr-e;* they thus serve to strengthen the two outer points of the tip of the epipharynx, while the labrum continues to a sharp point at the tip, and, united with the upper surface of the epipharynx tube, forms the middle point of the tip. The channel, or slit, along the under side of the epipharynx, widens toward the tip (fig. 6, *b*), leaving thus an opening for the passage of fluids into the tube of the epipharynx.

"The labrum itself is a thin lanceolate lamella of chitin, concave along the under side from the basal portion to the tip, and its concavity rests upon and fits to the convexity of the tubular part of the epipharynx, to which it is so lightly attached that they readily separate by application of caustic potash. The outer edges of the labrum roll slightly inward toward the epipharynx along most of its length. (See fig. 6, *d*.) At its base the labrum sends a chitinous support beneath the clypeus, where it separates more from the epipharynx and has its own muscles, indicating that the labrum has a degree of motion independent of the epipharynx, a motion allowed, perhaps, by the elasticity of the connection between the labrum and epipharynx. The muscles of the labrum (fig. 9, *pm'*) are inserted upon the upper side of its base and have their origin on the inner surface of the roof of the clypeus. These muscles are, at least in the females of *Culex rufus*, divided into three portions in their upper part, as shown in fig. 9.

"The hypopharynx of the female of *Culex* is a linear, lanceolate, transparent lamella of chitin, with a longitiudinal rod through the middle, the nature of which will be discussed later. At its base the hypopharynx forms the continuation of the under wall of the pharynx. (See fig. 11, *h*.) The hypopharynx is closely pressed upon the under side of the epipharynx, completing the tube nearly formed by the epipharynx. No muscles have their insertion on the base of the hypopharynx. Its tip is simply lanceolate (fig. 5, *h*). In *Culex pipiens* and *C. rufus* nothing further is visible (with a magnifying power of five hundred diameters), in sections of the thicker middle portion of the hypopharynx, than a simple rod of chitin; but, in *C. ciliatus*, a North American species of which the mouth-parts are larger, this rod appeared to be tubular. Is it a rod or is it a tube? Menzbier † writes (p. 25) that in diptera 'neither the labrum nor the hypopharynx possesses a completed tube, but only a channel' which leads into

* Macloskie, G.: The proboscis of the house-fly. (Amer. Naturalist, March, 1880, v. 14, pp. 153-161, figs. 1-8.)

† Menzbier, M. A. Ueber das Kopfskelet und die Mundwerkzeuge der Zweiflügler. (Bull. Soc. impér. natur. de Moscou, 1880, t. 55, no. 1, pp. 8-71, tabs. 2-3.)

the salivary duct. That Menzbier is incorrect in affirming that the hypopharynx has no complete tube I have clearly proved in my observations on *Bombylius* and *Eristalis;* but the question still remains unsettled whether *Culex* has any passage, either tube or groove, through the hypopharynx. Réaumur * (tome 4, *part 2, p. 396) discusses the probability of a poisonous fluid being secreted by Culex,* to cause the blood to flow more readily when it bites, and since his time writers have, on the one hand, accepted this statement, without proving the presence of such a fluid or of the glands to secrete it, or they have, on the other hand, denied the existence of such a fluid and affirmed, as Leeuwenhoek did, that the swelling subsequent to the bite of *Culex* was due to the irritation produced by the tearing of the mouth-parts in the skin, without the aid of a poisonous secretion. After having experimented a large number of times with the living mosquito, I am convinced that there is use made of a poisonous saliva; for, when biting, if the mosquito fails to strike blood, which it often does on parts of the back of my hand, it may have inserted its proboscis (labium of course excepted) nearly full length, in from one to six directions, in the same place, and withdrawn its proboscis; indeed it may have inserted its proboscis, as often occurs, in extremely sensitive parts; yet in such cases, if no blood be drawn, no more effect is produced upon my skin than is produced by the prick of a sharp needle; a red point appears only to disappear in a few hours. Certainly there has been as much tearing of tissues in such a case as the above-mentioned, as there is when *Culex* settles on a place richer in blood, and, with a single probing, draws its fill. When the insect is allowed to draw its fill on the back of my hand, the subsequent swelling lasts from forty to forty-eight hours, and the amount of poisonous effect upon me, as proved by numerous experiments, is in direct proportion to the length of time which the *Culex* has occupied in actually drawing blood. The above-mentioned facts would indicate a constant outpouring of some sort of poisonous fluid during the blood-sucking process, and would necessitate a tube or channel for its conduction. Now, no other channel exists through which saliva could pass from the base to the tip in the mouth-parts which *Culex* inserts in the skin, and this, together with the position occupied by the salivary duct in other diptera, leads me to believe, without as yet being able to give anatomical proof for it, that the hypopharynx of *Culex* contains a duct that pours out its poisonous saliva. Having no fresh specimens of *Culex ciliatus,* and the extreme minuteness of the hypopharynx in the species of *Culex* available, has precluded my determination of the actual presence of glands in connection with this mouth-part.

"The mandibles (figs. 1 and 8, *m*), the most delicate of the mouth-parts of *Culex* are two very thin linear-lanceolate lamellæ of transparent chitin, which rest with their inner edges beneath each half of the hypopharynx, their outer edges projecting beyond its outer edge, on each side. At the base of the proboscis they appear to have no muscular attachments. They are slightly tapering from the base to the tip, but are of equal thickness throughout their breadth; at the tip they have a slight thickening, in form of a letter V, with its opening turned toward their very delicate, almost invisible tip. (See fig. 5, *m.*)

"The maxillæ (mistaken by Gerstfeldt † for the mandibles, but correctly figured by Muhr ‡ on his diagram as maxillæ) are tapering lamellæ of chitin, apparently serrate at the tips. Each maxilla is thicker near the inner edge, the thickening being formed by a solid chitinous shaft, which is fixed longitudinally upon the upper side. (See figs. 5 and 8, *mx.*) The bases of the maxillæ join

* Réaumur, R. A. F. Mémoires pour servir à l'histoire des insectes. . . . [Edition 1737-1748, t. 4, part 2.]
† Gerstfeldt, G. Ueber die Mundtheile der saugenden Insecten . . . . 1853.
‡ Muhr, J. Die Mundtheile der Insekten dargestellt auf 5 Wandtafeln. . . . 1878.

the stouter maxillary palpi just before passing under the clypeus, and immediately afterwards they join the labium, and become imbedded, with the mandibles, in connective tissue. (See fig. 9, *mx*.) Their continuations in the head are two delicate chitin-supports, each of which ends in a strong muscle; this muscle, the retractor maxillæ (fig. 10, *rm*), passes backward and downward through the head, beneath the infracesophageal ganglion, and has its origin in the posterior basal part of the head. The maxillæ probably have no protractor muscle, their forward motion being due to the elasticity of the chitin frame-work of the head. The shaft of the maxillæ is very transparent, except near the inner side where the chitin-rod runs; here it is brownish and more opaque. Out from the above-mentioned chitin-rod extends a very delicate feathering, or corrugation, of chitin to the edge of the most transparent portion of each maxilla, as seen upon the basal portion of fig. 5, *mx*. The tip of the maxillæ (fig. 5, *mx*) is very acute, has none of the before-mentioned chitinous corrugations, but, in their place, near the outer edge, is a row of papillæ, which have their tips slightly recurved toward the head, and consequently appear serrate. These papillæ are upon the upper surface of the maxillæ, as can be readily seen, by preparing the mouth-parts by lateral pressure, as in fig. 1.

"The maxillary palpi (figs. 1, 2, and 9, *mp*) are four-jointed in some species of *Culex*, five-jointed in others. At first sight they appear to be three-jointed, but more careful examination serves to show that the apparent basal joint is made up of two joints, and oftentimes to reveal a very short, knob-like joint at the extremity of what appears to be, at first, the apical joint. At their base the maxillary palpi join the maxillæ just before the latter pass beneath the clypeus, and, with the maxillæ, join the other mouth-parts, as shown, in section, by fig. 9.

"The function of the maxillæ is, probably, to draw the other mouth-parts into the skin, when *Culex* bites, for if one watches the maxillary palpi of *Culex*, while the setæ are entering the skin, the setæ seem to pierce the skin, and enter it with a slow gliding motion, as if drawn from below, instead of pressed from above; meanwhile, if one observes carefully, with a lens, the maxillary palpi can be seen to be in an alternating motion, as if the maxillæ to which they are attached, pressed, first one then the other, into the skin, and then pulled the other parts after them. The muscles, retractores maxillarum, already described, lend weight to this view of the functions of the barbed maxillæ.

"The labium (figs. 1, 2, and 3, *l*), the largest of the mouth-parts of *Culex*, and the only one of them, helping form the proboscis, which contains muscles, forms a sheath opening along the upper side, and receiving in its channel the other mouth-parts (excepting the maxillary palpi), as seen in cross-section in fig. 8; it tapers from base to tip, is flexible, has a delicately annulated structure, and is clothed with hair and scales. At its base it unites with the maxillæ, mandibles, and hypopharynx, and continues into the under surface of the head. Throughout its length it contains, on each side, muscles, which have their origin in the base of the head and serve to control the motions of the labium. (See figs. 8 and 9, *ml*.) At the sides of the tip of the labium are attached two lobiform appendages, the labellæ, which are seen at *lb* in fig. 3 with the true tip of the labium proper between them. These terminal lobes are jointed to the labium, a little distance behind its tip, as can be seen in fig. 7, which is a cross-section of the labium a trifle anterior to the actual centre of motion of these joints. The section of that portion of the labium which extends forward to form its tip is seen in the middle of the figure, just below the section of the maxillæ (*mx*). Outside the section of each lobe is seen the section of a portion of the exterior edge of the labium itself, which here forms a double socket, or pair of acetabula, into which the heads of the two labellæ are set. Each of the lobes of the labium,—the labellæ,—is provided with an extensor and flexor muscle (fig. 7, *me*, and *mf*), and is attached to the labium by a true joint.

"The labium has for function, for the most part, the protection of the fine setæ which form the true piercing organ of *Culex*. In the females of *Culex* proper, the protective sheath is formed by the labium alone. When the mosquito has found a place which suits its taste for piercing, it plants its labellæ firmly upon the spot, and a moment later the labium flexes backward in its middle, the setæ, firmly grouped together, remain straight and enter the skin, while the two labellæ guide them, much as a carpenter guides his bit with his fingers while boring a piece of plank. When the setæ of *Culex* have entered the skin to nearly their full length the labium is bent double beneath the body of the insect, the labellæ still holding the base of the setæ at the point where they enter the skin. When the mosquito wishes to withdraw the setæ it probably first withdraws the two barbed maxillæ beyond the other setæ, that is, so that their barbs, or papillæ, will be kept out of action by the mandibles and hypopharynx; then it readily withdraws the setæ, perhaps aiding their withdrawal by the muscles of the labium, for, during the process of extracting the setæ from the skin, while they are slowly sinking back into the groove upon the upper side of the straightening labium, the mosquito keeps the labellæ pressed firmly upon the skin.

"The mouth-parts of *Culex*, as above described, are suspended under a clypeus, or epistom, which is figured from the side in fig. 1, *c*; from above in fig. 2, *c*; in length-section in fig. 11, *c*; and in cross-section in fig. 9, *c*. This clypeus is the hood-shaped forward continuation of the lower part of a ⅄-shaped piece of chitin which forms the framework of what may be termed the 'face' of *Culex*; right and left of the upper portion of this framework pass out the antennal nerves, the antennæ being supported by the framework itself.

"The pharynx (fig. 11, *p*), the tubular continuation of the epipharynx above and the hypopharynx below, as it passes backward, beneath the centre of the ⅄-shaped framework, turns somewhat upward, is narrowed to the valve previously described, then widens slightly again, and, as œsophagus (fig. 11, *oe*) passes through the œsophageal nerve-ring, in which it is supported by three delicate chitinous rods, which lie, one longitudinally on its ventral surface, and two to the right and left on its dorsal surface. Just posterior to the œsophageal nerve-ring, directly above the nerve-commissure which connects the infra-œsophageal ganglion with the first thoracic ganglion, the œsophagus suddenly expands into an œsophageal pump, or bulb, the longitudinal section of which is shown in fig. 11, *b*; the cross-section in fig. 10, *b*. This bulb, which is the chief sucking organ in the female *Culex*, and which I have found in no other dipteron, is supported by three longitudinal chitinous rods, which are stouter continuations of the three rods supporting the œsophagus through the nerve-ring. These rods (fig. 10, *r*) have between them chitin-plates (fig. 10, *t*) which are suspended from the rods by elastic membranes. On the dorsal plate is inserted a double muscle, or a pair of muscles (*bm*), the origin of which is in the dorsal part of the chitinous shell of the head. Each of the lateral plates has inserted on it a muscle (*bm'*), the origin of which is in the chitin of the lower lateral regions of the head. The origin of each of these muscles is in the so-called occipital region of the head, that is, behind the eyes. By the simultaneous contraction of these muscles (*bm* and *bm'*), the lumen of the œsophageal bulb is enlarged, and the blood flows into the bulb from the pharynx, and, upon their relaxation, the elasticity of the chitinous walls of the bulb, drives the blood, which can not return to the pharynx because of the closing of the valve at *v* (fig. 11), into the stomach."

In the male.

"The mouth-parts of the male of *Culex* have not been described, as far as I know, with any degree of accuracy, although, since Swammerdamm's time, the males have been distinguished from the females, by all scientific entomological writers on the subject, by means of their feather-like antennæ and maxillary palpi.

"The proboscis of the male of *Culex pipiens*, the only species the male of which I have studied, is slightly longer and slenderer than the corresponding organ in the female. The setæ are fewer in number and less completely sheathed by the labium than in the female; they consist of a well-developed labrum-epipharynx and two slightly developed maxillæ. The mandibles are absent, and the hypopharynx coalesces with the labium (fig. 12 *h* and *l*). The labium and maxillary palpi are more densely covered with hair and scales than they are in the females, and they contain muscles; the other mouth-parts, the setæ proper, are naked, chitinous, and contain no muscles. In comparative length the mouth-parts may be arranged, longest first: maxillary palpi, labium and labrum-epipharynx, maxillæ;—in comparative size they may be arranged, largest first: *labium, maxillary palpi, labrum-epipharynx, maxillæ. The relative position of* the mouth-parts of the male is different from that in the female (compare figs. 8–9 with 13–15) in that the short, rudimentary maxillæ are pushed out sidewise to allow the hypopharynx to coalesce with the labium. In the male the œsophageal pump, or bulb behind the nerve-ring, fails, and the sucking of fluids must be done by the pharynx alone, as it is done in most diptera.

"The labrum-epipharynx is nearly the same in general form and structure in the male *Culex* as it is in the female, it is a trifle longer and slenderer, but the same figures (5, *lr-e*, and 6) will serve for the tips of both. In section (fig. 12, *lr-e*), the labrum shows a groove on its upper surface, which deepens as it nears the base (fig. 13, *lr-e*). The apical four-fifths of the labium contains no other seta than the labrum-epipharynx, as seen in fig. 12, which is a section at about the middle of the proboscis. At the base of the labrum-epipharynx are pharyngeal muscles similar to those found in the female, and with similar insertions and origins, except that the median muscle (fig. 15, *pm'*) is not divided into three parts as in the female (fig. 9, *pm'*).

"The hypopharynx is, throughout its whole length, joined to the labium, and thus necessarily pushes the maxillæ, which would normally lie between it and the labium, to one side. (See fig. 13, *h* and *mx*.) The hypopharynx shows, in section (fig. 13–15, *h*), the same chitinous rod through the middle as in the females, but I was unable to detect any channel for saliva through this rod.

"The maxillæ are very thin lamellæ of transparent chitin, about one-fifth as long as the labium, and so delicate as to be easily overlooked. Although as broad at the base as is the tube of the epipharynx, they taper regularly from their base to their fine tips.

"The maxillary palpi are five-jointed, very hairy toward the tip, much longer than they are in the female, and when at rest their basal portions cover the labrum-epipharynx and maxillæ in the sheath of the labium.

"The labium of the male *Culex* is similar in general structure to that of the female, if one considers it together with the hypopharynx. It is, however, slenderer, more densely covered with scales, has a shallower groove for the reception of the labrum-epipharynx, and has a joint near the middle. The slenderness of the labium in the male extends itself to the labellæ. (Compare fig. 4, *lb*, with fig. 3, *lb*). The groove of the labium of the male increases in shallowness from tip to base; at the middle of the proboscis (fig. 12) it is so shallow that it fails to fully protect the labrum-epipharynx, and at its base (fig. 13) it is so shallow that the other mouth-parts rest only on top of the labium. To make up for this deficiency of protection by the labium, the maxillary palpi, as was previously mentioned, cover over the upper side of the enclosed parts (see fig. 13), and thus, although free from the labium, form a part of the protective sheath, which, in the female, is formed by the labium alone. Whether the joint near the middle of the labium of the male *Culex* is true or false I cannot say, since I have never seen it bent by the insect itself; its appearance is that of a true joint. Like the labium of the female, that of the male has two longitudinal main tracheal stems (figs. 12–14, *tr*), and two rows of longitudinal muscles."

Kraepelin expressed the opinion that the labrum is not formed by the union of two pieces, the labrum and epipharynx, but that it is an evagination of the head and in consequence necessarily hollow. "It can therefore, as all body-appendages are evaginations and consequently hollow, impossibly be interpreted as the fusion of an upper and lower lamina."

Becher was of the same opinion and states that the so-called epipharynx of the Diptera is never found as a free part; he calls the part the lower lamella of the labrum.

Meinert has traced the course of the salivary duct and found that it differs in the two sexes. His interpretation of the hypopharynx does not agree with that of Dimmock. In the female Meinert found that the salivary duct penetrates the posterior part of the hypopharynx; before entering it forms a large receptacle from the upper part of which a strong muscle extends to the under side of the pharynx. "In the male the hypopharynx does not protrude but is very short and rounded anteriorly and the salivary duct runs through the entire sheath [labium] along the under side of its floor until it terminates in the tongue."

Wesché considers the hypopharynx of the male as long, like that of the female, and the "tongue" of Meinert, protruding between the labellæ, as its apex. He speaks of the ciliation of the free apex, which he states to be present in all males, as "a surprising reversion"; perhaps it can be explained as readily as an adaptation to the feeding habits of the male. One gets the impression from Wesché's paper that he believed that the hypopharynx is free in the male throughout its entire length; such does not, however, appear to be the case. He figures the abnormal mouthparts of a male *Anopheles maculipennis* which approach those of the female. Not only the mandibles and maxillæ are present, but also a free hypopharynx which extends to the tip of the proboscis.

The mandibles of Diptera are present only in the females of the blood-sucking orthorrhaphous forms. Becher, whose work has been criticized for its inexactness, states that two parts can usually be clearly distinguished in these organs: "a basal piece, which lies in the interior of the head, and the mandible proper, which can be moved upon this base by means of a joint." None of the students who have followed exhaustive methods appear to have detected any such joint. Becher's interpretation of the mouthparts is at variance with the commonly accepted homologies in various details but his paper is neither clear nor convincing. Furthermore, he commits the error of basing his views on studies of the mouthparts of the higher Diptera and interpreting the lower forms from this standpoint; thus we can, with the more propriety, pass over a detailed consideration of his work. It may, however, be pointed out in passing, that while Becher rightly, we believe, rejects the idea, held by some of the earlier authors, that the maxillæ and even the mandibles may enter into the composition of the labium of the Diptera, he adopts Burmeister's view that the labellæ are homologous with labial palpi. None of the recent authors have concurred in this view. The three terminal lobes of the labium have been designated by Kellogg, who has given a very clear exposition of the mouthparts of the Nemocera, as, medianly the fused glossæ, and, outwardly the paraglossæ. This interpretation has been followed by Wesché and others. Other details, such as the attempts to find homologues of the components of the maxillæ and labium of mandibulate insects, can be passed over as purely hypothetical.

All the authors who have endeavored to homologize the mouthparts of the Diptera with those of the mandibulate insects have, with one exception, agreed as to the fundamental parts, the labrum, hypopharynx, mandibles, maxillæ, and labium.

John B. Smith, in a paper published in 1890, took an entirely different view and defended this in a further paper which appeared in 1896. This interpretation has been adopted in a recent popular book on mosquitoes. He used the mouthparts of certain highly specialized Hymenoptera and Coleoptera as a basis for his homologies. Smith found in *Simulium*, apically in the labrum, a pair of small dentate chitinous structures which he considered rudimentary mandibles; these structures appear to be absent in all other nemocerous Diptera. He supposed, not only that the parts usually considered mandibles are maxillary, calling them laciniæ, but that maxillary structures entered largely into the composition of the labial sheath. The parts supporting the labellæ are said to be part of the maxillæ, the subgaleæ, the labellæ themselves the galeæ. The labium is represented as a free piece, enclosed by the galeal structures, and the hypopharynx united with it. Smith's work has been adversely criticized by the students of dipterous mouthparts and moreover bears clear evidence that it was based merely on rough dissections; only recently Leon, in a paper on *Simulium*, discusses Smith's homologies and points out the relationships of the parts in accordance with modern studies.

Meinert developed views at variance with all the other students and did not believe that the mouthparts of the Diptera are homologous with those of mandibulate insects. While his interpretation is in the main controverted by the histological work of Kellogg, it still seems of sufficient interest for a brief notice, all the more as it has been generally ignored.

Like all other modern investigators Meinert recognized that generally the mouthparts of insects are homologous with the legs of the body and that, therefore, they are the exponents of distinct metameres. He demanded, however, that to identify them with these, and those of the different orders of insects with each other, something sufficiently characteristic should be in evidence and he says:

"I find this in the presence of a metamere and in the free jointing of the exponents to the under side of such a metamere, and according to this criterion I test, whether the mouth-parts (that is the mouth-parts proper, the paired ones) are homologous with appendages of the body on the one side, or among themselves on the other."

He considers that, of the three metameres bearing the mouth-organs in typical insects, the first metamere forms, above, united with the epipharynx, the labrum, which he calls "scutum dorsale" (of the first metamere), and below in large part the labium, which he calls "scutum ventrale" (of the first metamere). The second metamere, according to Meinert, in the Diptera, bears the two pairs of appendages usually called mandibles and maxillæ and which he calls respectively cultelli and scalpella. He does not consider these appendages homologous with the mouth-parts of other insects on the one hand, or with the limbs of the body on the other. He believes them processes or evaginations of the plates of the second metamere; the scalpella as processes of the ventral plate, the cultelli as processes of the pleural plates. The palpi are in his opinion homologous with the entire maxillæ of other insects. This last conclusion appears particularly interesting as Kellogg has found, in his study of the development of another nemocerous fly, *Bibiocephala,* that the palpi of the imago develop inside the maxillæ of the larva. The clypeus is designated by Meinert the "scutum dorsale" of the second metamere. The third metamere, the one bearing the mandibles in biting insects, is stated to be without appendages. More recent investigations have shown that it is impossible to trace the primitive metameres in the organization of the head of the fully developed insect.

In view of the differences in opinion in the interpretations of the dipterous mouthparts, and the impossibility of settling this question definitely by comparative studies, Kellogg took up the study of the development of the imaginal mouthparts within the larva. The larvæ of the more primitive Diptera are the essential ones in such an investigation, as they have a complete head and mouthparts corresponding with the typical ones of mandibulate insects. Kellogg studied forms with such larvæ. His investigations were made with *Simulium* and *Bibiocephala,* two Nemocera which, like *Culex,* have a complete set of mouthparts in the female. We quote the important part of Kellogg's paper:

". . . Can the homologies of the dipterous mouth parts be discovered by the study of the development of the parts?

"For a complete developmental study of the mouth parts of any dipteron it would be necessary to begin with the budding appendages of the head segments in early embryonic life, to trace the development of these appendages to their definitive form in the hatched larva, and finally to follow the transformation, if it occurs, of these larval parts into the ultimate imaginal ones. As a matter of fact, such actual transformation does not occur, so that the study of the post-embryonic development of the mouth parts consists of noting the ecdysis of the larval parts and determining the ontogenic relations of the new imaginal parts to the old larval ones.

"As for the embryonic development of the mouth parts—*i. e.,* the development from budding appendages to definitive larval parts, that has been done for several Diptera, and in particular by Metschnikov for Simulium, one of the two flies whose postembryonic development I shall describe. These embryonic studies make certain the homologies of the larval parts; in those flies like Simulium, whose larvæ are provided with a biting mouth with full complement of parts, it is easy to note plainly the development of mandibles, maxillæ, and labium from the successive pairs of budding head appendages, and thus to homologize these parts certainly with the mandibles, maxillæ, and labium of adult insects of incomplete metamorphosis. There remains to determine the relations of the larval mouth parts of Simulium with its very different imaginal mouth parts.

"In selecting flies for the study of the postembryonic development of the mouth parts I have chosen two which in the imaginal condition possess all the parts possessed by any fly, and these parts in as generalized condition as is to be found in the order, and which also possess in the larval stage a similarly full complement of mouth parts. Such larvæ as those of the Muscidæ, with their problematical hooks and lack of other parts, and such imagines as the muscid flies, with no parts left except proboscis and maxillary palpi, are impossible for the determination of the relation between larval and imaginal parts. From the mouth parts of the imaginal Simulium and of other nematocerous forms it is

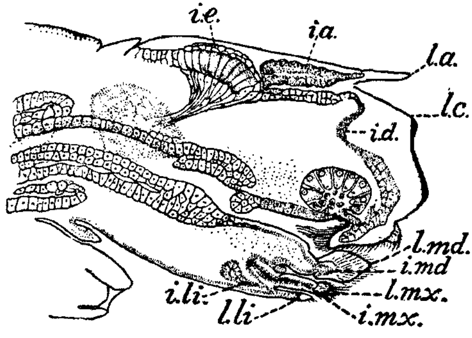


FIG. 1.—Sagittal section through head of old larva of *Simulium* sp., showing forming imaginal head parts within.
l.c., larval head wall; *i.d.*, imaginal derm; *l.a.*, larval antenna; *i.a.*, imaginal antenna; *i.e.*, imaginal eye; *l.md.*, larval mandible; *i.md.*, imaginal mandible; *l.mx.*, larval maxilla; *i.mx.*, imaginal maxilla; *l.li.*, larval labium; *i.li.*, imaginal labium.

not difficult to trace the evolution to the specialized muscid conditions, and if the mouth parts of Simulium and similarly equipped flies can be interpreted, the various members of the dipterous series culminating in the muscids can. So in Simulium and Blepharocera I have found suitable forms for study; both with females possessing the so-called mandibles, both with maxillæ and labium well developed in both sexes, and both with larvæ equipped with biting mouths with unmistakable mandibles, maxillæ, and labia, and in one case, that of Simulium, with the embryonic development of the larval mouth parts fully traced and the homologies certainly * determined.

"*Simulium* sp.—In the female imago † the mouth parts consist of a short liplike labium composed of a short basal sclerite and three terminal lobes, being the two large paraglossæ and a median short membranous lobe, the fused glossæ; a pair of maxillæ, each consisting of a basal sclerite, a long five-segmented palpus, and a single pointed, bladelike terminal lobe reaching nearly to the end

* Metschnikov, E. Embryologische Studien an Insekten. *Zeitschr. f. wiss. Zool.*, vol. xvi. 1866; embryonic development of mouth parts of Simulium described on pp. 392-421.

† "In describing the adult mouth I shall assign to the various parts those names which, from my earlier study of the comparative anatomy, seem correctly used, and the use of which is confirmed by the results of this ontogenic study."

of the third palpar segment, serrate on its inner margin at the tip and better developed than in most Nematocera; and a pair of short mandibles, broad, thin, and weakly chitinized. As in other nematocerous flies, there is a well-developed labrum-epipharynx and an elongate flattened hypopharynx. In the males the mandibles are wanting.

"In the larva the mouth is of the biting type, with short-toothed and heavy mandibles, short, jawlike maxilla with distinct one-segmented palpus, and a small, strongly chitinized labium or labial plate. In addition, labrum, epipharynx, and hypopharynx are all well developed.

"The head of the larva having a thoroughly opaque, strongly chitinized cuticle,

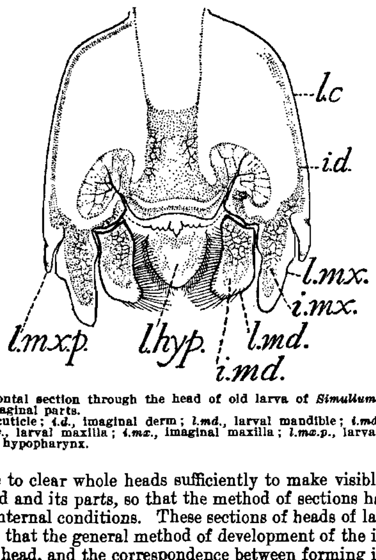


FIG. 2.—Frontal section through the head of old larva of *Simulium* sp., showing forming imaginal parts.
l.c., larval cuticle; *i.d.*, imaginal derm; *l.md.*, larval mandible; *i.md.*, imaginal mandible; *l.mx.*, larval maxilla; *i.mx.*, imaginal maxilla; *l.mx.p.*, larval maxillary palpus; *l.hyp.*, hypopharynx.

it was impossible to clear whole heads sufficiently to make visible the developing imaginal head and its parts, so that the method of sections had to be relied on to reveal the internal conditions. These sections of heads of larvæ of various ages show plainly that the general method of development of the imaginal parts within the larval head, and the correspondence between forming imaginal parts and the corresponding larval parts already noted in the other orders of holometabolous insects, hold good in the Diptera. Fig. 1 shows in sagittal longitudinal section the forming imaginal head parts within the larval head. This section shows particularly well the relation of the forming imaginal antenna to the larval antenna. In the larva the antennæ are very small compared with their size in the imago, and the imaginal antenna is thus forced, in its development, to occupy a region in the larval head not included in the larval antenna. But the tip of the imaginal organ lies fairly within the larval organ, thus indicating by correspondence in position, what is plainly obvious from anatomical consideration, the homology between the larval and imaginal organs. Similarly the forming imaginal mouth parts are to be found in unmistakable correspondence or homologous relation with the larval parts. By tracing the development of the parts, marked in fig. 1 as the forming imaginal mouth parts, through larvæ of successively older ages to pupation and the achievement of the definitive imaginal condition of these parts, it is certain that the parts marked respectively imaginal mandible, imaginal maxillæ, and imaginal labium, lying respectively in the larval mandibles, maxillæ, and labium (with homologies firmly based on ontogenic basis), do develop into those definitive imaginal parts named mandibles, maxillæ, and labium. . . . Fig. 2, a horizontal, frontal section through the head of a Simulium larva, shows also the forming imaginal maxilla and mandibles within corresponding larval parts."

Wesché has found that abnormal male Culicidæ occur with all the trophi present, as in the females, although in these cases the maxillæ and mandibles did not extend to the tip of the proboscis. Such males, to conclude from Wesché's work, appear to be not uncommon. Examining a number of males of different species, he found an abnormal *Anopheles* and also a male *Culex pipiens* with all the parts present.

It would seem that the mandibles and maxillæ may be absent in the female of certain species which do not suck blood. Such appears to be the case with the female of *Harpagomyia splendens,* recently described by De Meijere. This curious Javan species feeds upon honey which it obliges tbe ant, *Cremastogaster difformis,* to disgorge. In this mosquito the hypopharynx is free, as usual, but appears to lack the salivary duct. It is interesting to note that early in the pupal stage both mandibles and maxillæ can be readily seen in the developing imago. These gradually retrograde, until, by the end of the pupal period, they have become wholly atrophied, just as has been shown to occur in the development of the males of the blood-sucking forms.

While the external appearance of the proboscis is frequently described, we know practically nothing of the modifications of structure in the different species or genera—Wesché states that in *Anopheles* the mandibles are serrated at the tip. The sheath of the proboscis shows much variation in length and diameter in the different species and it is frequently expanded towards the apex. The labellæ also show much difference in shape and in details of structure but these need not be described. In *Megarhinus* the sheath is unusually rigid, tapering, becoming very slender at the tip, and the labellæ are narrow and much elongated. In this genus, in which both sexes feed wholly upon the honey of flowers, the labium can not be bent as it can in the forms which suck blood.

In the males of many species the sheath of the proboscis shows a suture outwardly from the middle. Usually it is indistinct, but in the male of *Deinocerites* there are chitinous margins connected by a membranous strip as in a true joint. Its significance is not clear; perhaps it indicates the limits of the true labial structures. It may be mentioned in this connection that Meinert considered the sheath of the proboscis as of composite origin and formed mainly by the greatly produced portion of that part of the head which he considers the ventral plate of the first metamere.

It has already been shown that there is a salivary duct in connection with the hypopharynx. Macloskie found that there were two sets of salivary and poison glands in connection with this duct. The glands are situated in the anterior ventral part of the thorax and each set consists of three glands, two of which are ordinary salivary glands and the third, between the other two, differs in appearance and structure and secretes the poison. Each set of glands discharges into a very fine duct and these ducts unite in the back of the head and continue forward as a single duct through the ventral region of the head. Macloskie's studies were made with *Aëdes tæniorhynchus* and a species of *Anopheles*.

At the base of the hypopharynx is the salivary pump into which the salivary duct empties, to be continued beyond it into the hypopharynx. Macloskie failed to recognize its true character and called it the salivary "reservoir." Its true character appears to have been first recognized by Annett, Dutton, and Elliott. The organ is fully described by Nuttall and Shipley, from whom we quote. As yet the organ has only been demonstrated in *Anopheles*.

". . . The structure is more than a receptacle, it constitutes a *pump*, the mechanism of which corresponds to that of the pharyngeal pump in a sense, that is, it depends upon the action of powerful voluntary muscles which overcome the elasticity of a chitinous membrane which, when released by the muscles becoming relaxed, rebounds or returns to its original form, as a bow does when the pull on the bow-string is released. . . . It will be seen then that the common salivary duct ends (lumen 5μ) in the centre of the chitinous membrane, the junction being strengthened by a chitinous thickening of annular form. The membrane is continuous with a highly chitinized cup, which tapers anteriorly, and is continuous with the hypopharynx, an opening therein connecting it with the groove described above. . . . Spicules of chitin occur about the duct on the pump-membrane, these serving for the attachment of the powerful muscles presently to be described. The thickened chitin surrounding the membrane is flattened on its dorsal surface which is applied to the floor of the buccal cavity. The pump-membrane is covered in the centre by the insertion of two stout hundles of muscle-fibres which pass backwards, parallel with one another, to their origin on the anterior surface of the chitinous flange which projects ventrally from the floor of the buccal cavity. When the muscles contract a partial vacuum is produced within the cup, saliva flows in from the glands, and when they relax the membrane rebounds forward, driving the saliva out of the cup into the salivary channel along the hypopharynx."

Leon, who investigated this organ independently, gives a description at variance with that of Nuttall and Shipley. He found that the salivary duct empties, not into the center of the posterior membrane of the cup, as described by Nuttall and Shipley, but into the side of the chitinous cup. The pumping device Leon describes as follows:

"The mouth of the cup, which is directed posteriorly and ventrally, is covered by an elastic chitinous membrane which is pushed back into the interior of the cup like the bottom of a champagne-bottle. Outside, in the middle of this membrane, a chitinous piston-rod is attached. This has the form of a round concave-convex disc and is more darkly colored; the convex side of the disc is attached to the elastic membrane, while in the middle of the concave side the rod is fixed. . . . The posterior end of the rod is thickened and muscles are attached to it."

THE PALPI.

The palpi, as they appear in both sexes of *Culex*, have been described in the foregoing in connection with the other mouthparts. Great diversities of opinion have been expressed by the different students as to their structure and the number of the joints. They show great diversity in the different genera and in the species. They differ greatly in length, in shape, and in the number of joints. The relative length of the palpi, without reference to the number of joints, has been generally considered as a character of primary importance in classification. Beyond that there has been general disagreement as to the number of component joints. Dimmock, whom we have quoted, considered the palpi of *Culex pipiens* as four-jointed in the female, five-jointed in the male. Meinert states for the same species, three-jointed in the female, four-jointed in the male. Both these authors found that in other species a small additional joint was present in the females. Ficalbi considered that in *Culex* the palpi of the female are three to four-jointed, those of the male three-jointed. Wesché considered the palpi four-jointed in both sexes. Felt states that in most Culicidæ the palpi are five-jointed in both sexes, except in certain females "when the rudimentary fifth appears to be wanting." Theobald, in Genera Insectorum, states that the palpi of the Culicidæ have from one to six joints.

The idea that the number of joints in the palpi is constant within groups and of great classificatory importance has been very generally accepted. The statement that the palpi of the Nemocera are four or five-jointed, which originated with Latreille (1809), has been widely followed with but little modification. Becher considered the palpi of the Nemocera four-jointed and called the basal part "Tasterschuppe," the equivalent of the palpifer, or, in its absence, of the maxillary stipes. Williston, in the introduction to his Manual of North American Diptera (third edition, 1908, page 26), states of the palpi of the Diptera:

"Perhaps the most important of all the mouth-parts, from the systematic standpoint, are the maxillary palpi. . . . They are variously described as being composed of from one to five joints. There are never more than four articulated joints, the basal joint being merely a process of the plate bearing the maxillæ. The tendency in diptera is toward their entire loss, and in the more highly specialized families there is never more than one joint."

Farther on (p. 65) he says of the Nemocera: "Palpi usually more or less elongate, composed of from one to five, usually four, joints, rarely absent." While there is undoubtedly a reduction in the palpi parallel with specialization, this reduction has taken place independently at different points, and, except in a very broad way, the palpi can not in themselves be considered as a safe index of relationships. The ideas of systematists have been based largely upon the study of a few typical forms, and no attempt appears to have been made to test their constancy within a family. In fact, within the Culicidæ the palpi may be said to be remarkably unstable in character. They range all the way from forms with several well-defined joints, as *Anopheles*, to forms in which they are reduced to a small club-shaped organ without trace of jointing. In fact, the homologizing of the palpal joints of the different forms, which Felt attempted to carry out, assuming five joints for the more generalized forms, is beset with peculiar difficulties. The conditions in the basal portion of the organ, which have generally been considered as true joints, are not clearly defined or sufficiently uniform within the group to be so interpreted. We have not found any mos-

quitoes in which either one or both of the two supposed basal joints are differentiated in such a manner that they may be called true joints. We doubt that these correspond to the two basal joints of the four-jointed palpus of the more primitive *Chaoborus;* the integument is of the same character throughout, simply that there is less chitinization at the "joints." Furthermore, it does not seem plausible that joints would tend to disappear at the very point where they would be most in use and most needed.

Should we accept the two basal modifications as true joints, we would then have, in the female *Anopheles,* which has in addition three well-defined joints, mosquitoes with six-jointed palpi. If, on the other hand, we carry out strictly the idea that these basal joints are secondary modifications, we must consider all that part of the palpus below the first true joint as a prolongation of the basal structure and a part of the maxilla itself. Thus we would have to consider the first "long joint" of *Anopheles*, there being no jointing apparent at the base of the palpus, as belonging to the basal structure. The palpi of *Anopheles* would then be three-jointed in the female, two-jointed in the male. In the normal *Culex pipiens* there would be but a single true palpal joint in the female, two in the male. In the higher forms, where there has been a reduction to a club-shaped organ, this appears to have been produced, not by fusion of the joints, but by their loss. This unjointed club would then represent the basal structure.

This process of reduction, first in the length of the joints, then in their number, can in fact be traced progressively through the genera and species of mosquitoes. The arrangement we have adopted in our classification, although it was founded upon other characters without reference to the palpi, follows very closely this process in the two tribes. It is interesting to note that this reduction has been the most rapid in the female, where the functions of the mouth-organs are of the most importance, and that in the majority of species the palpi of the male show the more primitive condition. Thus *Anopheles,* in which the palpi are long in both sexes and show several joints, is to be regarded as the most primitive mosquito, while such forms as *Uranotænia* and *Sabethes,* with greatly reduced and unjointed palpi, must be considered highly specialized.

We have already, on a previous page, called attention to the view of Meinert, apparently supported by Kellogg's histological work, that the palpi of the Diptera are not homologous with the maxillary palpi of other insects but are rather modifications of the maxillæ themselves. As this view has some bearing on the interpretation of these organs and the number of joints, we quote Meinert in part:

". . . The palpi are regarded by everybody as corresponding to the maxillary palpi of the other insects; but I shall here make some comments on this. The maxillary palpi always originate from a maxillary trunk, which, through an intermediate joint, the cardo, springs from the metamere. They are, in other words, only the outer joints (corresponding to the foot?) of the exponent. In the Diptera, on the other hand, the palpi originate directly from the metamere; and while in the several-jointed palpi the first joint might be regarded as a modified cardo, and consequently the outer joints of the palpi as homologous with the maxillary palpi, it is different when the palpi consist of only two, or even of a single joint, as is the rule in the Diptera, for there will then be no joint left to explain as maxillary palpus. I therefore prefer to regard the palpi of the Diptera as homologous with the entire maxillæ of other insects, only that they are oftenest unjointed and not divided into different components. Only in *Simulium, Tipula,* and *Limmobia* I have thought to find an indication, in the before mentioned appendix at the base of the palpi, of the different working divisions of the exponents of the second metamere of other insects."

The palpi are variously modified in the different forms. In *Anopheles* and in the males of a great many other forms the palpi about equal the proboscis in length, or even exceed it. In most of these forms the palpi are slender, particularly in their proximal halves, and furnished with false joints to increase their flexibility so that they can be folded back when the insects are feeding.

In *Megarhinus,* however, where the palpi are less in the way, on account of the downward-curved proboscis, they are stout and quite rigid, without basal false joints, and the joints are armed near their apices with heavy spines. In the males of *Anopheles* and of most species of *Culiseta* the palpi are enlarged apically into a distinct club. In *Anopheles* the club is composed of the outer two joints, while in *Culiseta* it may be composed of these same two joints or of the last joint alone.

In the males with long palpi of many species of *Culex* and *Aëdes* the outer half of the palpi is more or less thickened and densely hairy, the last joint, however, generally tapering to a point; the last two joints are usually curved upward.

In *Megarhinus* and *Bancroftia* we begin to get a reduction in the female palpi, and this occurs principally in the terminal joint. In the American species of *Megarhinus* the palpi of the female are about two-thirds the length of the proboscis, while in the Old World species of this genus the reduction has gone still farther and they are sometimes less than one-fourth the length of the proboscis. In the females of both the New and the Old World species of *Megarhinus* there is a minute terminal joint, and the number of joints is the same.

In *Bancroftia* the palpi of the female are about two-fifths the length of the proboscis, the terminal joint small; in the case of one species (*B. fascipes*) the terminal joint is about three times as long as wide, in another (*B. signifer*) it is nearly globose. In the male of this last-named species, although the palpi are as long as the proboscis, the last joint is similar in character to that of the female.

In the males of most species of *Aëdes* and of *Culex* the palpi are longer than the proboscis, curved upward, their outer halves densely hairy, the last joint long and tapering. In certain species of *Aëdes* the palpi of the male are slightly shorter than the proboscis, straight, less hairy, the last joint long but blunt at the tip. In *Aëdes fuscus* the palpi of the male are very short, in fact shorter than those of the female, and the terminal joint is indicated by a flattened tubercle. In the related genus *Stegoconops* the reduction of the male palpi has become more general. In *S. equinus* the palpi of the male are about three-fourths the length of the proboscis; in *S. albomaculatus* the palpi are practically alike in the two sexes, short and with a minute terminal joint.

In certain species of the genus *Culex* a similar reduction of the male palpi is found. In *Culex latisquama* the palpi of the male are about half as long as the proboscis. The reduction is in the apical portion; the apical joint is sub-globose, the one supporting it is less than three times its own diameter in length. In the female of this species the palpi are about one-fourth the length of the proboscis, but, as in the male, have a minute terminal joint. In *Culex bisulcatus* the palpi are slightly less than half the length of the proboscis in both sexes. In the female there is a single true joint, which makes up more than half the length of the entire palpus. In the male we have been unable to discover any differentiated joint except the minute terminal one.

In *Uranotænia* reduction has gone to the extreme. In both sexes of *U. sapphirinus* the palpi are very small, projecting but slightly beyond the clypeus, club-shaped and unjointed.

In the females of most Culicini the palpi are short, although differing much in length and configuration in the different species. They consist of a basal portion, which in most cases shows a triple false-jointing; beyond this there is a stout joint and in many species this bears at its apex another minute joint. Sometimes there is even what appears to be a second minute joint, inserted upon the other, but this is with little doubt produced by constriction of a single joint. Such a condition exists in *Mansonia fasciolatus*, as has already been indicated by Neveu-Lemaire. It may also occur as an abnormality, as in the case of a female *Culiseta annulata* figured by Dyé and Neveu-Lemaire. In the species in which the minute terminal joint is usually absent specimens may occur with this joint present. Dyé and Neveu-Lemaire describe such palpi in a female *Culex pipiens*. We have a *Culex tarsalis* with the same abnormality.

In *Deinocerites* and *Dinomimetes* the palpi are short in both sexes, but show considerable diversity of structure in the different species. In *Deinocerites pseudes* female there is a distinct terminal joint, more than half the length of the entire palpus. In the male of this species there is in addition a minute apical joint. The palpi of the male *D. troglodytus* are similar but the apical joint is still more minute, while in the female there is no distinct jointing. The palpi of *D. cancer* are unjointed in both sexes. In *Dinomimetes epitedeus* there is a single joint in both sexes.

In the group of Sabethini the reduction of the palpi is far more general and in most species these organs are short and unjointed in both sexes. In the forms examined the female palpi always proved unjointed, and although only a few forms have been studied it is evident that such is the rule in this group. In *Joblotia digitatus* the palpi are long and slender in the male, distinctly jointed; in the female the palpi are short and unjointed. In *Lesticocampa* the palpi are very slender. They may be long or short in the male, according to the species, but they are jointed like those of the male *Joblotia*. The palpi of the female, as in other sabethids, are unjointed.

THE THORAX.

The terminology of the parts of the thorax of mosquitoes is very confused and shows that its structure has not been generally understood. We, on this account, requested Mr. R. E. Snodgrass, formerly of the Bureau of Entomology, U. S. Department of Agriculture, who has made a study of the homologies of the thorax of insects of different orders, to prepare the following study, with figure, of the thorax of a mosquito, *Psorophora ciliata* (see plate III).

The thorax of the mosquito is conspicuously wedge-shaped, the base being uppermost and forming the large rounded dorsum of the thorax. The triangular sides form the pleura, while the apex is ventral and carries the legs. The wings (w_2) are inserted on the upper parts of the sides much behind the middle, so that the greater part of the thorax is in front of them, but the balance of the entire body is preserved by the long, slender abdomen extending posteriorly. The second wings are represented by the halteres (w_3) which, of course, take no part in the mechanism of flight. Consequently the great muscles of the mesothorax alone afford the motive power of flying. The active function of the prothorax and the metathorax is the support of the front and hind legs. Hence, both of these segments consist of little more than anterior and posterior collars against the great mesothoracic mass. The consolidation of the three segments is so complete that many entomologists find it difficult to define their limits with certainty.

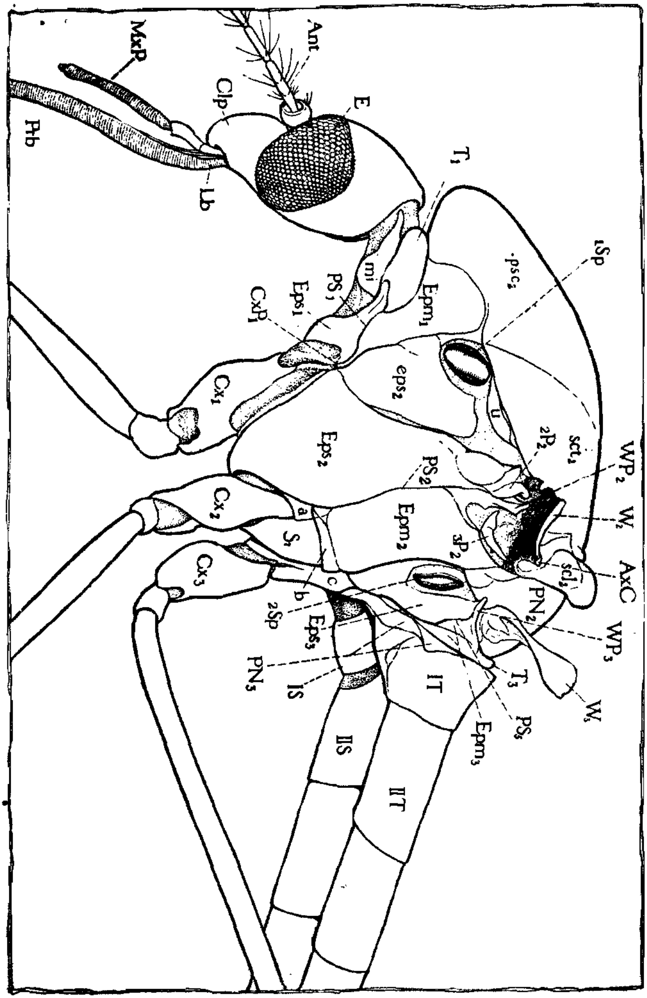
Two conspicuous points on each side of the thorax are the spiracles ($1Sp$ and $2Sp$). Each is a large black-rimmed aperture situated in a membranous area, one near the middle of the anterior half of the side, the other somewhat behind the middle of the posterior half. Since, in most adult insects, these thoracic spiracles are situated in the intersegmental membranes, it is a difficult matter to decide to which segment each belongs. The second is nearly always regarded as metathoracic, but entomologists are divided in opinion as to whether the first is mesothoracic or prothoracic. Amongst morphologists, however, the first view seems to have the greater support. However, this question is of little importance for the more practical needs of the systematist, who may avoid the difficulty by referring to them simply as the first and second thoracic spiracles.

The Prothorax.—The lateral walls of this segment consist of three plates (T_1, Eps_1, and Epm_1). Closely associated with them is a large cervical sclerite (mi) lying on each side of the neck and forming a support for the head anteriorly. The most conspicuous of the prothoracic plates is the prominent oval lobe (T_1) beneath the projecting anterior end of the mesotergum. This very probably is a lateral part of the protergum, for it is connected by a median narrow transverse bridge in front of the mesotergum with the corresponding part of the opposite side. These two lobes are called "patagia" by Christophers, a name properly belonging to the prothoracic tergal appendages of Lepidoptera, but of doubtful propriety when applied to similar parts in the mosquito, because there can be no homology between them. Connected with the lower end of the protergal lobe is a stalk-like piece which expands ventrally into a larger plate

Explanation of Plate III.

The individual segment of the thorax to which any part belongs is indicated by the small figure placed behind and below its symbol. The abdominal segments are distinguished by Roman numerals placed before the symbols of the parts. Arabic numerals placed before symbols signify numerical order of repetition.

Ant, antenna.
AxC, axillary cord of wing base.
Clp, clypeus.
Cx, coxa.
CxP, pleural coxal process.
E, compound eye.
Epm, epimerum.
Eps, episternum.
eps_2, detached part of episternum of mesothorax.
Lb, labium.
mi, cervical sclerite.
MxPlp, maxillary palpus.
P, parapterum.
PN, postnotum (postscutellum).
Prb, proboscis.
PS, pleural suture.
psc, prescutum.
S, sternum.
scl, scutellum.
sct, scutum.
Sp, spiracle.
T, tergum.
W_2, wing.
W_3, halter.
WP, pleural wing process.
a, small plate of mesopleurum bearing articulation of coxa.
b, accessory plate of mesoepimerum.
c, lower part of metapleurum.



Thorax of Psorophora.

Drawn by R. E. Snodgrass.

(Eps_1) above the base of the front coxa (Cx_1), and which is connected by a transverse arm with the prosternum. (The last is not visible in side view.) The third prothoracic plate (Epm_1) lies behind and above the other two and is much larger than either of them. It extends posteriorly almost to the first spiracle ($1Sp$) and sends a narrow strip downward to the precoxal membrane. It might be questioned whether this plate does not really belong to the mesothorax, but a little comparative study of other flies will make its morphological relations clear. It will be observed that in *Psorophora* the anterior coxa is not directly articulated to the side of the prothorax, being connected with it only by a wide membrane. In most other flies, however, it is articulated in normal fashion to the propleurum, at the ventral end of the pleural suture. In the lower flies this suture separates two distinct pleural plates—the episternum and the epimerum. In *Tipula* the first spiracle is much farther forward than in the mosquito and lies on a line which is clearly the boundary between the prothorax and the mesothorax, the epimerum of the prothorax being in no way expanded or specially developed. In *Bibio* the first spiracle is farther back than in *Tipula* and the epimerum is much extended posteriorly. In *Psorophora,* finally, this character is still more exaggerated, the first spiracle being halfway between the base of the wing and the front of the mesotergum, while the epimerum of the prothorax forms a large lobe reaching posteriorly to the spiracle, though its ventral extremity is reduced to a narrow band close to the posterior edge of the plate in front. The latter (Eps_1) we can, therefore, identify as the episternum, and the line (PS_1) between the two plates as the pleural suture. The only distinctive character in the prothorax is, therefore, the separation of the coxa from its pleural articulation.

The plate (eps_2) lying below and behind the spiracle is separated only by a weak line from the proepimerum, but for reasons to be given later it is regarded as belonging to the mesopleurum.

The prosternum consists of a transverse plate lying in front of the bases of the coxæ, connected laterally with the episterna, and having a median posterior intercoxal extension fused with the anterior sternal part of the mesothorax.

The cervicum or "microthorax" is represented by the two lateral cervical plates (mi) already mentioned. The two are connected with each other ventrally by uniting transverse arms.

The Mesothorax.—This segment, in the mosquito, forms the great bulk of the entire thoracic mass. The anterior end of its tergum projects over the top of the head and the posterior end is separated from the abdomen only by the narrow metatergal bridge (T_3). As in nearly all insects the mesotergum consists of two principal plates, a large anterior one (psc_2, sct_2, and scl_2) constituting the true notum and carrying the wings, and of a smaller posterior postnotal plate (PN_2) lying between the first and the metatergum and connected laterally with the epimera of the mesopleura. The first plate is indistinctly divided into a prescutum (psc_2), a scutum (sct_2) and a scutellum (scl_2). The second plate constitutes the postnotum, usually termed postscutellum in the higher orders. On account of the posterior location of the wings and the narrowness of their bases, both of the notal wing processes, *i. e.*, the lateral lobes of the notum to which the wings are articulated, arise near the posterior end of this plate. The first belongs to the scutum, the second to the scutellum. The scutum bears also a small lateral lobe (u) between the front spiracle and the base of the wing. The axillary cords (AxC), which form the corrugated cord-like thickenings of the posterior margins of the basal or axillary membranes of the wings, arise from the posterior margin of the scutellum. They thus mark the posterior limit of the true notum as distinguished from the postnotum, though the two plates are separated from each other by a membranous suture.

The mesopleurum is triangular, its corners being marked by the anterior spiracle ($1Sp$), the base of the wing (W_2) and the base of the middle coxa (Cx_2). Its two main plates, the episternum (Eps_2) and the epimerum (Epm_2) are separated by the pleural suture (PS_2) which extends from the coxal articulation into the pleural wing process (WP_2). In front of the main episternal plate (Eps_2) is a smaller one (eps_2) evidently derived from the first but separated from it, except ventrally, by a wide membranous suture. Its front edge is united along a weak suture with the prothoracic epimerum (Epm_1) and the plate itself, therefore, may appear to be a part of the latter, though its dorsal end projects upward behind the first spiracle. In *Tipula* there is no separate sclerite corresponding with this plate, the mesoepisternum being continuous from the pleural suture to the first spiracle. In *Bibio* there is a suggestion of the separation of the anterior plate from the rest of the episternum, while in all higher flies it forms a conspicuous sclerite on the anterior part of the side of the thorax. Some authors have regarded it as a part of the mesosternum, but this would involve the unseemly condition of having the sternum reaching to the tergum in front of the episternum.

The principal episternal plates (Eps_2) of the opposite sides meet on the ventral surface and fuse with each other along the mid line. In most of the Diptera a distinct longitudinal suture cuts off a ventral plate from the lateral episternal plate, which is usually regarded as a mesosternal sclerite, but no such suture is present in *Psorophora*.

The epimerum (Epm_2) of the mesothorax is a large plate lying behind the pleural suture (PS_2). Below it is a sclerite (S_2) lying posterior to the mesocoxa (Cx_2) and connected ventrally with the mesosternum. It may be regarded, in fact, as a postcoxal wing of the sternum, though there is no positive evidence that it does not belong to the epimerum. Its upper end is overlapped by a small marginal sclerite (b) on the edge of the epimerum.

The articulation of the coxa is against a small triangular plate (a) wedged in between the episternum (Eps_2) and the postcoxal sclerite (S_2), beneath the epimerum (Epm_2). The internal pleural ridge extends upward from this plate along the line of the pleural suture (PS_2) to the pleural wing process (WP_2). The latter is formed by the adjacent parts of both the episternum and the epimerum, and is the support of the wing from below.

The mesothoracic paraptera are not as well developed in the mosquito as in some other flies. The first is absent entirely and the second ($2P_2$) is fused with the episternum in front of the wing process. The third ($3P_3$), lying behind the wing process, is well developed.

The mesosternum is hard to define in the mosquito. A pentagonal sternal plate lies between the mesocoxal cavities behind the median ventral extension from the episterna already described. The postcoxal plates (S_2) of the mesothorax are attached to the posterior parts of its sides, while its posterior angles are prolonged into slender bands that extend outward and upward in front of the metacoxæ and become continuous with the lower parts (c) of the metapleura. Hence, this plate would appear to represent both the mesosternum and the metasternum, for otherwise there is no metasternal element.

The Metathorax.—The third segment of the thorax is difficult to describe. It is not only reduced in size, but the typical structure is so obscured by secondary modifications that it is impossible to say, from a morphological standpoint, what some of the parts are. The tergum (T_3) forms a narrow dorsal bridge between the postnotum (PN_2) of the mesotergum and the first abdominal tergum (IT). The upper part of the pleurum carries the halter (W_3) the representative of the hind wing. An irregular line (PS_3) extends downward from the wing support (WP_3), which may be known, by the corresponding internal ridge, to be the pleural suture, but it divides before it reaches the coxa and incloses an elongate area (c) that carries the coxal articulation. The plate (Eps_3) in front of this suture is, of course, the episternum, while at least some part of the surface behind it must be the epimerum (Epm_3). The structure of this part, however, is so broken up by accessory sutures that the limits of this sclerite can not be positively asserted. The ventral pleural plate (c) is anomalous and may represent the lower parts of both the episternum and the epimerum since it bears the articulation of the metacoxa (Cx_3). It is connected by a precoxal band with the pentagonal sternal plate, as described under the mesothorax. Behind the epimerum (Epm_3) are two plates (PN_3) reflected upon and fused with the anterior edge of the first abdominal tergum (IT). A study of other Diptera suggests that these two plates together represent the postnotum (postscutellum) of the metathorax, though, on the other hand, they may belong to the first abdominal segment.

The second spiracle is almost surrounded by the metaepisternum, an unusual condition, though it is generally conceded to belong to the metathorax.

To the preceding discussion of the thoracic structures by Mr. Snodgrass but little need be added. The thorax is remarkably uniform in structure within the Culicidæ and but few modifications occur that are of systematic value. In the systematic part of this work we call the most prominent parts of the prothorax, considered by Snodgrass as probably tergal, the prothoracic lobes. These lobes show considerable diversity in different genera. In most of the Culicini the prothoracic lobes are small and lateral. In the genus *Stegoconops*, however, they are large and very prominent, and nearly contiguous upon the dorsum. In the Sabethini a few genera have the lateral lobes well separated but rather prominent laterally (*Joblotia*, *Lesticocampa*, *Prosopolepis*). In most sabethids, however, the prothoracic lobes are large and prominent, contiguous or nearly so, and form a kind of projecting collar under which the head is inserted. The prothoracic lobes bear coarse bristles which are usually irregularly scattered over the surface; where the lobes are collar-like, as in *Sabethes*, the bristles are inserted along the anterior edge.

The scutellum is usually sinuate in outline posteriorly; there is a large median lobe and a smaller lobe on each side. Each lobe bears a group of coarse setæ. Theobald has described a curious mosquito (*Rachionotomyia ceylonensis*) from Ceylon which is characterized by the "scutellum drawn out into a large, thick, backwardly projecting spine, hiding to a large extent the metanotum." In *Anopheles* and a few other forms the scutellum is feebly arcuate behind without indication of lobes; there are, however, forms with feebly differentiated lobes which form the transition to the distinctly trilobate ones.

The region of the mesotergum lying in front of the scutellum is called mesonotum in descriptive work and for convenience we have retained this term. It offers no modifications in structure of a tangible character. It bears coarse setæ, variously disposed, and their arrangement and abundance are of some significance. There are always coarse setæ along the anterior and lateral margins and these are particularly coarse and abundant over the roots of the wings. In the Sabethini, and also in *Megarhinus*, the disk is devoid of setæ. In most of the Culicini there are numerous bristles upon the disk arranged more or less in longitudinal series. There is a double series along the median line which does not, however, reach the posterior margin. Two other rows of setæ form sublateral longitudinal series.

The part of the mesotergum behind the scutellum is called metanotum in most descriptive work. This term implies that the structure belongs to the metathorax whereas in reality it is mesothoracic. We have, therefore, in the systematic part of the present work, adopted the term postnotum. The postnotum shows no variations in structure of a tangible sort. Usually it is nude and smooth or pruinose. It may be indistinctly keeled. In the Sabethini there is a group of setæ, medianly near the posterior margin. In the genus *Dinomimetes* of the Culicini one or two coarse, spine-like bristles are present in the same situation; these arise from a common base, while in the Sabethini the setæ are inserted separately.

THE WINGS.

The wings are long and narrow. The venation is the same throughout the family Culicidæ and shows only variation in minor details. In the nomenclature of the veins we follow Williston. The costal vein encompasses the wing and is strongest along the anterior margin. The auxiliary vein encloses a narrow area, the costal cell, along the anterior margin and terminates in the costa about two-thirds the length of the wing from the base. Following this are six principal veins of which the second, fourth and fifth are forked. The first vein is separated from the auxiliary vein and the costa by a narrow cell, the subcostal cell, and joins the margin near the apex of the wing. The second vein originates from the first vein behind the middle of the wing. The third vein springs from the second beyond the middle of the wing and is angulate at its base; the small transverse portion has been frequently called the "supernumerary cross-vein." The fourth, fifth and sixth veins arise at the base of the wing. A small cross-vein, which joins the basal part of the third vein with the fourth vein, is called the anterior cross-vein. Another cross-vein joins the fourth vein and the upper branch of the fifth vein and is called the posterior cross-vein. The posterior cross-vein is usually a short distance behind the anterior cross-vein, it may, however, be in line with it or even beyond it. There is also a humeral cross-vein, close to the base of the wing between the costa and the auxiliary vein. Between the first and auxiliary veins and behind the origin of the second vein is the subcostal cross-vein. Besides these veins there are chitinizations resembling veins and sometimes in continuation of them. These are variously developed in the different forms. The second and third veins are usually thus continued longitudinally backward from the point of angulation. A particularly heavy chitinization follows the fifth vein on the anal side, and in *Megarhinus*,

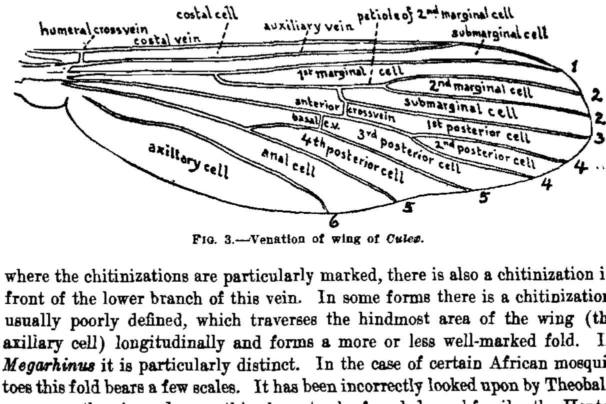


FIG. 3.—Venation of wing of *Culex*.

where the chitinizations are particularly marked, there is also a chitinization in front of the lower branch of this vein. In some forms there is a chitinization, usually poorly defined, which traverses the hindmost area of the wing (the axillary cell) longitudinally and forms a more or less well-marked fold. In *Megarhinus* it is particularly distinct. In the case of certain African mosquitoes this fold bears a few scales. It has been incorrectly looked upon by Theobald as a seventh vein and upon this character he founded a subfamily, the Heptaphlebomyinæ.

The relative length of the fork and the stem, particularly in the second vein, is in some cases of diagnostic value, not only specifically but generically. Thus the genera *Megarhinus* and *Uranotænia* are remarkable for the very short branches of the second vein. The part of the wing enclosed by the two branches of the second vein is the second marginal cell; it is often incorrectly called the first submarginal cell. The position of the posterior cross-vein in relation to the anterior cross-vein is also of significance in classificaton, although there is naturally some individual variation.

The wings are clothed with scales along the veins and along their margins. These scales show great diversity in shape and characters in different species and on different parts of the wing; they offer excellent characters for specific differentiation. Also the scales of the wing may be of different colors, either irregularly distributed or forming a definite pattern, as in many species of *Anopheles*. The vestiture is heaviest in the costal region, and the several series are often crowded and overlapping; sometimes there is a series of coarse scales which project spine-like from the costal margin. The wing-membrane is usually clear and transparent; sometimes, however, it is infuscated, particularly along the costa. Such infuscation is usually diffused over the entire wing. Sometimes the infuscation occurs in diffused spots in the region of the cross-veins, and elsewhere, as in certain species of *Culiseta*.

The shape of the wing often differs in the two sexes and the wing of the male is then smaller and narrower. The narrowing of the wing of the male is often very marked and is accompanied by differences in the proportions of the veins; particularly is there a tendency to crowding towards the costa and to the reduction of the second marginal and second posterior cells. When the male has much narrowed wings the scales are often very deciduous.

THE LEGS.

The legs are long and slender. They are composed of trochanter, femur, tibia, and a tarsus of five joints. The trochanters are short, jointed with the coxæ above, and with the femora below. They are freely movable upon the coxa but they are rather closely united with the femur and there appears to be but little motility at that point.

The femora are always long but show considerable variation in the different forms. Usually they are nearly alike in all three pairs of legs and are subcylindrical or compressed. In *Anopheles* they are very long and slender and of nearly equal thickness throughout. In *Psorophora ciliata* the femora are somewhat thickened towards their apices. In many forms the femora are compressed and more or less enlarged. This enlargement is usually most pronounced in the front and middle pairs; the middle femora, furthermore, are often fusiform, largest above the middle. In some Sabethids the front femora only are thickened. All three pairs of femora are usually of very nearly equal length. In most forms the middle femora are slightly longer than the other two pairs. In the Sabethini the hind femora are the shortest, in many forms appreciably so, and this characteristic is usually more marked in one sex or the other. In *Sabethes* the middle femora are much the longest. The femora are armed with a group of spines at their apices which differ in character and arrangement in the different genera. There are also longitudinal series of setæ, varying in number and coarseness. In *Megarhinus* these setæ are represented by spines.

The tibiæ are slender and of approximately the same length as the femora. They are subcylindrical and slightly thickened apically. This thickening is most marked in the hind tibiæ. In the Culicini the three pairs of tibiæ may be subequal in length, or the front pair may be markedly shorter. In the Sabethini the hind pair of tibiæ are always the shortest, although this character varies in degree with the species and the sex; they are also stouter and more incrassate.

The front tibiæ are often the longest in the Sabethini. At their apices the tibiæ are more or less excavate behind and bear several stout spines, and in addition, particularly on the front and hind pair, numerous stiff setæ. Upon the front and hind tibiæ these setæ are densely massed upon the broader portions of the tibiæ and in addition there is, subapically on the inner side, a transverse row of very densely placed setæ. Below this row of setæ are usually present several slender spines, also in a transverse row. These spines have been termed the tibial scraper and their presence or absence, on the hind tibiæ, and their number, are of systematic value. The tibiæ also bear longitudinal series of spines and these differ in character with the species.

The tarsi are slender, cylindrical and differ considerably in their proportions on the three pairs of legs. They are, as a whole, much longer on the hind legs and it is they largely that determine the predominating length of this pair of legs. The first tarsal joint is always very long in all three pairs of legs, although usually somewhat shorter than the tibia. In *Anopheles*, however, the first tarsal joint of the hind legs is longer than the tibia. The first tarsal joint is by many systematists called the "metatarsus." The application of this term is incorrect as it implies something beyond, or outward, from the tarsus. As the first tarsals differ from the following ones only in length, and this is not true of all Diptera, there is no reason why they should be designated by a special term. Furthermore the introduction of this term has brought about much confusion in descriptive work; when an author has been inconsistent in this usage it is sometimes impossible to determine if his "first joint" is in reality the first or the second.

Each tarsal joint is shorter than the one preceding it; the only interruption occurs, sometimes, in the last two tarsals of the front and middle legs, the fourth joint being in such case the shorter. This progressive reduction is most rapid on the front and middle legs, the hind tarsi are always much the longest. In many forms the front tarsi are, as a whole, noticeably shorter than the middle ones, while still more often they are nearly equal. In some Sabethini the middle tarsi are shorter than the anterior ones.

The fourth tarsal joint, as already indicated, is often shorter than the fifth, either upon both the front and middle legs or upon the front legs alone. This difference is greatest in those males in which the claws show the most sexual modification. In the female the fourth joint, if shorter than the fifth, is usually but slightly so; in *Bancroftia*, however, the fourth joint is very short, about as long as broad. In the females of *Anopheles* and in both sexes of most Sabethini the last tarsal joint is distinctly the shortest. All the tarsal joints but the last bear a pair of spurs apically beneath. In addition there are longitudinal series of spines or setæ; these, and the terminal spurs, are variously developed in the different genera and species. The last tarsal joint bears the two claws, or, in a few cases, a single claw. In the females, and in many males, the fifth tarsal joint is cylindrical, resembling in character the other joints. It is often obliquely excised at the tip beneath for the insertion of the claws and their mechanism. In the males of most Culicini, and in the male of *Joblotia*, the fifth tarsal joint of the front and middle legs, or of the front legs alone, differs considerably from the others. In these cases it is considerably longer than the fourth joint and is more or less deeply concave along nearly its entire under side. It is broadest at the base which is often produced beneath into a tooth. Sometimes there is a spinose process near the middle of the concavity. The fifth joint usually bears many setæ towards the apex, particularly when modified as just described. In the case of such modification it also generally bears a series of spines basally beneath. When the fifth tarsal of both the front and middle legs is modified as just described the development is greater on the front legs, indeed, forms occur in which the concavity is but slightly indicated on the middle legs.

The claws are inserted at the apex of the last tarsal joint. There are nearly always two claws but in a few cases (*Limatus, Lesticocampa*) there is but a single claw on the hind legs. They are curved and taper to a point. When without teeth the claws are said to be simple. When the two claws of the same foot are of the same length they are said to be equal. In the females each pair of claws is equal or nearly so, but they differ much in size in the different genera. The claws of the hind leg are often much smaller than the others. In the female the claws are most often simple. In the females of many species of *Psorophora* and *Aëdes,* and of some *Stegoconops,* at least the claws of the front and middle legs bear a distinct tooth before the middle. In certain species of these genera the hind claws also are toothed. This, however, appears to be a variable character in some species. In *Aëdes sylvestris* the hind claws of the female may be simple or toothed. Indeed we have a specimen of this species in which three of the claws of the hind legs are simple while the remaining one is toothed; in another specimen three claws of the hind legs are toothed and one is simple.

In the males the claws of some of the legs are usually modified in a striking manner. In the Culicini it is generally the claws of the front legs that show sexual peculiarities, and often also the claws of the middle legs. There is often considerable diversity in this respect among the members of a single genus. In *Culex pipiens,* and in many other species of *Culex,* the inner claw of the front and middle legs is much larger than its mate and bears a long tooth outwardly near the middle; the other claw bears a tooth on the opposite side near the base. The position of the teeth on the claws differs in some of the species; the tooth on the large claw may be nearer the base and the tooth on the small claw moved farther out. In certain species the tooth of the small claw is much reduced and in others it is absent. In *Culex latisquama* only the large claw of the front legs is toothed; the claws of the middle legs are simple, but unequal in shape and length. It may be remarked that in correlation with these simple claws of this species are the longer fourth tarsal joints of the front and middle legs. There is great diversity in the claws of the males of the different species of *Aëdes* and *Psorophora.* In *Psorophora,* irrespective of the claw structure of the female, the male has the large claw of the front and middle legs armed with two teeth, one near the middle, the other basal, while the smaller claw bears a single tooth. In those forms of this genus in which the claws of the female are toothed the hind claws of the male are also toothed. In the main group of *Aëdes*, in which the claws of the female are toothed, there is much diversity in the front and middle claws of the male. Thus in *Aëdes curriei* and other forms the large claw of the front feet bears two teeth, the smaller claw one, while on the middle legs both claws bear a single tooth. In *Aëdes sylvestris* both claws of the front feet bear a single tooth, while on the middle feet the large claw only is toothed. In *Aëdes fuscus* only the large claw of the front and middle legs bears a tooth. In all the forms in which the hind claws of the female are toothed these are also toothed in the male, and, as in the female, of equal length. In *Aëdes calopus* the female has toothed claws on the front and middle legs; the male has a tooth on the large claw of the front feet only, the claws of the middle feet are simple but unequal. In the males of other forms of *Aëdes* in which the claws of the female are simple, as *Aëdes fulvithorax,* the large claw of the front and middle legs is toothed, the smaller one simple. The same is true of *Mansonia perturbans* and other species of that genus. In *Bancroftia* the large claw of the front and middle legs of the male bears a single slender tooth near the middle, while the smaller tooth is simple. In the male of *Megarhinus* the larger claw of the front and middle feet bears a sharp tooth. In the male of *Stegoconops capricorni* both claws of the front feet bear a small tooth near the base; on the middle feet the large claw is simple, while the small one carries a tooth. The female of this species has toothed claws. *Stegoconops albomaculatus,* in which the claws of the female are simple, has the larger claw of the front and middle feet of the male armed with a single tooth while the smaller claw is simple. In *Culiseta,* where again the female claws are unarmed, the male has the claws of the front and middle legs toothed, the larger claw bearing two teeth, the smaller a single one.

In the genus *Deinocerites* the tendency in the male claws is towards simplicity. In *Deinocerites cancer* and *D. melanophylum* the claws of the front and middle legs are unequal in the male, the larger claw toothed, the smaller simple. In *Deinocerites troglodytus* the claws of the front and middle feet of the male are large but equal; both claws are toothed on the front feet, on the middle feet only one of them. In *Deinocerites pseudes,* finally, all the claws of the male are simple and equal; those of the front feet, however, are very large and sickle-shaped. In the male of *Uranotænia* all the claws are simple; those of the front legs are equal; the middle feet, however, have a single, large, strongly hooked claw which is inserted beneath, behind the apex of the tarsus.

In *Anopheles* the claws of the front feet only are modified in the male. There is one large claw with a tooth at the middle and another laterally at the base. The second claw is rudimentary and, with the empodium, inserted some distance behind the large claw. Theobald figures the large claw of *Anopheles grabhamii* without basal tooth; there is, however, a well-developed basal tooth in this, as in all the other species of *Anopheles* we have examined. In the closely related *Cœlodiazesis barberi* the small claw, together with the empodium, is placed well forward near the large claw; it is, however, very small and strongly curved. The large claw has an additional smaller basal tooth on the side opposite the other one.

In the males of the Sabethini it is usually the claws of the middle feet alone that show sexual peculiarities, and even these may be but slight. With a very few exceptions the claws are simple in both sexes and the male characters consist of differences in the length and shape of the claws. In *Wyeomyia trinidadensis* the claws of the middle feet of the male are nearly equal in length; one of them, however, is much stouter and more strongly curved, and the fifth tarsal joint is deeply excised apically beneath. In *Limatus durhamii* the claws of the male's middle feet are similar to those just described, the last tasal joint, however, is without excision and only slightly tapered towards the apex. In the male *Wyeomyia circumcincta* the claws of the middle feet are unequal in length, the large one sickle-shaped, the small one gently curved. In the male of *Wyeomyia smithii* there is one large sickle-shaped claw and the small claw is represented by a minute stout spine. In *Sabethinus undosus* the male has the claws of the middle feet of nearly equal length; however, one claw is deeply cleft and one of its branches, instead of tapering to a point, is flattened and truncated at the tip, the truncation bearing a series of very fine teeth. The claws of the middle feet of the male *Sabethes cyaneus* are very similar to those just described; the flattened branch, however, is much broader and covers the other, the point of which projects slightly from below.

In the Sabethini just discussed it is only the middle claws of the male that are modified; the front claws are simple and equal. In the genera *Joblotia* and *Lesticocampa* both the front and the middle claws are differentiated. In *Joblotia digitatus* the claws of the front and middle legs of the male are unequal but simple, those of the front legs being the larger and more curved. In the male of *Lesticocampa lampropus* the claws of the front and middle legs are unequal and simple, bent strongly backward so that the tip of the large claw nearly touches the fourth tarsal joint.

In *Joblotia trichorryes* the claws of the front and middle legs of the male are unequal; the large claw of the front feet has a slender tooth while all the other claws are simple. The claws of the male *Lesticocampa dicellaphora* are perhaps the most remarkable of any mosquito. The front claws are unequal, the larger with a tooth. The middle claws are also unequal; the smaller is slender and unarmed; the larger has along its under surface a comb, composed of about twenty very long, slender, sharp teeth.

The claws are supported by a membranous cushion which occupies the apical portion of the last tarsal segment beneath. This cushion may be nearly obsolete, as in the male of *Uranotænia,* when the claws are inserted close upon the tarsus and more or less ventrally. The cushion covers the ventro-apical excision of the fifth tarsal joint and upon the size of this excision the development of the cushion depends. On tbis account this cushion is well developed in most of the Culicini and produced forward beyond the tarsus to support the bases of the claws. The cushion is furnished with two, more or less lanceolate, chitinous pieces, the flexor plates. These flexor plates have muscles attached to their bases and hinge upon the tarsus; apically they are attached to the bases of the claws. By traction of the muscles the claws are drawn downward. When the cushion is well developed it is hairy and particularly on the apical half the hairs are long and stiff. The pulvilli, a pair of fleshy lobes present on the feet of the higher flies, are absent in the Culicidæ, as in most other Nemocera. Ficalbi wrongly showed pulvilli in the foot of the mosquito and has been followed in this by Blanchard and others. The error is based upon a misinterpretation of the cushion just described.

The empodium is an unpaired organ arising between the claws. It is usually slender and tapers outwardly into a bristle and bears a number of setæ. It differs much in length and development and may even be absent altogether. It is, however, well developed and long in the front feet of the male *Anopheles*, where one claw is rudimentary; but in this case it is inserted at a considerable distance behind the large claw. In *Lutzia bigotii* it is broadly compressed, with a setose margin; at the base of the claws, externally are a series of long setæ, the whole forming a mechanism to enable this large mosquito to rest upon the water. In *Culex melanurus* the empodium has the form of a chitinous plate the outer margin of which is produced into a series of long spines.

THE ABDOMEN.

The abdomen is elongate, more or less cylindrical, and is composed of ten segments. Of these the first eight are similar in character while the last two are greatly reduced and modified for the sexual functions. Each of the first eight segments consists of chitinized dorsal and ventral plates, the tergum and sternum; these are connected at the sides by a broad area of flexible membrane which is folded when the abdomen is not distended. The segments are connected with each other by flexible membrane which is normally retracted in such a manner that each segment projects over the succeeding one. There are six pairs of abdominal spiracles. These are small and situated before the middle in the pleural membrane of the second to seventh segments. The first segment is shorter than the succeeding ones and its tergite bears many long hairs upon its surface.

THE ABDOMEN OF THE FEMALE.

The oviduct opens in the membrane behind the eighth sternite; the orifice is large and is surrounded by chitinous strips. The ninth segment is small and bears a small chitinous tergite while the sternite is carried outward and projects beyond the tenth segment. The ninth sternite bears a pair of gonapophyses which are variously developed. They may be nearly obsolete, represented by a pair of blunt tubercles; in other forms they are long and slender and bear many coarse hairs. The tenth segment is greatly reduced, without tergite or sternite; it bears the cerci and in it is the anal opening. The cerci are not jointed, but present great variation in form and size. There is often present a third chitinous appendage which apparently also belongs to the tenth segment; in certain forms this is large and of nearly equal length with the cerci and may be emarginate at the apex. The general form of the abdomen of the female differs greatly, and correlated with this difference is the form of the terminal appendages. To a certain extent at least these modifications are correlated to the mode of oviposition. Thus in *Culex, Culiseta, Mansonia* and *Uranotænia,* which lay their eggs in a raft, the tip of the abdomen is blunt and the cerci are small and broad and not promiment. In *Psorophora,* and most species of *Aëdes,* which deposit their eggs singly, the abdomen tapers towards the tip and the cerci are long, slender and exserted.

In *Psorophora* the eighth segment is flexible and completely retractile within the seventh. Basally on the eighth segment there is a broad area of membranous tissue; outwardly are the tergum and sternum and these are also membranous in character but differentiated in structure by the presence of numerous minute transverse strips of chitin. Internally the two plates are supported by two pairs of slender chitinous rods and these probably also form part of the mechanism for retracting the segment. The sternite is broadened posteriorly and projects considerably beyond the tergite, thus forming a ventral support for the greatly reduced ninth segment. The eighth segment when fully protruded is longer than the preceding one. In most species of *Aëdes* the eighth segment is partly retractile, having a broad basal membrane, but this is not as extensive as in the forms just described. The tergal and sternal plates are, however, in *Aëdes,* continuously chitinized and clothed with hairs and scales.

In the females of *Deinocerites* and *Dinomimetes* the abdomen is long, somewhat compressed, and slightly tapered towards the tip; the eighth segment is peculiarly modified. The tergite of the eighth segment presents nothing unusual but the sternite is larger, compressed, and produced posteriorly, the apical portion heavily chitinized. In *Dinomimetes epitedeus* and *Deinocerites pseudes* the sternite is much produced in the form of two rounded lateral lobes, their upper portions most prominent; the margins of the lobes are closely beset with coarse setæ inserted in tubercles. In *Deinocerites cancer* and related forms the lobes of the eighth sternite are roughly quadrate and very heavily chitinized, with the lower angle somewhat produced; upon this angle and along the lower margin are a series of tubercles bearing coarse setæ which give the margin a serrate effect. In this last-described type of *Deinocerites* the cerci reach an unusual development. They are large, conical, heavily chitinized, and have inserted at their apices a pair of long, slender flattened appendages. The gonapophyses are inconspicuous in these forms. The shape of the sternal lobes and of the cerci differs in the different species. In *Deinocerites pseudes* and *Dinomimetes epitedeus* the cerci are, as in other mosquitoes, without terminal appendages; they are, however, rather large, leaf-like and heavily chitinized. In these two species the gonapophyses are well developed, heavily chitinized and setose.

The eighth abdominal segment of the female *Mansonia titillans* is remarkable in that it is completely retractile within the seventh while its tergite is membranous and bears at its apical margin a row of stout chitinous hooks. In many forms the abdomen is more or less depressed, particularly towards the base. In *Carrollia* and in *Wyeomyia codiocampa* the abdomen is strongly compressed. In the Sabethini the abdomen is usually subcylindrical and blunt at the tip, and sometimes it is very elongate. The surface of the tergites and sternites bears many scattered hairs and these vary in coarseness and abundance with the species; there is a series of coarser and longer hairs along their posterior margins. These marginal hairs, and still more so the others, are much less conspicuous in the Sabethini; in this tribe, however, the eighth segment bears numerous stiff bristles posteriorly, particularly beneath.

THE ABDOMEN OF THE MALE.

The abdomen of the male is often much longer than that of the female. The ninth and tenth segments are crowded together and carry the genital armature. Often the abdomen is depressed and of nearly uniform width throughout. The tergite of the first segment, as in the female, bears many long hairs. The abdo-

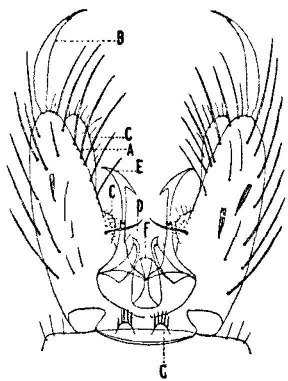


FIG. 4.—Diagram of the male genitalia of *Aëdes*: *A*, Side piece; *B*, Clasp filament; *C*, Lobes of side piece; *D*, Harpe; *E*, Harbago; *F*, Uncl.

men is often strongly ciliate along the sides, numerous long hairs being inserted laterally on the tergites. This is true of *Anopheles, Megarhinus* and most species of *Culex* and *Aëdes* as well as of many others. In other forms there is no obvious lateral ciliation but there is a tendency to increased coarseness of all the setæ towards the tip of the abdomen. Sometimes the eighth segment is armed with many coarse setæ. Usually the setæ of the sternites are coarser in the male than in the female. In the Culicini there is a reduction in the size of the segments near the tip of the abdomen. In many Sabethini the abdomen is distinctly expanded towards the tip, and the sternite of the eighth segment particularly, bears many coarse bristles. The male genitalia are very important in classification and for systematic purposes may be described as follows:

The Male Genitalia (fig. 4).—The male genitalia consist of two thick conical appendages, the side-pieces (a). These each bear a smaller terminal *appendage, the clasp-filament (b) and also occasionally certain lobes near base or tip (c), designated as subapical or subbasal lobes.* There are three sets of paired basal appendages, the harpes (d), harpagones (e) and unci (f). The penultimate segment generally has a pair of setose appendages, the basal appendages (g). In the simplest forms these smaller basal appendages, harpes and harpagones are absent, as in *Anopheles,* though the unci are always present. In the succeeding higher forms the harpes appear and still later the harpagones. The harpes are present in all the genera above *Anopheles, Aëdeomyia* and *Uranotænia* and are probably homologous throughout the group as they have essentially the same form in all, only becoming modified in *Culex.* The harpagones, or at least a third pair of appendages, appear in all the highest forms, but it is doubtful if they can be regarded as strictly homologous as they seem to have arisen three times independently, once in *Aëdes,* once in *Culex* and once in the sabethid line. We have, however, uniformly designated the third pair of appendages as harpagones. Several different lines of modifications are found in the different groups. The *Anopheles* are all very simple, having besides the side-pieces, clasp-filament and unci, nothing but various spines and hooks without forming definite accessory clasping organs. In the most specialized species, such as *bellator* and *barberi* there is a rounded basal lobe bearing a tuft of long hairs. Next to *Anopheles* in simplicity comes *Aëdeomyia,* in which there are present only somewhat complex unci. The side-pieces have a small basal lobe while the clasp-filament has a multiple terminal spine. Next comes *Uranotænia,* in which there is a complex series of small basal appendages perhaps representing divisions of the unci, hut no recognizable harpes. The side-pieces bear a more or less well-developed conical basal lobe. Next come the lower Sabethids, *Lesticocampa* and *Joblotia,* together with the lower Culicids, *Megarhinus, Bancroftia, Mansonia* and *Culiseta.* These have the harpes well developed but no harpagones. There is generally present a basal lobe to the side-piece, which in *Mansonia* becomes modified into a ribbon-like appendage or a rod carried on the basal lobe. In the Sabethid line a division of the small basal parts occurs, so that in many forms a third pair of appendages or harpagones can be recognized. The characteristic development of the line, however, takes another direction, that of the modification of the clasp-filament, which becomes lobed and distorted, culminating in *Sabethes,* where a truly wonderful structure is produced. In a few forms the clasp-filament is reduced to a rudiment, its place being taken functionally by an expanded outer angle of the side-piece, and in others a basal lobe of the side-piece is developed (as in *Wyeomyia eloisa* and allies) in which case the clasp-filament is more or less reduced. In the *Aëdes* line the lower forms are simple. In *calopus* there are no harpagones and in other tree-hole species the first rudiments of these organs are seen as a conical basal lobe of the side-piece bearing a seta (for instance in *walkeri, albonatata,* etc.). Later this becomes developed into a rod bearing a filament. *Sylvestris* and *fuscus* have no harpagones, but in these cases the organs have not improbably retrograded. In the *Janthinosoma* group the rod bears several filaments and in *Psorophora* a capitate tip is developed with a large group of filaments. The harpagones of

Aëdes are derived from basal lobes of the side-pieces, but have reached a differentiation of structure such that we consider them as separate organs, while we do not so consider the similarly derived structures of *Mansonia.* In the *Culex* line we find two simple forms, *dyari* and *melanurus*. In these the side-pieces are simple with basal lobes only. The unci and harpes are normal while the harpagones are undeveloped or indicated by a division at the base of the harpes. This is essentially the structure of *Culiseta,* etc. But in this line the harpagones arise as division from the base of the harpes and not as basal lobes of the side-piece In *Culex* proper and its derivatives *Carrollia* and *Lutzia* both harpes and harpagones are progressively notched and divided into lamellæ, the harpes evolving a curved basal branch and the harpagones becoming divided. The unci are not recognizable in these highly developed forms. The side-pieces of *Culex* generally bear a lobe near the middle which carries setæ or filaments and generally a leaf-like appendage. The *Deinocerites* group is apparently a development from *Culex* in which one of the lobes of the harpagones has grown out into a long spatulate process. The clasp-filaments are thickened and hirsute, somewhat as in some *Culex,* and there are a number of smaller modifications rendering the type distinct in appearance in this line.

THE SCALES.

It has already been stated that the wings bear scales along the veins and on the margins. The body and the legs, proboscis and palpi of mosquitoes are always more or less scaled. Scales are modified hairs. Among the least specialized mosquitoes, the *Anopheles,* we find in the body vestiture of the different species an imperceptible transition from hairs, through "hair-like" scales, to well-differentiated scales. The scales differ greatly in form and size on different parts of the body. They also show important specific differences and may even present peculiar characteristics within a certain group. The color of the scales in great measure gives the different species their characteristic appearance and upon vestiture-coloration specific identification largely depends. There is great range in the coloration of the scales. Many mosquitoes show only dull colors, such as black, brown, and dull reddish or yellowish shades, variegated with white. Others show a pattern of silvery or golden scales, while still others are clothed for the most part with scales of brilliant metallic blue, green or purple.

Theobald, who has utilized to the utmost in his systematic work the character of the scales, in Genera Insectorum, Culicidæ (1905), enumerates seventeen types of scales, as follows: "1, Flat or spatulate scales; 2, Broad Mansonia scales; 3, Broad Aëdomyia scales; 4, Curved hair-like scales; 5, Narrow-curved scales; 6, Spindle-shaped scales; 7, Small spindle-shaped scales; 8, Inflated or parti-colored scales; 9, Pyriform scales; 10, Upright forked scales; 11, Twisted upright scales; 12, Lanceolate scales; 13, Linear scales; 14, Tæniorhynchus-like scales; 15, Melanoconion scales; 16, Cycloleppteron scales; 17, Heart-shaped scales." In addition Theobald has introduced other terms, such as "fan-shaped," "long twisted" and "obovate" and he has differentiated further by the use of adjectives so that his distinctions become highly complex and often very vague. In many cases intergrades between the different types of scales occur so that the application of the terminology becomes necessarily a matter of opinion. *In fact the differences in the conception of these terms as employed by different authors has brought about great confusion in the systematic literature.*

Part of the above terms are self explanatory, others can hardly be interpreted without recourse to specimens. The wing-scales show the greatest diversity and have been utilized the most and eleven of the types enumerated above, and their modifications, are employed by Theobald as wing-characters. Along each wing-vein there are two paired series of scales and the scales of these two series often differ greatly in form and size. The non-biting Culicidæ of the group Corethrinæ show the most primitive condition of wing vestiture. In *Chaoborus* the scales along the wing-veins are long and hair-like and the two series are not differentiated. Among the biting Culicidæ the Anophelines show the most generalized condition. In most species of *Anopheles* the scales along the veins are narrow, lanceolate, and, while there are distinctly two series, the scales of these series are often much alike. In other forms of *Anopheles* there is some differentiation, the scales of the lower series being smaller, shorter and less divergent. In *Anopheles grabhamii* the scales are much broader but of the lanceolate character; irregularly scattered among these, and with a tendency towards grouping, are larger and darker very broad scales, their apices broadly rounded or subtruncate. These large, broad scales are the "Cycloleppteron scales" of Theobald and are said by him to be inflated; they are, however, flat like other scales.

The wing vestiture is remarkably diversified in *Uranotænia.* On nearly all the veins one of the series consists of small, truncate scales arranged in a single row and overlapping. On the outer part of the wing the veins also have lateral series of large scales and these differ in shape on some of the veins. Finally on the basal portion of the fifth vein there is, in most species, a double series of very broad small scales of a silver-blue color. In some species the scales on certain parts of the wing are white.

In *Culiseta* the wing scales are narrow and in two double series along the veins. The lower series are of smaller shorter scales, closely applied to the veins; the upper series consists of long and very narrow outstanding scales. A very unusual feature occurs in certain species of this genus; the anterior cross-vein bears scales. In most species of *Culex* the appearance of the wing is similar to *Culiseta.* There are, however, three double series of scales outwardly on some of the veins. The long scales are usually narrow and blunt or truncate at the tip; these are the "linear" scales of Theobald, and we have termed these "ligulate." In many forms the scales are broadened and rounded at their apices and there is an increased tendency to crowding towards the apex of the wing. This constitutes the so-called "Melanoconion scales" of Theobald; however these are not separable as a distinct type, but, through different species, intergrade with the ordinary *Culex* scales, and the tendency to crowding towards the apex of the wing is a very general one. The smaller scales when broad are often obliquely subtruncate. In most species of *Aëdes* the wing scales are entirely similar to the typical *Culex*. In *Aëdes squamiger* and some other species the scales of the upper series are broad and subtruncate and these are the "fan-shaped" scales of Theobald. While in most species of *Aëdes* the color of all the scales is dark, in certain species there is a sprinkling of light-colored scales. This is also the case with certain species of *Psorophora*, and in some species the scales are grouped to form a definite pattern (*P. discolor, P. signipennis*).

In the genus *Mansonia* the scales of one series are more or less broadened with a tendency to oblique truncation. This is the least marked in *Mansonia fasciolatus* of any of the species we have examined and in it many of the scales are hardly different from the "fan-shaped" ones above mentioned. These are the so-called "Tæniorhynchus scales" of Theobald. In *Mansonia titillans* these scales are differentiated most and very broad and asymmetrical and many of them are shallowly emarginate at their apices. This constitutes the "Mansonia scales" of Theobald. A similar type of scales, but with more rounded apices, occurs in *Bancroftia fascipes*. Hardly distinguishable in character are the wing-scales of *Aëdeomyia squamipennis*, designated as "Aëdeomyia scales" by Theobald; their angles are somewhat more rounded.

Along the costal margin there is often a series of scales which are combined into groups of several in such a way that they give the effect of stout spines and this has led to the introduction of the term "spinose." The spinose effect is produced by the crowding together of the pointed apices of several scales. Frequently this spinose arrangement is hidden by overlapping broader scales.

The head behind the eyes is covered with scales. The covering may be entirely of broad scales lying flat, as in *Megarhinus*, or there may be several types of scales present. Very often there is an area of greater or less extent on the vertex covered with "narrow, curved scales." In addition there is frequently a mass of "upright forked scales" upon the vertex. These are narrow scales with a long slender stem and expanded fan-like apically; the apical margin is roughly spinose, or it may be emarginate or tridentate. Transition forms may occur between these and the other scales. Usually these "upright forked scales" are in a dense mass on the vertex. In *Joblotia* and *Lesticocampa* they are arranged in a long, regular, transverse row on the occiput. When the prothoracic lobes are large the upright forked scales are absent.

The thorax is more or less clothed with scales. This scale covering is least developed in the lowest forms, the Anophelines. In these there is but a sparse vestiture of hair-like scales upon the mesonotum, so that the integument itself remains plainly visible. When the scale-covering is sparse the integument usually shows peculiarities of coloration and it may be ornamented with spots, as in many *Anopheles* and *Aëdes fulvus*. The prothoracic lobes are usually more or less scaled. There may be but a few loose scales or the lobes may be densely covered with them. This latter condition is particularly true of the Sabethini and other forms with large prothoracic lobes and the coloration of this vestiture is often important for specific determination. The mesonotum is usually for the most part densely covered with scales. In many forms a median depression in front of the scutellum, the ante-scutellar space, is devoid of scales. The scales of the mesonotum vary much in size and shape. They are sometimes very small and hair-like, or they may be larger and slightly broader and are then the "narrow curved" scales of Theobald. They may be broad, more or less truncate at the apex and are then Theobald's "flat or spatulate" scales. There may be broad, flat scales pointed at both ends and these are the "spindle-shaped scales" of Theobald. The scales of the mesonotum may be all of one type or several kinds may be present. The scales may be diffierent in color as well as form and thus produce more or less distinct patterns. A curious type of scales is present on the mesonotum of certain species of *Bancroftia*. These are white, very long, narrow, flat scales arranged in longitudinal rows; some of these rows are continued over the scutellum, the end scales projecting far beyond its posterior margin. The scutellum is covered with scales of similar character with those of the mesonotum. The scales on the scutellum may be broad while those on the mesonotum are narrow. In many species there are areas or longitudinal stripes upon the mesonotum which are devoid of scales.

The postnotum is usually naked; in a few Sabethini, however, scales are present. There may be only a few scales arranged in one or more rows, or the entire postnotum may be covered, as in some species of *Sabethes* and *Sabethinus*.

The pleuræ and coxæ are generally more or less covered with pale scales, but these are often very deciduous or they may be absent altogether. Sometimes a part of the scales on the pleuræ are of another color.

The abdomen is usually covered with broad overlapping scales. In many *Anopheles* there is only a sprinkling of hair-like scales; in others flat scales are present on the last segment, or on all the segments. In certain species of *Anopheles*, and in some other mosquitoes, there are tufts of erect, flat scales on some of the abdominal segments. In certain species of *Megarhinus* there are long scales which extend laterally as fan-shaped tufts on the apical portion of the abdomen. In a few cases the cerci are covered with scales.

The legs are covered with scales in all mosquitoes and usually these scales are small and closely applied to the surface. Sometimes the scales are long and more or less raised, usually most pronounced on the hind legs, as in certain species of *Psorophora* and *Lesticocampa*. In some cases very long, narrow scales, which extend outward in a plane, are present on certain parts of the legs. These in *Sabethes* give the well-known "paddle" effect. These paddles involve parts of the tibia and the tarsus. Such paddles may be present on one pair of legs or on all the legs. In *Aëdeomyia squamipennis* the femora are furnished with rough scale-tufts nears their apices.

The proboscis and palpi are clothed with scales. These are usually small and closely applied, but sometimes they are more or less raised and long and give a shaggy effect.

In a few cases scales are present upon the clypeus. The tori or globose basal joints of the antennæ often bear scales. The first joint of the shaft is densely scaled in *Megarhinus* and in other mosquitoes still other antennal joints bear scales, but these forms are exceptional.

THE INTERNAL ANATOMY OF MOSQUITOES.

Early investigators already did considerable work on the internal anatomy of mosquitoes and since the discovery of their relation to disease there has been much activity along this line. Already in 1851 Dufour, in his monumental work on the anatomy of the Diptera, gave a very clear description of the digestive and reproductive systems of mosquitoes, based largely on dissections of *Culiseta annulatus*. In a work like the present which attempts to cover the greater part of the field of our knowledge of mosquitoes, this important subject should not be omitted, but time has not permitted us to make original studies of the internal anatomy which has seemed to us to demand less attention than the other aspects. Several papers bearing upon this subject might be mentioned, especially the studies of Pressat and of Nuttall and Shipley, the careful paper on the alimentary canal of the mosquito by Millet P. Thompson, and others. In order that this work shall not be published without some consideration of this topic, the authors have asked the permission of Dr. J. W. W. Stephens, of the Liverpool School of Tropical Medicine, to use the chapter on this subject from the excellent work entitled " The Practical Study of Malaria and Other Blood Parasites," by Stephens and Christophers, published by The University Press of Liverpool, 1908. Doctor Stephens has consented, and the following account of the anatomy of a female *Anopheles* is taken from this work:

GROSS ANATOMY.

"THE ALIMENTARY CANAL.

" The alimentary canal is specialized on account of the blood-sucking habits of the mosquito. It differs from many insects in not possessing any cæcal diverticula of the mid-gut. It also differs in the possession of five malpighian tubules, these being in insects usually even in number.

" The parts of the alimentary canal are as follows:

The mouth The pharynx with pumping organ The œsophagus The œsophageal diverticula	The fore-gut.
The homologue of the proventriculus The stomach (so-called) The pylorus	The mid-gut.
The pyloric dilatation The ileum The colon The rectum with rectal papillæ	The hind-gut.

" The mouth, pharynx, and œsophagus are ectodermal in origin, and both the mouth and pharynx are lined with chitin. The hind-gut is also ectodermal in origin; it does not possess, however, any portion lined with chitin. The mid-gut is the true digestive portion of the tract.

" *The Pharynx.*—The pharynx, which is lined throughout its extent with chitin, passes upwards and backwards through the ganglionic ring formed by the supra and infra-œsophageal ganglia and their commissures. At first it is narrow, but posteriorly becomes a large chamber (the pumping organ).

"The pumping organ occupies with its muscles a large portion of the head behind the level of the cerebral ganglia. In the state of rest its lumen is triradiate in transverse section. The walls are formed of three large and thick chitinous plates, one placed on either side, and one superiorly. Into each of these plates powerful muscles are inserted. The plates are connected by thin non-chitinous membrane, and their edges are rolled so that they form a spring capable of returning to their original position so soon as the separating force of the muscles ceases.

"Posteriorly, where the pharynx becomes very narrow, a sharp bend occurs and a valvular action is produced. The whole forms a very powerful suctorial apparatus.

"*The Œsophagus.*—Immediately beyond the pumping organ the chitinous layer ceases, and the rest of the fore-gut is formed of excessively thin membrane. At the junction of the two portions a sharp bend occurs, and the floor projects so as to form a valvular flap.

"The thin-walled œsophagus is a large dilated sac, whose walls are supported by surrounding structures. Into the posterior wall of the dilated and thin-walled œsophagus projects the papilla-like anterior portion of the mid-gut.

"*The Diverticula of the Œsophagus.*—From the œsophagus two or three diverticula, similar in nature to the œsophagus, extend backwards. Of these, one is of great size, and usually contains gas bubbles. This usually extends into the abdomen, and is a prominent object in dissections and sections.

"*The Homologue of the Proventriculus.*—There is no true proventriculus as in many insects. There is, however, an interesting fold of the fore-gut into the mid-gut which represents this organ. The muscular bundles are here increased, and the whole forms a valvular muscular organ.

"*The Mechanism of Feeding.*—The powerful pumping action which must result from a drawing asunder of the three large chitinous plates of the pumping organ is very evident. These plates, also, when drawn apart must, by reason of their spring-like shape, revert to their original positions close together, without any muscular aid. Posteriorly the valve-like arrangement mentioned before prevents regurgitation. Further, when the blood reaches the junction of the œsophagus and mid-gut the invaginated portion is withdrawn, and is distended by the entering blood into a distinct 'crop,' the valvular function is suspended, and the blood flows onward.

"*The Mid-gut.*—The mid-gut extends from the proventriculus to the origin of the malpighian tubes.

"The anterior narrow portion of the mid-gut lies in the thorax, and does not become distended with blood. The posterior portion when fully dilated fills the greater portion of the abdomen, the viscera being pushed into the last few segments.

"*The Hind-gut.*—The hind-gut is short and passes in one or two bends from the pylorus to the anus. Immediately beyond the pylorus there is a considerable dilatation which is poorly supplied with muscular fibres: into this open the five malpighian tubules. For a short distance beyond this the lumen is narrow (ileum), but becomes gradually larger (colon). At the termination of the colon there is a slight constriction, after which the canal dilates again to form the rectum.

"Into the rectum project six solid growths, the so-called rectal glands, which are, however, papillæ. Posteriorly the rectum ends in the anus close above the genital canal.

"The appendages of the alimentary canal are:—

"*The Salivary Glands.*—The salivary glands consist of six tubular acini lying three upon either side. A duct can be seen traversing almost the entire length of each acinus. Shortly after leaving the acinus, the three unite to form a single duct. Beneath, and in contact with the lower surface of the subœsophageal ganglion, the ducts of each side unite to form a common salivary duct which passes forwards and enters the chitinous first portion of the alimentary canal close to the base of the proboscis.

"*The Malpighian Tubules.*—These are five in number and open into the first portion of the hind-gut immediately beyond the pylorus. Their blind ends are held in position in the neighborhood of the rectum by tracheal branches. They pass forwards in loops above their origin, so that, in transverse section, as many as ten may be seen cut across.

"*The Vascular System.*—As in most insects where the respiratory system ramifies throughout the whole body, the vascular system is not well developed. A dorsal vessel or heart and an anterior prolongation of this (aorta) are the only closed blood-vessels. Apart from the dorsal vessel the blood circulates in large blood spaces, which lie between the lobes of the fat-body and among the muscles and viscera.

"The dorsal vessel passes close beneath the tergal plates throughout the abdomen. It is very thin walled, and is not provided with valves. The upper portion is attached to the dorsum at intervals by suspensory fibres (muscular), so that a festooned appearance is given in longitudinal section. There is, however, no true division into compartments. Laterally large cells (pericardial cells) are arranged throughout its entire extent, and fibres of a muscular nature (alary muscle) pass from the body wall and end in branches in close connexion with the dorsal vessel.

"At the first abdominal segment the dorsal vessel dips down beneath the mesophragma, lying as it does so in direct contact with the cuticle. In the thorax it again arches upwards, and lies between the lower portions of the antero-posterior wing muscle close above the anterior portion of the mid-gut.

"In the anterior third of the thorax it divides into two smaller portions which pass outwards, and coming in contact with the salivary ducts enter the neck.

"Blood spaces without definite walls occur throughout the body. The thorax especially contains large spaces among the muscles, and the complex fat-body which lies between and supports the organ is everywhere bathed with blood fluid."

The diverticula of the œsophagus are of sufficient interest to warrant further remarks. There are three of these diverticula, arising near the posterior end of the œsophagus. Two of them are dorso-lateral and small, the third one is ventral and very large and extends into the abdomen. Dufour examined these organs carefully and speculated regarding their possible function, assuming that they were in some way connected with the digestive process. He called the smaller pair "*bourses ventriculaires,*" the large one "*panse*" or paunch. In fact this paunch is the so-called "sucking stomach," "food-reservoir" or crop of many other insects. In the mosquito it is, when expanded, globose, ovoid. Dufour states that when empty it is folded into plaits. Graber has determined that in flies this organ actually serves as a food-reservoir by feeding them with colored liquid. Dufour found that when the stomach of the mosquito is distended with blood the paunch is filled with a colorless or faintly amber-tinged liquid. He supposed that this liquid was lymph from the cutaneous tissues, which the mosquito must suck before the flow of blood into the capillaries is brought about. He thought that possibly this liquid was afterwards rejected by disgorging, or that it was held in reserve against future needs. The two smaller diverticula Dufour found to be filled with an amber-colored liquid and with bubbles of air and he states that their volume is variable, according to contents. Thompson and others have observed that all three of the diverticula are usually filled with air. Christophers, in considering the mechanism of feeding, discusses the diverticula as follows:

"In mosquitoes as usually killed, the proventriculus and anterior portion of the mid-gut are considerably distant from the posterior end of the pumping organ, so that the large delicate walled œsophageal chamber with its extensive diverticula intervene. Immediately after feeding, however, though blood is very evident in the mid-gut, and even in the calyx-like proventriculus, yet in the œsophagus there is no trace. As this latter is so large and has such delicate walls, it is evident that, in the act of feeding, the calyx-like proventriculus must be applied directly to the posterior opening of the pharynx, thus shutting off the capacious œsophageal pouch. The large œsophageal diverticulum probably acts, not only as an air chamber to specifically lighten the body of the mosquito, but also as an air pad to distribute the pressure of the large coagulum formed in the mid-gut after feeding. In a fed mosquito a transparent area is generally to be seen in front of the opaque mass of blood in the abdomen. This transparent area is the abdominal portion of the air-containing œsophageal diverticulum."

It is undoubtedly the presence of air that led Giles to the view that the diverticula belonged to the tracheal system. He calls them "pneumatic sacs" or "aspiratory vesicles" and claimed that they were part of the tracheal system and not connected with the digestive tract. This view has been thoroughly controverted and Thompson states that the diverticula "have a less extensive tracheal supply than any other part of the alimentary canal, except possibly the pharynx and antlia." Giles thought that there were two ventral sacs and that they have an aerostatic function. He makes the interesting statement, which should be investigated further, that "the more gorged the insect or the heavier it be with eggs, the larger will these sacs be found . . . ."

Eysell appears to have studied the diverticula and their function most carefully. He calls the large ventral diverticulum "Vorratsmagen" (reservoir-stomach) and the two dorsal diverticula "Flugblasen" (flight-bladders). He states that the dorsal diverticula are always filled with air and that this is usually also the case with the ventral one. However, after a meal the ventral diverticulum is filled with nectar, fruit juices or blood which remains there for hours, and with low temperature even for days.

"Sweetened watery solution of litmus is readily taken by mosquitoes. As long as it remains in the reservoir-stomach it retains its beautiful blue color. Transmitted to the mid-gut it turns red at once and also remains red in the hind-gut. Only when the blue color has completely given way to the red has the reservoir-stomach given up the last vestiges of the sugar solution to the mid-gut. By this simple experiment, which can be easily repeated at any time, one can determine with certainty how long nourishment remains in the reservoir-stomach at determined temperatures.

"When the reservoir-stomach, which is supplied with longitudinal and encircling muscles that furthermore are assisted by the pressure of the body, has little by little given up the nourishing liquid to the mid-gut air again takes its place.

"The air is in part swallowed, as one can observe in emerging* mosquitoes by the increasing inflation of the abdomen and the movements of the pharynx-pump, very nicely visible through the as yet unpigmented clypeus. Later, however, it is also produced *in situ,* in the form of carbonic acid, through vegetable comensals, an yeast mould (Laveran, Schaudinn); at the same time an enzyme is formed in which Schaudinn has recognized the poisonous, wheal-producing substance which the mosquito introduces when stinging."

"THE REPRODUCTIVE SYSTEM.

"The organs of the reproductive system are:

1. Ovaries.
2. Oviducts and common oviduct.
3. Mucus gland and duct.
4. Spermathecæ and ducts.

"The ovaries occupy a variable position dependent upon the state of their development. In the newly-hatched mosquito they are small bodies lying in the fourth and fifth abdominal segments close by the posterior portion of the mid-gut, hind gut, and malpighian tubes towards the venter, so that eventually the ovaries occupy nearly the whole of the posterior portion of the abdomen. Each ovary consists of very many follicular tubes, each containing egg follicles in different stages of development. In the mature ovary the lower follicles have in every tube become the large completely-formed egg.

"The oviducts are muscular tubes passing from the ovaries. They join beneath the rectum to form the common oviduct, which is still more abundantly supplied with muscle fibres, and which eventually opens beneath the anus.

"The spermatheca is a chitinous sac, which in the impregnated female is filled with a mass of spermatozoa. Its duct is long and twisted and opens into the common oviduct near its termination. (In *Culex spp.* there are three spermathecæ.)

"The mucus gland, globular or ovoid in shape, opens by a short duct into the same region."

Neveu-Lemaire has shown that the number of spermathecæ or receptacula seminis present in the female differs in certain genera. He determined that in *Anopheles* there is but a single receptaculum seminis, in the oriental *Mansoniodes uniformis* there are two receptacula seminis and in *Culex pipiens* there are three of these receptacles. We have found that in *Uranotænia* and *Aëdeomyia* there is, as in *Anopheles,* but a single receptaculum seminis. In all the other American mosquitoes we have examined, including several species of *Mansonia,* there are three receptacula seminis. When three receptacula are present one of them is often larger or smaller than the other two.

"THE FAT-BODY.

"The adipose tissue is disposed in two ways.

"1. As a general lining to the body wall, being nearly everywhere present directly beneath the cuticle, and

"2. As lobular masses lying in among the organs and muscles. Thus a large pad lies over the compound thoracic ganglion, and sends processes which lie in

* "During the pupal stage the diverticula contain no air whatever, in the newly emerged imago they are on the contrary dilated with air. The newly issued mosquito therefore floats even on alcohol."

among the salivary glands and other viscera. Other smaller masses lie in the head and abdomen."

THE TRACHEAL SYSTEM.

There are two main tracheal trunks, passing along each side of the body near the digestive canal. A branch is sent off to each spiracle and other branches pass to the different organs and ramify through the body. The thoracic spiracles are described on another page in connection with their function in the production of sound. Both spiracles and tracheæ of the thorax are greatly developed. The abdominal spiracles are very small and the tracheal trunks are much more slender in this part of the body than in the thoracic region. No large air-sacs belonging to the tracheal system are present. The branches of the tracheal system are described by Christophers as follows:

"*The Tracheæ.*—Very large tracheæ pass inwards from the anterior thoracic spiracles.

"1. A large branch passes forwards towards the neck and gives off a branch which passes down on either side of the middle line to the two anterior coxæ and the salivary glands. The main branch continues on through the neck, and supplies the head with numerous large branches.

"2. A large branch passes upwards and backwards along the edge of the mesoscutum, and gives off branches which supply the wing muscles. A smaller branch also passes forwards and supplies the muscles of the thorax.

"3. The largest trachea in the body (main trachea) passes downwards, backwards, and inwards, so as to lie on either side of the anterior portion of the alimentary canal. Numerous branches are given off from this trunk to the thoracic muscles, the alimentary canal, and legs. Posteriorly the trunk is continuous with a trachea passing forwards from the second thoracic spiracle, thus forming on either side a large tracheal loop.

"Large tracheæ also pass inwards from the posterior thoracic spiracles.

"1. Branches pass forwards and join in a loop with the main trachea, also backwards to join the abdominal system.

"2. Branches pass downwards to the meta-thorax and posterior pair of legs.

"3. Branches pass inwards to the muscles and mid-gut.

"From each abdominal spiracle a short thick trunk passes inwards which gives rise to the following branches:—

"A dorsal branch ramifying beneath the tergum and joining the branch of the opposite side.

"A sternal branch supplying the sternal plate and muscles, also joining the branch of the other side.

"Loop branches passing to the trunks anterior and posterior.

"Branches passing inwards and supplying viscera. Branches from the first, second, third, and fourth abdominal tracheæ supply mainly the mid-gut, those from the fourth and fifth the ovaries, those from the sixth and seventh the genital organs."

"HISTOLOGY.

"THE ALIMENTARY CANAL AND APPENDAGES.

"The epithelial lining differs considerably in the mid-gut from either the fore-gut or hind-gut. In the mid-gut the possession of a marked striated border by the epithelial cells is characteristic. The muscular fibres of the alimentary canal are striated throughout.

"*The Fore-gut.*—The anterior portion of the fore-gut is lined by chitin and does not differ from the cuticle in structure. It consists of a single layer of cubical cells of small size. The œsophageal dilatation and its diverticula resemble one another in structure. In the adult mosquito they consist of an extremely delicate membrane formed of a single layer of flattened cells, with externally some scattered muscular fibres. In fresh preparations peculiar wrinklings of this membrane are seen, which may appear like bundles of sporozoits. A similar appearance is seen in the dilated portion of the hind-gut just beyond the pylorus.

"In the majority of mosquitoes the walls of the œsophageal diverticulum are crowded with micro-organisms and bodies which appear to be protozoal in nature.

"*The Mid-gut.*—The epithelium consists of a single layer of large cells, which are columnar in the undistended organ, but become flat and pavement-like when the organ is full of blood. They have a finely-reticulated protoplasm, which stains more deeply towards the free border. Stained with Heidenhain's hæmatoxylin, alcohol-hardened specimens are seen to contain numerous stained granules, collected especially in the outer portion of the cell. These are especially abundant in the anterior portion of the mid-gut. They have also, very frequently, a number of small clear vacuoles (droplets), which become more frequent and of larger size towards the free border of the cell. The most marked feature of the cell is the clear striated border which is present in all the cells of the mid-gut, but absent in all other portions of the alimentary canal. The striated border is best marked in the undistended organ, and becomes almost invisible in the fully distended state, when the cells are much flattened.

"The nucleus of these cells is large and centrally situated.

"The muscular coat is very thin. It consists of an open mesh-work of long muscular fibres running longitudinally and circularly.

"The individual muscle fibres are very long, fusiform, striated fibres. On the outer surface of the mid-gut lie numerous large branched cells in which the small tracheæ end, and from which bundles of minute structureless air tubes pass into the wall of the mid-gut. These cells are frequently well shown in gold chloride specimens. Similar cells occur throughout the viscera in connexion with the tracheal endings.

"*The Hind-gut.*—Structurally the small and large intestine are similar, whilst the dilatation beyond the pylorus, and especially the rectum, differ from these.

"The dilatation which occurs at the origin of the malpighian tubules is thin-walled and poorly supplied with muscle fibres. The cells lining it are small and flattened.

"The intestine is lined with a single layer of large cubical cells; external to these is a muscular coat. The cells of the intestine have large nuclei. The protoplasm is finely reticular, and stains less deeply than that of the cells of the mid-gut. Stained with Heidenhain's hæmatoxylin, no granules are present as in the cells of the mid-gut. They have no striated border.

"In the rectum the cells become small and flattened. There are here, however, bodies usually termed rectal glands. These are papillæ covered with a single layer of much hypertrophied cells resembling those lining the small intestine and colon.

"*The Salivary Glands.*—The salivary acini lie in a cleft in the fat-body, which latter comes in close contact with the glands. Each gland acinus consists of a single layer of large cells, limited externally by a delicate sheath (basement membrane) and internally by the intra-glandular duct wall.

"In *Anophelines* the intra-glandular duct becomes larger as it approaches the termination of the acinus, and forms a large cavity.

"In *Culicines* the duct remains of the same diameter throughout the acinus, and terminates abruptly near the end of the acinus without any dilatation.

"In both *Culicines* and *Anophelines* there are two types of gland acinus. These are recognizable both in the fresh gland and in fixed specimens. From their appearance in the latter they may be termed

(1) The granular type.

(2) The clear or colloid-like type.

"*The Granular Type.*—The greater portion of the acinus consists of cells whose nucleus and protoplasm has been pushed to the outer portion of the cell by a large mass of secretion which occupies almost the whole of the cell. In the fresh gland this secretion appears as a clear, refractive substance, and can, by pressure, be made to exude from the cell in refractive globules. In specimens hardened in alcohol, this clear secretion appears as a granular mass, occupying the greater portion of the cell. It stains faintly with hæmatein, and shows under high powers a coarse reticulum and isolated globules, an appearance probably due to the precipitation or coagulation of the secretion by the alcohol.

"The protoplasm of the cell occupies, in the fully-matured gland, only the extreme periphery, and the nucleus, which is much degenerated, is pushed to the outer portion of the cell, and usually lies in the angular interval left at the base of two or more contiguous cells.

"*The Clear or Colloid-like Type.*—Of this type there is but a single acinus upon either side, which usually lies between the two acini of granular type.

"In the fresh gland the cell outlines are not so distinct as in the granular type, and the secretion, when extended by pressure, is much less refractive. In alcohol-hardened specimens, the acinar cells contain a large mass of clear, homogeneous secretion which, as in the last-mentioned type, fills almost the entire cell, and pushes the protoplasm and nucleus to the periphery.

"In the clear type, however, the protoplasm is always in greater amount than is the case with the granular type, and the nucleus never becomes so greatly degenerated. The clear, homogeneous secretion stains readily with hæmatein, and may even stain quite deeply. With Heidenhain's hæmatoxylin it frequently becomes almost black. It resembles very much in appearance colloid substance as it is seen in the mammalian thyroid.

"In *Anophelines* this substance also distends the central duct space within the acinus. In this situation an appearance is sometimes produced which resembles faintly-stained sporozoits, but which is a normal condition.

"*The Malpighian Tubules.*—The malpighian tubules are tubular bodies with cæcal ends, which open into the hind-gut. The cells are extremely large, being, next to the pericardial cells, the largest in the body. Each cell contains a large nucleus, and contains numerous large granules which stain feebly with hæmatein, but powerfully with Heidenhain's hæmatoxylin. Numerous fatty granules are also present. Each cell is wrapped round a central lumen, the cells being arranged alternately, so that a zig-zag appearance is given in section. The inner portion of each cell is markedly striated, the lumen being thus bounded by a striated area. In relation with these tubules, a large number of tracheæ and tracheal end-cells exist.

"In certain conditions the malpighian tubule cells may be found quite free from granules, though otherwise unchanged. This change occurs in mosquitoes with large numbers of flagellates in the rectum and hind-gut.

"*The Vascular System.*—The dorsal vessel is a delicate-walled tube composed of longitudinal and oblique fibres with a nucleated inner layer. The fibres may be traced directly from the terminations of the branched alary muscle fibres. The alary fibres break up into fibres which pass in close connexion with the large pericardial cells, and eventually form (1) fibres passing into the dorsal vessel as longitudinal fibres, (2) fibres joining in an anastomosis in connexion with the floor of the dorsal vessel.

"The pericardial cells are extremely large cells lying on either side of the dorsal vessel throughout its whole extent. They are by far the largest cells in the mosquito, varying from 30μ to 50μ in longitudinal diameter. They are elongate or pear-shape in form, and contain several nuclei. The nuclei usually show signs of degeneration. The peripheral portion of the cell stains more deeply than the central portion, which contains the nuclei and small stained granules. There is a considerable number of masses of a light yellowish pigment resembling that found in the large visceral ganglia cells. The fibres from the branches of the alary muscles pass over and around the pericardial cells to reach the dorsal vessel. From their structure and situation the pericardial cells appear to be of the nature of ganglion cells.

"*The Fat-body.*—The fat-body, both where it occurs as a portion of the body wall and where it lies as free lobulated masses, consists of cells containing numerous oil globules. The cells are of considerable size, and their borders may be frequently traced as polygonal areas. The nuclei are oval in shape with a central mass of chromatin and chromatin threads. Besides oil globules the cells contain granules staining with hæmatein, and minute droplets of a highly refractive, dark substance, which gives the appearance of pigment. These droplets are larger in amount in old mosquitoes than in those freshly hatched."

THE REPRODUCTIVE SYSTEM.

"Each ovary consists of a large number of follicular tubes whose lower ends open into the ovarian tube, and whose upper ends terminate in a delicate supporting filament (terminal filament). The apex of the ovary is formed of a single follicular tube, whose filament is attached to the fat-body of the fourth segment.

"Around the whole ovary there is a delicate nucleated sheath.

"Each follicular tube contains one or more egg-follicles in different stages of development. In the freshly-hatched mosquito each follicular tube contains an undeveloped egg-follicle. As this develops, a second and a third undeveloped follicle appear above it, which again undergo development into mature eggs. The follicle at first consists of two to four large cells, with large nuclei surrounded by a single layer of smaller epithelial cells.

"The central cells then increase in size and number, so that many very large cells are contained in the now enlarged follicle. The surrounding epithelial cells also become larger, and rapidly increase in number so as to form a layer of regular cubical cells surrounding the follicle. The central cell nearest the ovarian tube is the ovum, the rest are nurse cells, and eventually disappear. Both the ovum and the nurse cells increase greatly in size.

"Frequently in *Anophelines* a large portion or the whole of the adult ovum consists of a mass of Sporozoa. These consist of numerous small cysts, each containing eight round or crescent-shaped bodies, each with a central chromatin spot.

"The ovarian tube arises in the centre of the ovary, and receives on all sides the follicular tubes. It is lined with a single layer of small cubical epithelium. After passing out of the ovary, a considerable number of striated muscular fibres are arranged in a loose net-work around it, and pass from it to surrounding structures.

"The spermatheca consists of a chitinous sac, with large cells lying externally. These resemble the cells of the cuticle, and contain droplets. They do not cover the whole of the surface of the spermatheca. The spermatozoa have a narrow, slightly-curved head and a long tail. The duct of the spermatheca is narrow and thick-walled, and contains muscular fibres. Certain large cells lie in connexion with the duct externally. The mucus gland contains cells filled with secretion."

THE LARVA.

All mosquito larvæ are aquatic. They possess a complete, well-chitinized head with the typical mouth-parts of mandibulate insects. The thorax is broad and its three segments are fused. The abdomen is long and slender with nine well-defined segments. There are no ambulatory appendages. The anal opening is at the apex of the ninth segment and is surrounded by four more or less developed tracheal gills. The tracheal system is metapneustic with the openings dorsally on the eighth segment, usually through a chitinous tube of greater or less length. The larvæ are active and move backward through the water by jerking the body from side to side. They also can move slowly forward by the action of the mouth-brushes. By means of a mechanism at the end of the respiratory tube the larva can suspend itself from the surface film in order to take in air. Raschke has pointed out that the breathing tube has the further function of an hydrostatic apparatus. It will be most convenient to discuss in detail the structures of the larva of *Culex* and afterward point out the various modifications that occur in other mosquito larvæ.

THE HEAD AND MOUTH-PARTS.

The head of the *Culex* larva is broad, rounded, and somewhat flattened. It is inserted upon the thorax by a narrow neck, the opening into the head being surrounded by a heavy chitinous collar, the foramen. The antennæ are prominent and inserted anteriorly upon the outer angles of the head. Between the antennæ the head is arcuate and a narrow clypeus forms its anterior margin. In front and beneath is the labrum with its appendages. The median free lobe of the labrum is attached between two long, stout spines which project forward and downward from the anterior margin of the clypeus. The other mouth organs are upon the ventral side of the head and the anterior part of the head may be considered a broad rostrum which projects over them. The eyes are placed laterally and consist of two pairs, the large compound eyes, and behind them the accessory eyes.

The antennæ consist of a single chitinous piece and are cylindrical and slightly curved. About two-thirds from the base the shaft is suddenly narrowed and at this point is inserted a fan-shaped tuft of long feathered hairs. The slender apical third is obliquely truncate at the tip. Upon the tip is inserted a conical sensory organ surrounded by three long setæ and a shorter spine-like seta. Raschke interprets the sensory cone as an olfactory organ. It has a chitinous cylindrical basal portion with a minute spinous process upon its side and a very delicate conical sensory portion at the apex. The antennal shaft is beset with numerous small spines. The antennæ have but little motility. They are controlled by a single rather weak muscle, inserted at the base and running backward to the hind margin of the head. The antennæ are connected with the head by an elastic membrane which has some small chitinizations imbedded in it. A spine-like projection of the side of the head prevents the antenna from turning outward.

Several hairs or hair-tufts are inserted on the head integument of the larva. Three pairs of these are situated dorsally on the front or epistoma. One pair is inserted close to the antennæ and is usually the best developed; the other two pairs are inserted nearer the median line and more or less approximated. These hairs or hair-tufts differ in development, and also in position, in different forms and are valuable for specific diagnosis.

The mouth-parts consist of labrum, mandibles, maxillæ with their palpi, and labium, grouped around the pharyngeal opening.

The labrum plays an important rôle in bringing food to the mouth and on this account is highly developed and complex; its position is on the under side of the anterior portion of the head. Three parts of the labrum can be distinguished, two lateral portions and a median one which projects freely from the anterior margin of the head and has been called the palatum. The lateral pieces have inserted upon them dense masses of long yellow hair, the so-called mouth-brushes. By the action of powerful retractor muscles and their relaxation the side-pieces are jerked backward and forward and communicate to the mouth-brushes a lashing motion. The labrum and adjoining parts are described by Thompson as follows:

"The relations of the pre-antennal region of the head are hard to describe. As noted, the dorsal surface is convex and heavily chitinized. The ventral face slopes sharply inward and downward toward the entrance to the pharynx, a point almost in the center of the head. Thus the pre-antennal region is in reality a broad rostrum which overhangs the mouth-parts, situated near the transverse line below, slightly forward of the entrance of the pharynx. Its cross-section would be the segment of a circle, the arc being represented by the convex dorsal surface. In the mid-ventral line, about halfway between the anterior shelf-like fold and the entrance of the pharynx, a crest is formed. This bears four stout setæ and is flanked by setose areas. Here the thin chitin characteristic of the ventral face of the rostrum generally, is strengthened by a triangular sclerite. I regard this structure as an epipharynx. It receives a pair of slender muscles (Raschke, 1887) which arise on the top of the head and probably function as retractors.

"The border line and shelf-like fold already described, mark the boundary between the heavier chitin of the dorsal and the thinner chitin of the ventral face of the rostrum, above and in front. But on either side, near the antennæ, the thicker chitin involves part of the ventral face of the rostrum. These inflected areas of heavy chitin I call the black-spot areas, because each bears a conspicuous patch of pigment. From either area a narrow-linear 'line' of heavier chitin traverses the ventral face of the rostrum to strengthen the sclerite of the epipharynx. In the bay of thin cuticle bounded in front by the anterior shelf and border line, and posteriorly by the black-spot areas, lie the small, median palatum and the larger, lateral flabellæ. These are protuberances, densely clothed with fine hairs, the flabellæ having in addition a peculiar arrangement of long yellow setæ. Black-pigmented apodemes that are continuous externally with the black-spot areas enter each flabella and the two flabellæ are united by a transverse rod. To the apodemes the flabellal muscles are attached, two for each flabella, an inner and an outer, both retractor in function and acting simultaneously. When these muscles contract the seta-bearing area of the flabella is depressed and the setæ come together in a brush whose tip points caudad. On their relaxation the flabellæ protrude beyond the front of the head and the setæ stand out in great yellow fans. The median prominence or palatum passively follows the movements of the flabellæ, which are strictly synchronous, as far as I have observed."

The palatum is clothed on its dorsal surface with short but coarse spine-like hairs; ventrally is inserted a dense tuft of long pendant hairs which swing in unison with the lateral brushes. In the region of the epipharynx are two fringes of dense hairs arranged in closely approximated longitudinal series. According to Raschke the epipharynx when in repose reaches down to the hypopharynx and closes the mouth. In swallowing, the epipharynx is raised and drawn back by two muscles inserted at its base.

The mandibles are large and elaborate in structure. In a ventral view they lie behind the maxillæ and are in large part hidden by them. They are very broad and situated well apart. The apices facing each other bear a group of projecting irregular teeth and near these on the outer side a large movable spine is inserted. Below the teeth there is a broad truncate chitinous projection. On the dorsal margin is a series of seta-bearing tubercles and at the outer angle several long spines. On the inner side there is a fringe of long hairs, inserted on a crescentic chitinous ridge near the apical margin, which helps to sweep the food into the mouth. The mandibles are moved by two pairs of powerful muscles. A muscle attached to the lower inner angle draws the mandible downward and inward, another muscle at the outer lower angle draws it outward. At their opposite ends the muscles are broadly attached in the posterior part of the head to the epicranium walls.

The maxillæ are large but very simple, showing none of the components traceable in most mandibulate insects. They are flattened, roughly conical with a small basal appendage, the maxillary palpus, on the outer side. The maxillæ are situated upon the apical ridge of the under side of the hypocranium and cover the mouth from beneath. Like the mandibles they are well separated, leaving an open space between them, which is however closed by projecting hairs. There is a longitudinal suture and the surface is more or less hairy, particularly towards the apex where the hairs are dense and long. The small palpus bears at its apex several spine-like sensory appendages. Raschke does not think that this palpus can be homologized with the maxillary palpus of the typical mandibulate insects and he points out that different components of the maxilla of such insects can not be traced in the maxillæ of the mosquito larva. The maxillæ are broadly attached to the hypocranium by a membrane and but slightly movable. Two weak muscles effect the movement of each maxilla, both inserted at the middle of the base and passing back are attached posteriorly to the epicranium walls.

A broad median region of the hypocranium, bounded by strong longitudinal sutures, constitutes the mentum.

At the attachment of the maxillæ the hypocranium terminates in a sharp transverse ridge, somewhat lobed outwardly from the maxillæ. Behind this ridge the parts supporting the mental and labial structures turn abruptly to the hypopharynx and pharyngeal opening. Medianly, and immediately behind the ridge, are four successive chitinous structures. In a ventral view these are in order: (1) a delicate roughly triangular plate with a marginal hair-fringe and produced into a long tooth at the middle; behind this is (2) the "mental sclerite," a heavily chitinized, dark, roughly triangular, dentate plate; and back of this (3) a complicated plate with teeth and spine-like structures, the labium; farther back, at the margin of pharynx is the hypopharynx, a simple chitinous cone.

The first two plates are excrescences of the mentum; the labium is attached to the mentum on the inner side by a flexible membrane. The labium, although complex in structure, allows none of the typical parts of that organ to be recognized; it presents very different aspects in dorsal and ventral view. It can be drawn back by two muscles attached to its outer angles.

The mental plate is conspicuous in preparations of mosquito larvæ by its dark color and serrate anterior margin and is frequently alluded to in systematic writings as the "labial plate." Miall and Hammond have termed this plate the submentum.

THE EYES.

The organs of sight of the mosquito larva consist of two pairs of eyes. In most insects with complete metamorphosis the eyes of the larva (when present) are larval organs, independent of the eyes of the imago; these latter only develop towards the close of the larval period and do not become functional until the imago-state is reached. In the mosquito, however, and in other Nemocera, the eyes of the larva are compound in character and are those of the future imago; they are retained throughout the different stages. Ocelli, like those of other insect larvæ, are absent. The two pairs of eyes are situated laterally, a small pair posteriorly and just in front of these are the large eyes which become the compound eyes of the imago. The large eyes in the advanced larva are crescent-shaped, the concave side turned posteriorly and the horns of the crescent extending backward over the dorsal and ventral surfaces of the head.

When the larva first hatches only the smaller posterior pair of eyes are present and before hatching these are already visible through the egg-shell as two reddish spots. The character of the eyes at the time of hatching, and their subsequent development, are described by Zavrel as follows:

"The rose-red to brown pigment is differentiated into three portions: two round ones and one in the shape of a band. With high magnification one finds structures upon its margin similar to the lenses of a compound eye, which, however, are here only faintly indicated. Its nerve forms a small round ganglion in front of the brain. On the fourth day the band or sickle-shaped main eye appears in front of the accessory eye; first it consists of rust-brown ommatidia, later it is pigmented black. The entire main eye does not develop at once.

"In young pupæ the main eye is in the form of a band pointed at the ends. It is always pigmented deep black and one also finds scattered groups of black pigment in its vicinity. One can never detect that it is composed of separated red ommatidia, as it is in the young pupa of *Anopheles*. Only later does it take on its final ovate form. The accessory eye is short and broad, at first separated somewhat from the main eye, later partly covered by it. In young pupæ one can distinguish three darkly pigmented portions in it, later it becomes entirely black."

Raschke states that the accessory eye has an outer transparent gelatinous layer; out of the pigment mass projects a single crystalline column. The cornea of the main eye is represented by a smooth layer of crystalline hypodermal cells. The lateral parts of the supraœsophageal ganglion send large nerve trunks to the main eyes and these each send out a branch to the accessory eyes.

Similar to what Weismann has shown in the larva of *Chaoborus* a kind of regressive metamorphosis takes place in the accessory eye, while the main eye becomes highly developed. Nevertheless the accessory eye persists in the imago as a pigment spot, but it is hidden by the scale-covering of that part of the head.

Rádl has shown that in Arthropods the compound eyes are developed from two foci; in the course of development both of these may unite to form the eye, or one of them may be wholly or partly suppressed. The latter is the condition in the Culicidæ and other Nemocera.

THE THORAX.

The thorax consists of the fused first three segments of the body, and its integument is membranous. It is broad and somewhat flattened, broadest at the middle, and without prominent angles. There are hairs present, mostly long, along the anterior and lateral margins; these show a definite arrangement and indicate the three elements of the thorax. At the middle and hind angles there are large fan-shaped tufts of ciliate hairs with a common base. These hinge, to bend forward, upon low tubercles, and are prevented from bending backward by a small chitinous plate.

THE ABDOMEN.

The abdomen is long, slender and cylindrical and consists of nine well-defined segments. The integument of all but the ninth is entirely membranous. The divisions of the segments are marked by constrictions and the integument is more delicate and flexible in that region. The first seven segments are alike in character but differ in size, the anterior ones being much shorter and the seventh much the longest. The first six segments bear lateral groups of long hairs; the hairs in the groups of the first two segments are more numerous than in the succeeding ones and are curved and stouter. In addition to the larger lateral hairs there are other smaller hairs, singly and in groups, which form various series, lateral, dorsal and ventral.

The eighth segment is shorter than the preceding ones and bears dorsally the chitinous respiratory tube. At the apex of the tube is the opening through which the larva takes air into its tracheæ. The tube can be closed by a set of flaps and these, with their mechanism, will be described later. Close to the apex of the tube, dorso-laterally, are a pair of small movable spines. Basally on the tube are a pair of ventro-lateral longitudinal series of dentate flattened spines which point obliquely backward. These have been termed the pecten. At intervals along the tube are long hairs, in several groups of twos and threes with a common base.

Another peculiar structure of the eighth segment are the lateral groups of small scales which form large patches behind the middle. Behind these, inserted on a small chitinized tubercle, are large fan-shaped tufts of ciliate hairs. Similar tufts are present, near the base of the breathing tube and also ventro-posteriorly.

The ninth segment is not in a plane with the others but is inserted upon the eighth segment ventro-posteriorly, pointing obliquely downward. It is short and its diameter is less than that of the other segments. In the final larval stage it is in large part covered by a chitinous plate which completely surrounds it. In the previous stages the plate is smaller, dorsal and saddle-shaped. Beyond the plate the segment is fleshy, cushion-like with the anal opening in the middle. Surrounding the anus are four cylindrical transparent appendages, the tracheal gills. Dorsally, at the apex, the segment bears a group of very long setæ which are inserted upon two chitinous pieces. Ventrally and outwardly the anal plate is excised to make room for a fleshy portion upon which is situated a remarkable organ, the ventral brush. The ventral brush consists of a series of long fan-shaped tufts with curved stems, inserted close together along the ventro-median line. Each tuft hinges upon a slender transverse strip of chitin and, towards the middle, where the tuft is inserted, these strips are thickened and perforated. Outwardly these transverse strips are joined to a pair of longitudinal strips. The tufts are not inserted exactly upon the median line but alternately a little to one side or the other, thus showing the bilateral origin of the structure. There are no muscles to control the ventral brush. Its function is that of a steering or steadying apparatus.

THE RESPIRATORY ORGANS.

The respiratory system of the mosquito larva has been carefully investigated by Raschke. His studies were apparently based upon larvæ of two species, *Culex pipiens* and a species of *Aëdes*. We give herewith a translation of the part of his paper dealing with this subject.

"It is perhaps rarely that one finds in the insect world such many-sidedness with reference to respiration as in our larva. We must here consider a stigmatal respiration, an intestinal respiration, a respiration through the tracheal gills and finally such a one through the external skin, therefore four different modes of taking in gases. Naturally one of the mentioned modes will have to be considered as the most important and there can hardly be a doubt that this is the stigmatal respiration, the breathing of atmospheric air by means of the siphon.

"When the larvæ were deprived of the opportunity to breathe air directly, by confining them in a receptacle covered by gauze and placing this in an aquarium so that it was entirely surrounded by water, they showed great unrest; after a short time they shrank noticeably and died after about ten hours.

"On account of the enormous exchange of gases the tracheal system is very extensively developed. Two strong tracheal trunks extend from the apex of the breathing tube of the penultimate body segment to somewhat before the middle of the thorax, and these are united apically by a strong tracheal bridge. In addition there are transverse connecting tubules in each segment, which however are not in the form of a simple bridge but formed like the two links of a rectangular triangle. In each segment branches go out from the longitudinal trunks which ramify in the manner of capillaries and twine about all the organs. The foremost ends, which are bent like knees, divide into several branches of which two on each side pass into the head and there take a branching development.

"From the penultimate segment two small trunks go to the last segment.

"At the point where the colon begins a countless number of weak, small tracheal branches arise which run to the colon, where they resolve themselves upon the previously described papillæ into innumerable branchlets. Haller, who also saw these fine tubes, explains them as an air reservoir. This, however, without considering that this would be a most unfavorable reservoir, appears fallacious because the branches are exceedingly fine and in comparison with the two large tracheal trunks can only hold a very small amount of air.

"Histologically nothing remarkable can be said of the tracheæ. Inwardly, bounding the lumen, lies the chitinous integument showing the spiral threads; around it and in intimate connection with the fat body lies the peritoneal envelope. It is remarkable that the tracheæ of the colon are without spiral threads.

"The already frequently mentioned larval organ arising from the penultimate segment, the siphon, shows the following conditions: The two tracheal trunks pass upward to the right and left inside the tube; towards the end they lose their spiral-thread structure and become firm cylindrical cups which are differentiated by a considerable constriction at their bases. Between them lies a stiff, hollow, chitinous rod which unites with the two cups where they come together and helps to bound the hollow space thus formed; thus this hollow space is formed by the cups on the right and left and by the hollow rod above and below.

"Thus the two tracheal trunks do not empty separately to the outside, as Haller asserts, but through a single common orifice.

"On the lower side the part of the wall of the common hollow space, which arises from the firm chitinous tube, is continued as two flaps which rest upon the siphon. The outer basal margins of these flaps are connected with the siphon by an elastic membrane. On the dorsal side the wall of the common hollow bears a median and two small flaps which are also connected with the end of the breathing tube by flexible membrane.

"If now, by the contraction of the muscles pertaining to this apparatus, the entire upper tract is pulled down the result is twofold: first the rigid end-cups (of the tracheal tubes) are pressed down upon the constriction and bring about a closure at this point; secondly by the traction upon the chitinous rod, and through the muscles of the flaps, the flaps are brought together in the form of a three-sided pyramid composed of the three large flaps. When the apparatus is closed and forms, as it were, a pyramid resting with its base upon the tube, the two small dorsal flaps lie against the ventral flaps.

"When the larva wishes to breathe air, it sticks the end of the tube out of the water and opens the flaps. Thereby a wreath-like formation results which enables the animal to remain suspended from the water surface.

"The muscles of the closing apparatus originate in the penultimate body-segment and remain free in their passage through the breathing tube. In all five pairs of these muscles are present. Two pairs belong to the ventrally located flaps, two pairs to the flaps lying opposite, and one pair belongs to the median chitinous rod.

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"The anus is surrounded by four lanceolate tubes which are to be looked upon as tracheal gills. They have an extremely fine and delicate cuticle under which extends a rather thick layer of plasma with scattered nuclei. Each tube contains a tracheal trunk which sends off numerous branches to the sides; the tube is hollow and represents a blood sinus. The tracheal gills are connected with muscles and thereby serve as closing apparatus of the colon. While ordinarily they are disposed wreath-like around the anus, they can, by muscular exertion, fold together into the form of a wedge."

MODIFICATIONS OF LARVAL STRUCTURE.

Other mosquito larvæ present essentially the same structures as the larva of *Culex*, although variously modified. With a good knowledge of the *Culex* larva there should be no difficulty in understanding the structures of other larvæ. Many of these differences are brought out in the systematic part of this work, others may be briefly noted here.

The most striking difference is presented by the larva of *Anopheles* in the absence of a respiratory tube and its adaptation to the surface-feeding habit. Aside from its adaptation to habits the larva of *Anopheles* is primitive, as is indicated by many of its structures. The larva when at the surface of the water is still submerged; it is suspended from the surface-film by means of the structures surrounding the spiracular openings on the eighth segment and by the "stellate tufts," situated on the dorsal surface of the body. These stellate tufts are little rosettes of leaf-like hairs with a common stem which spread out upon the surface of the water. The stellate tufts are situated dorsally in pairs on certain of the abdominal segments, and in some Old World species also upon the thorax.

The head of the *Anopheles* larva is narrower and more elongate than in other mosquito larvæ. The elongate appearance is due to the fact that the dorsal region of the head is well produced between the antennæ. The "mouth-brushes" are more compact and closer together than in the *Culex* larva and their mechanism is simpler. The primitive character of the larva is indicated by the comparatively simple mandibles, the large, square maxillæ and the very large, nearly independent, maxillary palpi. These latter are not inserted in a plane with the maxillæ but hinge farther back upon a part of the ridge of the hypocranium, which is interrupted at this point.

The tracheæ open separately through spiracles on the eighth segment. Another primitive character of the *Anopheles* larva is the presence of chitinous dorsal plates on the abdominal segments. These are small and transverse, situated at the anterior margin on all but the ninth segment. This last has a large saddle-shaped dorsal plate.

The "lateral comb" of scales of the eighth segment of the *Culex* larva is represented by two large chitinous plates, situated laterally near the posterior extremity of the segment. These are attached to the sides of the segment by their upper margins and project downward and slightly outward; the lower margin is produced into a series of long irregular teeth, which point backward. The two plates are connected posteriorly by a chitinous strip in continuation of the thickened upper margins. These structures serve as a support to the mechanism surrounding the spiracles. In the first stage larva of *Anopheles* there are in place of lateral plates series of large simple spines such as are present in some larvæ of *Aëdes*.

As before stated the tracheæ open separately. The spiracles are situated well back on the dorsum of the eighth segment, in a slight depression surrounded by chitinous plates. When the larva is at the surface of the water these plates are spread out in such a manner that they support the larva and at the same time expose the spiracles to the air. When the larva wishes to go down the plates are folded together and form a nearly closed cavity over the spiracles. The air held in this cavity prevents the water from entering the spiracles.

The mechanism has been described by Nuttall and Shipley and by Imms, but neither of these descriptions are clear or wholly correct. There are six chitinous elements in this closing mechanism. These range themselves about the spiracles as an anterior piece, a pair of lateral flaps and three posterior pieces. Just in front of the spiracles and overshadowing them is a small median transverse plate, the "anterior fan-shaped plate" of Nuttall and Shipley. This plate is so hinged that it can be turned back over the spiracles while these latter are withdrawn far beneath it. Close to each spiracle outwardly, is a leaf-like fleshy flap which is strengthened distally by a small chitinous strip surmounted by a sensory seta. When the larva is at the surface of the water these flaps are directed outward and prevent the water from entering the spiracular depression from the sides. When the larva goes down these flaps are turned upward and inward and thus help to form the air-containing cavity over the spiracles. The structures behind the spiracles consist of a very large, median, roughly triangular plate and two smaller plates which support it. The acute anterior end of the large plate intervenes between the spiracles and its apex is strengthened by a chitinous peg which is attached keel-like beneath. Nuttall and Shipley, and also Imms, claim that this chitinous peg is connected with the anterior transverse plate, but careful study has convinced us that this is not the case. The two rounded hind angles of the plate project well beyond the end of the segment and the plate slopes upwards towards these angles. Medianly the plate is flexible while the sides, and particularly the angles, are well chitinized; anteriorly there is a median suture. Powerful muscles attached to the middle portion of the plate beneath, and to the anterior peg, can draw the plate downward and forward. When this is done the posterior angles are bent broadly upward and inward and constitute a pair of flaps which close in the spiracular depression behind. The supporting plates support the projecting hind angles of the median plate. They are irregular in outline, almost quadrate, and rest with their proximal basal portions upon the thickened rim of the lateral serrate plates.

The breathing apparatus of *Anopheles*, just described, is the most primitive found among mosquito larvæ. From it the breathing tube of the other larvæ is evolved and the components of the closing apparatus are homologous with the six pieces present in *Anopheles*. In *Culex* and other larvæ the stirrup-shaped piece within the tube, through which the tracheæ communicate with the outer air, is homologous with the large triangular plate of the *Anopheles* larva; the five flaps surrounding the rim of the tube correspond with the five other pieces.

In *Uranotænia,* which is closely related to *Anopheles,* the closing mechanism of the breathing-tube is simpler than in the more specialized larvæ and clearly shows the derivation of the parts. The piece within the tube is large, of irregular shape, and concave, the concavity towards the mouth of the tube. Its position in the tube is transverse. The long spur which exists in *Culex* for the attachment of the retractor muscles is absent, but two chitinous strips extend to the tracheæ and support them. The opposite end is bent upward and pointed, and against its sides the two large flaps at the rim of the tube rest. These large flaps are ventral in their position at the apex of the tube and represent the two posterior supporting plates of the *Anopheles* mechanism. The three remaining flaps represent the two lateral flaps and the anterior plate of the *Anopheles* larva. The chitinous rings of the spiracles are represented in the *Uranotænia* larva by short chitinous tubes which cap the tracheæ. Both orifices of these tubes are oblique and the upper ones are prolonged on the outer side and in contact with the lateral flaps which they control.

In *Culex, Aëdes* and other more specialized larvæ we find the conditions as described by Raschke. The triangular posterior plate of *Anopheles* has now become folded and elongated to the peculiar stirrup-shaped piece within the tube which is such an important component of the closing mechanism. In these forms the broad, hollowed out, apical portion of the stirrup closes the end of the tube and through it the tracheæ open and communicate with the outer air.

The greatest specialization of the breathing apparatus is presented in the larvæ of *Mansonia.* The tube is modified for insertion into the roots of aquatic plants through which the larva obtains its supply of air. The outer portion of the tube is greatly attenuated and furnished with serrations, while the flaps at the apex are transformed into a complex set of spines and hooks. With this apparatus the larva can pierce the plant tissues and then, by spreading the hooks, maintain a firm hold on the plant. The chitinous piece in the interior of the tube, which in large part controls the mechanism, is highly developed and extends back through the tube into the body of the larva.

In the Sabethini the mechanism of the breathing tube is rather simple. The flaps are small and the chitinous piece within the tube is reduced to a long slender strip. The tracheæ are continued as long chitinous tubes which terminate in oblique openings that face each other. The tubes are approximated apically and attached to the long chitinous piece. When the larva takes in air they are slightly protruded beyond the orifice of the breathing tube and push the flaps out of the way. In most sabethine larvæ there is a pair of well-developed freely jointed hooks dorsally at the apex of the breathing tube. In most of the culicine larvæ these hooks are present but very small; they may, however, be well developed, as in certain species of *Culex* where the larva lies on the bottom back down and uses the hooks to maintain its position.

The pecten of the air-tube is absent in the larvæ of *Megarhinus, Mansonia* and *Bancroftia,* and in the Sabethini; in certain larvæ of the latter there are a few spines on the tube which do not, however, appear to correspond with the true pecten. The other appendages of the breathing tube, hairs and hair-tufts, differ greatly according to the genera and species and these differences are brought out in the systematic part of this work.

The lateral comb of the eighth segment shows great variation, not only in the shape of the scales, but their number and arrangement. The scales may even be absent altogether, as in *Joblotia*, where they are represented by single spinose tubercles, or in *Megarhinus* by a chitinous plate. In other cases, as *Uranotænia* and *Anopheles*, there is a plate with a series of teeth along the margin. The larvæ of *Bancroftia* are remarkable in that both comb-scales and plates are present, and in the last stage chitinous dorsal plates are also present on the sixth and seventh segments.

On the ninth segment the chitinous plate differs greatly in shape and size in the last stage larva of different species. It may completely encircle the segment or be reduced to a dorsal saddle. In some forms there is a group or row of spines or scales, laterally along the hind margin; in *Megarhinus* these form an elaborate fringe. Laterally, on each side, is usually inserted a small hair or hair-tuft, occasionally this becomes conspicuous. The ventral brush also varies much in development; in some cases it is continued into the chitinous plate, in others it is much condensed. In some cases the ventral brush is inserted upon a separate chitinous plate which is perforated for the insertions of the hair-tufts. In the Sabethini there is no ventral brush but only a pair of lateral tufts or hairs below the margin of the dorsal plate.

The tracheal gills show great modifications in adaptation to larval habits. In certain larvæ which do not come to the surface for air the tracheal gills are very large and are traversed by a large trachea. In other forms they are obsolete and only represented by fleshy papillæ. This is particularly true of the species inhabiting saline water.

The larva of *Sabethinus* is remarkable in the presence of a pair of chitinous hooks upon the seventh segment, situated upon fleshy tubercles, dorsally, near the end of the segment. In some larvæ the entire integument is covered with minute hairs or spicules and this may also be true of the plate of the ninth segment and sometimes of the breathing tube.

In certain larvæ there are small chitinous plates at the insertions of the large hairs on the thorax and sides of the abdomen. These plates are particularly well developed in *Megarhinus* and *Aëdeomyia*. In many larvæ there are stout spines at the angles of the thorax which prevent the long hairs from being bent backwards.

There is wide diversity in the coloration of mosquito larvæ. While certain forms have a characteristic coloring there is often great variation in this respect; color, beyond the fact that certain genera show a characteristic coloring, can not be used for identification.

All the larvæ of the tribe Sabethini that we have seen have a characteristic pale appearance. The body is opaque creamy white and the head and other chitinous parts light yellow. Only the foramen of the head is more or less broadly edged with black, and sometimes the anal plate also shows a dark margin. The larvæ of *Megarhinus* are dark and the integument shows a more or less pronounced wine-red coloring; the chitinous parts are brown or piceous. Certain South American forms of *Megarhinus* are said to show an iridescence, similar to mother-of-pearl. The larvæ of *Bancroftia* also show a pronounced red color of the body.

Generally speaking the body of mosquito larvæ is pale, more or less translucent. It may be modified within the same species by a great variety of circumstances, such as age, condition of health, food, exposure to light, and the presence of internal or external parasitic fungi or bacteria. The *tracheæ* usually show through the integument as wavy lines of a silvery or golden luster from the air contained in them. They become less distinct as the larva with approaching maturity grows more opaque. The chitinous parts may be yellow, brown or nearly black. Sometimes the head shows darker spots dorsally, characteristically arranged. We have seen larvæ in which the head was entirely yellow, others with brown maculations, others entirely dark brown, all belonging to one species.

ADAPTATION OF THE MOUTH-PARTS OF CULICID LARVÆ TO THE PREDACEOUS HABIT.

The habit of feeding exclusively upon living organisms, principally upon other culicid larvæ, has arisen several times independently among the Culicidæ. The mouth-parts have been correspondingly modified in every case that the habit has been developed. It so happens that the organ which has been modified for prehension differs in the several groups. The Corethrinæ are all predaceous and seize their prey with the antennæ. These organs are consequently modified for this special purpose, differing in the several genera. In these forms the mandibles have the toothed parts well developed but the hair fringes undeveloped, being confined to a few filaments. The maxillæ in all the forms known to us, *Eucorethra, Corethrella, Corethra* and *Chaoborus,* are progressively reduced, being slight rudiments only in the latter two genera. This is a special modification in this line of descent and does not represent the condition in the generalized culicid stock. No predaceous form will be found in a primitive condition as the habit is secondarily acquired and accompanied by special modification. The most generalized condition of the culicid larva is found in *Dixa.* This larva is a vegetable feeder with mouth-brushes on the labrum and a coarse hair-fringe on the mandibles. It is a surface feeder. The mandibles are dentate on the inner side toward the base. The maxillæ are quadrate and furnished with a long functional palpus, comparable to the antennæ in shape and size. From such a form the culicid series is derived. The lowest mosquitoes, *Anopheles,* are still surface feeders, retaining square maxillæ, the palpi of which, though much reduced, are still comparatively large. The square maxillæ may be regarded essentially as organs of mastication. They are modified in the higher forms, whose manner of feeding has become more refined, into a conical or pointed shape with papillæ and hairs. There is, however, a tendency to the reappearance of the square maxilla in the predaceous genera, in adaptation to the new habit which requires more mastication. Throughout the Culicid series there is a progressive degeneration of the maxillary palpi, whether the predaceous habit has been acquired or not, and this serves as an index to the systematic position of the form in question. As we have before pointed out, the Sabethini form a separate group from the other mosquitoes. This line is not entirely ancestral, having been derived from the culicid stem at a point near *Megarhinus*, above *Anopheles*, *Aëdeomyia* and *Uranotænia*. The mouth-parts therefore were originally in a certain state of modification, now still shown in the lowest genera such as *Joblotia* and *Lesticocampa*. In these the maxillary palpi are rather large, much more so than in the higher forms, such as *Wyeomyia*. In the Sabethini, the predaceous habit has been twice acquired, in *Lesticocampa* and in *Sabethinus* (presumably in *Sabethes* also, the larvæ of which are unknown). In both cases the maxillæ have been modified into organs of prehension, but with essential differences. *Lesticocampa* is an old predaceous type, profoundly modified, derived from a generalized sabethine form (such as *Joblotia*). The maxillary palpi are long and distinct, the maxillæ bearing semi-jointed appendages, and the mandibles are much modified. *Sabethinus* is a recent predaceous type, little modified, derived from a specialized non-predaceous form (such as *Wyeomyia*). The maxillary palpi are rudimentary, the maxillæ of the general type but bearing teeth and an apical horn, which is not jointed, while the mandibles are scarcely changed from the usual non-predaceous form. In the American Culicini, the predaceous habit has been acquired thrice, in *Megarhinus*, *Psorophora* and *Lutzia*. We do not consider the *Anopheles* true predaceous forms though some of them have the habit developed to some extent (*e. g.*, *Cœlodiazesis barberi*), because there is as yet no essential modification of the mouth-parts for this purpose, and the larvæ are able to subsist also on a vegetable diet. No doubt the habit indicates the beginning of such a modification, and, if persisted in until it became the only method of feeding, structural modifications would follow. The *Anopheles* must hold their prey by the mandibles, as no other organs are sufficiently developed for the purpose. The antennæ have already too far degenerated to become functional for the purpose, while the maxillæ are of a too primitive flat type. It is necessary for the maxilla to have progressed from this type to the conical form of a species feeding only on particles in suspension in water before its modification into an organ of prehension would be possible. The mouth-brushes are not strongly developed enough to be of service in holding prey. We therefore venture to predict that if any strictly predaceous *Anopheles* larva exists it will be found to have the mandibles modified into organs of prehension. In the truly predaceous Culicini above mentioned the mouth-brushes have become organs of prehension. *Megarhinus* is derived from low on the culicine stem. Its maxillæ consequently show a large palpus. They are short and square, the shape being partly, no doubt, ancestral on account of the primitive origin of the genus. The mandibles are not especially noteworthy, the toothed surface being well developed, the hair-fringe slight. The predaceous *Psorophora* are derived from the lower, non-predaceous *Janthinosoma* group. The maxillæ have regained secondarily the flattened quadrate form but the palpus is still a small rudiment borne upon the body of the maxilla. The modification appears at first sight profound, but is in reality superficial, all the parts present in *Psorophora* (*Janthinosoma*) *sayi*, for instance, being easily traceable on close examination in *Psorophora ciliata*, the shape only being altered. The mandibles have the toothed area well developed, the hair-fringe much reduced.

Lutzia is derived from *Culex*, from the more generalized part of that genus. The maxillæ have a generally quadrate shape, but the modification from the usual *Culex* type is not great. The median suture is still distinct, the papillæ are present, even the crown of hairs is represented by shortened appendages. The mandibles have the toothed area well developed and terminally placed owing to the reduction of the other parts.

Though the three genera above mentioned, *Megarhinus*, *Psorophora* and *Lutzia*, are all predaceous with their mouth-brushes, the individual hairs of the brushes are differently modified in each, as would be expected from the independent evolution of the predaceous habit in the three cases.

MOULTING AND NUMBER OF LARVAL STAGES.

The larvæ of mosquitoes have four stages, that is, they moult four times, transforming to pupa with the fourth moult. Apparently the number of moults is constant and is the same for all species. The newly hatched larvæ already show all the organs of the mature larva but they are much simpler. The chitinization of the head and breathing tube are less evident and complete than in older larvæ. The breathing tube is only chitinized in its apical portion and the chitinous plate of the anal segment is very small. The principal hairs present in the older larvæ are already found on the first-stage larva; but all of them are simple, whereas in the later stages many of them become composite. The ventral brush of the culicine larvæ is absent in the first stage. The first-stage larva may be recognized by the presence, on the head, of the egg-burster. This is situated dorsally on the middle of the head and consists of an oval, pale, depressed area in the middle of which is situated a chitinous disc surmounted by a small, black, chitinous peg.

When the larva is about to moult the hairs of the following stage may already be seen beneath the skin. The long hairs of the sides of the thorax and abdomen are wrapped about the body transversely and show as transverse blackish lines. Immediately after moulting the color of the chitinous parts is pure white; gradually these assume their characteristic color. The approach of the last moult may be recognized by a number of changes in the appearance of the larva. The coloration of the body becomes more opaqne. Most striking is the increase in the size of the compound eyes, these becoming gradually drawn out dorsally into a sharp point until they nearly meet upon the median line. This change is particularly striking in the Sabethini where the compound eyes do not become evident until late in larval life. A short time before pupation two dark spots appear on the thorax, dorsally at the anterior angles. These are produced by the breathing trumpets of the pupa lying underneath.

The moulting larva or pupa makes its escape from the old skin through breaks in the dorsum of the head and thorax. The head splits open along the epicranial suture. This suture extends posteriorly in two branches from the bases of the antennæ, the two branches uniting behind a short distance before the foramen; from this point backwards it forms a single median suture. It is along these lines that the head splits open and in continuation a rent appears along the median line of the thorax. The head moult remains attached to the skin of the body.

The last moult, or transformation to pupa, is described by Hurst as follows: "Towards the end of larval life the animal becomes sluggish; profound changes in its mouth-parts deprive it of the power of eating, and it floats with its siphon-stigma at the surface. Shortly the cuticle bursts in the thoracic region, along the mid-dorsal line; the pupal 'horns' or siphons are protruded, the abdominal tracheæ appear to collapse, and the animal floats with the anterior end upwards, the new siphons coming to the surface. The old larval siphon, or rather its soft parts, are withdrawn from the cuticle and *invaginated into the eighth segment of the abdomen;* the intima of the abdominal and thoracic tracheal trunks beak up into pieces, which in the abdomen correspond to body-segments. The body of the escaping pupa is gradually withdrawn from the larval cuticle, and the eighteen fragments of the old tracheal intima are drawn out of the body by nine pairs of stigmata, and cast off with the exuviæ. These nine pairs of stigmata are situated, one in the hinder part of the thorax, one in each of the first seven segments of the abdomen, and the ninth pair are united to form a single aperture, the old respiratory opening at the end of the larval siphon."

THE PUPA.

The pupa of mosquitoes, like the larva, is aquatic, but depending upon communication with the air for respiration. The pupa is active and capable of moving rapidly through the water but it takes no food, the appendages of the head and thorax of the future fly being enclosed in a common chitinous covering.

The appearance of the pupa differs greatly from the larva. The anterior portion is large and very robust and composed of the head and thorax enclosed in a common casing, in which, however, the component parts, the head with its appendages, and the three segments of the thorax with their appendages, can be distinguished. The head, wings and legs are packed together ventrally and laterally, so that in a dorsal view only the dorsum of the thorax is visible. The abdomen consists of nine flattened segments, freely movable, of which the first eight are roughly quadrate in outline and slightly broadened posteriorly. The eighth segment bears at its apex a pair of large chitinous plates, the "paddles" or "fins."

Respiration in the pupa takes place through a pair of appendages on the thorax, the "respiratory trumpets" or "horns." The respiratory trumpets are inserted at their bases on the mesothorax, anteriorly to the bases of the wings, and communicate with the anterior pair of thoracic spiracles. When the pupa is at the surface of the water the trumpets break through the surface film and admit the air to their interior and into the tracheæ.

When the pupa is at rest at the surface of the water the dorso-ventrally flattened abdomen is curved under the bulky cephalo-thorax and almost in contact with its ventral surface. In this attitude the "paddles," which are terminal in position, point directly forward. By lashing with its abdomen the pupa can descend rapidly into the water. Owing to the fact that the specific gravity of the pupa is less than the medium containing it, the pupa is rapidly carried to the surface as soon as it ceases its efforts. It should be noted that the specific gravity of the pupa differs with age, the pupa becoming lighter as it approaches maturity. There is also considerable difference according to species, the pupæ of some being so nearly of equal specific gravity with the water that they can remain nearly stationary at the bottom or at a certain depth. Certain pupæ, when alarmed, can remain below for some time by clasping objects with the abdomen.

The pupa is very easily alarmed and at the appearance of a shadow, or at a slight disturbance of the water, it immediately darts towards the bottom. Hurst has found that the cephalo-thorax of the pupa contains a large air-cavity, *which must be very effective in lightening it and in maintaining its equilibrium.* The pupa is additionally lightened towards the period of eclosion by the secretion of air beneath the pupal skin, as will be described in connection with the emergence of the imago. Hurst describes the cavity just referred to as follows:

"The pupa does not eat. It breathes air through the apertures at the ends of its siphons. It floats, thorax uppermost, by virtue of a large air cavity lying under the hinder part of the thorax and the anterior part of the abdomen. This cavity is bounded in front by the legs, at the sides by the wings, and below by the mouth-parts. It extends up at each side of the first segment of the abdomen, where it is covered by the halteres, and into this part of the cavity at each side opens a large stigma, held open by the fairly well-developed cuticular lining ('intima'), and guarded near its entrance by numerous spines. These two stigmata belong to the first abdominal segment, and put the air-cavity just described into direct communication with the tracheal system. As already mentioned, I regard this cavity and these stigmata as being mainly, if not exclusively, hydrostatic in function, serving not only to make the pupa float when at rest, but to make it float in a definite position, with the thorax uppermost and the apertures of the siphons at the surface of the water."

There is no special necessity for dealing here with the internal anatomy of the pupa, as will be understood from the following statement by Hurst:

"As to the anatomy of the pupa, it is only necessary now to state that at the beginning of pupal life the internal arrangements are those of the larva; at the end of that period they are those of the imago."

Hurst has given an excellent description of the external conditions in the pupa of *Culex*, which we quote herewith. We must, however, call attention to one discrepancy: The region called by him the "prothorax" is in reality the mesothorax. De Meijere, in an extensive paper on the anterior spiracles of dipterous pupæ, considers the anterior thoracic spiracles and their appendages as prothoracic, which, of course, also involves the region in question. A careful examination of the external conditions leads us to differ. In dipterous larvæ the spiracles in question are prothoracic, in the imago they occupy a position which can not be designated as such with certainty. Hurst's description of the pupa of *Culex* is as follows:

"The *head* is broad from side to side; the epicranium has a well-marked median groove; the clypeus, broad above, is gradually narrowed below, and continued without any distinct line of demarcation into the labrum. At the sides are a pair of compound *eyes*, to be regarded rather as the rudiments of the eyes of the future gnat than as the visual organs of the pupa itself. . . . During pupal life they increase in size till they almost encircle the head. Corneal faceta are never formed in the pupal cuticle, but beneath it the convex facets of the imaginal cornea are formed during pupal life.

"Behind the compound eye, on each side of the head, is an *ocellus* with fully-developed lens, etc. In the youngest pupæ it is separated by a small interval from the compound eye; but the growth of the latter obliterates this interval, and the ocellus is in the older pupæ not readily distinguishable except in sections. The statement, found in systematic works, that the Tipulariæ are devoid of ocelli is, however, not strictly true; in Culex, at least, they are well developed, though, as they abut upon the compound eye, they are in the imago so inconspicuous that they may easily be over-looked.

"In the *mouth-parts*, the labrum, epipharynx, mandible, maxillæ with their palps, labium and hypo- and epipharynx are present, though the two last can only be seen on dissection.

"Of their mode of origin in the larva I as yet know nothing. At the time of escape of the pupa from the larval cuticle they are of the full size, which is considerably greater than in the adult. . . . That I may not have to refer to these parts again, I will at once say that the chief changes which occur in them during pupal life are: (1) The development of a cuticle within the pupal cuticle, and this, in the case of the labium (fused second maxillæ), is covered with scales closely resembling those found in Lepidoptera; (2) a considerable shrinking; (3) in the male only, atrophy of the mandibles, which in a young pupa are as large as in the female, but in the adult are not recognisable.

"The *antennæ,* which were folded and telescoped at their bases in the larva, are in the pupa laid upon the sides of the thorax. . . . Their hinder (distal) extremities are hidden by the wings. The swollen basal joint of the antenna of the imago is hardly recognisable on the surface, although it is already a conspicuous object in sections of the youngest pupæ, and even in the larval state. I shall describe it with the other sense organs. The shaft of the antenna is segmented, but the external segmentation loses its correspondence with the segmentation of the developing antenna within it early in pupal life.

"The *thorax* is large and rounded, but somewhat compressed from side to side. Mid-dorsally the cuticle of the prothorax * is marked by fine transverse corrugations, and this is the part which ruptures to allow the imago to escape. A pair of branched setæ arise from the dorsal region of the hinder part of the thorax.

"The *respiratory siphons* are nearly cylindrical, narrowed at their bases and curved forwards to be attached by flexible membranes to slight prominences on the sides of the prothorax.* Above they are obliquely truncate and open, and the margin is slightly notched on the inner side. The outer surface is marked so as to resemble imbricated scales, each with a minute spine at its apex. The cavity of the siphon communicates directly with that of a tracheal trunk at its base. Palmén says that after a 'close investigation' he has found that there is no opening. The tone of assurance in which he contradicts all previous observers led me to put the question to the test. I removed the side wall of the thorax, with some of the underlying muscles and tracheæ, from a specimen preserved in alcohol. I drew out the alcohol from the cavity of the siphon by means of blotting-paper, and then touched the tip with a minute drop of glycerin. I watched the effect under the microscope, and saw the glycerin force its way into the siphon, driving the air before it into the tracheæ. Palmén, morover, says the organs are gills! Each is a thick chitinous tube, the cavity guarded by numerous hooked spines, the walls consisting of hardly anything but the chitinous cuticle, the epidermis ('hypodermis') between its two layers being barely recognisable on account of its thinness. The 'tracheal gills' on which Palmén lays much stress have absolutely no existence.

"The *wings* of the pupa, that is the organs within which the wings of the imago are developing, are a pair of oblong plates about 2 1/2 mm. in length. They are closely applied to the sides of the hinder part of the thorax, and directed downwards and backwards. They are immoveable.

"The *halteres* are a pair of elongated triangular plates lying along the dorsal and hinder border of the wings.

"All these three pairs of dorsal appendages arise within the larva in the same way, and their bases or points of attachment all lie in the same horizontal plane. Each is at first (in the larva) a fold of the epidermis; each acquires a cuticular covering (like all other parts of the body), and the first pair become rolled up to form tubes, the respiratory siphons, while the other two remain flat plates.

"The three pairs of ventral appendages of the thorax, or *legs,* are long cylindrical bodies folded upon themselves, and lying beneath the thorax and between

* This is in reality the mesothorax. The prothorax is represented by a very small field anteriorly, just above the base of the antennæ. H. D. & K.

the wings. The same segmentation into femur, tibia, etc., is recognisable as in the adult gnat, but the segments are more nearly equal in the pupa, and the *joints of the developing and shrinking legs* of the future imago soon lose their correspondence with those of the pupal cuticle enclosing them. They arise in the larva, like other appendages, as folds of epidermis enclosing mesoblastic tissues.

"The *abdomen* is dorso-ventrally compressed and exceedingly flexible dorso-ventrally, though not from side to side. It is the only part of the pupa in which the segmentation of the body is readily recognisable, and as I shall very frequently have to refer to the various segments by number, *I shall use the terms 'first segment,' etc., to signify 'first segment of the abdomen,' etc.*

"Nine segments are readily recognised in the abdomen, and the last one, though it is probably composed of no less than three condensed and highly modified segments, I shall call simply 'ninth segment.'

"Each abdominal segment has a chitinous tergum and sternum, and setæ are distributed sparingly over them, being almost confined to the hinder parts of the terga. The terga and sterna of successive segments are united by soft arthrodial membranes.

"Of the *setæ*, only one pair need special mention. These are placed on the hinder part of the first segment, the base of each being a triangular plate attached by one angle to a soft membrane, and the distal side of the plate is divided into a number of bars which, by repeated division or branching, give rise to about one hundred setæ all lying in one plane parallel to the median plane of the body. Each seta bears a few fine hairs. When at rest, the pupa floats with the tips of these setæ, and the tips of the respiratory siphons, at the surface of the water, and these setæ probably assist in maintaining the equilibrium of the animal in this position, as well as serving as sensory organs by means of which any disturbance of the surface is felt.

"The eighth segment bears a pair of large *fins*, thin oval plates about 1.2 mm. in length, attached by the narrow end beneath the tergum behind. Each is stiffened by a midrib which projects beyond the hinder border of the fin as a spine.

"Beneath the fins and behind the eighth segment is the '*ninth segment*' with its appendages. Though this region is probably made up of more than one segment, its composite nature is not easy to recognise, as the plates supposed in other insects to represent the terga and sterna of tenth and eleventh segments [see, for instance, Huxley and Miall and Denny] are not developed in the young pupa, nor, indeed, is there in any stage any such development of the pupal cuticle, though plates developed within as parts of the imaginal cuticle may perhaps represent some of these parts.

"The appendages of the 'ninth segment' of the pupa are a pair of blunt processes arising below and in front of the anus, and directed backwards below the fins. They are much larger in the male than in the female. A pair of appendages are already recognisable in this region in sections of the larva, and I think even two pairs, but this portion of the larva is particularly difficult to cut, and I am not yet certain as to the hinder of the two pairs. Of the existence of one pair I have no doubt."

Some mention must be made of the modifications of structure which occur in the pupæ of different species or groups of species. The early writers on the biology of *Anopheles* made much of the difference in the shape of the respiratory trumpets between *Anopheles* and "*Culex*." Their statements appear to have remained unchallenged and are still widely quoted. The variations in the shape, size and length of the breathing trumpets between different species of mosquitoes are numerous, but they furnish no characteristics which are diagnostic for genera or larger groups. The differences assumed to exist were based on the study of a very few species and with larger series they are bridged over by intergrading forms. Moreover, differences occur between species within a genus far more striking than any between genera. The best illustration of this is a species of *Wyeomyia* (*W. circumcincta*) which has exceedingly long and very slender respiratory trumpets; no characters appear on either the imago or the larva that are in any way abnormal for the genus. Another striking modification is found in the respiratory trumpets in the pupæ of certain species of *Mansonia*. These pupæ do not come to the surface of the water, but remain submerged, attached to aquatic plants by their respiratory trumpets. Here the trumpets are armed at their apices with a stout chitinous spine by means of which the pupa pierces the stems or roots of aquatic plants to extract the necessary air from them.

There is considerable difference in the shape of the paddles but the remarks just made regarding the respiratory trumpets will also apply here. It may be stated, however, that there is a striking difference between the two tribes Culicini and Sabethini. In the Culicini the paddles are large, broad and rounded in outline; they are strengthened by a stout longitudinal mid rib which bears a spine or seta apically. In the Sabethini the paddles are much smaller, narrower and tapered to a point; the mid rib is either absent or poorly developed and there is no terminal spine or seta.

Perhaps the greatest diversity among the pupæ of mosquitoes will be found in the number and arrangement of the setæ on different parts of the body. These, we are sorry to say, have not been adequately studied, but we are convinced that they will furnish both generic and specific characters. Again there is a well-marked difference in the two tribes above mentioned. In the Sabethini the seventh and eighth abdominal segments each bear a pair of ample fan-shaped tufts at the apical angles; these are absent in the Culicini.

There is, of course, some difference in proportions in the pupæ of different species. Generally speaking the pupæ of the Sabethini have a more slender and elongate abdomen. There is also much diversity in coloration. The Sabethini have pale yellow pupæ, in some cases marked with a dark pattern. The pupæ of the Culicini are invariably darker, shades of brown and black being the usual colors.

ECLOSION OF THE IMAGO.

Towards the end of the pupal period the pupa becomes gradually inflated with air. It grows so light that it at last experiences great difficulty in going down into the water and when it succeeds it is carried to the surface again with great rapidity. Ecdysis takes place at the surface of the water and requires but a short time, although it is by no means as rapid a process as one would be led to suppose from the statements of certain authors. It is accomplished by the employment of air and Eysell has given a very excellent description of the process of which we give a translation herewith.

"The pupa begins to straighten the abdominal part while in the meantime the cephalothorax retains its position. The straightening does not occur suddenly or by jerks, but steadily. *After 10–15 minutes the operation is concluded.* Already before this the excretion of air between the epidermis (of the imago) and the pupal skin has begun; the pupa then appears silver-white. Finally the anterior parts of the cephalothorax are raised by a powerful jerk and now the *pupa touches the water-surface, in front with the dorsal parts of the pro- and mesothorax, in the middle with the stigmata of the breathing tubes, and behind* with the end of the body. The previously strongly convex dorsal surface of the animal has become concave.

"Now the pupal skin breaks exactly along the median line on that part of the cephalothorax touching the water-surface, and at once there issues into the air, through the gaping slit, the scale-covered, dry dorsum of the imago. By jerks the slit is widened; soon two transverse slits are added on each side, and after *the pupal skin has receded about ten times (synchronous on the two sides)* the thorax in its entire width appears in the cleft. Now the scutellum, the stretched neck and the vertex of the strongly downward bent head also appear. The pushing forward of the mosquito's body by jerks then ceases and the animal issues from its prison, like the actor from a trap-door, with truly ghost-like steadiness of motion.

"When the head is born the antennæ, which lie in special chitinous sheaths on the sides of the cephalothorax, first become free; then the palpi and proboscis, which are enclosed in a tapering sheath lying loosely upon the pupal case, are disengaged.

"The abdomen in the meantime has of course also moved further forward and the last segments of the pupal skin are inflated with air.

"The insect now raises the head and extends the antennæ, palpi and proboscis; then it draws the anterior pair of legs from their sheaths by bending the knee-joints, and later also the joints of the feet, in a plane with the body-axis. After the front legs are freed the middle legs are extracted in the same manner *and now both anterior pairs of legs are extended forward and outward as far as possible and the tarsal joints are placed gently upon the water.* Now the mosquito's body, which had heretofore only balanced on the air-filled pupal skin, is supported at five points and its equilibrium has become very steady. Then finally the hind legs follow.

"All the legs are disengaged independently of the movement of the body itself. They are extracted from their sheaths in pairs, by repeated very short movements.

"Finally the wing tips and the end of the abdomen become free.

"The entire process is completed within a few minutes.

"The complete insect issues from the floating pupal skin almost colorless, translucent and strongly inflated and assumes its permanent color and form after some hours.

"The study of the motive power in the process of ecdysis gives highly interesting results.

"In the first place, as already remarked above, the pupal skin, which had before been in close contact with the mosquito's body, is detached and inflated to the utmost by a layer of air which is pressed out of the stigmata of the imago. The previously dark pupa becomes shining silvery. The increasing pressure within causes the pupal skin to burst at its weakest point over the thorax and at the same time tears the connection of the breathing trumpets with the tracheal system of the mosquito.

"Now the layer of air surrounding the mosquito's body stands in direct connection with the atmosphere and at once the animal begins to swallow great quantities of air.

"Hereby the volume of the mosquito is considerably increased; the pupal case can no longer hold it, and, at a time when the hind end of the body still remains exactly in the same position as during the pupal stage, the greatly lengthened body is already forced a considerable distance through the slit in the thorax. Through the ingorged air the abdomen loses its limpness, it is stiffened like an air-inflated bladder and continues to increase in volume proximally. The conical form of the body thus brought about causes it to glide forward in the anally narrowed pupal skin, and under normal conditions this motion needs hardly any assistance from the abdominal muscles.

"The *specific weight of the animal is greatly diminished by the taking in of* great quantities of air, a circumstance which is equally important for the imago when issuing and immediately after."

It appears from the observations of Eysell that the three diverticula of the œsophagus perform an important function at this time, they receive the swallowed air and it is by their means that the volume of the insect is so much increased. During the pupal stage the diverticula contain no air whatever, but immediately after ecdysis they are found inflated to the utmost. We have already discussed (page 78) the double function of the large diverticulum and shown that in the mature insect it serves as a food-reservoir. The two smaller diverticula remain filled with air at all times.

HABITS OF ADULT MOSQUITOES.

THE FOOD-HABITS.

Mosquitoes have engaged the attention of man largely through their bites and on this account they have been considered blood-suckers as a group. This, however, is far from being the case. There are a great many species, perhaps more than half, which never suck blood at all, while others do so but rarely. On the other hand there are many species in which the craving for blood is evidently very powerful. Everyone will have noticed the impulsiveness of attack in certain mosquitoes. Many of these will attack all warm-blooded animals indiscriminately. Grassi states that with such species the largest animals attract the most; thus a horse will attract mosquitoes more than a man, a man more than a dog. Certain species of mosquitoes have a decided predilection for certain animals. The yellow-fever mosquito under normal conditions probably feeds exclusively upon man: more than this, it will be seen in the chapter on yellow fever that this mosquito even discriminates between the different races of man. *Culex pipiens* and *Culex quinquefasciatus* are closely associated with man yet they do not persecute him with the same persistence as *Aëdes calopus*. There is reason to suppose that these species of *Culex* are primarily persecutors of poultry.

It will be remembered that Ross, in India, in his original investigations with a malarial disease of sparrows, found that this was transmitted by *Culex quinquefasciatus*. There are malarial diseases of other birds, probably carried by other mosquitoes. MacCallum's original observation in which he discovered the true meaning of the flagellate bodies, the real males of *Proteosoma*, was made in studying a malarial disease of the American crow.

Captain James, who investigated the blood diseases of birds, states that "the voracity with which *Culex* mosquitoes (*C. fatigans*) [=*C. quinquefasciatus*] will gorge themselves upon the blood of sparrows is extraordinary, and if too many mosquitoes are put in the cage with the same sparrow they will literally bleed it to death."

Goeldi, in discussing the habits of *Culex quinquefasciatus* in comparison with *Aëdes calopus*, touches upon this adaptation as follows:

"I have the impression that, in general, *Culex fatigans* behaves more contrary, obstinate, timid, refractory to domestication and comprehension: I believe that I can perceive significant proof of this in the singular circumstance that in all the trials made with this species of mosquito I only succeeded in inducing a single individual to bite, either among those captured or those bred in captivity. I attribute to it a degree of intelligence decidedly inferior to that of *Stegomyia fasciata*. This accords well with my idea that, in the same manner as the other blood-sucking insects, this species of Culicid has a primary relation to a definite and determinate species of vertebrate host. I feel induced to say that in *Culex fatigans* we have a mosquito primitively less addicted to the human species than to certain domestic animals, amongst which, my suspicion points principally towards an inquiline of our poultry-houses. And may it not be possible that, furthermore, in the marked intellectual diversity between *Culex fatigans* and *Stegomyia fasciata* there is reflected the primitive diversity between their respective hosts? It is certain, and no one will dispute me, that a mosquito must be more expert to persecute man than to persecute poultry, cats or dogs, as the case may be. And are not the rats and house mice, and, among insects, the repulsive roaches proof bow much effect the daily association with 'homo sapiens' has upon intellectual development and refinement?"

Culex erythrothorax occurs in Californian swamps exclusively among the tall reeds. Dyar found that "a person sitting on the bank was immune from their attacks, but among the reeds they bit viciously in the daytime." These reeds were inhabited by numerous water-fowl and it is upon these that this species of *Culex*, without a doubt, normally feeds. Pet caged birds, in regions of mosquito abundance, are reared with difficulty, and young birds are often killed by mosquitoes.

There is reason to believe that many of the species of *Aëdes* prefer mammalian blood. The females of the species breeding upon the salt marshes of our coasts migrate inland in large swarms and these journeys are very probably undertaken in search of mammalian blood. The ferocity of the mosquitoes in northern regions is remarked upon by all who have visited sucb regions. Linnæus early testified to it from bis Lapland experience. Many other authors could be cited. One of us (Knab) experienced it on the prairies of Saskatchewan.

In the opinion of Knab the blood-sucking instinct is so strong and so precisely adjusted to circumstances that it must be looked upon as a function of the greatest importance to the mosquito. In the case of *Aëdes spencerii*, the most abundant species of the prairies of the northwest, Knab has observed that it has the habit of flying towards prominent objects. Under natural conditions upon the open prairies such prominent objects would always be some warm-blooded animal and this habit demonstrates a very fine adjustment on the part of the mosquito.

Some writers have held that but few of the mosquitoes which are so numerous in far northern regions could obtain a meal of blood and therefore the blood-sucking habit could not be considered normal or important in the economy of the insect. This idea is based upon an erroneous conception of the fauna of these regions. In fact the northern countries in former times teemed with warm-blooded animals; it is only necessary to mention the great herds of bison, elk, deer and antelope. Today, where the former inhabitants have disappeared before the settler, they are replaced by horses and cattle, and there is sufficient testimony as to how viciously these are attacked.

Galli-Valerio and Rochaz de Jongh, in their investigations upon European mosquitoes, noted that certain mosquitoes showed a preference to animals over man. One of them noted that in a locality in which he had always been bitten by many *Aëdes nemorosus* when there alone, when another person and a white dog were also present these mosquitoes attacked and greatly worried the dog while the persons sitting near were spared. This was the more remarkable as the persons should have been preferred on account of the dark color of their clothing.

Some species, and among these may be counted many of those in temperate and tropical regions, seem to have the appetite for blood but weakly developed. Such species only bite occasionally and they have been observed sucking ripe fruit, watermelons, and even boiled potatoes.

With reference to certain species the observations of different authors conflict. According to most writers the European *Culiseta annulatus* does not bite. Ficalbi states that he has never known this species to bite either man or animals and he believes it to be phytophagous. Theobald states that in England it bites in some localities but does not do so in others. We believe that these discrepancies may be explained by differences in season and in temperature. It may be stated in a general way, that mosquitoes increase their activity in ratio with the rising temperature and increasing humidity of the atmosphere. During hibernation they show little inclination to feed, even when the temperature is comparatively high. It should be noted that in certain European species of Culicidæ which have long been associated with man, and the species just discussed is included in these, the inclination to bite man seems to be weak at best. Perhaps this can be explained in that the most blood-thirsty individuals would be the ones to be destroyed; thus, by a process of elimination, the least aggressive individuals would be the ones to perpetuate the species and transmit this characteristic to their offspring.

Cold-blooded vertebrates are also attacked. Brakeley, of New Jersey, has seen a black terrapin surrounded by a swarm of mosquitoes, but she paid no attention to them, possibly because she was engaged in egg-laying. It would be an interesting observation to find whether the mosquitoes ever had an opportunity to pierce the terrapin eggs. Brakeley states that they also bite lizards, snakes and frogs. Unfortunately we have no record of the species concerned.

There are several records that mosquitoes have been seen to puncture the heads of young fish, but these observations apply to biting flies of another family, namely, Simuliidæ. One of these observations was made by C. H. Murray in the mountains of Colorado near the snow line. He found a small swarm of "mosquitoes" circling about over a quiet shallow pool in a mountain stream; in this pool were very young trout and when these came to the surface of the water they would be pounced upon by a "mosquito" and sucked to death. The behavior of the insects, as described, suggests *Simulium*, as does the locality, and it must be remembered that the observer was not an entomologist. P. Combes gives an account of similar observations made in the island of Anticosti. He calls the insects "moustiques," but from the detailed description of their habits it is very clear that it was *Simulium* he had under observation. The confusion has come about through the loose application of the popular term "mosquito" or "moustique."

But blood-sucking mosquitoes are by no means absolutely confined to a vertebrate diet. They attack other insects, particularly the soft-bodied ones, although direct observations upon this point are rare. Veazie, of New Orleans, has seen mosquitoes piercing a cicada, or "locust," as it is incorrectly called in this country, and also the soft-skinned pupa of the same insect. Hagen has recorded an observation in the northwest United States in which he saw a mosquito engaged in feeding on the chrysalis of a butterfly. Theobald has on two occasions seen *Culex nigritulus* sucking at the body of *Chironomus* and other small Diptera.

Male mosquitoes do not suck blood. In the chapter on the anatomy of the mouth-parts we have shown that some of the mouth organs are absent or greatly reduced in the male and on this account it is unable to pierce the skin. There are, however, records by good observers of male mosquitoes sucking blood. One of these is quoted herewith from Howard's "Mosquitoes":

"In spite of what we have just said about the non-penetrating mouth parts of male mosquitoes, Dr. C. W. Stiles informs me that he and Hurst (the author of an important paper on the pupal stage of Culex, Manchester, 1890) made an observation in the summer of 1889, at Leipsic, which convinced him that either the males do occasionally bite or that occasionally females possess feathered antennæ. Stiles and Hurst were out in a row-boat one evening and were bitten a number of times by *Culex nemoralis*. One individual which bit Stiles on the left hand was crushed, and in the crushing act a considerable quantity of blood exuded—enough to make a fair-sized blood-stain on his skin. Upon examining the dead body he was surprised to note that it possessed male antennæ. Hurst also examined it, and remarked that it was the first instance he had known where a male Culex had actually been caught sucking blood. Dr. Stiles tells me that Hurst intended to place the observation on record, but that he does not think it was ever published. Dr. Stiles is so well known as an accurate observer, that some other explanation than faulty observation must be offered in this instance."

Ficalbi makes the following statement regarding *Aëdes calopus:* "A most remarkable peculiarity of this species is that *the male stings* as well as the female and sucks blood, producing a puncture equally painful with that produced by the female." The statement has been widely quoted but we have been unable to find independent observations in confirmation of Ficalbi's statement. In our own wide experience with this species we have never known the male to bite nor, of the numerous specimens handled by us, has there been any male with traces of a blood-meal. W. Wesché, on account of the reports of the male biting, has examined the mouth-parts of several male *Aëdes calopus*. He states that he "found very short atrophying maxillæ, no mandibles, a ciliated hypopharynx, and the labrum and labium well developed," a condition which does not support the idea that the male bites.

There is still the possibility that the observations just quoted, of males sucking blood, are based upon abnormal indviduals. Wesché found that aberrant males occur in which the mouth-parts are fully developed. But one would still have to assume that, along with the complete mouth-parts, such males had inherent the appetite for blood otherwise peculiar to the female.

It seems certain that the females of many species and of certain genera are unable to pierce the skin of human beings and do not suck blood. The large and brilliant mosquitoes of the genus *Megarhinus* do not suck blood. The proboscis is so modified, the labium being entirely rigid, that they can not pierce with it; recent observations show that both sexes are habitual flower-feeders. Recently Mr. Edward Jacobson has discovered a mosquito, *Harpagomyia* *splendens* de Meijere, in Java, which obtains its food by causing a certain ant, *Cremastogaster difformis* Smith, to disgorge the liquid in its crop. This mosquito habitually sits upon the ant-streets on the tree trunks to waylay the ants. The observer writes as follows:

"They sit mostly immediately upon the ant-streets and constantly rock themselves back and forth, from left to right and the reverse.

"When now an ant comes down the tree and, so to speak, runs between the legs of the mosquito, she is at once held up by the latter by rapidly tapping the ant with fore legs and palpi, upon the head and vertex. Most of the ants then immediately stand still, press the body firmly against the tree, fold the abdomen towards the front and open the mandibles wide, at the same time drawing back the antennæ. The mosquito at once ceases its rocking movements and brings the wings into rapid vibrations.

"While the ant now vomits a drop of food-liquid the mosquito licks it up with great haste, upon which the ant goes on its way. The mosquito again begins to rock itself back and forth until another ant allows itself to be robbed by the waylayer.

"However, not all ants permit themselves to be robbed and many hurry rapidly upon their way without paying toll. The mosquito then often attempts to bring the escaping ant to a standstill by flying down the tree in front of the ant, at the same time constantly touching it with its fore legs and palpi. Thereby she often accomplishes her object."

The mosquitoes of the genus *Deinocerites*, which breed in crab-holes along the coast, are not blood-suckers. There are several species of *Culex* which are exclusively crab-hole breeders and none of these appear to suck blood. We have specimens of *Culex extricator* from Panama in which the abdomen is distended by a whitish substance, showing that they had fed on something else than vertebrate blood.

The little pitcher-plant mosquito, *Wyeomyia smithii*, does not suck blood. Neither does *Culex territans*, a very common species throughout the summer in eastern North America. *Culex melanurus* apparently does not bite. These species probably obtain nourishment from plants in some form or other. Observations on the habits of such species are yet to be made.

Ficalbi discovered a species in Italy which punctures plants and feeds upon their juices and which he therefore gave the name *Culex phytophagus*. In specimens that had fed, the distended abdomen distinctly showed the green color of the chlorophyll within. Theobald cites an observation by Dr. W. Hatchett Jackson that *Culiseta annulatus* apparently sometimes sucks plant juices. . . . "on a warm sunny day in November the ♀'s settled on the stems of periwinkle and wall-flowers and inserting their proboscides, apparently engaged in sucking."

The whole question of the feeding of mosquitoes upon plants has been rather carefully gone over by one of us (Knab) in an article entitled "Mosquitoes as Flower Visitors," published in the Journal of the New York Entomological Society, Volume XV, December, 1907, pages 215–219. This article also includes certain original observations, and for convenience we reproduce it in full:

"In discussions of the feeding habits of mosquitoes one often finds the statement that mosquitoes suck the juices of plants and visit flowers to obtain honey. Generally, however, no details are given that would convince one that these itements are based upon actual observation. During the past season I found species of mosquito frequenting flowers in large numbers. It was obvious from e behavior of these mosquitoes that the habit is quite normal with them. Con- .ent that the habit, of mosquitoes, of visiting flowers could not have altogether caped observation I made a hasty canvas of the available literature and brought gether the following records of a more definite character.

" Theobald states: 'I have frequently seen Culicidæ settled on Compositæ, cking the juices of the flowers, both males and females.' * According to Giles hey are frequently found on flowers, and especially in England on the catkins the willow.' † Ficalbi found the first male of his *Culex albopunctatus* upon lower, sucking the honey, and upon searching the woods he found numbers of ales thus engaged upon flowers of the same kind.‡ A number of records re traced through Knuth's Handbuch der Blütenbiologie. Hermann Müller s observed the male of *Culex pipiens* sucking on the flowers of *Rhamnus angula*.§ He has observed, in his room, this same species of mosquito effect- g the fertilization of *Lopezia coronata* by releasing the pollen and transmitting to the stigma of an older flower.‖ Burkill, in observations on the flower- sitors of *Mentha aquatica*, made at Scarborough between September 20 and ctober 7, found an *Anopheles* species 'four times, seemingly sucking honey.' ¶ ie sex is not indicated.

" The foregoing records are all European. Several American observers have ted mosquitoes on flowers. Robertson, in a list of insects found on the flowers *Ceanothus americanus* between June 19 and 29, includes an undetermined ecies of Culicidæ.** Smith has found the males of *Aëdes sollicitans* 'in great imbers in wild cherry blossoms in the early evening, apparently busied in tting at the nectar. Females have been observed at the same time; but ap- irently these abandoned the vegetable food readily, when the animal odor lvised them of something more to their taste.' †† Dr. Graenicher lists *Aëdes imulans* among the flower-visitors of *Smilax herbacea* and *Smilax hispida*.‡‡ o further data are given and upon inquiry Dr. Graenicher informed me that has no notes which would supply details regarding these observations. How- er he has very kindly furnished me the following interesting observations upon *ëdes sylvestris*, recently made by him, which I give verbatim.

" ' At the beginning of August, while collecting the visitors of our earliest ecies of goldenrod, *Solidago juncea*, I came across a species of *Culex* on two fferent occasions. Before writing to you on this subject I preferred to follow p the matter more closely. Last Sunday [Sept. 1] the opportunity presented self, and I found *Culex sylvestris* Theo. (determined by Mr. C. T. Brues, ublic Museum of Milwaukee) on the flowers of the following three species of *olidago*: *juncea* Ait., *canadensis* L., and *lanceolata* L., (*Euthamia gramini- lia* (L.) Nutt. in Britton's Manual). This species of *Culex* is common in our gion, and it was well represented on the flowers throughout the afternoon, but pecially towards evening. Males and females were present, *both* eagerly suck- ıg nectar. By approaching them cautiously I was able to observe their actions

* Theobald, F. V.: Monogr. Culicidæ, vol. 1, 1901, p. 69.

† Giles, G. M.: Handbook of Gnats or Mosquitoes, 2 ed., 1902, p. 114.

‡ Ficalbi, E.: Venti specie di zanzare (Culicidæ) italiane. Bull. Soc. Ent. Ital., vol. 31, 399, pp. 107, 186.

§ Müller, H.: Die Befruchtung der Blumen durch Insekten, 1873, p. 153.

‖ L. c., p. 198.

¶ Willis, J. C., and I. H. Burkill: Flowers and Insects in Great Britain, pt. 1, Annals of otany, vol. 9, 1895, p. 256.

** Robertson, C. H.: Flowers and Insects, III. Bot. Gazette, vol, 14, 1889, p. 304.

†† Howard, L. O.: Mosquitoes, 1902, p. 36, and Smith, J. B.: Report, mosquitoes of N. J., 304, pp. 27, 203.

‡‡ Graenicher, S.: Flowers adapted to flesh-flies. Bull. Wis. Nat. Hist. Soc., vol. 1, no. 1, 302, pp. 33, 34.

very distinctly with the aid of a lens. During the earlier part of the afternoon the females (which by some are supposed to partake of animal juices only) were present in greater numbers than the males, but later on both sexes were about equally represented.'

"My own observations were made last spring upon *Aëdes spenceri* Theo. during my stay in Saskatchewan. I shall give some particulars of the life history of this species as they throw some light on its feeding habits. This species develops in immense numbers from the numerous ditches and temporary pools of snow-water scattered over the prairie. The females are voracious blood-suckers and in the early part of the summer make life on the prairie a torture for man and beast. The species is strictly diurnal. The season was an unusually late one this year, and the first mosquitoes were seen flying on May 30. The first males were seen swarming on June 5. After several cold, damp days the mosquitoes were again active on June 9, the females biting, the males swarming. The following day there was a very high wind which confined the mosquitoes to their retreats in the grass. June 11 was a hot day with only light wind. On an excursion into the prairie, early in the afternoon, the female mosquitoes were found much fewer in number, perhaps as a result of the great heat. No males were seen swarming, as had been the case on previous favorable days. However, upon examining the willow bushes along the margins of ponds and ditches the males were found in numbers upon the willow catkins. Often there were five or six on one catkin, confining themselves to that part of it which was in full bloom. They climbed about on the stamens and probed down amongst them to get the honey. They appeared very eager in this work, plunging the proboscis down for a second then quickly withdrawing it to reinsert it in another place, sometimes even scrambling over each other in their eagerness. The palpi, together with antennæ, are held erect nearly at right angles to the proboscis. There were also a few females at the willow catkins, feeding in the same manner as the males but less eagerly. The following day, June 12, was warm but very windy. Along the river bank the mosquitoes were again found abundant upon the willow blooms, and this in spite of the high wind which must have made it very difficult for them to maintain their position. As before, most of the mosquitoes on the catkins were males. Although there was an abundance of flowers of various kinds on the prairie at this time none of these were visited by the mosquitoes. A period of continuous violent wind followed. When this had subsided the mosquitoes were again investigated on June 18. The males had now nearly all disappeared; there were none upon the willow catkins and only a very few could be obtained by beating.

"Several points are brought out by these data. The life of the male mosquito does not, at the most, extend over more than two weeks. The males do not appear to take food until after the period of swarming or copulation, nor, in spite of the food taken, do they survive long after the mating period. The females probably only resort to flowers when very hungry and blood is not obtainable. It should be borne in mind that these deductions apply in particular to *Aëdes spenceri*. Now that we are more familiar with the habits of individual species of mosquitoes it is obvious that no statements which apply generally can be made from observations on the habits of one species. Thus, according to Dr. Graenicher's observations, the females of *Aëdes sylvestris* visit flowers in equal numbers with the males. This species, although a well-known blood-sucker, is not so aggressive and persistent in its quest for blood as *Aëdes spenceri*. Moreover it is crepuscular in habit and therefore most abundant on the flowers in the evening, while *Aëdes spenceri* frequents them during the day. *Aëdes sollicitans*, both sexes of which have been observed by Smith upon flowers, is noted as a most persistent blood-sucker. In fact in all the species recorded in the foregoing as ower-visitors the females suck blood. In these hæmatophagous females the ectar of flowers may be considered as a supplementary food which prevents tarvation when blood is not available. With the males nectar appears to be he natural food. It is hardly to be supposed that species of mosquitoes limit hemselves to particular flowers, nor is there any structural modification that rould indicate adaptation to certain flowers, such as exist, for example, in the ower-visiting Hymenoptera. The great diversity of flowers visited by mosuitoes bears this out. With the mosquitoes it is probably merely a question of asy accessibility of the nectar and also of the season in which a particular pecies of mosquito makes its appearance. As the appearance of many species of osquitoes is regulated by conditions of rainfall which vary from year to year, he flowers available to a given species can not always be the same.

". . . In conclusion I wish to place on record an observation on *Megarhinus eptentrionalis* D. & K., our largest mosquito. On July 14 of this year I found female of this species at Glen Carlyn, Virginia, probing for honey upon a cyme f *Hydrangea arborescens* L. The mosquitoes of the genus *Megarhinus* are so are that very little is known of their habits, but it appears quite certain that ey do not attack animals, indeed, their proboscis is unfit for piercing the skin. 'robably they feed wholly upon the nectar of flowers, but as they are very rare, ven in their proper home—the tropics, and withal very shy, it is not strange at they have escaped observation."

It is worthy of note that Réaumur fed *Culex* upon syrup and believed aat the greater part of them are contented with a diet of the sap of plants. Iosquitoes have been observed to come to exposed honey in large numbers.

There is a decided difference in the food of the male and female of most osquitoes. Goeldi, referring to this difference, says:

" A curious phenomenon is the difference in the methods of alimentation beween the mosquitoes of the male and female sexes. The former out of doors eek ripe fruit and flowers, and when they visit our houses frequent the sugar asin, coffee, tea, wine, soups, the cups and saucers and plates of our tables—all weet substances in a word—abstaining as a rule from drinking blood. The emales, participating up to a certain point in this diet, are at the same time ddicted to the vice of blood-sucking. They are blood-suckers by choice, which arms us, and it is chiefly against them that our hatred, the result of desperaion, is directed."

Making experiments in this direction he found that out of thirty-seven mosuitoes captured in a sugar-bowl there were one female and one male of *Aëdes alopus* and two females and thirty-three males of *Culex quinquefasciatus*, 'hereas, crushing, with one blow of his hand, a number of mosquitoes trying o enter a mosquito bar, he found that he had killed twenty-three specimens of *'ulex quinquefasciatus*, all of which were females.

Goeldi also calls attention to the attraction which perspiration has for the ellow-fever mosquito, both males and females, and shows that males often alight pon the skin and drink the perspiration. He believes that the biting mosquitoes *ere originally attracted by perspiration and that the females have developed* ato blood-drinkers while the males have preserved the original condition. It aay be that the few reported cases in which males have been supposed to bite re based upon a faulty deduction, males being seen in a biting position but nly drinking the perspiration and perhaps slightly irritating the skin.

Smith, in discussing the question of the food of adult mosquitoes, states that he has examined the stomachs of a number of specimens, and has found some of them filled with a colorless liquid like plant nectar. On the other hand, with *Aëdes sollicitans,* a salt marsh species, he has found the stomach filled by a mass which he could not distinguish from thin marsh mud.

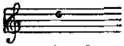
Some very interesting observations have been made upon biting of corpses by mosquitoes. In our section on yellow fever we have given an account of experiments made with captive *Aëdes calopus* at Vera Cruz. In these it was shown that one female feeding upon a corpse twelve hours after death apparently obtained blood, but this was only one of a number; three of a number in another case, one-half hour after the death of the patient, succeeded in feeding with blood. Christy, in making a post-mortem examination in Nigeria, found a number of a large brown *Anopheles* feeding upon the body of a non-commissioned officer who had died three and a half hours previously.

The laboratory studies consequent upon the discovery of the relations between mosquitoes and certain diseases have brought about necessary experimentation as to the kinds of food upon which to prolong the life of blood-sucking mosquitoes used for experimental purposes, and it has been found that they will live almost for indefinite periods upon a vegetable diet, bananas, dates, raisin-grapes, and other fruit used for this purpose, and it has been found that frequent meals of water are necessitated in order to prolong life. One of us (Dyar) has reared two successive generations of *Aëdes atropalpus* in captivity by feeding the adults upon sugar and water.

MOSQUITO SONGS AND THEIR POWER OF HEARING.

Probably owing to an association of ideas, the curious sound made by mosquitoes as they approach one's ear is to most people extremely irritating. This faint sound will waken many from the soundest sleep. It is not loud, and in quality may perhaps best be compared to the distant note of a bagpipe.

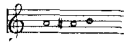
As with flies and other dipterous insects the sounds emitted by mosquitoes are not a true voice. It has been supposed that the sounds are produced in two ways, by the vibration of the wings and by air forced through the thoracic stigmata. Landois, in his classical paper on the sound-producing organs of insects, apparently proved the latter to be the case, but more recent investigations show that he was at fault in his conclusion that the stigmata emit sound.

Landois thought that mosquitoes produce sounds in two ways. The normal tone, which can not be modified in any way by the insect, is produced by the wing stroke. The common *Culex pipiens* during flight produces the sound  (*d'*). If one removes the wings, head, and all the legs of such a mosquito she emits a sound which is much higher than that produced in flight. This sound Landois thought to be produced by the stigmata of the thorax and said it might be called the voice of the mosquito. He found within the spiracle, a membrane, stretched like a double curtain, which he supposed produced the sound when the air was forced through it. He considered the posterior thoracic racles those most concerned in sound production, but that the anterior ones) took part. He found that the insect was able to modulate the sounds within onsiderable compass and he explained this by the fact that the spiracles are ler the control of muscles. By means of these muscles tension can be exerted m the chitinous ring of the spiracle and the position of the membranes nged and this, Landois thought, modulated the sounds. Landois further con- ered that the halteres helped to control the sound from the metathoracic racles.

Shipley and Wilson, in 1902, described a stridulating apparatus on the basal t of the wings of *Anopheles* which is most probably the principal sound pro- ing organ. These authors call attention to the careful investigations of J. ez which prove, experimentally, that no sounds are produced by the stigmata. isset de Bellesme reached the same conclusion and quite recently C. E. Pem- ton has made experiments with confirmatory results. This last investigator, Nuttall, found that if in removing the wing a stump remained the insect tinued to emit a sound; if, however, the stump of the wing was entirely re- ved, all perceptible sound ceased.

The apparatus described by Shipley and Wilson is very complex and lies ong the series of nervures and ridges on the narrowed basal portion of the g. It consists of two structures which rest against each other and are capa- of a certain limited amount of movement. "The anterior system consists of ightly movable bar, which covers a thickening in the tissue of the wing. This -named ultimately passes into the subcostal nervure. The bar extends from articulation of the wing to the humeral cross-nervure, and, as we have stated, consider it to be slightly movable. On its hinder, free edge the bar carries a es of thirteen to fifteen well-marked teeth, which, under certain circum- nces, rasp across a series of ridges borne on the second part of the system." is second part "consists primarily of a chitinous blade, shaped something a butcher's knife, which is ridged on its upper surface with thirteen to fifteen rply-defined elevations placed slightly obliquely. It is against these ridges t the teeth of the bar mentioned above rasp. The relative position of the bar l the blade is not constant. The latter is usually lying partly under the mer, but at times it is free from it, and it seems as though it were hinged at handle and can oscillate through a few degrees, around an axis at the base he proximal end. But it can not rotate very far. A little way behind the k of the blade is an upstanding flange of the membranous tissue of the wing, ch we have called the trough. This trough catches and holds the blade, and vents the latter being thrown too far back." The authors then describe the nplex structures at the base of the wing which in their opinion constitute t of the mechanism for producing sound by means of the above-described ans. They further state that the area over which the blade travels is the only t which "is quite smooth and entirely free from the minute hairs and minences which cover the rest of the wing." These authors also found cer- n minute structures upon the halteres which they thought might be used to duce a sound, although they consider that the principal function of the teres is one of balancing and orientation.

The exact musical note of the different species of mosquitoes seems to hav been investigated only in a few cases. Marked differences have been found i the notes of different species. Both sexes emit a sound but there is a marke difference, the note of the males being much higher than that of the femal There is also a slight difference in the note of fed and unfed individuals of th same species.

Landois found that in *Culiseta annulatus* the male range is throug ; the female .

Goeldi, in Brazil, has made an effort to determine the note of the yellow-feve mosquito (*Aëdes calopus*). It has several times been stated by observers th this mosquito makes no sound when it flies, but this Goeldi denies. Aided b two of his Museum colleagues who were musicians, he made his experiments a follows:

"For this purpose we made use of the inhabitants of two cages, one contai ing only males; the other only females. An hour of the afternoon was selecte and the cages exposed to the mild rays of a partly cloudy day. We made use o a zither and of a tuning fork of a known number of vibrations. We found th the pitch of the female corresponded to C while that of the male corresponded A. The two sounds hold the relation of a sixth to each other; the A of the ma corresponds to 880 vibrations; the C of the female to 480 vibrations. In ea case we had the impression that along with the principal sound there was hear from time to time, the respective octaves so that the timbre seemed to be covere by the proper concomitant sounds ('Obertöne' in German technico-acoust language). It is evident that a certain effect is produced upon the pitch of th sound by the greater or less dilation of the abdomen with food, and who kno whether not also under the psychic effect of the influence of mutual suggestion

The musical note of *Anopheles* has been studied by Nuttall and Shipley a their results will be found in our section on malaria in a later part of th volume (p. 211).

The curious reaction of a swarm of mosquitoes to sound of a certain pit was related to Osten Sacken by a Cuban naturalist. While a swarm of mo quitoes was hovering over the head of the observer a band was playing at a di tance. Whenever the note A was struck the mosquitoes were all precipitat downward, striking against the face of the observer. The following observati along the same line is from Howard's "Mosquitoes."

"Mr. A. DeP. Weaver, an electrical engineer of Jackson, Miss., wrote m that while engaged in some experiments in harmonic telegraphy, in which musical note of a certain pitch was produced by electrical means, he was amaz to find that when the note was raised to a certain number of vibrations p second, all mosquitoes, not only in the room where the apparatus was, but al from other parts and from outside, would congregate near the apparatus an would be precipitated from the air with astonishing force, striking their bodi against the apparatus. He states that he therefore covered a large surface wit sticky fly-paper and after sounding the note for a few second captured all th mosquitoes in the vicinity. He then devised an apparatus to electrocute the A section of wire window screen with the paint removed was mounted on a boa and small pins were driven between the meshes, the heads coming flush with th face of the screen. All the pins were connected together electrically, the ɔle forming one electrode of the secondary coil of induction coil, while the e screen formed the other electrode. An alternating current of high potential then passed and when the note was sounded the insects precipitated them-es against the screen and were immediately electrocuted. Mr. Weaver, un-:unately, does not state whether males only were captured in this way."

Nuttall and Shipley point out that Grassi (1900) states that persons are more ıle to be bitten by *Anopheles* when engaged in conversation than when silent, : that Joly (1901) in Madagascar observed that mosquitoes were decidedly cted by music and that if he played a stringed instrument the mosquitoes an to fly about in the room and flew in from the outside, gathering about the yer in great numbers. They also state that Ross has been informed by Mr. ;nnen, of Jamaica, that he has seen mosquitoes there " respond to such sounds ı continuous whoop or hum," stating further, " I have tried the experience :ly, and find swarms gather round my head when I make a continuous whoop."

ı very interesting instance of the attraction of mosquitoes to sounds of certain .b, as related in a letter to the London Times of October 29, 1901, by Sir ·am S. Maxim, is published by Nuttall and Shipley:

In 1878 I made and erected an apparatus for lighting the grounds of the ınd Union Hotel at Saratoga Springs, New York, by electricity. The lamps ɔloyed were rather large and each was provided with its own dynamo machine. ; of the lamps worked something like a telephone and gave a note the pitch vhich corresponded exactly with the strips on the commutator passing under brushes of the dynamo machine. Some of the other lamps would occasionally ; off a musical note, but only for a few minutes at a time. With this one, vever, the note was practically constant, and no adjustment of the carbons . the least effect upon it. One evening whilst examining this lamp I found t everything in the immediate vicinity was covered with small insects. They not appear to be attempting to get into the globe, but rather into the box that ; giving off the musical note. Upon a close examination of these insects I nd that they were all the same kind—viz., mosquitoes, and, what is more, all !e mosquitoes. Although there were certainly 200 times as many female mos-toes on the grounds as males, I was unable to find a single female mosquito t was attracted in the least by the sound. When the lamps were started in beginning of the evening every male mosquito would at once turn in the ;ction of the lamp, and as it were face the music, and then fly off in the ;ction from which the sound proceeded. It then occurred to me that the two ie feathers on the head of the male mosquito acted as ears, that they vibrated ınison with the music of the lamp, and as the pitch of the note was almost ıtical with the buzzing of the female mosquito the male took the music to be buzzing of the female. I am neither a naturalist nor an entomologist, still ·as much interested in this peculiar and interesting phenomenon. I wrote rn a full account of it at the time and sent it to a scientific paper, but it ap-red to be too stupid to find a place in that particular publication. However, ow appears that others have stumbled across the same thing. A very interest-experiment may be easily made in the following manner:—Obtaining a ing-fork which gives a musical note as much like the hum of the female mos-to as possible. If you strike this fork within 20 ft. of a male mosquito he l at once turn about, face the music, and erect the two little feathers on his d, something after the manner of a cockatoo."

TIME OF ACTIVITY.

Mosquitoes are generally looked upon as nocturnal in habits but this is probably true of only a small number of species. Our house mosquitoes of the genus *Culex* are nocturnal. *Culex quinquefasciatus*, the house mosquito of the tropics, is strictly nocturnal and bites in complete darkness. Many species of mosquitoes are crepuscular, confining their activities to the twilight of evening and early morning. This is the case with most *Anopheles* and the peculiarities of some of the species, in this respect, are discussed in our chapter on malaria. The yellow-fever mosquito (*Aëdes calopus*) is strictly diurnal; its behavior is fully discussed in connection with yellow fever. In far northern regions the mosquitoes are of necessity diurnal. One of us (Knab) found that the mosquitoes of the Saskatchewan prairies are active throughout the day, during the hours of full sunlight. At evening their attacks ceased, and indeed the rapid fall of temperature at that time puts an end to all insect activities. In the tropics, at least in America, a large proportion of the species of mosquitoes are strictly diurnal. It is true of many, if not all, the mosquitoes of the tribe Sabethini; they are forest inhabitants and fly about during the hours of full sunshine. The large and showy members of the genus *Megarhinus* appear to be diurnal. Lutz states that the males of *Megarhinus solstitialis* are seen flying rapidly by day. Knab has found a female of *Megarhinus septentrionalis* sucking honey from a flower in broad daylight. It is probable that all brilliantly colored mosquitoes are diurnal. The species of *Aëdes* of our northern woods appear to be crepuscular. Yet, while they are normally quiescent during full daylight, they are easily aroused. The presence of food, in the shape of a human being, will attract them, apparently from a considerable distance, as one can ascertain by remaining in one spot for a time. *Aëdes canadensis, Aëdes stimulans* and related forms attack viciously during midday. *Aëdes atropalpus* will bite by day and we have known it to bite so late in the evening that it could no longer be seen. Knab found that at Winnipeg *Aëdes riparius* came to bite in numbers during the middle of the day; it also bit at night in bright moonlight. *Mansonia perturbans* is strictly crepuscular but in dark woods will attack in the daytime.

Different situations are sought out by the different species to pass the time of quiescence. Certain species which have become more or less associated with man seek shelter within houses or other structures. Certain species of *Anopheles* frequent cellars, out-houses and culverts, and certain species of *Culex* are even more domestic. The majority of the species of mosquitoes, however, are practically never found in houses. They hide in the woods, on the under side of leaves, upon tree trunks, in hollow trees or under old logs. The prairie species hide in the grass.

LONGEVITY.

The question is frequently asked, how long a mosquito lives; the adult form alone being in mind. The males are very short-lived, in most cases probably a matter of a few days only. Their only office is to fertilize the female and this is usually very soon accomplished. Observations made by Knab in Saskatchewan upon *Aëdes spencerii*, under unusually favorable conditions, indicate a length of life of from two to three weeks for the males of that species. Indications are that only a very few of the males live to the maximum of three weeks. It was possible to gauge the length of life of these males thus accurately because this species has but a single brood and all the adults issued within, at the most, a week.

The length of life of the female exceeds that of the male but differs with the species and with circumstances. In temperate regions certain species hibernate and these probably live longest as their activities are divided by an intervening long period of quiescence. In these cases the length of the winter will determine the longevity of the mosquito and we must look upon certain species of *Culiseta* and *Anopheles* which occur far to the north as living longest.

There is a correlation between the habits of oviposition and length of life. Members of the genera *Culex, Culiseta, Lutzia* and *Uranotænia* deposit all their eggs at one time in a mass and death ensues immediately or soon after the eggs are laid. The females of these genera may be said to be short-lived, the species being perpetuated through a rapid succession of broods during the warm months. In *Aëdes*, where the eggs are deposited in small lots, at intervals, the female lives much longer, in many cases several months. Accurate data can not often be had on account of disturbing factors and we must rely largely upon our general knowledge of the species. In a few cases, however, we have experimental or other evidence which is conclusive. *Aëdes calopus* has been a frequent subject of experiment and females have been kept in captivity as long as 154 days, although this appears to be far in excess of the normal span of life. Observations by Knab, made in western Massachusetts in 1903, indicate that the females of certain species of *Aëdes* live at least three months. He found that *Aëdes stimulans, A. fitchii* and *A. abfitchii* have but a single brood which develops early in the spring. The data for the three species coincide so closely that they may be considered together. The earliest capture (as appears from preserved specimens) of a female was April 29; they continued abundant and troublesome through May and June but showed some decrease during August. We have specimens captured as late as September 12.

HIBERNATION AND ÆSTIVATION.

With the majority of the species of mosquitoes the unfavorable season is passed in the egg state. Certain genera, however, pass the winter, and in certain tropical regions the dry season, in the adult state. In such cases it is only the female that survives, having been previously fertilized, to deposit her eggs at the beginning of another season. Theobald states that the male of *Culiseta annulatus* hibernates in England but this record stands quite alone. It is certain that at least in the genera *Culex* and *Anopheles* no males survive the winter. The hibernating females seek shelter with the approach of cold weather and at this time they show no inclination to feed. Those species more or less associated with man take advantage of the shelter of cellars, stables, sheds and other buildings, the darkest ones apparently being the most favored. They have also been found hibernating in caves. Other species retire to hollows in trees, crevices in the bark or other protected situations. There they remain quiescent until the return of warm weather, closely hugging the surface upon which they rest.

Stephens and Christophers state that in India the *Anopheles* pass the season of hot, dry weather in the houses. They found that while they feed regularly they do not lay eggs even when breeding opportunities are present. The species of *Culex* must also, in the absence of breeding-places, pass the dry season in the adult state, although no exact data concerning them are available.

In temperate North America a few species pass the winter in the larval state. Such is well known to be the case with *Wyeomyia smithii*. Larvæ of all sizes are overtaken by cold weather in their habitat, the water in the leaves of the pitcher plant. They become enclosed in the solid ice and when liberated in the spring continue development in the normal manner. This appears to be the only way in which this species passes the winter and the hardiness of these larvæ can be understood when one considers that the species occurs as far north as Minnesota and Ontario. *Culex melanurus* hibernates in the larval state. The larvæ live in spring-holes in marshes and remain at the bottom during cold weather. The larva of *Megarhinus septentrionalis*, which normally lives in water in hollow trees, hibernates, although, apparently, it will not survive freezing. It goes to the bottom in cold weather and remains submerged. The larva of *Bancroftia signifer*, which usually is found associated with *Megarhinus*, also hibernates.

In England and in the more southerly part of Europe, where the winters are much less severe than in North America, one species of *Anopheles* (*A. bifurcatus*) regularly hibernates as larva. The larvæ in various stages of development have been found in the winter, living beneath the ice, by a number of observers, and these larvæ later produced imagos. In Switzerland, Galli-Vallerio and his collaborators have made observations through about ten consecutive winters that show that *Anopheles bifurcatus* and *Culiseta annulatus* regularly hibernate there as larvæ.

The majority of the mosquitoes in temperate climates hibernate in the egg-state and in far northern regions this is the only mode of hibernation. These hibernating eggs hatch in the spring, in the water from the melting snow; consequently these larvæ appear very early. Galli-Vallerio and Rochaz de Jongh found that in Switzerland the hibernating eggs hatch during the winter if pools are formed by rains or by a thaw. The larvæ survived under the subsequently formed covering of ice and later produced imagos.

MATING-HABITS.

The mating-habits of a very limited number of species of mosquitoes are known. From the observations at hand it is evident that there is considerable diversity and it must be pointed out that for one large group, the Sabethini, we have no records whatever. With many species the males "swarm," that is, they gather and hover in the form of a cloud, to which, it seems, the females are attracted. In some cases there are two swarms or clouds, one of males the other of females. There are species, it seems, that do not swarm and others have the habit but weakly developed.

The attitude assumed during the copulatory act differs according to the structure of the claws of the female. In the forms with simple claws (*Culex, Anopheles*) the position is end to end, the pair facing in opposite directions. The forms in which the female claws are toothed copulate face to face, clasping each other with their claws. The first exact observation of the mating habits of mosquitoes was based on such a species (*Aëdes calopus*) and to this may be traced the repeated statement that mosquitoes all copulate in this way. This early account, by Godeheu de Riville, will be found abstracted in the chapter on the yellow-fever mosquito (p. 276).

One of us (Knab) has published his observations on the mating-habits of mosquitoes in a series of papers which are brought together here. The first is on the swarming of *Culex pipiens* (Psyche, October, 1906, pp. 123–133), and is based on observations made by himself in Illinois, and in it he includes accounts of many former observations. The general question of swarming and mating as considered in this article is herewith largely quoted from:

"It has been the writer's good fortune to observe the swarming and mating of *Culex pipiens* upon four consecutive evenings, October 15–18, 1904. Many notices of the swarming of Culicidæ and related forms have appeared, but most of the accounts deal with the swarming simply as a remarkable phenomenon while its significance escaped them. It therefore seems worth while to record my own observations. Following these I shall give the more interesting data of previous writers, and at the end, a bibliography of the subject.

"My observations were made at Urbana, Illinois, under exceptionally favorable conditions. Although the country about Urbana is well drained and there is but little water, mosquitoes were remarkably abundant. As far as could be determined all came from one source. On the outskirts of the town is a small stream, known as the Salt Fork, which, during dry weather, becomes practically stagnant. About a mile up the stream the water was polluted by the discharge from an abattoir. The foulness of the water was such that the fish normally present in the stream were all destroyed and thus an ideal breeding-place for mosquitoes was created. Early in October the writer found the larvæ of *Culex pipiens* present in immense numbers, and when the shrubbery bordering the stream was disturbed the imagos rose in great clouds. These mosquitoes, however, showed no inclination to leave the water-side and would quickly return to the shelter of the marginal vegetation.

"October 15 was a warm autumn day and its close was marked by one of those clear calm evenings when not a leaf stirs and the air appears to be perfectly still. At five o'clock the writer was crossing a corn-field not far from the stream. The sun was already near the horizon and its direct rays were cut off by an intervening line of tall trees. When near the middle of the field a cloud of mosquitoes was noticed directly overhead. The lowest mosquitoes were about the writer's head and shoulders, the topmost ones perhaps five feet higher; the transverse diameter of the swarm was about two feet. The high-keyed piping, vibrating between two notes in constant rapid reiteration, was very distinct. The variations in tone seemed to correspond to the upward and downward movements of the individuals. In the light of the succeeding observations it would seem that this swarm had been forming above the writer's head from the time he entered the field. The swarm was watched for about twenty minutes. The individuals in the swarm flew up and down amongst each other with a kind of weaving motion—a downward and forward plunge and back again, performed without unison or regularity. The movements were sufficiently slow to allow the plumed antennæ of the males to be clearly distinguished and it appeared that the swarm was composed wholly of males. Once a female was seen to dash into the midst of the swarm and emerge on the other side united with a male. The insect-net was swept through the swarm a number of times. At each stroke the mosquitoes would disperse somewhat but returned at once to their former position and continued their dance, and there was no perceptible diminution of their numbers. An examination of the captures showed 897 males and four females. This count includes the female observed passing through the swarm, as narrated above, and it is obvious that the other three females in the capture are not to be considered as members of the swarm. They may have entered the swarm unnoticed in the manner described, or they may even have been hovering about outside of it. The observations of T. H. Taylor (in Miall & Hammond, The Harlequin Fly) show a like condition in Chironomus. On a still evening his captures from a swarm were 700 males, no females. On a windy evening, when the swarm was thrown more or less into disorder by the breeze, a capture of 4300 specimens included 22 females.

" Upon turning to leave the mosquito-swarm another one was discovered close by, hovering over and about a corn-stoock. The swarm extended about half way down the side of the stook and kept on the south side of it, the mosquitoes all facing northward. Although there was no perceptible breeze it was thought that the attitude of the mosquitoes was in response to a current of air and subsequent observations confirmed this supposition. It was hut seldom that one of the mosquitoes alighted on the corn, and as in the cloud first observed, all appeared to be males. A round of the field showed that each corn-stook had its swarm of mosquitoes, and furthermore, single stalks that remained standing had small swarms dancing over them—sometimes of only six or eight individuals —and the hushes and small trees on the edge of the field had their swarms. In every case the mosquitoes faced northward and the swarm kept on the south side of the object of attraction. Always the mosquitoes gathered over some promiment object such as a tree or a projecting branch, a bush, a corn-stook or a person. In this last case the swarm would move with the person and the only way to get rid of it was by passing under some taller object where the swarm would then remain.

" On the following evening at five o'clock the field was again visited. Upon approaching the region of the creek swarms of mosquitoes were noted over every tall object—at the tops of telephone-poles, orchard-trees and shrubbery. On a very tall elm, standing alone in a pasture, a swarm was dancing before a projecting branch. In the corn-field the swarms were found, as on the evening before, over every prominent object and as the writer entered the field a swarm immediately began to form over his head. This time, however, the position of the swarms in relation to the objects was the opposite of the evening before—the mosquitoes were now all facing southward and they kept on the north side of the objects. The trees on the south side of the field, some of them 25 or 30 feet high, had immense clouds on their north sides. As on the evening before, there was no perceptible breeze but the drift of smoke showed that there was a current of air from the south. Station was taken near the row of trees bordering the field and some swarms dancing before projecting limbs kept under observation. Repeatedly females were seen to issue from the foliage, dash into the swarm, and emerge united with a male. When in copula the male and female face in opposite directions, their bodies in a horizontal plane; the female dragging the male after her.* The pair (or rather the female) would fly upward for a while and

* " Goeldi (Os mosquitos no Pará, 1905, p. 74, pl. I, fig. 3a) describes and figures the copulation of *Stegomyia calopus*. In that species the male clings to the under side of the female."

then slowly drift towards the ground. Once a pair in copula was seen to issue from one swarm and plunge into another swarm close by. The pair made great haste to extricate itself while the swarm was immediately thrown into frantic excitement and the mosquitoes danced up and down at a furious pace for some time, until at last the ordinary measure of speed was regained. With the growing darkness the excitement in the swarms increased and the movements became more rapid. Few successful unions now took place. Females entering the swarm would be pounced upon by two or three males, and together, tumbling over each other, they would fall to the ground and there separate. Towards the last no more females appeared and with the increasing darkness the swarms rapidly diminished, the males flying off into the air.

"At 5 o'clock on the following evening the swarms were found as before, dancing over every object projecting above the general level. Single mosquitoes were seen flying rapidly and straight. These looked larger than the dancing males and when captured proved to be females. The air was again very still with a current from the south and, as before, the dancing males faced towards it and kept on the opposite side of the objects. The west side of the field was bounded by tall trees and high up on these, at least fifty feet from the ground, before projecting branches, clouds of mosquitoes could be distinguished while lower down on these trees there were none. Station was taken at a corn-stook to determine how long the dance would continue. As the darkness grew the numbers began to diminish, and at 5.50, when the darkness was almost complete, the last male flew away. The departing males flew upward and none of them alighted on the stoock.

"On the fourth evening the field was visited nearly an hour earlier than before. The sun was still shining and there were no mosquitoes present. Later, when the sun had disappeared behind the trees, the swarms were again present just as on the previous evenings. On this evening, however, there was quite a breeze blowing and the mosquitoes could not maintain their position over the projecting objects and swarmed altogether on the leeward side of them. Otherwise their behavior was much the same, only that the freshening wind occasionally threw the swarms into confusion and greater activity. Rain and cold weather followed the next day and put an end to further observations and presumably to the swarming.

"There are many records of swarms of Culicidæ and related forms, although in many cases there is no exact indication of the identity of the insects in question. I am convinced that all such records, in so far as they refer to swarms of the nature described above, apply to Nemocera and probably in every case either to Culicidæ or Chironomidæ. I believe that these swarms of dancing males, congregated for sexual intercourse, are peculiar to the Nemocera. Many of the records from untrained observers, called forth by the appearance of these Diptera in extraordinary numbers, though incomplete, are nevertheless of interest. In nearly all of them the fact that the swarming leads to sexual union has been entirely overlooked.

"Moufet, in 1634, already speaks of these swarms and notes how they gather at the gables of houses and over the heads of people passing over bridges. It should be noted that in his chapter 'De Culicidum' the Culicidæ and Chironomidæ are not distinguished, as indeed has been the case with many a writer since.

"The oldest record of the copulation of Culex appears to be that of the Spaniard Diego Reviglias, communicated to the Leopold-Carolinian Academy in a letter dated 4 March, 1728, but not published until 1737. Reviglias observed under the microscope, and described at considerable length, the sexual union and the copulatory apparatus of the mosquito. He treats his discovery as a very *important one, which indeed it was in those days of lingering belief in spontaneous* generation. However he does not mention swarming and there is reason to believe that he had before him a species which does not swarm—a matter which I shall take up again farther on. Later the French commander Godeheu de Riville also claimed as the first his observation of the copulation of mosquitoes, made on board his ship. The account is quite detailed and it is evident that in this case likewise copulation took place without swarming.

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"There are a number of accounts of such swarms about church steeples causing alarm of fire. We have them from Germar (1813), Boll, Kirby and Spence, and Hagen. Boll records three such swarms. One of them on the steeple of the Nicolai church in Hamburg took place on a June evening at nine o'clock. The discovery of the true nature of the apparent smoke, after the fire-department had been called to the spot, caused great merriment in the crowd of spectators. In 1807, when the St. Mary's church in Neubrandenburg served as a powder magazine, the sudden news that the steeple was on fire caused many of the inhabitants to flee precipitately from the city. As the column of smoke about the steeple did not increase, some courageous men finally ventured onto the tower and discovered that the source of alarm was an immense swarm of gnats. Another swarm was observed about the cross of this same church-steeple, at a height of 300 feet, on the afternoon of August 20, 1859. Hagen relates that dense swarms of gnats about the church-steeple at Fischhausen caused an alarm of fire which has earned for the inhabitants the nickname of 'Mückenpeitscher.' Koch has reported a swarm from the wings of a windmill, at a height of perhaps a hundred feet from the ground, curled by the breeze and resembling smoke.

"Haliday states that *Culex detritus* * occurs at Holywood, County Down, 'in multitudes, during the day among hedges on the seacoast, in the evening in columns about the tops of trees, appearing like smoke at the distance of a furlong.' Weyenbergh records two swarms of *Culex pipiens* from the vicinity of Haarlem, observed in 1857, dancing in perpendicular columns.

"Mott gives an interesting account of an unusual gathering of gnats observed by him in 1879. As the article is not generally accessible and describes well the phenomenon, I quote it nearly in full. 'On the evening of September 1st, between six and seven, after a fine, sunny day, the sky being clear, and the full moon just rising as the sun went down there was a grand festival among the gnats. Above the tops of the trees and hedge-rows in the low meadows north of Leicester these little Diptera were out in immense numbers. . . . They assembled in groups of various shapes, sometimes a vertical column from 6 ft. to 20 ft. high, and 1 ft. to 3 ft. diameter, rose from a tree top like a pillar of smoke. Sometimes a sheet 4 ft. or 5 ft. high and 10 ft. long hung above the hedgerow, but seemed never more than a foot or so in thickness. The following evening, at the same hour, the sky being more clouded, a few gnats only were to be seen; but on the evening of the 6th, with the sky again cloudy, there was a still more remarkable display of gnat life. The little creatures were out again in millions, but this time the vertical column formation was adopted by nearly the whole of them. These columns rose from the hedges on either side of the road, and were visible for half a mile ahead at irregular distances, averaging, perhaps, 21 ft. or 15 ft. They formed an avenue of such a singular and unusual appearance that everyone who passed along the road paused at intervals to watch and wonder at them. This piece of road is about half a mile long, on the top of an embankment which carries it over the low meadows and the river. At the farther end

* "Haliday's *Culex detritus* greatly resembles the common *Culex pipiens* and most probably the observation should be credited to the latter species."

there are a number of trees, and from the top of nearly every tree three or four of the strange, smokelike columns could be seen standing up in the air, always straight but not always vertical, some of them being inclined at small angles. . . . On watching one of the columns closely, it was apparent that all the gnats had their heads one way, facing the breeze, which, however, was a very light one. It was a calm evening; what air-current there was came from the south-east. It seemed to be sufficient occasionally to press back the column a few inches from its normal position, and whenever this happened the whole body of gnats jerked themselves forward again with one perfectly synchronous impulse.'

"A picturesque account of a remarkable swarming of Culices, at Lewisham Road near London, is given by Douglas. During ten days he observed 'the air thick with millions of them, at times charging in close column up the road, like a squadron of cavalry, at other times engaged in dancing up and down, after the manner of their race.' These swarms were in evidence only during the hour before dark and it appears were over or near the road, within reach of the riding whips and sticks of the '*profanum vulgus.*' Near by 'are several tall trees, and round the top of the highest one only, at the same hour of the evening that the periodical saltatory performances are going on in the road, enormous swarms of gnats congregate. At first they appear as a small black cloud curling about the ends of the branches, and soon, when the air is calm, rising in a close column, like smoke from a chimney, for a distance of some 20 or 30 feet, the bulk gradually becoming more grey and attenuated until lost to sight in the upward progress. When a breeze is moving, the insects, always preserving close order, are blown out laterally, and after skirmishing with the wind return to their cover among the top leaves of the tree.' This last remark may be an assumption and at such distance from the ground could hardly have been based upon actual observation. Douglas suspects that the species in the tree was 'not the same as that of the acrobats of the road,' and with right; unfortunately neither form was definitely identified. It further appears from the remarks of Douglas that these swarms are an annual occurrence, only that the nnmber of individuals varies greatly from year to year.

"In all the foregoing notes the writers failed to notice the true function of these gatherings of Nemocera. However it had not escaped that keen observer Gilbert White. He was evidently uncertain of the identity of the insects concerned, for in his posthumously published notes he calls them '*empedes* or *tipulæ.*' Speaking of their swarms at evening he says: 'At this juncture they sport and copulate; as it grows more dark they retire. All day they hide in the hedges. As they rise in a cloud they appear like smoke.' No further mention of copulation in connection with swarming appears until Taschenberg's popular account of *Culex pipiens,* published in 1882. He notes their habit of gathering at the gables of houses and other prominences and describes how the females fly to the swarm of males to effect copulation. In the notes on the swarming of Chironomidæ which follow, Taschenberg describes the formation over trees and in tall columns, and we are left to infer that the *Culex* swarms do not assume the columnar form—at least not in the same degree.

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"Radl has written two most interesting and suggestive papers on the light-reactions of Arthropods and a great part of his discussion is based on the behavior of swarming insects, particularly of Culicids and Chironomids. It would lead too far to enter into a discussion of these papers, but the fact is brought out that these insects orient themselves towards some definite object which is differentiated from its surroundings either by greater prominence or a difference in color. He not only cites instances of orientation towards trees, bushes, sign-posts, or even heads of grass, but others where the swarms hovered over paths through fields, or spots of different color but not elevated above the surroundings. The swarms over spots on the ground in all probability belong to different species from those attracted to prominent objects. Radl confesses that he made no attempt at close determination of the insects under observation and it is evident that he had no conception of the number of forms of similar but distinct habits that he might have before him. In consequence his statements are far too general and much that might have been used for or against his contention has escaped him.

"Little as we yet know of the subject, it will be well to state right here that, even within the Culicidæ, there is not only a marked diversity in the mode of swarming of different species, but that there are many forms which do not swarm at all. In the case of the almost exclusively house-inhabiting *Stegomyia calopus*, as Goeldi has shown, there are no such swarms as in *Culex* proper. The males congregate in little groups of 15 or 20, hovering over the corner of a cabinet or other prominent object, and pounce upon the females that come within range. I can add that copulation frequently takes place when there is no evidence of even such weak swarms. It should be noted that in *Stegomyia* copulation takes place during the brightest part of the day. On the other hand I have upon two occasions observed small swarms of *Stegomyia* (presumably males) hovering over the heads of persons, in both cases shortly before sunset. Once this occurred upon the hotel veranda at Cordoba, Mexico, and again in the street at Acapulco, over the heads of passers and keeping along with them. In this case the meaning of the swarms would be hard to interpret.

"Upon a recent trip to the west coast Dr. H. G. Dyar found a pair of *Culiseta consobrinus* * in copula, resting on the under side of a board. This observation shows a wide departure from the short copulatory act of *Culex* and *Stegomyia*.

"The crab-hole inhabiting *Deinocerites cancer* swarms during the short twilight period just outside the crab-holes and copulation takes place then.

"Goeldi has given a vivid account of the swarming of the common house-mosquito of Pará which he designates as *Culex fatigans*.† Swarming takes place indoors when it is nearly or quite dark and there are separate swarms of males and of females. Such peculiar mating-habits surely indicate a distinct species. In the case of our *Culex pipiens* the males are never found in houses—unless, indeed, they happen to come from larvæ developed indoors.

"Mr. E. A. Schwarz has kindly placed at my disposal his observations made on a species of *Culex*, probably the *Culex cubensis* of Bigot,‡ at Cayamas in Cuba. The swarming occurred in the house, always on the side away from the sun, and when it was almost fully dark. The mosquitoes could only be seen against the sky, when between the observer and the open doors and windows and close observation was impossible under the circumstances. However, the swarms in this case were made up of both sexes and copulation freely took place. A capture of 60 specimens from such a swarm contains 44 males and 16 females."

In a later paper entitled "The Swarming of *Anopheles punctipennis* Say" (Psyche, February, 1907), Knab published some novel observations on the swarming of the species mentioned. This is quoted:

"Upon October 7 and 14 the writer observed the mating habits of *Anopheles punctipennis* and as, up to the present, nothing appears to have been made known

* = *Culiseta inornatus.*

† = *Culex quinquefasciatus.* The passage will be found in translation in the systematic part of this work.

‡ The specimens on which the observation was made have since been identified as *Culex quinquefasciatus.*

regarding the mating habits in the genus *Anopheles*, the following notes are offered. Much to his surprise the writer found that the males of *Anopheles* swarm as do those of *Culex*, although the behavior in the two forms is quite different.

"The observations were made on Plummers Island (Maryland) in the Potomac River, about ten miles above Washington. Near the highest part of the island is a ledge of rock forming an open space surrounded by the woods on three sides. The side towards the river is open, save for a couple of small trees at the edge, and terminates in a nearly perpendicular cliff. On October 7, shortly before 5 o'clock, the writer visited the spot to enjoy the sun-set. The ledge is about sixty feet above the water and on its highest part, where some tufts of tall grass grow in a crevice of the rock, was a swarm of dancing Diptera. The swarm was directly over the tufts of grass, its base seven or eight feet from the ground, the apex five or six feet higher. Although in appearance and action quite unlike *Culex pipiens* (observed on previous occasions) they were recognized as mosquitoes by the prominent palpi and the plumed antennæ. With a sweep of the net fifteen were secured and proved to be males of *Anopheles punctipennis*. Their appearance in flight differed from *pipiens* mainly by the position of the legs which were held straight behind and close together. The palpi and antennæ, directed straight forward, also appeared much more prominent than in *pipiens*, which, together with the much longer legs, extending out behind, gave them a very characteristic appearance.

"In their actions, too, they differed markedly from *pipiens*. The swarm was small, composed of less than a hundred individuals, and was not as compact as the swarms of *pipiens*. The movements of these males were far more free and varied than those of *pipiens* which constantly repeat the same circumscribed movements. The *Anopheles* flew about in the swarm in a circling upward or downward 'corkscrew' course. Their movements were more rapid than those of *pipiens* and often irregular; single individuals would at times leave the swarm, and cutting a wide circle, return into it. Sometimes these stray individuals would fly for a short distance with a peculiar rapid zig zag motion—a series of short sidewise jerks—and then return with the ordinary steady flight. In spite of these varied evolutions the mosquitoes showed a tendency to face in one direction, presumably towards the wind, although the evening was perfectly calm and there was no breeze apparent. As it began to darken the males began to leave the swarm one by one, flying upward, either into surrounding trees or more often they would disappear into the sky. On this evening copulation was not observed and from the following observations it may be assumed that union only takes place during the early part of the swarming.

"Although stormy and cold weather intervened, the following Sunday proved fine and the ledge on the island was again visited. Shortly before 5 o'clock, with the sun still shining but near the horizon, a few males were found already assembled and engaged in their circling flight above the grass-tufts. Others came from different directions and joined the swarm and by sunset it consisted of perhaps sixty or seventy mosquitoes. It was difficult to follow the movements of single mosquitoes but it seemed that in circling about they described a figure-of-eight—sometimes on a plane, or ascending and descending. At 5.15 a pair was seen falling out of the middle of the swarm, grappling each other as they fell. They had not dropped far below the swarm when union was effected, and, swinging out in opposite directions, still united they drifted slowly away towards the ground. Within ten minutes six pairs were seen to drop out of the swarm and copulate in this manner but after that no more. Three of the pairs were captured in the net; one pair rested in the bottom of the net about a minute, then separated and flew out; the other two pairs remained united even after death in the killing-bottle. It could not be determined if in the slow flight of the united pair the female leads off as is the case with *pipiens*, but it is to be presumed so, as she is the larger. Neither could it be positively ascertained whether any females formed part of the swarm. None were seen to enter at the time copulation took place, but with the rapid and confused movements of the members of the swarm (some flying out of the swarm and back again, as described above) it was impossible to keep all the individuals under close observation. However it is safe to conclude that, as in *pipiens*, the swarm proper consists wholly of males—certainly the fifteen specimens captured out of the swarm on Oct. 7 were all males. If there is any choice made in the selection of a mate it must be on the part of the female, for there appears to be no effort made, or any struggle, on the part of the males to secure the female entering the swarm.

"An interesting fact was the prompt reaction of the entire swarm to sound. The sound of the voice in conversation would, at the first shock, precipitate the entire swarm about a foot, and the mosquitoes would continue in rapid and confused movement while the speaking continued. This effect could be noticed even when one spoke in quite a low voice, and a pistol-shot, perhaps half a mile off, precipitated the swarm in the same manner. When silence was restored the swarm immediately resumed its normal flight. The experiment was repeated many times and each time the effect was instantaneous.

"At about 5.30 the swarm began to diminish, the males flying off singly into the air. Very often a male would start off with a hesitating flight, and after flying some distance and hovering about as if reluctant to leave, would again return into the swarm. At last the swarm was reduced to three males which remained for some time, and at the last a single male remained, continuing his evolutions alone for fully three minutes, when, at 5.45, he too flew off.

"A curious circumstance was the presence, on both occasions, of a swarm of minute Chironomidæ in close proximity to the swarm of *Anopheles*. Mr. D. W. Coquillett kindly determined these as *Ablabesmyia pilosella* Loew. While these did not mingle with the swarm of *Anopheles* they were as close as they could be without interference. Apparently the spot which the *Anopheles* had fixed upon had the same attraction for them. This swarm seemed likewise to be composed wholly of males.

"It seems remarkable that the attitude taken by *Anopheles* in copulation, end to end and facing in opposite directions, is identical with that of *Culex pipiens*. This remarkable agreement is significant when the structure of the tarsal claws is considered. In both forms it is practically the same and all the claws of the female are simple. In both cases the legs are not made use of in the copulatory act itself but only in the preliminary scuffle. Dr. H. G. Dyar has found that *Culiseta consobrinus*,* another form with simple claws and quite a distinct generic type, takes the same position in copulation. It is fair to assume that this is the mode of copulation in all the forms in which the female has simple claws. On the other hand it appears that in those forms in which the female has toothed claws the position in copulation is face to face, the pair clasping each other. The writer can confirm Goeldi's observation that *Stegomyia calopus* copulates in this manner. Dr. Dyar has observed the same method of copulation in *Aëdes varipalpus* Coq. One can not avoid the inference that the difference in the structure of the claws is closely correlated with the mode of copulation. . . ."

Since the publication of the above article we have found that Curtis, in his British Entomology, vol. 5, no. 210, quotes the observations of Haliday on the

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* = *Culiseta inornatus* Will.

mating-habits of two European species of *Anopheles*. Of *Anopheles bifurcatus* it is said that "the males hover in small flights about the skirts of groves near rivulets in the still evenings of June," and of *Anopheles maculipennis*, "these also fly in small swarms in the evenings of June, when I have taken them paired in the air."

In their "Report of the malaria expedition to Nigeria" Annett, Dutton and Elliott give a short note on the swarming of male *Anopheles* in west Africa.

"But after sunset, clouds of mosquitoes were often observed flying and hovering in characteristic flocks in the neighborhood of native huts, about eight feet above the ground. On capturing and examining many of these, all were found to be *Anopheles* males."

F. C. Willcocks has recently published observations, made in Egypt, in the vicinity of Cairo, on the mating-habits of several species of mosquitoes. He points out the difference in behavior of the different species in an interesting manner.

"The aerial dances performed by male mosquitoes at sunset are perhaps worthy of note. The males of *Culex*, spp. dance in columnar form, well in the open, or in some cases, near or above bushes, and from fifteen to twenty feet from the ground. Thousands of individuals may be present in one of these dances, all in extremely rapid movements of limited range. They produce a very audible hum. The males of *Cellia* [=*Anopheles*] *pharoensis* dance as a rule in the open, but much nearer to the ground than *Culex*, nor do they collect together in such large numbers. Their flight is also much slower. The aerial dances of the males of *Grabhamia* [=*Aëdes*] *willcocksii* are again different. They appear almost invariably to take place close to bushes, under trees or sheds; the males fly backwards and forwards with a slow and easy flight, about three feet from the ground, columns not being formed. One rather striking fact concerning these aerial dances is the comparatively small numbers of females which join them in order to pair with the males."

An overlooked paper by Wahlberg, published in 1848 (Öfversigt Kongl. Vetenskaps-Akad. Förhandl., v. 4, p. 257) describes the mating-habits of far northern mosquitoes, undoubtedly belonging to the genus *Aëdes*, as follows:

"It has been noted as strange, that the males of mosquitoes (*Culex*) are only found in very small numbers in the extensive moors of the far north, where the bloodsucking females surround and attack the traveller in numberless swarms.

"Rev. Læstadius of Karesuando has informed me that these males are often found on the surface of the lakes, beaten down by rain or wind, in such endless numbers, that, when blown ashore, they form thick windrows.

"One wonders then why they are not observed more commonly together with the females.

"I have recently had opportunity to convince myself of the reason for this, during my stay at the 'Great Oive' mountain. On the top of this mountain we were surrounded and pestered by female mosquitoes in great numbers, but not a single male was observed until I became aware of a loud singing noise, which on investigation was found to be produced by immense swarms of mosquitoes high up in the air, dancing in separate flocks.

"On examination these swarms were found to consist nearly exclusively of males.

"This indicates that the males of the *Culex*—like those of Chironomids and some other non-biting gnats—keep to themselves in a higher stratum of the air, where they, especially towards evening, flock together in dancing swarms and tempt the females to come up by the noise of their wing-beats.

"When a female comes up into this dancing cloud it is chosen by a male and the two separate themselves from the rest, while the male swarm continues the dancing with uninterrupted music at varying heights in the air."

The swarming of *Aëdes spencerii* has also been observed by Knab, on the Saskatchewan prairies. This is described in Smithsonian Miscellaneous Collections, volume 50, part 4, pages 542–544.

"Adults of this species first appeared active on May 30 and a few came to bite. They were first noted in numbers on June 5, a warm, sunny day following four days of cold, cloudy weather. They came drifting before the wind, and during calm intervals were very annoying. At 10.45 a. m., on a rise of ground west of the town, the highest rise on that part of the prairie, a swarm of about 50 males gathered above my head. They emitted a high-keyed piping sound, swinging backward and forward and swaying sidewise, all the time facing the wind. With every gust of wind they were scattered toward the ground, only to reassemble when the wind decreased. When I passed the place again, at 12.45 p. m., the males were still in evidence, although much interfered with by the wind. The same day, at 5.30 p. m., another swarm of males was observed in the upper part of a ravine, where the slopes were gentle. They were going through rapid evolutions, darting forward and upward and dropping back again, but without unison. When disturbed by the wind their flight became more rapid, and sudden gusts caused them to fly to the ground. Several pairs were seen flying off in copula, and once the female was observed approaching the swarm from beneath. There was a second swarm of males farther down the ravine, about half way up the slope, and, like the other, at the margin of the shrubbery filling the bottom of the ravine. In this case a swarm of very small Chironomids was mixed with the lower part of the swarm. In crossing an open field in the river valley at 6.30 p. m. a swarm of males formed over my head and, following me, increased to the number of perhaps two hundred. They disappeared when I approached the woods on the edge of a ravine. This experience was repeated in the field beyond, and upon nearing the edge of the woods the swarm again departed and could be seen in the middle of the field. Several days of cold and cloudy weather followed, during which the mosquitoes remained quiescent. After the heavy rain of the previous night, the afternoon of June 9 was warm and sunny and the mosquitoes exceedingly abundant and active. At 6.30 p. m. I walked toward the river with a companion. As soon as we had left the town the female mosquitoes began to rise out of the grass and alight upon us. There was a brisk breeze blowing and the mosquitoes settled on the leeward side of our bodies, and a cloud of them followed us, keeping for the most part about our legs. These clouds increased rapidly and became very aggressive as we passed down into the valley, where we came upon a cloud of males on the open prairie. When we approached them they formed in two swarms over our heads. My companion, being the bulkier man, attracted a much larger swarm. We thus each had two swarms of mosquitoes about us; the one, of females, kept about the lower part of our bodies, while the other one, of males, kept above our heads. Several copulations were noted. Upon entering a ravine the males all left us and only a part of the females followed. Upon emerging on the other side of the ravine a new swarm of females quickly gathered, and shortly we came upon another large swarm of males, which again concentrated above our heads in separate swarms. It was now 7 o'clock, but still bright daylight at this season of the year. The swarms of males I judged to contain many hundreds, if not a thousand, individuals. These swarms, in close formation, followed us up the long hill and continued with us nearly to the town, in the end being much disturbed by the wind. About 7 o'clock quite a number of copulations were observed. The females approached the swarm from beneath and left it united with a male, the pair drifting away toward the ground and the union lasting but a short time. They copulate face to face, grasping each other with their long legs, the female in the upper position, the male back downward. This day proved the maximum of activity for this species of mosquito. No more swarming of males or matings were observed."

In the same paper occurs an account of the swarming of *Aëdes fitchii,* also in Saskatchewan. Following is the description:

"On the evening of June 19 I was fortunate enough to observe the swarming of this species in a shallow depression at the head of one of the ravines near Oxbow. The ground sloped gently from the prairie, which at that point was 15 or 20 feet above the bottom of the depression. When the swarm of males was first noticed, at 8.30 p. m., it was loosely organized, and there were perhaps forty individuals, which gyrated and circled about close to the ground. Close by there were some thorn brushes, and between and round these were several swarms of Chironomidæ, but no mosquitoes. In a short time other swarms of mosquitoes began to form in the open, along the bottom of the depression and on the western slope, where they were protected from the wind. These various swarms kept close to the ground and spread out in such a way that they might be said to have been loosely connected, but still there were foci where the mosquitoes were massed closer together. At no time was the top of a swarm more than four feet above the ground, while it spread out to at least twice that diameter. The size of the swarms gradually increased until, at 9 o'clock, one swarm contained several hundred males. Copulation took place most frequently between 9 and 9.15, but matings were observed both earlier and later. The females entered the swarm from beneath, when they were seized by one or more males. Union takes place 'face to face,' the pair flying obliquely upward for several yards. Then the pair would either separate promptly or swing out end to end and struggle to disengage themselves. In this latter case both of them could be seen to jerk violently and rapidly in their efforts to free themselves, and the pair would slowly rise, but make no appreciable progress in either direction. When two males seized a female the group would rise straight into the air, apparently engaged in a violent struggle, one of the males finally uniting with the female or all of them separating. In one case four individuals rose thus, scrambling over each other, so to speak. The swarm was watched until 9.30, when the twilight was already quite deep; copulation appeared to have ceased and the swarms were gradually breaking up."

Surgeon E. H. Ross remarks as follows regarding the mating-habits of *Aëdes* [*Acartomyia*] *zammittii* of the Mediterranean region. "Coitus does not necessarily take place on the wing, for I have observed it occur when the female is resting on the edge of the glass jar or sitting on the rock; the male clasping the female when she is sitting."

Knab has observed that the males of *Megarhinus* tend to congregate upon a certain bush, alighting upon prominent leaves. Near Puntarenas in Costa Rica he captured six males of *Megarhinus moctezuma* upon a single bush. When approached they would fly up but alight upon another leaf of the same bush; two that were frightened away returned to the bush after a short time. No others could be found anywhere in the vicinity. Mr. J. K. Thibault, Jr., of

Scott, Arkansas, has observed the same habit in Megarhinus septentrionalis. He took a large number of males of this species upon a certain vine of poison ivy (*Rhus toxicodendron*) and always upon this one plant; none could be found elsewhere. Such bushes are undoubtedly places of rendezvous in connection with the mating-habit.

Many species of Culicidæ, on account of their specialized mating-habits, can not be bred in captivity. The yellow-fever mosquito, the mating-habits of which are discussed in another chapter (p. 275), can be bred successfully for a number of generations in comparatively small receptacles. Dr. Dyar has bred two generations of *Aëdes atropalpus* in a quart jar containing a small quantity of water.

ABUNDANCE OF MOSQUITOES.

In our treatment of the subjects of the migrations of mosquitoes, of their carriage by wind, of far northern mosquitoes, and of early accounts of mosquitoes, we give many instances of mosquito abundance, and there will be mentioned here only certain recent observations. We have just discussed how at times mosquitoes may be found gathered in concrete swarms for sexual purposes and these swarms are appropriately considered under mating-habits. In so far, however, as they are an indication of unusual abundance of mosquitoes they may be mentioned here.

Theobald briefly describes a few swarms, probably of this character, as follows:

"Occasionally cloud-like masses of various *Culices* are seen. I remember twice having noticed dense swarms of them in the fens; in both cases the insects were male and female *C. cantans*. So abundant were they that the air was quite darkened by them. These insect-clouds were constantly moving up and down about ten to twelve feet above the ground. At times the noise they produced could be heard a quarter of a mile off, then it would suddenly cease for some time and commence again.

"Mr. W. W. Smith records a case in New Zealand where 'a train passed through a wall of mosquitoes three-quarters of a mile in length, twenty feet high, and eighteen inches thick.' This abnormal swarm was composed of *Culex* (*Uranotænia*) *argyropus* Walker.

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"During the present year I had reported that dense masses of gnats were seen along the Downs near Wye, appearing like columns of smoke in the valley, rising and falling. I did not see this, but visited the Down-sides the next day and found great numbers of male *C. pipiens* about in the evening, dancing in little clouds where they were sheltered from the wind."

"Romolo Gessi Pascha, in his book 'Seven Years in the Soudan,' p. 47 (1892), speaks of 'myriads of mosquitoes which obscured the air' at Meshra-el-Rek. If we go to the Arctic regions we get similar phenomena, for Dr. Lugger informs Professor Howard that Dr. Emile Bessels, of the Polaris Expedition, was obliged to interrupt his work in Davis Straits (latitude 72° N.) on account of the multitude of mosquitoes."

The above notes on *Culex pipiens* clearly refer to swarms of males such as have been described under mating habits. This may also be the case with the above-mentioned swarms of *Aëdes cantans* and *Uranotænia argyropus*, but there are too few details to justify a conclusion. The abundance of such mating swarms and the numbers of mosquitoes in them is, of course, an indication of the abundance of the species as a whole. Such abundance may be normal and occur from year to year, as with our northern mosquitoes, or it may be due to unusually favorable conditions, such as increased breeding facilities for the larvæ.

One of us has elsewhere stated (Howard, "Mosquitoes") that Prof. E. W. Hilgard, of the University of California, once wrote him that up in northern Washington, in the pine forests north of Spokane, a gray mosquito seems to be the sole possessor of the land, and is as fearful a nuisance as the mosquitoes in arctic regions. "The first thing on going into camp is to establish a close line of smudges above the wind, so as to enable the pack animals and the men to eat in comparative peace, but about midnight the entire swarm is back again." Professor Hilgard further wrote that in Montana he has seen all the work-horses in the field sheathed in sheets during the day, to protect them from the swarms of mosquitoes, and these were dotted with small blood spots.

Schwarz at Corpus Christi, Texas, in the late 90's wrote that at that place, "when the wind blows from any other direction than south, 'hundreds of thousands of millions' of mosquitoes blow in upon the town. Great herds of horses run before the mosquitoes in order to get to the water, but with a change of wind the mosquitoes disappear." Many parts of the North American continent are famous for the numbers of the mosquitoes in the neighborhood. Felt has called attention to the fact that these insects are so aggressive in some localities as to give name to a place. For example, there is a town named "Mosquito" in Illinois, a village bearing the same title in Newfoundland, a Mosquito Creek in Indiana, another in Iowa, and still another in Ohio, while the whole eastern coast of Central America is known as the Mosquito Coast. Riley is quoted as stating that the bravest man on the fleetest horse dares not cross some of the more rank and dark prairies of Minnesota in June.

Captain Butler in "The Great Lone Land" gives a vivid description of the abundance of mosquitoes on the northwestern prairies in the early days.

"As soon as the sun had dipped beneath the sea of verdure, an ominous sound caused me to gallop on with increasing haste. The pony seemed to know the significance of that sound much better than its rider. He no longer lagged, nor needed the spur or whip to urge him to faster exertion, for darker and denser than on the previous night there rose around us vast numbers of mosquitoes,—choking masses of biting insects, no mere cloud thicker and denser in one place than another, but one huge wall of never-ending insects, filling nostrils, ears, and eyes. Where they came from I cannot tell: the prairie seemed too small to hold them; the air too limited to yield them space. I have seen many vast accumulations of insect-life in lands old and new, but never anything that approached to this mountain of mosquitoes on the prairies of Dakota. To say that they covered the coat of the horse that I rode, would be to give but a faint idea of their numbers: they were literally six or eight deep upon his skin, and with a single sweep of the hand one could crush myriads from his neck. Their hum seemed to be in all things around. To ride for it was the sole resource. Darkness came quickly down, but the track knew no turn, and for seven miles I kept the pony at a gallop; my face, neck, and hands, cut and bleeding.

"It took us but little time to rush over the gangway and seek safety from our pursuers within the precincts of the steamboat. But they were not to be baffled easily: they came in after us in millions; like Bishop Haddo's rats, they came '*in at the windows and in at the doors*,' until in a very short space of time the interior of the boat became perfectly black with insects. Attracted by the light they flocked into the saloon, covering walls and ceiling in one dark mass."

Mr. L. A. Fuertes, the well-known ornithologist, tells us that on the western plains in Saskatchewan, at Maple Creek along the line of the Canadian Pacific Railroad, in June, 1908, mosquitoes were so numerous and were such a pest that, unless there was sufficient wind blowing to keep them down, it was almost insupportable, and the sheep herders and the laborers on the railroads daily were forced to wear head-nets and gloves in the pursuit of their occupations. On nights when there was a slight wind, the cattle would trot up the breeze and could be with certainty found at the farthest fence that they could get to.

Mr. H. W. Henshaw, of the Biological Survey, U. S. Department of Agriculture, relates the following:

"While in camp on the western shores of Kern Lake, California, in the fall of 1875, about 4 o'clock in the afternoon, the light breeze which had been blowing steadily all day suddenly ceased. Within a few moments the air was so filled with hosts of mosquitoes which came from the swampy land adjoining the lake that it was impossible to talk without dozens of the insects entering the mouth and nostrils. The mules which were picketed out on grass became frantic, and it was only with the utmost difficulty they could be restrained—in fact, so persistent were the attacks of the insects that the camp equipage was immediately packed on the animals and the place vacated."

When mosquitoes appear in such enormous numbers this is due to the simultaneous development of immense numbers of larvæ. In cases of excessive abundance the species concerned are nearly always single brooded. As the best example we can give the northern species which must develop their single brood in the early spring from the water of the melting snows. Naturally, in these cases, there is a very evident relation between the amount of snow and the number of mosquitoes in different seasons.

It was until recently believed that mosquitoes reached such enormous abundance by rapid progression through a series of generations. Careful observation, however, shows that those species which breed continuously throughout the summer, while they increase somewhat in numbers as the season advances, never reach the enormous numbers of the single-brooded species. It has been assumed by some writers that an almost unlimited number of mosquitoes can be bred from a single rain-water barrel. Lugger has attempted to estimate the actual number of mosquitoes (eggs, larvæ and pupæ) present at one time in such a barrel, as follows:

"July 6th, 1896, the water in one barrel was filtered. It contained 35 grams of mosquitoes, each gram, by count, numbering 217, hence $35 \times 217 = 7{,}595$ larvæ and pupæ. Besides this 32 egg-masses, each containing on an average 302 eggs, were found, which would hatch into $302 \times 32 = 9{,}664$ mosquitoes. Total number of eggs, larvæ and pupæ 17,259. July 22d, 1896, by a similar process, 19,110 mosquitoes were counted."

At first sight these figures appear overwhelming; in fact, however, they are insignificant. It must be remembered that the mosquitoes in a barrel are of all stages, from egg to pupa, and that only a very small proportion reach maturity each day. The greater the number of larvæ present in a barrel the slower will be their development, on account of the limited food supply, and it is by no means certain that anywhere near all the larvæ in such a barrel ever attain the adult state. Moreover the above figures appear exaggerated; thus counts by others show an average, in some cases of about 200 eggs, in other cases less, in the egg-masses of the common species.* Experience has shown us that the amount of annoyance to the inhabitants of a house, from the mosquitoes of a single well-stocked rain-water barrel, is not so great as would be thought, and beyond a very limited area there is no perceptible effect.

One of us (Knab) has observed a case of extraordinary abundance of *Culex pipiens* at Urbana, Illinois, due to unusual breeding facilities. A creek in the vicinity of the town is practically stagnant in the late summer. At a certain point this creek received the waste from an abattoir and, as a result, for some distance was so charged with decomposing animal matter that no fish could live in it. In this strongly polluted water immense numbers of *Culex* larvæ throve. They were so numerous that their breathing-tubes produced the appearance of a scum upon the surface of the water. The imagos covered the foliage of the trees and bushes along the stream; they were present in millions and they continued to reproduce until cut off by cold weather. Yet their presence was not felt at even a short distance, and very few of these mosquitoes found their way into the town—perhaps a mile away.

Thus it will be seen that great mosquito abundance in any region is not the result of the accumulated products of successive generations but the practically simultaneous development of large numbers over a wide area.

MOSQUITOES IN THE FAR NORTH.

As is well known, mosquitoes abound, for a short season, even in arctic regions. The writers have made a number of efforts to secure good mosquito material from the arctic regions, but very few specimens have been sent in, so it has been impossible to study the species. As a matter of fact, mosquitoes seem to be even more numerous in individuals in the far north than they are in certain parts of the tropics; in the tropics, on the other hand, there is a very much greater variety and very many more species. Many accounts of arctic exploration and of travels in the far north dwell upon the extraordinary abundance and ferocity of the mosquitoes during the short arctic summer. Such accounts are merely a part of the record of the travellers' experiences and are almost wholly prompted by the discomforts endured. They contribute practically nothing beyond the facts which were forced upon the travellers—abundance and ferocity.

That mosquitoes should develop in such extraordinary numbers in the arctic regions seems remarkable when we consider the extreme brevity of the summer season. In fact, however, it is this brevity of the summer which brings about

* Weber, S. E.: Entom. News, v. 17, pp. 214-217; Davis, J. J.: *Ibid.*, p. 369.

the extraordinary abundance of mosquitoes. There is, so to speak, over the entire Arctic region, one enormous brood, which reaches maturity within a very short time. The eggs, which have lain dormant from the previous summer, hatch in the pools formed everywhere by the melting snows, and the larvæ develop rapidly under the constant influence of the midnight sun. The abundance of these northern mosquitoes, then, is not due to accumulations of the product of a number of generations, but rests mainly upon the unlimited breeding facilities furnished by the great number of pools of snow-water, for it is the opportunities for larval development that largely determine the abundance of mosquitoes.

Linnæus in the "Flora Lapponica" dwells at some length upon the great abundance of mosquitoes in Lapland and the torments they inflict upon man and beast. He states that he believes that nowhere else on earth are they found in such abundance and he compares their numbers to the dust of the earth. Even in the open you can not draw your breath without having your mouth and nostrils filled with them; and ointments of tar and cream or of fish grease are scarcely sufficient to protect even the case-hardened cuticle of the Laplander from their bite. Even in their cabins the natives can not take a mouthful of food or lie down to sleep unless they be fumigated almost to suffocation. The Lapps of the desert keep their houses filled with a dense smoke by the burning of fungi. The reindeer come to the houses of their own accord twice a day and the herdsman fumigates them thoroughly by approaching the herd from the windward side with the smudge of fungi. The animals show the relief they experience from this treatment by chewing their cud and almost falling asleep.

The abundance of mosquitoes in the arctics is mentioned in the narrative of nearly all arctic expeditions.

Sir John Ross in the appendix to the "Narrative" of his second voyage states: "Of this genus [*"Culex"*=*Aëdes*] only one species was observed. It first appeared about the 10th of July, on the 15th it became very numerous, and on the 22d so extremely troublesome, as to prevent the necessary duties of the ship. They were in perfect clouds over the marshes, and their larvæ constitute the principal food of the trout that inhabit the lakes. It was only in the beautiful summer of 1830 that we found them so very numerous. On the 13th of August of that year they came out again after the rain, but were no longer very troublesome, being apparently nipped by the frost at night; indeed soon after this time the ground was again covered with snow, and all entomological observations were terminated."

The expedition of the "Alert" and "Discovery" found mosquitoes extremely troublesome when off the lower portions of the coast of Greenland; in the extreme north they still found them common but not troublesome.

Lundbeck found that mosquitoes occur in enormous numbers on the west coast of Greenland. He states that their bites are very troublesome and cause swellings, particularly when one is attacked for the first time. "Larvæ and pupæ are common in all water holes all through the summer and the mosquito itself is found from mid-June into August. The plague of mosquitoes reaches its culmination in the district of Kristianshaab; at Upernivik, on the other hand, it is considerably lessened."

Among modern writers Mr. Ernest Thompson Seton gives an interesting account of his experiences with northern mosquitoes on a journey to the Great Slave Lake region of Canada. This will be found in Scribner's Magazine for November, 1910, under the title: "The Arctic Prairies; i. The Land of the Buffalo; 6. Mosquitoes (pp. 522–526). It quite substantiates the accounts of the earlier travellers.

A. S. Packard, in his book entitled "The Labrador Coast" (New York, 1891), on page 86, refers to mosquitoes on Caribou Island. He writes concerning an alder swamp:

"Here mosquitoes and black-flies swarm; we are under shelter of a cliff, and there is no wind to keep off these horrible pests. How they rage and torment, these myriad entomological furies! Now for a frantic rush out of this purgatory, and a tiresome climb of a hundred feet up this cliff!"

Again, on page 191, referring to Strawberry Harbor—which, by the way, he thinks must have been called "Strawberry" because it is but little larger than that berry—he writes:

"Deep and seemingly inaccessible to outside life as Strawberry Harbor promised to be, the next day, which was nearly calm and sunny, with a little breeze from the east, the mosquitoes, swarming from land and peering over into our den, swooped down upon us and made life miserable. Ashore with my insect-net, they fairly drove me off the hunting ground, which proved to be richer in arctic insect life than any yet experienced."

The explorer, Charles F. Hall, gives many instances of mosquito abundance during his extensive visits to Arctic America. The citations given here are from the narrative of his second expedition, published in Washington in 1879. On page 75 the statement is made that he went into winter quarters north of Depot Island and had his beard cut, "Its length had been a special protection in the summer months against those tremendous blood-suckers called in the English tongue mosquitoes, which abound in swarms here." Again, on page 322, the statement is made that at Ships Harbor mosquitoes made their appearance as early as the 4th of July. Again, on page 426, an account is given of a walk on one of Hall's trips to Talloon, as follows:

"The sun was about 5 degrees high. Not a breath of air stirring, the sun shining hot, and the mosquitoes desperately intent on getting all the blood of the only white man of the country. I kept up a constant battling with my seal-skin mittens directly before my face, now and then letting them slap first on one and then on the other of my hands, which operations crushed many a foe. It seemed to me at times as if I never would get back. Minutes were like hours, and the distance of about two miles seemed more like half a score. At length I got back to my home, both temperature and temper high. I made quick work in throwing open the canvas roof of our stores, and, getting to our medicine-chest, snatched a half-pint bottle of mosquito proof oil, and with a little of this besmeared every exposable part of my person. How glorious and sudden was the change. A thousand devils, each armed with lancet and blood-pump, courageously battling my very face, departed at once in supreme disgust at the confounded stink the coal-oil had diffused about me."

In the Bulletin of the New York Zoological Society, January, 1905, Mr. C. H. Townsend, Director of the New York Aquarium, says:

"The writer has had very trying experiences with mosquitoes in the Arctic portions of Alaska. During the short Arctic summer the cold, moss-grown morasses of that region breed mosquitoes in vast numbers, and life is almost unbearable if one is not protected against them by gloves and veils. Sleep is scarcely possible against them without the protection of netting."

In his narrative of the Harriman Alaska Expedition of 1899, John Burroughs, writing of Port Clarence, the northernmost point reached by the expedition says:

"And mosquitoes, how they swarmed up out of the grass upon me, when in my vain effort to reach a little volcanic cone that rose up there before me like a haystack in a meadow, I sat down to rest. I could not seem to get nearer the haystack although I sometimes ran to get rid of the mosquitoes."

Miall, in his excellent work entitled "The Natural History of Aquatic Insects" (London, 1895), says of northern mosquitoes (pp. 109–110):

"They have been found in immense numbers in uninhabited parts of Labrador, on the tundras of Siberia and in the desolate Kerguelen Island. 'Of the millions of mosquitoes which in the short Norwegian summer often thicken the air of the Tromsdal—a wild valley within the Arctic Circle, practically uninhabited either by man or probably by beast—how few are ever likely to taste blood!,* Sir James Ross and his men found it necessary in their polar expedition to wear gauze over their faces in the summer months as a defence against Gnats."

The stories which the returning gold hunters from Dawson City and other Alaskan localities told of the abundance and ferocity of Alaskan mosquitoes are almost beyond belief, but are vouched for by scientific men, belonging to the U. S. Coast and Geodetic Survey, to the U. S. Geological Survey, and to the Signal Service of the Army, who have come back to the United States with similar and even stronger stories. An Alaskan traveler, the late W. C. Henderson, of Philadelphia, said, concerning Alaskan mosquitoes, "They existed in countless millions, driving us to the verge of suicide or insanity."

Capt. A. T. Clifton, U. S. A. (Signal Corps), who has spent much time in official work in Alaska, writes as follows (*in litt.*):

"Mosquitoes in Alaska seem to be numerous and poisonous pretty much over the whole country. They are a hardy insect apparently, as they rise out of the tundra from under the patches of snow in the spring, and in my quarters in St. Michael they have appeared quite lively in December when a chinook sent the thermometer up above 50 degrees above zero. Like the rest of their tribe, they do not like wind or smoke, though they were so fierce at St. Michael that in a thirty-mile breeze clouds have fallen in behind me as I breasted the wind, taking advantage of the slight protection afforded by my body to alight on my back. In central Alaska in the vicinity of Fairbanks and Fort Gibbon they are just as fierce and if anything much more numerous, as the country is wooded and covered with bushes as well as tundra. From May to August they are at their worst.

"The only protection the prospectors, wood-choppers and Indians have is from the use of smudges made of green grass, sticks and anything that will throw

* A. D. Michael, in Natural Science, vol. 1, p. 203.

off a dense smoke. I have seen telegraph operators ticking messages out at isolated stations with their heads in a cloud of smoke from a smudge in a bucket under the table, while mosquitoes hummed thick everywhere except in the immediate vicinity.

"Stock has to be well protected in summer from their bites. I have seen and heard of numerous cases where the poor animals have been driven frantic from bites when not protected with empty gunny-sacks or nets of some kind. The mosquitoes alight on the animals in such swarms as to entirely change the color of the hide. Anything with blood seems to be a sweet morsel, and mosquitoes seem to race to see which shall be the first at it and the last to leave it.

"The Alaskan mosquitoes are huge, fierce, aggressive, and extraordinarily persevering, and stop at nothing, for I have been well bitten through the pores of my buckskin gauntlets.

"When steamers stop at a wood-pile to 'wood-up' the deck hands wrap their heads up, leaving only the face exposed, and consequently only one spot to defend, and each will move with his own attentive following in a dense and close formation around his devoted head.

"The use of head-nets—a form of mosquito bar which is worn over the head and comes down on the shoulders—is very common except in the timber, but it is a fine scheme for torture if it gets torn, for the mosquitoes are always on the alert unless prevented by rain, wind or smoke. The Indian smears his face, neck and hands with a thick coating of mud and uses a smudge.

"In Rex Beach's good story, 'The Barrier,' his killing a man with mosquitoes is by no means far-fetched, for one can well imagine a man being stung to death by the pests when left bound for insect slaughter. Personally I heard of a prospector in the Inuoko country who had lost his bearings and wandered around in the brush and timber with no means of warding off the attacks of mosquitoes, and when found he was a raving maniac and never recovered. The Jersey branch of the family is a mild suggestion compared with the Alaskan branch. In Alaska the mosquito seems to breed in the tundra, brush, trees, anywhere where there is moisture. The clearing off of the brush seems to lessen the swarms in the immediate vicinity. I have watched a ball game at Fairbanks, standing in the smoke of a smudge, and after the sun set, 10.30 p. m., was driven to cover by them. They are as bad on the coast as in the interior, in the old settlements as in the new, and are generally warred upon without seeming effect."

EGGS AND OVIPOSITION.

The mode of disposal of the eggs shows wide diversities in different genera and species and these affect the entire life-history of the species. The method of oviposition best known is that of the typical species of *Culex,* and this is shared by *Culiseta, Lutzia, Mansonia* and *Uranotænia.* In these forms the female lays all her eggs at one time, grouping them together in the so-called raft or egg-boat. These eggs are cylindrical, rounded at the ends, and taper slightly towards one end. The eggs are placed in an upright position with the larger end downward and are fastened together along their sides by a viscous secretion which quickly hardens. The slight upward taper of the eggs brings about the characteristic convexity of the bottom of the egg-raft and this prevents it from being overturned. These egg-rafts are deposited either upon the water or close to it. We have found egg-masses of *Culex* upon the sides of rain-water harrels, some distance above the surface of the water. Egg-masses so placed are probably carried to the water by rain-water, or perhaps even water from a heavy dew, trickling down the walls of the barrel.

Réaumur, in his classic work, gives a detailed and most interesting account of the egg-laying process in the common house-mosquito, *Culex pipiens.* The account of this wonderful observer is so faithful that we reproduce it here:

"Towards the end of May I left my laboratory work at about 6 o'clock in the morning, to watch the mosquitoes. The thermometer stood at 13-1/2 degrees . . . On arriving I first noticed more than thirty egg-masses which had just been laid, but fortunately I saw also a mosquito which had not yet finished oviposition. This mosquito was clinging by her four anterior legs to a bit of leaf touching the side of the bucket. Her body was above the leaf, the penultimate segment touching the water. A raft of eggs which was placed near the end of her body and which had not yet reached full size indicated that the laying was well advanced but not yet finished. The mosquito, busy with this important measure, did not notice my presence, and permitted me to approach near enough to her to watch her through a strong lens. I soon knew how it happens that the eggs are placed perpendicularly to the surface of the water and how they are arranged. It is the end of the abdomen which does it all. We have said that the penultimate segment of the body touches the water, and we can now say that the last segment (that which carries the anus) forms with the rest of the body a kind of hook elevated a little above the surface of the water. From this last segment, *thus turned up, I soon saw an egg come out; I saw that it came out* in a different direction from that in which the eggs ordinarily issue with other insects. The latter are placed horizontally, or lying down, while these are placed upright, in a vertical direction. The egg issues very near the mass of eggs already put in place. As soon as it is entirely, or almost entirely out, the mosquito has only to push it against those of the little boat which it is nearest to; for this egg, like those of almost all insects, are without doubt provided with a sticky substance which fastens it to the object to which it is applied.

"The laying of an egg and the placing it in position is for the mosquito an affair of an instant, and as soon as she has placed one another begins to issue from her body. The mosquito which I observed laid in this way, without interruption, more than thirty eggs in less than two minutes; either because the laying was then finished, or because she was finally disturbed by my presence, she flew away and left the little floating boat upon the water, but the shape of the boat was not as regular as that of the majority of the other egg-boats. I searched further, but could find no other mosquito engaged in laying. However, I had not yet seen everything essential to the operation; I had been sufficiently instructed in the method by which the mosquito was able to place each egg perpendicularly on the surface of the water and to attach it to the mass composed of eggs already laid, but it remained to be found out how the mass is sustained upon the water when the base is still too small in relation to the height, how the first egg is sustained or a small group of only two or three eggs. The mosquitoes which I watched on the following days at 6 o'clock in the morning or thereabouts gave me a complete explanation of this. I found them occupied in laying, finding some in which the oviposition was very advanced and others in which the mass was very small. These latter instructed me sufficiently concerning what occurs at the instant when the first eggs are laid, a moment which is very difficult to observe. Among the mosquitoes which I watched in this operation were several which were clinging with their four anterior legs to the wall of the bucket, and others which, like the first one described, were standing upon a floating fragment of leaf. The abdomen in both cases stretched over the surface of the water and touched it only by a part of the penultimate segment. But what was essential to notice was the position of the two hind legs, which are the longest, or rather their positions, for I observed two different positions. The mosquitoes which had almost finished laying and whose little boat was almost completed had these two long legs extended and almost parallel to each other. The end of each one reached to the surface of the water and even a little raised above it, but they were both thrust a little in the water near the end, as though forced by a weight, this weight being that of the little boat. This little boat was, so to speak, on a dock. It was not abandoned to the water. The two legs, like two long beams, sustained it at the surface of the water or a little above the water. The mosquito held this boat in this way while she was adding eggs to it, *and she did not set it afloat until all the eggs had been placed.*

"The mosquitoes which had advanced but slightly with egg laying and whose boats had not yet reached half size had their legs in a different position from that of which we have just spoken. Here the legs crossed each other in the form of an X, and the place where they crossed was nearer the anus when the assemblage of eggs was smaller and the boat was shorter. The interior angle of the legs sustained this little mass of eggs. From this it is easy to divine that when the mosquito lays its first egg the legs are crossed very close to the end of the body so as to support the egg; that they hold up the eggs which are successively placed against this one; that in proportion as the mass of eggs lengthens the space between the place where the legs cross and the end of the abdomen grows; and that finally the two legs assume a parallel position when the boat is half or more than half done; and that thus, from the placing of the first egg until the end, the eggs are always held up by the hind legs. It is only when the laying is finished that the mosquito abandons the little boat, which is then in condition to sail without risk."

One of us (Knab) has observed the process of egg-laying in *Culex territans* and found that it agrees substantially with the account of Réaumur. St. George Gray, in the Journal of Tropical Medicine, vol. 6, page 313, has described the remarkable manner of forming the egg-raft in an African mosquito.

"The fore and mid legs of the mosquito rested on a couple of the egg-rafts that had been deposited at an earlier hour, and the two hind legs were stretched out on the surface of the water behind her, parallel to each other, ***not crossed*** as some observers state. A single row of creamy white eggs had been laid ***flat*** on the surface of the water and were kept in position by the two hind legs. . . .

"When the first row of eggs was completed she laid another row on the top of it, and then another on the top of that, and so on until the raft was finished. Then by a movement of the hind legs she tilted the raft so that the eggs stood on end."

In the genera *Culex, Culiseta* and *Mansonia* the egg-mass rests upon the surface of the water. The mass has a certain repellant quality, inherent, it seems, in a covering of delicate air-cells on the under surface. In the genera *Uranotænia* and *Lutzia* the egg-boat is in part submerged, only the upper part of the eggs protruding from the water. Thus, Dyar states that in the egg-boat of *Uranotænia sapphirinus* the middle eggs are nearly half submerged. In the case of *Lutzia bigotii*, as observed by Jennings, the egg-boat is in large part submerged, only the apices of the eggs protruding above the water. The eggs, which are arranged in a double row, are remarkable in coloration; the submerged portion is pale yellow with a golden luster while the exposed part is pale blue.

The number of eggs and their mode of arrangement varies for the species, and to a certain extent within the species. The egg-raft of *Lutzia bigotii*, just mentioned, is composed of about fifty eggs arranged in a double row. The eggs of *Mansonia fasciolatus* and *M. arribalzagæ* are arranged in a long, ribbon-like, double row with a gentle convexity upon the under side. Goeldi states that there are about 60 eggs in these egg-rafts but his reproductions of photographs of such egg-masses show from 70 to 80 eggs in a row, therefore 140 to 160 in the entire mass. Our *Mansonia perturbans* forms an egg-raft similar to that of *Culex*, that is, with the eggs in a number of rows forming an elongate mass and the under surface of the mass convex. In *Culex, Culiseta* and *Uranotænia* the egg-masses are elongate, and, on account of the convexity of the lower surface, the sides are somewhat upturned.

Few exact data are available as to the number of eggs laid, even for the commonest species. With reference to the common house mosquito, *Culex pipiens*, 250–300 is generally given as the normal number, a statement to be traced back to Réaumur's work. Our American observations are unsatisfactory, as a number of species have undoubtedly been confused under the one name. Davis, in Illinois, found the number to vary from 120 to 309 in a count of ten egg-boats. Smith states that normally the number of eggs laid by *Culex pipiens* in a single raft is about 400 but that if the female is disturbed in the process there may be two or more smaller rafts formed. Goeldi (at Pará), in a count of two egg-masses of *Culex quinquefasciatus* found 225 and 270 eggs respectively and his pictures show that they are arranged in from 9 to 11 rows. C. S. Banks, with the same species before him in the Philippines, found the number of eggs from 180–350, arranged in from 6 to 9 rows. In *Culex territans* two egg-masses counted by Knab contained respectively 105 eggs in six rows and 132 eggs in eight rows.

A singular departure in the mode of egg-laying, or rather in the character of the eggs, has been recorded by Busck in *Culex jenningsi*, and this is probably shared by other bromelia-inhabiting species of *Culex*. In this case the eggs are deposited in the water and surrounded by a gelatinous substance. Busck found about twenty-five of these eggs united in an ovate gelatinous mass, each egg surrounded by its own spherical gelatinous envelope and supplied with an air-bubble which helped to keep the mass afloat. Mr. Jennings has since repeated this observation. The gelatinous matter furnished the first food to the newly hatched larvæ.

So far *Joblotia digitatus* stands unique, not only among the members of the genus, but in the entire tribe of Sabethini, by depositing its eggs in a raft. Its raft is a type entirely distinct from those previously described. It is flat and circular in outline, instead of elongate and concave as in the egg-boats of *Culex*.

Anopheles deposits its eggs separately in small numbers, upon the surface of the water. The eggs lie upon their sides and are kept afloat by a peculiar structure, a partial envelope which is more or less expanded, particularly along the median portion of the egg. This hydrostatic organ is variously shaped and developed in the different species of *Anopheles*. In one case, *Anopheles turkhudi* of India, this apparatus is nearly obsolete and the only trace remaining is a small rudiment concentrated near the larger end. In a remarkable Brazilian anopheline, *Chagasia fajardoi*, the hydrostatic apparatus reaches a remarkable development, completely surrounding the egg and forming a series of longitudinal, remarkably constructed, air-chambers.

So far as we are aware the eggs of all *Anopheles* are provided with the hydrostatic organ and are normally laid upon the water. The eggs of such a large proportion of the species are now known that we can expect no exceptions. The eggs of *Anopheles turkhudi* and *Chagasia fajardoi*, just described, probably represent the two extremes of modification of the hydrostatic organ. Recently H. I. Cazeneuve claims to have found that in northern China *Anopheles* pass the winter in the egg-state, the eggs being frozen into the mud and hatching when thawed out. The observation evidently is based on an error in determination. Cazeneuve has undoubtedly taken the males of certain species of *Aëdes* (which agree exactly in habits with his observations) for *Anopheles* on account of their long palpi. This is the more excusable as several famous entomologists, in their systematic work, have fallen into the same error and have described males of culicines as *Anopheles*.

The eggs of *Bancroftia signifer* are laid singly upon their sides, at the margin of the water. These eggs are remarkable in that they are fastened down by a gelatinous covering which extends all around them in the form of a broad, curiously sculptured, rim. *Megarhinus* lays its eggs singly upon the water. Goeldi found the egg-shells of *Megarhinus hæmorrhoidalis* floating separately upon the water in little groups of from four to six and this has given rise to the statement that the eggs are laid in chains. Green, in Ceylon, has obtained the eggs of *Megarhinus immisericors* from a confined female and found that they were scattered singly over the surface of the water. The eggs are regularly oval and their surface is closely studded with spinose tubercles which hold the air between them and keep the egg afloat. "The actual operation of egg-laying was not seen, but the female was observed jerking itself up and down in the air just above the water, and it seems probable that the eggs were shed at that time."

All the mosquitoes we have so far considered, with the exception of *Bancroftia*, lay their eggs upon the water, or, in the case of *Culex jenningsi*, into the water. In these the development of the larva within goes on uninterruptedly and the eggs hatch within a short time. We now come to a group of mosquitoes in which the eggs lie dormant for some time to await favorable conditions for the development of the larvæ. These are the species of the genera *Aëdes* and *Psorophora*. In these forms the eggs are laid singly or in small batches, never fastened together in the form of a raft, and, in most cases at least, not upon the water. That they are not laid upon the water is shown by the fact that, where for a long time there has been no water, the larvæ appear promptly when puddles are formed. In these mosquitoes the female does not mature all her ova at one time; therefore they are deposited in several batches, at intervals. To *Aëdes* belong the mosquitoes which are so troublesome in the northern regions and we have already touched upon their breeding-habits in our discussion of the adults. The eggs are laid in the summer and they do not hatch until the following spring, when the larvæ appear in great numbers in the water from the melting snows. The females must deposit their eggs upon the ground, at least in most cases, for by the time they have developed their ova the breeding-places have usually dried out. Galli-Valerio and Rochaz de Jongh, in Switzerland, have found hibernating single eggs attached to fallen leaves in depressions of the ground. It appears that the hibernating eggs, although they may be repeatedly submerged, will not hatch before they have been subjected to freezing temperatures. Thus these mosquitoes appear in one great annual brood, in spite of the fact that the eggs are not all laid at one time. With a few species of these northern *Aëdes*, for example *Aëdes fuscus* and *A. canadensis*, larvæ appear in small numbers at intervals during the summer, after heavy rains. These larvæ are undoubtedly from hibernated eggs which failed to hatch in the spring, and not from freshly laid ones. Eysell, who observed species with similar habits in Germany, suggested two ways in which such subsequent appearance of larvæ might be accounted for. Eggs which were not submerged in the early spring might be washed into the pools by heavy rains. Or the water in the pools might be raised to a higher level and reach eggs until then unsubmerged.

A peculiarity of the eggs of the group we are now considering is that not all of them hatch at one time; a certain number lie over until later in the season or even until another year. To the southward the species of *Aëdes* depend for the most part upon the rains for their development. In regions with a well-marked dry season the eggs must withstand desiccation for a long period. Here the eggs lie upon the ground from one rainy season to another, hatching with great promptness when submerged by the rains. Viereck found that in the case of one of our salt-marsh mosquitoes (*Aëdes sollicitans*) that upon immersing a piece of sod which contained eggs the young larvæ appeared within three minutes. This prompt hatching is of the greatest importance as in hot climates rain-puddles dry out very rapidly and the mosquito must reach full development before this occurs. As it is, whole broods must often perish through the too rapid drying up of their breeding places. Another provision, to insure the species against destruction in such case, exists in the fact, already mentioned, that not all the eggs hatch, a part of them lying over until again submerged by subsequent rains.

Certain species of *Aëdes* and *Stegoconops* are partial to the water in hollow trees and these are almost continuous breeders during favorable conditions and, while they are dependent to a certain extent upon rains, they show no well-marked broods. These species deposit their eggs near the water, usually close to the moist margin above it, and the eggs hatch when the water rises to them. The water in such holes in trees is usually well protected against desiccation and every slight rain contributes to it; as a comparatively slight rise of water will reach the eggs, these can hatch at frequent intervals. The yellow-fever mosquito (*Aëdes calopus*), although so closely associated with man, is in its habits essentially a tree-hole species. The eggs are deposited in the same manner, only, through the fact that they are deposited in water receptacles which are being constantly refilled by man, the chances for the hatching of the eggs are greatly increased and, to a large extent, made independent of weather conditions.

Little is known of the eggs or egg-laying habits of the tribe of Sabethini. We have already mentioned that *Joblotia digitatus* lays its eggs in a raft. Other species of *Joblotia* lay their eggs singly upon the water.

Smith found that with the pitcher-plant mosquito (*Wyeomyia smithii*) the favorite place for the disposal of eggs is the younger leaves which had not yet filled with water. The eggs were found in abundance upon the inner surface of such leaves; they were also found in lesser numbers, floating upon the water in the older leaves, and the oldest leaves had the fewest eggs. Busck, in Trinidad and Panama, found certain species of *Wyeomyia* breeding in the flower-spathes of *Heliconia*. The eggs were found deposited in the uppermost, still unexpanded, spathes of the series, which as yet contained no water.

HABITS OF THE LARVÆ.

So far as known the larvæ of all mosquitoes are aquatic. The larval forms of so many of the genera are now known that it can be considered safe to assume that there will be no exceptions found. It has already become apparent from the egg-laying habits that mosquito larvæ occur in a great variety of situations. What has not been sufficiently understood until recently is that each species, or group of species, has its own very definite habitat—a fact of the greatest economic importance. By far the most of the mosquito larvæ occur in small deposits of water. While certain species do occur in large bodies of water, such as ponds and streams, this is under unusually favorable circumstances, and even then they are present only in small numbers. In the larger bodies of water fish and other life act as a check upon mosquitoes, if, indeed, their eggs are deposited there at all, which there is reason to doubt.

Those species of mosquitoes which appear in the greatest abundance develop in transient deposits of water. This is the case with the mosquitoes of the genus *Aëdes* which are so troublesome in our northern woods and in the arctic regions in early summer. The eggs of these mosquitoes are deposited upon the ground during the summer. There the eggs lie until the following spring; although they are repeatedly wetted or even immersed in water they will not hatch until the following spring. Then, with the melting of the snows, the eggs promptly hatch and the larvæ appear in the pools of snow-water in immense numbers. The previous freezing appears to be a necessary stimulus to their development. In the course of a few short weeks the entire mosquito crop of those regions is produced.

It has often been noted that upon the plains of the arid and semi-arid west mosquitoes occur at times in immense numbers and their presence, in the absence of all water, has seemed inexplicable. Yet these too pass their larval life in the water. On the northern plains these mosquitoes develop in the very transient snow-water, in the manner described above; south of the regions of heavy snow-fall they depend upon temporary deposits of water resulting from heavy rains. Similarly, in semi-arid tropical regions the appearance of mosquitoes depends upon the heavy rains of the summer months. The rapidity of development of the larvæ in such regions is astounding, but it is conditioned by the rapid evaporation of the rain puddles in such a climate. The eggs which had lain upon the ground for a year, and perhaps two years, upon being submerged hatch at once; the larvæ reach their full growth within one or two days and the pupal period is a matter of hours. Even so a whole brood may perish from the too rapid drying of the pools. There is a remarkable provision to prevent the extermination of the species through such circumstances, in the fact, above mentioned, that not all the eggs hatch at one time. Part of them lie over until a succeeding rain, and some of them even until another year. Thus the survival of the species is assured. All the forms so far discussed, and to them belong by far the most mosquitoes in point of numbers, being dependent upon seasonal conditions, show a marked periodicity. This is also true of the salt-marsh mosquitoes, although their development is governed by somewhat different conditions and there may be, and usually are, a number of broods during a season. Here the determining factor is the flooding of the marsh, either by rains or by a high tide, the higher ground along the beach preventing the escape of the water. Here again the eggs lie buried in the mud or sod and hatch when submerged, and here, also, a part of the eggs lie over until another flooding of the marsh. On the Pacific coast, where no rains occur for many months, a crop of salt marsh mosquitoes appears every four weeks following the monthly high tides that overflow the upper reaches of the marshes where the eggs are. All these species in which a long unfavorable period is passed in the egg state are closely related and belong to the genera *Aëdes* and *Psorophora.* The genus *Psorophora* is most adapted to the conditions in the semi-arid tropics. Simultaneously appear, and developing with equal rapidity, the non-predaceous larvæ of the subgenus *Janthinosoma* and those of *Psorophora* proper which prey upon them.

In marked contrast to the forms just discussed are those which breed continuously, as long as breeding-places exist and temperature conditions are favorable. Such are the forms in which the eggs are deposited upon the water and which hatch soon after being deposited; these are the species of *Anopheles, Culex, Culiseta, Uranotænia* and *Lutzia.* The growth of the larvæ depends upon food conditions and upon temperature, so with these forms there are no well-marked broods or generations; adults and larvæ in all stages may be found at all times until frost cuts the larvæ off. As it is the hibernating females that preserve the species until the following season, and many of these females die off in the course of the winter, these species first make their appearance in small numbers and gradually increase to the end of the season. Never, however, do they reach such enormous numbers as the periodic species. To the continuous breeders belong the house mosquitoes which breed in rain-water barrels or other artificial receptacles. Other species of *Culex* breed in natural pools of a more or less permanent character, in swamps, or along the margins of streams. Others breed in the water of various water-bearing plants, such as the bromeliads, *Heliconia* and *Calathea* of the tropics. In these continuous breeders the eggs are laid upon the water and develop at once, hatching within a few days. Certain forms of *Aëdes* take a position intermediate between the forms with well-marked broods and the continuous breeders. Such are the species of *Aëdes* and *Stegoconops* which breed in the water in hollow trees and in similar situations. With these the eggs are laid above the water line and they hatch when the water rises to them. As the result of successive rises, due to rains or other causes, eggs hatch at brief intervals and larvæ of various sizes are always present. Thus mosquitoes of these species are continuously present while there is warm weather and occasional rain.

An important fact to be considered is the habitat peculiar to each species or group of species and this, of course, is intimately connected with the feeding habits. Thus certain species are found only in rain puddles charged with mud. Other species thrive in pools and ditches full of dead leaves and other vegetable debris, or in sphagnum swamps. The *Anopheles* larvæ are surface feeders and often occur where there is a slight flow of clear water which favors the growth of the algæ upon which they feed. Some species of *Anopheles* thrive, however, in other situations. We have found the larvæ of certain species plentiful in temporary rain puddles which showed no trace of algæ. Other species of *Anopheles* breed in the water in holes of trees and between the leaves of bromeliaceous plants. Tree-holes form the habitat of the larvæ of a number of species of mosquitoes which breed nowhere else. Plate x, fig. 3, shows such a mosquito breeding tree-hole. Others, while strongly attached to tree-holes, show a certain degree of adaptability, breeding in rock-pools, tubs and barrels under suitable conditions. It is to be supposed that the food conditions along with the general environment are here the determining factors.

In the tropics the larvæ of many species live in the water or liquid held by various plants which are modified for this purpose. While this water or liquid furnishes a breeding-place for mosquitoes and other insects it fulfills a more or less important function in the economy of the plant. Thus in many Bromeliaceæ water collects at the bases of the leaves and this water serves as a barrier to prevent the access of ants and other injurious insects to the flowers. With certain tropical American species of *Heliconia* and *Calathea* the flower bracts form a receptacle whose office is probably primarily to protect the flower itself. In the case of *Calathea* at least the liquid held by the bracts is dark and thick and is probably secreted by the plant itself. In America certain species of *Sarracenia* and in the East Indies certain *Nepenthes* have leaves peculiarly modified to hold liquid. These leaves act as traps to most insects, which, having entered, can not escape and are finally drowned. Their decomposition is supposed to furnish food for the plant. In our common pitcher plant (*Sarracenia purpurea*) the leaf cups are open and have a broad lip to catch the rain-water and dew. In the case of *Nepenthes* the leaf cup has a lid which projects over its mouth and which, while it does not close it, prevents water from entering; the cups are filled with a viscous liquid secreted by the plant itself. All these plants support mosquitoes peculiar to themselves. In tropical America the many species of the tribe Sabethini inhabit almost exclusively such plants. Certain species of *Culex* are peculiar to the bromeliads, as are also a few species of *Anopheles* and *Megarhinus*. Most of these larvæ are scavengers and feed upon the remains of insects that have been trapped by the plants. A few are predaceous and prey upon the larvæ of the other species. Such are *Lesticocampa* and certain species of *Megarhinus*. A remarkable fact is that even these cannibalistic forms are confined to a single plant, each species of plant thus having a fauna peculiar to itself. The only case in our temperate zone, of such close adaptation to a single plant, is the pitcher-plant mosquito, *Wyeomyia smithii*. Our plates iv, v and vi show water-bearing plants known to harbor mosquito larvæ and other aquatic insects in the American tropics.

In the moist tropics the water-filled ends of broken bamboos furnish breeding-places to a number of species. In America among the bamboo inhabitants the sabethids again rank first in number of species belonging to several genera: of culicines there are representatives of *Culex, Carrollia, Stegoconops* and *Megarhinus.* Here again we have, among these species restricted to a peculiar habitat, predaceous forms (*Sabethinus, Megarhinus*) which prey upon the others. A few species of Sabethini breed in the water of cocoanut and cacao-husks and their larvæ are rarely found elsewhere. The larvæ of *Limatus* and of *Joblotia digitatus* are constantly found in these husks and they thrive there no matter how foul the liquid, as a result of the decomposing vegetable matter, may become.

A peculiar habitat is furnished by certain reeds growing in swamps. The leaves begin to spread below the surface of the water and thus form a chamber isolated from the surrounding water. The larvæ of several species of *Wyeomyia* have been found in this situation and Lutz has found there the larva of *Menolepis.*

In the tide-water regions of the American tropics certain crabs live in holes in the soil which go below the water level. In the water in these holes, sometimes at a considerable depth below ground, certain species of mosquitoes breed. Most remarkable of these are the specialized forms of *Deinocerites* and related genera. Besides these there are a number of species of *Culex* peculiar to the crab-holes and even structurally these show more or less adaptation to their habitat.

The most peculiar and specialized larvæ of mosquitoes yet discovered are the species of *Mansonia* (*Tæniorhynchus,* auct.). The habits of these larvæ have recently been worked out with our common *Mansonia perturbans* and the same habits are indicated for *Mansonia fasciolatus* and *M. arribalzagæ.* The eggs are laid in swamps where there is a dense growth of grass and sedges. The newly hatched larvæ make their way down through the water to the roots of these plants and there they attach themselves by inserting the apex of the peculiarly constructed breathing-tube. Here they remain anchored until full grown, obtaining air through the vascular tissues of the plant-roots. The pupa, it appears, remains in the same situation, deriving air from the roots by means of its peculiarly modified thoracic "breathing trumpets." The habits of *Mansonia titillans* are similar according to the observations of H. W. B. Moore, except that the host plant is *Pistia,* an aquatic plant belonging to the Araceæ, which grows in floating tufts, the roots loosely entangled in the mud.

The subject of the character of water frequented by the larvæ of different species has already been touched upon in the discussion of their habitats. By far the largest number of species frequent fresh water. Certain species, however, occur in saline water and some in water charged with alkali. Some species thrive in sea-water of full strength and even in water, as a result of evaporation, of much greater salinity. The larvæ of these same species will do equally well in brackish or even in entirely fresh water. This is important in the economy of the species as opportunities for larval development may be produced at one time by overflowing sea-water from a high tide or storm, at another by the flooding from heavy rains. On the Panama coast the larvæ of a species of *Stegoconops* and of *Aëdes fluviatilis* occur in rock pools of concentrated sea water resulting from the splash of high seas. The larvæ of these identical species occur inland in perfectly fresh water. Of most of the salt-water species it may however be said that they adhere closely to the tide-water region; *Aëdes sollicitans* may almost be said to be confined to the pools immediately back of the sea beaches. While these larvæ occur in salt or fresh water and will survive a certain change of density of their medium, as in the case of a salt-water pool being diluted by rains, transfer from one medium to the other is fatal to them. The cause of death in this case is the osmotic action of the media of different density.

Perhaps the most remarkable of the species breeding in salt water is *Aëdes zammittii* of the Mediterranean region. According to Surgeon E. H. Ross they occur only in highly concentrated sea-water as it occurs in the rock-pools left by high tides. He states that while, in summer Mediterranean sea-water contains twenty-eight grammes of salt per litre, this species "can only live in water containing from forty-eight to eighty-seven grammes per litre of salt. As soon as salt begins to be formed on the surface of the pool, the larvæ and pupæ move on to another part of the pool, which is often most extensive. These pools may be very deep, but, in common with all the sea-water pools on the shore of the Mediterranean, never contain fish or shrimps. When a thin layer of salt forms on the whole surface of the pool, the larvæ die." Carter found that if the water was sufficiently saline the larvæ were present, regardless whether the water was strongly polluted or very clean. At Port Said he found them in cesspools under the houses in which there was a large percentage of salt.

THE FOOD OF MOSQUITO LARVÆ.

The larvæ of many species undoubtedly swallow anything in the water that they inhabit which can enter their mouths. With many of the species the mouth-brushes produce a vortex into which pass all minute objects floating on the water or suspended in the water. The spores of algæ, particles of dust, bacteria, protozoa, minute aquatic animals of many different kinds, are thus swallowed. With many species it seems that the important food is animal. *Anopheles* has been found feeding upon the dead bodies of other culicid larvæ. In studying the larvæ of *Anopheles quadrimaculatus* in the laboratory, these insects seemed to thrive best in water containing green algæ, and this observation has been confirmed by other laboratory workers; but it has been suggested that perhaps the important food of these larvæ is after all the microscopic animal life which swarms among these algæ and of which the algæ themselves constitute perhaps part of the food. The algæ in our experiments belonged to the genera *Aëdogonium, Cladophora, Spirogyra* and in lesser degree *Oscillaria*. Stephens and Christophers have found that the food of *Anopheles* larvæ examined at Accra consisted of a unicellular organism (*Protococcus?*). Theobald found that the food sucked into the mouth of the larvæ of *Culex pipiens* and *C. nigritulus* consisted of algæ and water crustacea such as *Daphnia* and *Cyclops*. He has bred *C. nigritulus* almost exclusively upon flagellate protozoa which seem to be a very favorite food of this species. In our experience the larvæ of *Aëdes*, which occur in early spring, when small crustacea often abound, do not feed upon these latter. In confinement the *Aëdes* larvæ do not thrive if many crustacea are present in the water and probably these deprive the mosquito larvæ of their food. In nature these *Aëdes* larvæ are largely bottom feeders and they may be seen vigorously working over the dead leaves and vegetable debris with their mouth organs, apparently removing the fuugoid growth which covers them.

Certain larvæ thrive best where animal refuse abounds in the water and this is particularly true of the species associated with man. The larvæ of *Culex pipiens* and *Culex quinquefasciatus* develop most rapidly in water charged with fæcal matter or animal refuse. The same has been asserted for the yellow-fever mosquito by the Brazilian observers. We have found that the larvæ of this species thrive in comparatively pure water, in collections of rain-water, in jars or bottles of drinking water. Unavoidably such water, kept in or near the house, although clear, does contain a certain amount of animal matter and it is upon this the larvæ feed.

The food of the larvæ of the pitcher-plant mosquito (*Wyeomyia smithii*) consists altogether of the remains of insects that have been trapped by the plant. The presence of such food, and its amount, are largely a matter of accident and upon it the growth of the larvæ depends. Sometimes no insects find their way into a water-filled leaf for a considerable time but the larvæ can endure starvation for a long period. Larvæ of this species which we have kept without food in the laboratory, lived nearly a whole year. Probably the larvæ of all the species of *Wyeomyia* are scavengers feeding upon insects' remains, although those in the bromeliads at least, have access to vegetable debris. The larvæ of *Joblotia* and *Limatus* appear to feed wholly upon dead insects and their remains and their powerful mandibles are well fitted for this work.

It has already been mentioned that the larvæ of certain genera are predaceous, in every case feeding upon other mosquito larvæ. The genera known to have predaceous larvæ are *Cœlodiazesis, Megarhinus, Psorophora, Lutzia, Lesticocampa* and *Sabethinus*. Each of these larvæ has its own peculiar habitat and as a result it is limited in its food to the larvæ found there. The larvæ of *Cœlodiazesis barberi* occur in water in hollow trees and there they prey upon the larvæ of *Bancroftia signifer* and *Aëdes triseriatus*. These larvæ have another formidable enemy in the larva of *Megarhinus septentrionalis* which usually occurs singly or in small numbers in tree-holes. Some of the tropical species of *Megarhinus* also live in tree-holes—others are partial to bromeliads and to bamboos, while one occurs in cocoanut-husks and preys upon the larvæ of *Joblotia digitatus*. The larvæ of *Psorophora* occur almost wholly in rain-puddles where the predaceous species feed upon those of the subgenus *Janthinosoma* and of *Aëdes*. They are extremely voracious and consequently their development is very rapid. *Lutzia* is a continuous breeder and consequently preys more largely upon *Culex* larvæ. The habits of the predaceous sabethine forms are very imperfectly known. The larvæ of different species of *Lestico-*

campa appear to be restricted in habitat, each to a particular plant, where they prey upon the other mosquito inhabitants.

Certain mosquito larvæ may be said to be partly cannibalistic, feeding upon their own kind and upon other species when pressed for food. This has been observed with *Anopheles*, and in Brazil *Aëdes calopus* and *Limatus durhamii* have been shown to behave in the same way by Peryassú and his associates.

It would seem, on the whole, that the presence of mosquito larvæ in water must be beneficial rather than the reverse, and this is probably the only good thing from the humanistic standpoint which can be said about mosquitoes. Of course there is no doubt as to the benefits derived from the larvæ of *Psorophora, Megarhinus, Lutzia* and the like, since they destroy the larvæ of other biting mosquitoes, including those forms which carry disease. As to the others, their effect upon the water on the whole must be purifying, and there is an idea in parts of Texas and others of the southern United States that where mosquito larvæ occur in the rain-water tanks and wells—the tanks in many places furnishing the drinking water supply—this water is purer and safer than water which does not contain these larvæ. We have had drinking water served at table in small hotels in the South, which contained *Culex* or *Aëdes* larvæ, and, on requesting a glass of water without larvæ in it, have been assured by the waiters that this was an evidence of the purity of the water. This possibly restricted popular idea may have a sound basis, since certainly mosquito larvæ eat many organisms and among these must often be such as are injurious to the human species. It must be remembered, however, that with bacilli this function may not in the least reduce their vitality and they may pass through the alimentary canal of the mosquito larva unharmed.

Recently Boyce and Lewis have attempted to show that bacteria thrive better in the presence of mosquito larvæ, and this may be true under some circumstances. They point out that there is some opposition to the destruction of the larvæ of the yellow-fever mosquito (*Aëdes calopus*) in receptacles with drinking water on account of their supposed purifying function. To test the truth of this belief they made a series of experiments. These consisted in placing larvæ of *Culex* and of *Culiseta annulatus* "in a flask of non-sterilized drinking-water, and comparing from day to day the number of bacteria present in the water with the number present in a control flask to which no larvæ had been added. The number of bacteria was estimated by plating 1 cc. of the water in gelatine and incubating at 21° C. for 72 hours." In all but one of the four experiments the bacteria showed greater increase in the flasks with mosquito larvæ. This increase might easily have been due to the introduction of further bacteria together with the mosquito larvæ, although it finds its readiest explanation in the organic substances discharged by the larvæ. The experiments are inconclusive as they were carried out under artificial conditions and as, furthermore, it is impossible to avoid all sources of error. The fact that the larvæ of different species differ in feeding habits also must not be lost sight of as it will affect the bacteria.

There is great diversity in the behavior of mosquito larvæ. Some live almost wholly at the surface of the water, others at the bottom, while many rise and descend—seeking their food along the bottom and being obliged to come to the surface for air. The larvæ of *Anopheles* normally remain at the surface. They lie with their bodies extended straight and locked to the surface film by the chitinous flaps surrounding the sessile breathing-tube and by the stellate tufts of the abdominal segments. When they move they do so in very rapid jerks, either along the surface, or, when alarmed, descending into the water. When the *Anopheles* larva is at rest its body is always extended in a straight line and this gives these larvæ a curiously rigid appearance which is very characteristic. The head is very motile and in feeding its ventral side is usually turned upward, while the mouth-brushes, in constant vibration, produce a current which brings floating particles to the mouth.

The larvæ of other mosquitoes progress through the water with a peculiar snake-like motion, most marked in the species with the longest bodies, such as *Aëdes calopus* and *Aëdes triseriatus*. The movement is a lashing one; the body is bent in the shape of a letter " S " and lashed from side to side. Certain larvæ can also be seen, at times, progressing merely by the action of the mouth-brushes. In the former case the larva progresses through the water backwards, in the latter case it moves head foremost.

The larvæ of many *Culex* and *Aëdes* feed mostly while suspended from the surface film by the end of the breathing-tube, obtaining their food by the action of the mouth-brushes. Other larvæ feed at the bottom and only come to the surface at intervals to obtain air, this interval differing with the species. Some, indeed, never rise to the surface and obtain the necessary oxygen from the water by osmosis, or, in the case of *Mansonia*, from the vascular roots of aquatic plants.

The attitude, when suspended from the surface film, differs with the species. *Uranotænia* maintains a horizontal body-position and this, together with the similarity in the shape of the head, produces a resemblance to *Anopheles* which has often proved deceptive. The larva of *Culex territans* holds its body in a nearly horizontal position when suspended from the surface film, but the long perpendicular breathing-tube and the broad deflexed head give it a characteristic appearance. Other species suspend themselves with their bodies at more or less of an angle. In certain species of *Aëdes* the body hangs nearly straight down.

Certain larvæ feed altogether at the bottom and only come to the surface at long intervals. Such is the case with many species of *Aëdes*. *Wyeomyia* and other sabethids are bottom feeders and are busy most of the time working over the rubbish at the bottom of the breeding-places; they seem to require but little air and never remain suspended from the surface film for any length of time. The larvæ of certain species of *Culex* lie upon the bottom back downward, anchored, so to speak, by a pair of hooks at the tip of the breathing-tube; the head is somewhat deflexed and the large mouth-brushes procure the food; they rise at intervals for air. *Psorophora discolor* has a larva of very similar habits; however, it never comes to the surface, procuring oxygen from the water by means of the highly developed anal gills.

The predaceous larvæ can not be said to hunt their prey. They remain quiescent until a larva comes within reach when they seize it with great rapidity.

One of their own kind is as likely to fall a prey as any other species and in fact the confinement of several of these larvæ in a narrow compass usually ends in the destruction of all of them but one.

HIBERNATION OF MOSQUITO LARVÆ.

The continuous breeders, such as *Anopheles* and certain species of *Culex*, develop while temperature conditions are favorable. Cold weather puts an end to their activities and the larvæ are destroyed by the freezing over of the water, or perhaps even before. However the larvæ of certain species normally hibernate. This is the case with the pitcher-plant mosquito, *Wyeomyia smithii;* the larvæ survive the complete freezing up of the water in the leaves of the plant and complete their development the following season. The larvæ of a few other species of the eastern United States hibernate regularly although they do not withstand actual freezing; these larvæ remain dormant at the bottom during cold weather. The tree-hole breeders *Bancroftia signifer* and *Megarhinus septentrionalis* hibernate as larvæ and the same is probably true of *Cælodiazesis barberi*. *Culex melanurus* hibernates as mature larva. The larvæ live in spring-holes in swamps or in the woods and the last brood appears very late in the season. They remain at the bottom during cold weather, and do not produce the imago until the following April or May.

All the foregoing species, with the exception of *Wyeomyia smithii*, may be said to be rare and the larvæ are not generally in evidence. The observations of Galli-Valerio and Rochaz de Jongh, in Switzerland, show that in Europe the larvæ of certain species of mosquitoes hibernate in great numbers. Thus it appears that the larvæ of *Anopheles bifurcatus* hibernate normally, remaining in hiding among the leaves of water-cress (*Nasturtium officinale*) and other aquatic plants. In the case of *Culiseta annulatus*, which was observed in a water-barrel in an open field, even pupæ continued to appear throughout the winter at temperatures but little above freezing. These observers found that larvæ of *Anopheles* and *Culex* (?) survived in the thin layer of water between two sheets of ice. These observers also found that the larvæ of *Aëdes nemorosus* occur during the winter in great numbers. On December 2, 1906, they found great numbers of these larvæ in an ice-covered puddle. This puddle had a depth of five centimeters and an area of six square meters and they calculated that it contained about 3,750,000 larvæ. The larvæ in these puddles did not increase in size during the winter; early in April they finally began to grow and transformed to pupæ towards the end of that month. From another observation by these investigators it appears that such larvæ are hatched from eggs in midwinter. Thus they found on January 15, 1902, great numbers of very small larvæ in a puddle thickly covered with ice; this puddle had been dry between December 1 and January 1 and had, as the result of warm weather in early January, afterward filled with snow-water. This last species, then, may be classed with those species of *Aëdes* the larvæ of which elsewhere appear in the snow-water of early spring.

THE PUPAL PERIOD.

The pupæ of mosquitoes are aquatic. They are active and extremely sensitive to external stimuli. With most species the natural position is at the surface of the water, where they take in air by means of the two thoracic respiratory trumpets. Upon the slightest alarm they go down into the water; they progress rapidly by powerful strokes of the abdomen which is furnished at the apex with paddle-like organs for this purpose. While the specific gravity of the larvæ is greater than the water, so that they sink when not held by the surface film, the pupæ are usually much lighter than the water. Vigorous strokes with the abdomen are required to carry the pupa down into the water and as soon as its exertions cease the pupa rises to the snrface—unless, indeed, as is often the case, the pupa gets under some object or holds fast by clasping with its abdomen. Towards the period of eclosion the pupa grows rapidly lighter, so that, towards the last, it can hardly go down. As we have shown in our discussion of the ecdysis of the imago on a previous page, this increase in buoyancy is intimately connected with the process of eclosion.

The pupæ of some species are much lighter than those of others. Thus the pupa of *Aëdes atropalpus* is of about the same specific gravity as the water. When after going down into the water a certain distance, it ceases its efforts it remains stationary, neither rising nor sinking.

The pupæ of *Mansonia* are exceptional in that they do not, like the others, rise to the surface for air, but attach themselves to the roots of aquatic plants.

The thoracic breathing-tubes of the *Mansonia* pupa are pointed apically; by inserting them into the vascular roots of aquatic plants the pupa obtains the necessary air from the plant. The process of eclosion of the imago has not been observed in *Mansonia.*

The pupal period of mosquitoes is brief, in many cases by far the shortest period of the mosquito's life. It varies with the species and with the temperature. In the case of the very rapid breeders, such as *Psorophora,* it may be less than a day. Ordinarily it is a matter of two or three days, and the period is prolonged by low temperature. It appears that the large forms, like *Megarhinus,* have the longest pupal period, even under favorable conditions as much as five or six days.

NATURAL ENEMIES.

The subject of the practical use of natural enemies of mosquitoes is considered in the section of "Remedies." As virtually the only natural enemies of mosquitoes which can be used practically are fish, a rather full consideration of fish will be found in that portion of this work, and is omitted in this present treatment.

PLANTS.

At least two groups of herbaceous plants contain mosquito destroyers. The bladderworts (Lentibulariaceæ) of the genus *Utricularia*, living in water, have little bladders which trap small aquatic animals. The bladders have each a valve-like door through which the animals enter when looking for food or when trying to escape from their natural enemies. Darwin, in his work on insectivorous plants, cites observations made by Mrs. Treat in New Jersey with *Utricularia clandestina*. It was found that larvæ, probably those of mosquitoes, when "feeding near the entrance, are pretty certain to run their heads into the net, whence there is no retreat. . . ." Fully nine out of every ten bladders contained these larvæ or their remains. The species which grow in stagnant waters have the most effective bladders. Mosquito larvæ inhabiting stagnant pools in which the *Utricularia* grows are quite often entrapped in this way.

Recently J. H. Hart has kept under observation a species of *Utricularia* which occurs in pools at the Pitch Lake in the island of Trinidad. He found dead mosquito larvæ in the bladders and also newly caught ones struggling for freedom which afterwards succumbed. Eysell gives photographic reproductions of *Utricularia* with mosquito larvæ in the bladders.

Ernst Krause * has called attention to the presence of *Utricularia*, in Brazil, in the water accumulations between the bases of the leaves of bromeliaceous plants, and as these water accumulations have since been shown to be fertile breeding-places for certain species of mosquitoes, it is very probable that the *Utricularia* here exercises a certain degree of mosquito control.

Another Brazilian bladderwort, *Genlisea ornata*, is said by Dr. Adolf Eysell to capture mosquito larvæ. He compares the tubular leaves of this plant to an eel-trap.

According to the same author a member of the sundew family (Droseraceæ), which grows submerged, captures mosquito larvæ. This is the *Aldrovanda vesiculosa* of southern Europe and the adjacent warm countries, the leaves of which have a structure and function similar to that of the well-known Venus's fly-trap (*Dionea muscipula*), its leaves closing quickly upon any insect that touches them.

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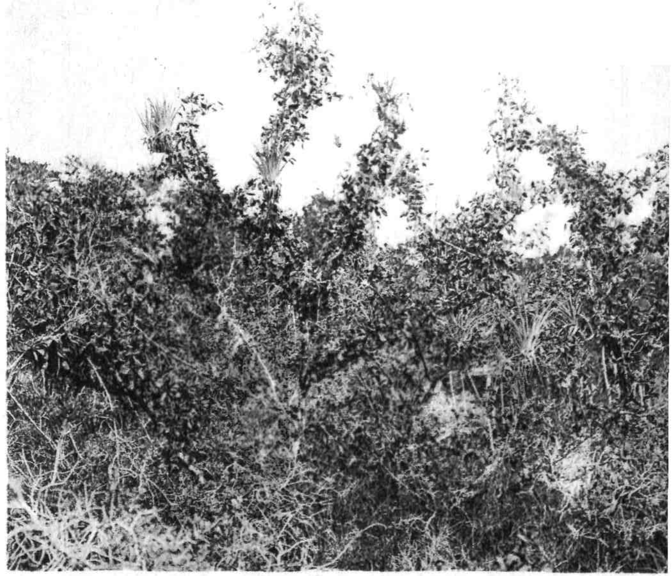
* Die Schutzmittel der Blüthen gegen unberufene Gäste (Kosmos, 1887, vol. 1, p. 80).

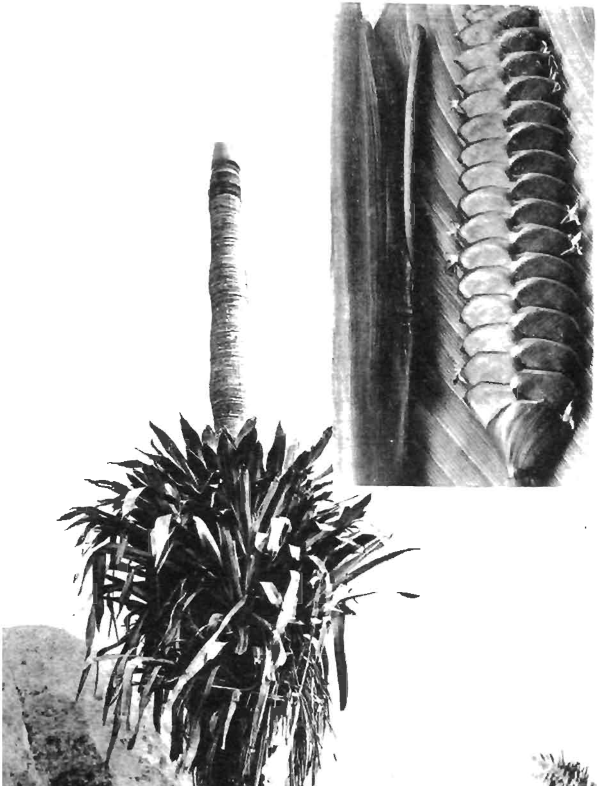
1. Heliconia champneiana *Griggs*. Eastern Guatemala.

2. Bromeliads. Córdoba, Mexico.

1. Heliconia champneiana *Griggs.* Eastern Guatemala.



2. Epiphytic Tillandsia. Florida Keys.



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1. Flower-spike of Calathea. Eastern Guatemala.

FUNGI AND BACTERIA.

Thaxter has recorded attacks on adult mosquitoes by the fungus known as *Entomophthora sphærosperma*. It reaches Diptera generally, but is especially noticeable with the mosquitoes. Another fungus (*Empusa culicis*) also destroys mosquitoes in both Europe and America. Thaxter also states that *Empusa papillata* destroys small gnats (probably mosquitoes among them). The eggs of *Psorophora howardii* were found in the summer of 1901 to be covered with a fungous growth which has been determined by Mrs. F. W. Patterson, of the U. S. Department of Agriculture, to belong to the genus *Polyscytalum*.

A most interesting instance of the destruction of mosquitoes by *Entomophthora* is described by Mr. R. H. Pettit in Special Bulletin No. 17 of the Michigan Agricultural Experiment Station (see pl. VII, fig. 2).

"On August 5, Mr. Barlow found a number of adult mosquitoes killed by a fungus, *Entomophthora* sp. nov. They were very numerous on the margins of one of the pools in the north woods, sometimes almost covering the soil and the pieces of bark to which they clung. Some were just killed and showed little, if any, external growth, and some were covered with a dense dull white growth. All were within a few inches of the water and all faced away from it. Imagine thousands of mosquitoes all headed away from the water as if they were trying to get away from it.

"It would seem that the effect of the disease is to draw the affected insects to the water, possibly by creating a thirst, after slaking which the insects, in trying to retreat, are caught and stopped in their course by numerous rhizoids or anchor ropes which are sent out by the fungus in the body to fasten the victim permanently to the place where its ill luck overtakes it. Unfortunately for the mosquito host, the diseased individuals die just in the right place to infect their fellows as they go to the pool to drink or to lay eggs. This is a case where the fungus seems to influence the host in such a way as to lead to the spread of the disease. *Similar impulses seem to be induced in the case of other species—the Sporotrichum* that is used against chinch-bugs seems to impel the diseased individuals to hide under clods or in other moist and protected places, just the places where the young bugs come to shed their skins or to molt. This is of course the best possible way to spread the disease. Then, too, in the case of the common grasshopper disease, *Empusa grylli*, the dying hoppers are impelled to climb to the tops of weeds and plants, and as the fungus throws its spores to some distance, there is a good chance that some of them will fall on the bodies of other grasshoppers.

"The appearance of the mosquito fungus is quite characteristic. The entire body is swollen and covered with a dull white growth, sometimes almost plumbeus. The body is fastened down by many slender brownish ropes. A microscopic examination shows the growth to be made up of fine threads (mycelium) bearing spores at their distal extremities. These threads are usually simple, though sometimes bearing a few short branches. They are septate at long intervals, granular, and contain vacuoles. The spores are lunate, bluntly rounded at both ends. In size they measure about 50 microns long by 13 in diameter, some being as long as 55 microns and a few as short as 28 microns. They are finely granular, with oil globules usually near the ends. In a single specimen large numbers of resting spores were found. In this case the mycelium had largely disappeared. The resting spores were spherical, hyaline, with many small translucent interior globules. They measured from 40 to 44 microns in diameter.

"The fungus also was found at the same time on several specimens of Muscidæ, on a *Chironomid,* and on *Diplax,* probably *D. rubicundala.* Attempts were made to introduce the disease into new regions, but with little success. In the laboratory, a large piece of bark bearing mosquitoes killed by the disease was placed in a cage with many mosquito larvæ and pupæ. A few adults died after emerging but not nearly all of them.

"On August 7, a number of pieces of bark covered with mosquitoes killed by the fungus, were placed on the margins of a pool in the river woods. The disease had not previously appeared in that section. On August 13 a few dead mosquitoes were found near the place where the infection was made. On August 23, the disease was widespread throughout these woods."

Marchoux, Salimbeni and Simond found that in Brazil the yellow-fever mosquito (*Aëdes calopus*) was the bearer of several fungi. These fungi they found to be very abundant at certain seasons of the year. These parasites not only invade the digestive tract but also the body-cavity, in that case causing the mosquito's death.

Perroncito found a bacterial parasite in *Anopheles* in Italy. This parasite proved pathogenic, in fact it was the mortality it caused among mosquitoes that led to its discovery. The parasite infests the larvæ and finally destroys the mosquito soon after it has transformed to adult.

Dyé, in 1904, in an excellent summary on the parasites of mosquitoes, discussed the yeasts found in mosquitoes as follows:

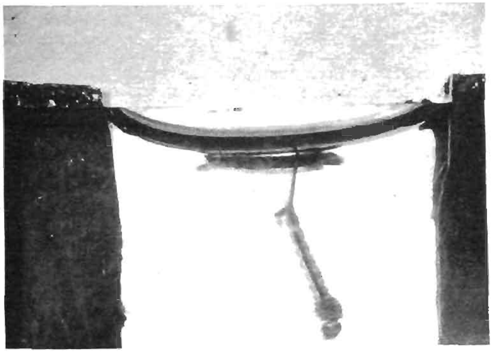
"We ought to give some words to the yeasts found by several authors in mosquitoes.

"In October, 1900, Laveran announced a case of an yeast parasitic on Culicidæ. This author has observed, in sections of *Anopheles maculipennis,* the existence of an yeast in the cœlomic cavity of mosquitoes coming from Rio-Tinto (Spain); they had sucked malarial blood and had been well preserved in absolute alcohol. According to Laveran this yeast presented the appearance of minute ovate elements, measuring from 2 to 5 μ in length; a certain number of these cells had at one extremity a small bud; each one of them possessed a nucleus which was readily stained by the process of Heidenhain.

"The greater part of the yeast cells are free in the cœlomic cavity, or they are grouped in small masses. In a number of longitudinal sections of these *Anopheles* Laveran saw clearly that this yeast passes through the epithelium of the walls of the digestive tube and falls into the cœlomic cavity.

"This yeast appears to be pathogenic for the mosquito; in fact, following the observations of Laveran, Dr. Macdonald of Rio-Tinto investigated systematically these small cell-elements which he succeeded in finding again. He noted, moreover, that the larvæ of *Anopheles* die rapidly at the season of the year at which one finds the *Anopheles* infested by the yeast described by Laveran. Hence it is probable that the yeast is transmitted from the larva to the adult insect, as in the case of the parasitic fungi of Culicidæ observed by Perroncito.

"Marchoux, Salimbeni and Simond also have observed yeasts in most of the *Stegomyia calopus* which they had occasion to examine in the course of their investigations on yellow fever. They found them particularly in mosquitoes dissected soon after their emergence: they exist in abundance, especially in the cœlom of the mosquitoes, in individuals fed with honey, with fruits and with sweet substances. These authors note that these yeasts differ according to the character of the food of the insect.



1. Anopheles and Culex larvæ in natural position in water.

2. Adult mosquitoes destroyed by fungus.

"Contrarily to the fungi, announced previously by the same authors, these yeasts do not become pathogenic to the culicids; neither can one, according to them, attribute any rôle whatever in the aptitude of *Stegomyia calopus* for transmitting yellow fever.

"Nevertheless the study of these yeasts is not devoid of interest: the spherical or irregular masses formed by these yeasts, which one encounters in the large air-sac of the culicid, may be easily taken, upon superficial examination, for sporozoans, and the authors are not far from supposing, as we shall see farther on, that these yeasts were taken by the Americans Parker, Beyer and Pothier, for one of the stages of the parasite which they described under the name *Myxococcidium stegomyiæ*. It is well to indicate, now, the possible errors of interpretation to which the encountering of these yeasts, parasites of culicids, can give place.

"Schaudinn, in his remarkable work, interprets in a wholly individual manner the rôle of these yeasts, which he nearly always found in the diverticula of the stomach (air-sac, sucking stomach, food reservoir) of the numerous culicids which he dissected in the course of his beautiful researches. According to him these yeasts have a purely physiological rôle: by his investigations he has been led to conclude that the irritating effect of the bite of *Culex* is due, not alone, as it had been thought up to now, to the saliva secreted by the salivary glands, but as well to the combined action of gas and diverse products, secreted by the yeasts of the œsophageal diverticula. We will not follow the author in his very concise demonstration of this rôle of the yeast parasites in any physiological way; we have only to mention this original interpretation in passing, which shows us how much all these questions of the parasites of culicids need to be seriously studied. We see in fact, on the subject of these yeasts of the stomach of the mosquito, three authors, studying them successively in different countries, Schaudinn in Germany, Parker, Beyer and Pothier in Mexico, Marchoux, Salimbeni and Simond in Brazil, and each one of them attributing a totally different interpretation from the viewpoint of their parasitic rôle."

ANIMALS.

PROTOZOA.

Parasites of mosquitoes belonging to the Sporozoa and Flagellata have been described by many authors. Among the Sporozoa are Myxosporidia, Hæmosporidia and Gregarinæ. To the Hæmosporidia belong the malarial and other blood parasites of mammals and of birds. These are grouped in the family Plasmodidæ and, as is well known, have a life-cycle which necessitates two hosts. The agamic phase is passed in the blood of a vertebrate, the sexual phase in some blood-sucking insect. These parasites are discussed in a later chapter, in connection with malaria (p. 188). A nearly related group of Hæmosporidia is the family Hæmogregarinidæ, a large proportion of which live in cold-blooded animals (reptiles, batrachians and fishes) but also some in warm-blooded animals (mammals and birds). It was in a species of this group, an *Hæmoproteus* from the crow, that MacCallum was the first to prove the existence of sexual phases in the Hæmosporidia. Several Hæmogregarinidæ are known to be transmitted by mosquitoes. According to Schaudinn, *Hæmoproteus noctuæ*, a blood-parasite of owls, is transmitted by *Culex pipiens*. Another species, *Hæmoproteus danilewskyi*, and probably still other species, all living in the blood of birds, conjugate and undergo sporogeny in mosquitoes. Before leaving these blood-parasites it should be stated, however, that Dr. Fritz Schaudinn, in 1904, expressed his belief that the parasite of malaria and also a trypanosome and a spirochæte might be hereditary in mosquitoes.

A spirochæte was found to be an abundant parasite of mosquito larvæ by Jaffé. It was described by him as *Spirochæta culicis* and is a relatively large species, its length being from 10–20 microns. It occurs in the digestive tract of the larva of an undetermined mosquito; in the vicinity of Berlin as many as 90 per cent of the larvæ were found infested. Very rarely the parasite was also found in the imago, in the malpighian tubes. Its mode of reproduction is unknown. The Sergents have found a similar organism in the larva of *Anopheles maculipennis* in Algeria. Patton has determined that in India *Spirochæta* occurs in mosquitoes in great numbers.

The Gregarinæ are perhaps the most abundant protozoan parasites of insects. They have been observed as parasites of mosquitoes by various authors. Ronald Ross found gregarines in mosquito larvæ at Secunderabad. Léger and Duboscq, in Corsica, found a gregarine, which they assign to *Diplocystis,* in a mosquito larva. The French investigators at Rio de Janeiro found gregarines in adult *Aëdes calopus.*

The French Commission at Rio de Janeiro, in its first memoir, gave a description of a microsporidian parasite of the yellow-fever mosquito which they called *Nosema stegomyiæ* and frequently met with in this mosquito. In their early researches the manner by which the mosquito becomes infected with this parasite escaped them, but later they determined that the ordinary method is by heredity, and this is stated in their second memoir, published in the Annals of the Pasteur Institute, vol. 20, January, 1906. They show that with females strongly infected with *Nosema* these reach the ovary and penetrate the eggs. The egg parasitized in this way does not always die, and when it develops with the spores in its interior it gives birth to an infested larva. Larvæ carrying the parasite are easily recognized from the beginning of their development by a microscopical examination. The parasite attacks particularly the transparent vesicles situated near the anus, and in the interior of these vesicles they can be distinguished either in the developing stage or the sporulating stage. Later the digestive tube and the other organs are infected, and the larva is killed by the development of the parasite. The mortality of larvæ brought about by the parasite appeared to be considerable, but there was almost none with the perfect insect. The investigators were able to bring about a direct infection of larvæ by taking the spores of the *Nosema* from other larvæ or from adult mosquitoes and mixing them with their food. They remark that this is not surprising, since with Lepidoptera, parasites of the same group are easily transmissible to caterpillars by the ingestion of spores, while hereditary transmission occurs at the same time. The occurrence of this parasite in the yellow-fever mosquito has no relation with the transmission of yellow fever; but the investigators thought the knowledge of its hereditary propagation none the less interesting, and it induced them to carry out studies concerning the possibility of the hereditary transmission of the organism of yellow fever. These are discussed in our section on yellow fever.

Various flagellate Protozoa have been reported as parasites of mosquitoes. These forms do not require an intermediate host. They may be transmitted hereditarily by breaking through the digestive tract and, invading the body-cavity, entering the eggs of the insect. One of these forms has been described by Léger as *Crithidia fasciculata,* as an intestinal parasite in *Anopheles maculipennis* in France. Novy, MacNeal and Torrey report the same form from *Culex* in Michigan. The brothers Sergent have described a form of *Herpetomonas* (*H. algeriense*) from females of *Culex pipiens* and *Aëdes calopus.* Ronald Ross, Chatterjee, Léger, Patton and Stephens and Christophers have found similar parasites in mosquitoes. A form described by Novy, MacNeal and Torrey, from various mosquitoes occurring about Ann Arbor, Michigan, as *Trypanosoma culicis* is now referred to the same genus. There appears to be some reason to believe that the genera *Herpetomonas* and *Crithidia* represent merely different phases of the same organisms and that the same forms have been described in both genera.

Giles, in India, found a stalked infusorian attached in numbers to mosquito larvæ. In the second edition of his " Gnats or Mosquitoes," p. 151, he says:

" I have repeatedly found every larva in a pool simply covered by these parasites, which lie crowded together in enormous numbers, attaching themselves especially to the softer parts of the integuments, such as the angles between the anal tubercles, and the soft membranes between the segments. Larvæ affected in this way have a peculiar, slimy appearance, and seldom appear healthy, though it is difficult to see how these ecto-parasites can be harmful, unless it may be that being, at the very least, greedy mess-mates, they may appropriate to themselves an undue share of the food that would otherwise fall to the share of their hosts. Nevertheless, I strongly suspect that they may be the cause of the inexplicable disappearance of larvæ, already alluded to, from situations where they were just before present in abundance."

Vorticellids have also been often found upon mosquito larvæ in this country. H. P. Johnson, in an appendix to Smith's report for 1902, states that he frequently found beautiful clusters of these creatures on the thorax, abdomen, and even the head of the larvæ of *Culex pipiens.* He states that they may be so abundant as to give the thorax especially a whitish gelatinous appearance to the naked eye. He believes that it is unlikely that these vorticellids do the larvæ any harm, and that the latter simply afford them an attachment and transportation; possibly also food, brought by the vortex which the mosquito larva creates in the water. In fact vorticellæ are very common on larvæ in open pools. The only harm we ever saw done by them was in the case of an *Anopheles* larva observed by one of us (Dyar); this was so loaded with *Vorticella* that it could not turn its head to feed properly and eventually died.

OTHER LOWER ANIMALS.

The common fresh-water hydras (*Hydra viridis* and *Hydra fusca*) will destroy mosquito larvæ that come within reach of their tentacles. One of us

(Dyar) has seen a *Hydra*, accidentally introduced into a breeding-jar, kill a mosquito larva. When *Hydra* is abundant, as it sometimes is in ditches and small ponds, it may become to some extent a check upon mosquitoes.

VERMES.

Martirano has described a minute trematode (*Agamodistomum martiranoi* Stiles, 1903) found in the body-cavity of *Anopheles maculipennis* in Italy. Grassi, in his "Studi di uno zoologo sulla malaria" (edit. 1901, p. 197) states that both in the pupa and the imago of *Anopheles* a trematode is found encysted, and most likely this is identical with the form observed by Martirano. Since then these "*Distomum*" forms have been further studied. They have been most intelligently discussed in a recent paper by Alessandrini, who throws some light on their life-cycle. He believes that these distomi are the larval form of *Lecithodendrium ascidia* (v. Beneden), a common parasite of the European bat (*Pipistrella europæi*). The bats are infected by eating mosquitoes which contain the *Distomum* encysted; the mosquito larvæ become infected in turn from the fæces of the bat, containing *Distomum* eggs, being dropped into the water. The eggs hatch in the water and the larvæ of the *Distomum* enter a mosquito larva and become encysted. These distomi are usually found in cysts on the walls of the stomach or œsophagus of the imago, but sometimes they occur free in the body-cavity. Alessandrini thinks that the *Distomum* described from *Anopheles* by Schoo is the same as that of Martirano. On the other hand, he considers a *Distomum* found in *Anopheles* by Ruge to be the larva of a form (*Distomum globiporum*) described much earlier by Linstrow from a snail (*Limnæa ovata*) and which becomes the intestinal parasite of a fish.

Nematode parasites of mosquitoes were observed in Europe by Stiles as early as 1889 and were at that time already known to Professor Leuckart. However, no record of them appeared until the same or a similar form was discovered in this country, in 1902, by Dr. J. B. Smith. This parasite was described by Dr. Stiles as *Agamomermis culicis*. In this connection Dr. Stiles discussed the European forms as follows:

"In the summer of 1889 I collected a number of specimens of *Agamomermis sp.* from mosquitoes of the species *Culex nemoralis* taken in the vicinity of Leipzig, Saxony. Whether they were identical with the present form I am unable to state. The interesting fact may be mentioned, however, that the Leipzig *Agamomermis* was decidedly injurious to the mosquitoes. It was found in the abdominal cavity of larvæ, pupæ, and adults, so that infection must have taken place in the water, namely, in the larval and pupal stages of the *Culex*. The infested insects were very sluggish in their movements and could usually be easily recognized as diseased. Many of them died from the effects of the parasite, and the ovaries of infected females were underdeveloped. Professor Leuckart informed me at that time that he had frequently found *Culex nemoralis* infected with this worm, and that during the years that the worms were most common the mosquitoes seemed to be less numerous."

Agamomermis was first found by Dr. John B. Smith in the course of his early New Jersey work, while examining the females of *Aëdes sollicitans*, in order to determine the development of the ovaries. He saw a strange enlargement of the alimentary canal, and on one occasion, tearing the abdomen in two, he found that this enlargement contained two worms. These were the types of Stiles's *Agamomermis*. In 1903, examining a large series of *sollicitans*, Smith found a considerable number of adults infested by these worms, and from that time on he made careful examinations of all material that came into his laboratory. The result was that every collection, from the Raritan River to Cape May, was found to be more or less parasitized. None, however, were found on the Newark or Elizabeth marshes. The records made by Mr. Viereck at Cape May, and published in Smith's report on the mosquitoes of New Jersey, although incomplete as omitting the month of August, are very interesting in showing the proportion of infestation:

"Date.	Number of specimens taken.	Number parasitized.
June 25	113	3
July 1	148	15
" 10	151	88
" 27	137	10
" 31	309	112
Sept. 13	100	50
" 14	100	39
" 17	77	16
" 18	62	2
" 21	100	8
" 22	100	1
" 25	82	2"

In Doctor Smith's opinion, this roundworm is a very material check to the multiplication of *Aëdes sollicitans*, for in no case where a parasitized specimen was examined were the ovaries developed. Several of the worms will sometimes occur in a single adult mosquito, completely filling the body-cavity. As abundant, however, as the parasites were they did not reduce the mosquitoes appreciably even in those localities where they were most abundant. But it must be remembered that any such reduction would not become apparent until a later generation of the mosquitoes. The life of the adult is probably shortened to some extent by the parasite, which does not, however, prevent migration, since parasitized mosquitoes were taken far inland. Neither does the presence of the parasites prevent the mosquitoes from feeding, for Doctor Smith killed infested specimens that had actually bitten him. In fact, he sat for an hour one afternoon at Anglesea, capturing such specimens as came to bite, and found that nearly or quite one-half were infested.

Doctor Smith also records the fact that in 1902 one of his assistants, Dr. H. P. Johnson, found the young of an intestinal worm in an *Anopheles* larva.

E. Gendre has recently found a similar larval nematode parasite, at Labé in French Guinea, infesting the larvæ of the yellow-fever mosquito (*Aëdes calopus*). The worms were always found in pairs, one large and one small, and inhabited the general body-cavity of the mosquito larva, rolled up in the thorax. The mosquito larvæ, while they were growing, did not appear to suffer from the presence of the parasites but retained their appetite and vivacity. No injurious effect was apparent until the larvæ were about to pupate; then the worms, having probably completed their parasitic stage in the mosquito, leave the host. They break forth from the posterior end of the body by perforating the membrane surrounding the anus. The larger worm leaves first, the smaller following a little later, and the mosquito larva dies as a result of the injuries. The *Mermis* larvæ died some hours after leaving their host. In one catch all the mosquito larvæ were infested, but parasitized lots of larvæ were rare; only two out of 26 lots were infested and these came from water in trees. No parasites could be found in adult *Aëdes calopus* and Gendre considered the infestation accidental.

INSECT ENEMIES.

Many insects and nearly all of the predatory aquatic forms that are able to master mosquito larvæ, will feed upon them and they form an important article in the diet of many species. Most of these carnivorous insects, however, are not prolific breeders, and they seldom deposit their eggs except in rather permanent pools; as a consequence their importance as mosquito destroyers is not so great, though nevertheless considerable. Mosquitoes breed practically unmolested in artificial receptacles for rain-water and in transient pools.

The larvæ of the predatory water-beetles of the families Dytiscidæ and Hydrophilidæ eat many mosquito larvæ, although from their great activity these often escape and the beetle larvæ derive the greater part of their subsistence from other forms.

Dr. W. E. Britton, of New Haven, Conn., who has made careful study of the mosquito problem in Connecticut, has found that the larva of *Hydrophilus obtusatus* Say (Schwarz det.) is one of the important natural enemies of mosquito larvæ in the vicinity of New Haven.

One of us (Howard) has recorded an observation in the course of which he took a half gallon of water from a stagnant pool which was teeming with aquatic insects, including hundreds of mosquito larvæ. Among these insects were three Hydrophilid larvæ and in the course of a week these three larvæ devoured practically all of the other animal life in the jar in which the half gallon of stagnant water had been placed.

Dr. J. B. Smith thinks that the larvæ of the Dytiscidæ are among the greatest enemies of mosquitoes. He is inclined to attribute the comparative freedom from mosquitoes of the hilly section of New Jersey very largely to these insects, and he quotes an interesting observation by Doctor Johnson in support of this conclusion. He also notes an observation by Mr. Viereck in which one good-sized dytiscid larva was seen to devour 434 mosquito larvæ in two days. Galli-Valerio and Rochaz de Jongh found that an adult water-beetle, *Dytiscus marginalis,* although it had been previously fed with meat, destroyed great numbers of mosquito larvæ and pupæ. Dr. Adolf Eysell states that a single, nearly full-grown, larva of *Acilius sulcatus* destroyed more than forty mosquito larvæ over night.

Dr. Smith states that the Gyrinidæ or so-called "whirligig beetles," which live nearly wholly at the surface of the water, are great destroyers of mosquito larvæ;

he asserts that "no *Anopheles* larva has a chance in any bit of water inhabited by them. . . . Their surface habit and their tendency to get near the edges make them especially dangerous to *Anopheles* larvæ, which absolutely fail to maintain themselves within the range of these beetles." The larvæ of the Gyrinidæ are also predaceous but live at the bottom and no observations of their preying upon mosquito larvæ have come to hand.

Dr. Eysell dwells upon the efficiency of aquatic Hemiptera as mosquito destroyers. He states that of the forms living beneath the water *Nepa, Ranatra, Naucoris, Notonecta* and *Corixa* destroy great numbers of mosquito larvæ. The forms living upon the water-surface, like *Limnobates* and *Hydrometra*, destroy emerging imagos or females in the act of depositing eggs.

In German New Guinea, Drs. Dempwolff and Wendland, in the course of their malaria work, found that waters which contained many *Notonecta* harbored no mosquito larvæ. This led them to introduce these insects into the 17 water-tanks of an European settlement with the result that within a week the mosquito larvæ had all disappeared from the tanks and the number of mosquitoes inside the houses was considerably diminished. Further experiments with *Notonecta*, initiated with mosquito-breeding pools, gave no practical results on account of the rapid drying up of the pools.

Doctor Smith also gives observations upon several aquatic bugs, indicating that *Notonecta, Nepa*, and *Ranatra* are effective enemies of mosquito larvæ but that, owing to the fact that they occur chiefly in permanent waters, their usefulness is restricted. He quotes an interesting observation by Mr. Viereck, as follows:

"The early stages of *Ranatra fusca* were destructive to wrigglers. With their raptorial legs they nip the larva near the breathing tube, then either drop or suck it. Quite a number were nipped and dropped, and, once dropped, they rose no more. Pupæ, both of *Anopheles* and *Culex*, were expert in evading the grasp and were not readily caught. In less than an hour three *Ranatra* killed and sucked ninety-eight larvæ. It is a question whether *Ranatra* would be useful in stagnant pools, because the specimens used in the experiment could only be found in the clear water of a lily pond where, no doubt, they controlled the *Anopheles;* but when put into the stagnant water which *sollicitans* inhabits, they died."

Dragon flies feed upon flying mosquitoes, and their larvæ feed upon mosquito larvæ and pupæ. This propensity of dragon flies is so well known that in some sections of the country they are popularly termed mosquito hawks. The late Dr. R. H. Lamborn, of New York City, was so impressed with the voracity of dragon flies, from observations made while engaged in railroad building in the swampy forests around the head of Lake Superior, that, in 1889, he offered three prizes for the best essays on the mosquito and the house fly. These essays were to include observations and original investigations regarding methods of destroying the mosquito and the house fly, observations and experiments to best accomplish the artificial multiplication of dragon flies to breed them in large numbers, and to include an estimate of the cost of producing them by the thousand. How feasible his plan seemed, not only to himself, but even to as experienced an entomologist as Doctor P. R. Uhler, of Baltimore, appears in the following letter from Doctor Uhler to Doctor Lamborn, written in 1889, just before the prizes were offered:

"Permit me to say that you have taken hold of one of the hobbies of my young manhood, in which I have never ceased to take an interest, and that is the development of the Odonata in our rivers and marsh ditches to such an extent as to greatly reduce the number of mosquito larvæ, as well as those of other pestiferous Diptera which develop in such places.

"How extensively this can be done I do not know; but as I have raised all the common forms of our Atlantic coastal plain region, I know that the dragon fly larvæ can be reared in vast numbers.

"Of course, you know that each locality supports its own species, and the *forms which develop in the brackish drains and pools near tide, where they are* covered twice each day by salt water, cannot flourish in fresh water. Accordingly, for the littoral belt from Long Island to Beaufort, N. C., I would select Diplax berenice, Libellula auripennis, and Mezothemis longipennis. For the region next inland from this, multitudes of common species could be had, such as *Anax junius, Æschna heros, Libellula pulchella, L. luctuosa, L. semifasciata,* Plathemis trimaculata, and most of the species of Diplax. In the clear streams which rush down from the hills, Cordulia, Epitheca, and Gomphus prevail. In order to raise any of the species, Cyprinodonts and all other carnivorous fishes will have to be excluded.

"I agree *with* you *that* the *mosquito nuisance* might be greatly lessened by filling the mosquito breeding waters with the larvæ of dragon flies.

"I believe this might be done by securing vast numbers of the eggs of dragon flies, protecting them until hatched, and then turning them loose in the waters where the mosquitoes breed most abundantly.

"Along the seacoast, however, most of the eggs and hibernating female mosquitoes might be exterminated by burning the grass, in early cold weather of autumn, all over the marshes.

"Permit me to say that I hope you will offer the prize, as stated in your letter, and agitate the subject quite extensively."

The letter is also of interest as indicating Doctor Uhler's idea as to the most valuable species.

The three prizes were awarded to Mrs. Carrie B. Aaron, of Philadelphia; Mr. A. C. Weeks, of Brooklyn; and Mr. William Beutenmüller, of New York City; and were jointly published in a volume entitled "Dragon Flies *vs.* Mosquitoes" (New York, 1890). The essays were all admirable and brought together a great deal of useful information on the subject of mosquitoes and mosquito enemies; but they did not solve the problem of the commercial breeding of dragon flies for the destruction of mosquitoes.

In the course of these essays, no doubts were expressed as to the value of dragon flies as natural enemies of mosquitoes, and in fact Mr. Beutenmüller quoted from an army correspondent a rather striking statement of observations indicating their effectiveness. But Doctor John B. Smith concludes from his observations that, not only do the adult dragon flies fail to lessen materially the mosquito supply, but that the dragon-fly larvæ are as little entitled to credit for effective work as are the adults. He points out that they are bottom feeders as a rule, and usually below the range of "culex," while *Anopheles* is in no danger from them. It may be mentioned, however, that one of us (Knab) has seen agrionid larvæ come to the surface of the water and seize *Culex* larvæ.

We are of the opinion that dragon flies do destroy a great many mosquitoes. While they show no preference for mosquitoes there seems to be, on the part of adult dragon flies, a marked preference for Diptera; with their great rapidity and activity, where mosquitoes are abundant, a considerable number must be destroyed by them. This must be particularly true of the large crepuscular species, such as *Æschna,* their time of activity coinciding with that of most mosquitoes. Mr. Nathan Banks tells us that, at College Station, Texas, he has observed a large dragon fly capturing flying insects in rapid succession, presumably mosquitoes, as a great many of these were flying about at the time. Mr. McAtee, at Church's Island, North Carolina, has seen a dragon fly (*Erythemis simplicicollis*) pick *Anopheles quadrimaculatus* off the weather-boarding of a house.

Certain ephemerid larvæ are active destroyers of mosquito larvæ. Foley and Yvernault found that in Algeria ephemerid larvæ are more efficient destroyers of mosquito larvæ than Dytiscidæ.

Some very efficacious natural enemies of mosquitoes are to be found in the family Culicidæ itself. The larvæ of *Psorophora, Megarhinus, Lutzia* and *Lesticocampa* are voraciously carnivorous and even cannibalistic, while the larger larvæ of *Anopheles* will attack one another and the larvæ of other mosquitoes. In a lot of larvæ of *Anopheles quadrimaculatus* and *A. punctipennis,* kept in the laboratory in a large battery jar for study by one of us, the larvæ were noticed to disappear, and one morning nine heads were found of which the bodies were gone. Nothing but mosquito larvæ were in the jar. One larva was noticed which looked as if it had two heads, but upon examination it was found that the body of one had been almost devoured aud the survivor was eating the head which was all that was left of the victim. Several larvæ were found which had been half eaten. The *Anopheles* larvæ were several times seen eating the young *Culex* larvæ. The cannibalistic tendencies of *Anopheles* larvæ have been noted repeatedly by a number of writers. The larvæ of certain species, having a restricted habitat in the water in holes of trees and between the leaves of bromeliads, are probably entirely predaceous.

Dr. Oswaldo Cruz, of Brazil, while on a visit to Washington, stated that in Rio de Janeiro *Lutzia bigotii* is used practically to destroy the larvæ of *Aëdes calopus.* The *Lutzia* larvæ are introduced into receptacles in which the *calopus* breeds and soon destroy the larvæ of this dangerous insect.

The habits of *Psorophora* in the larval stage are such as to make them very desirable inhabitants of stagnant pools. They have been frequently described, but the series of observations made at the request of one of us by Dr. W. E. Hinds, in the summer of 1901, and hitherto unpublished, will be of interest here. The following extract from Doctor Hinds' notes, treats of the feeding methods of the larvæ:

"August 16. A. M. Received a lot of *Psorophora ciliata* larvæ from W. P. Seal, Delair, N. J. They came in a large quart bottle and with them were quite a number of living *Anopheles* and *Culex* larvæ. The bottom of the bottle was literally covered with heads, breathing tubes and decaying parts of the larvæ which these big cannibals had destroyed on the way. There were no plants in the bottle.

" [I] observed one *Psorophora* attack another. It seized its victim in the thin tissue which unites the breathing tube to the body. With its own breathing tube at the surface, it held its victim firmly in spite of its wiggling in its struggle to escape, keeping it always below the surface. Of course with its advantageous hold it could quite easily keep its victim from getting a fresh supply of air and thus it was drowned. I did not see that the victim made any attempt to bite its captor, only wiggling violently. After several minutes it seemed to be nearly dead, struggling occasionally and the valves at the end of the breathing tube could be seen to frequently open and close in the water. When disturbed the victor would now swim down with its prey, soon coming to the surface again but never once losing its hold.

" Another larva came up and proceeded to assist the victor, eating off all the anal flaps of the victim. When disturbed again the second one let go but the first one held on and was taken out in a watchglass, nearly all the water removed therefrom, and examined under a compound microscope. It still held to the same place, the mandibles working far into the mouth and carrying the tissues with it but without appearing to masticate them. It was apparently sucking the juices from the victim *which was shrinking in size.*

" Another *Psorophora* was observed to take a 3/4 grown *Culex* larva by the head and swallow it whole as a snake does a frog. The whole operation did not take more than half a minute.

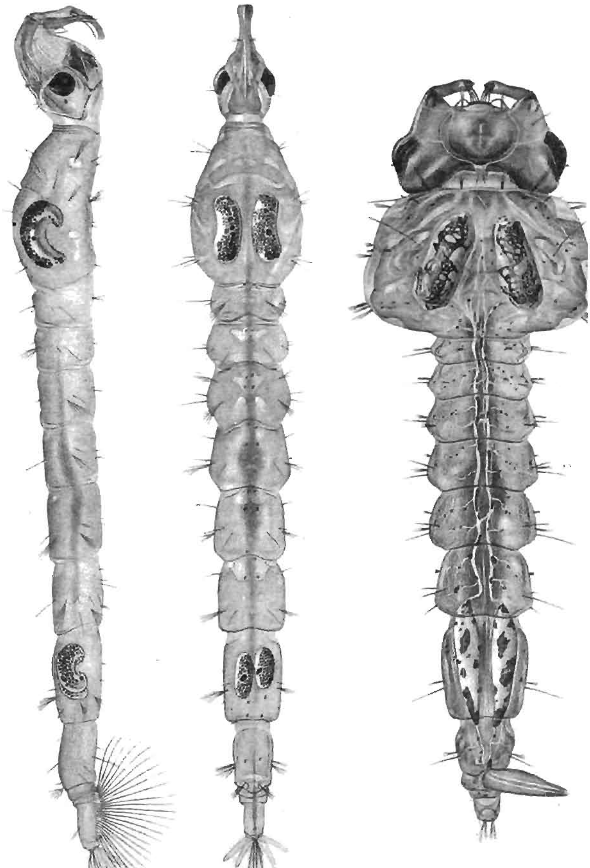
" The mouthparts are rarely moved except when attacking prey. Yesterday I saw one *Psorophora* seize a piece of water plant and bite enough to pull it along with it.

" I divided the *Psorophora* larvæ into three lots of 16 each in evaporating dishes and from a bucket of standing water back of insectary, I procured a large number of *Culex* larvæ which I put into the *Psorophora* dishes. Immediately they seized upon the *Culex* and 8 or 10 at one time had *Culex* larvæ part way down. In only one case out of many (probably 40–50) did I see a *Culex* seized tail first. It took from 2 to 3 minutes to swallow the largest *Culex* larvæ and from that to perhaps 20 seconds for very small ones.

" The method of catching is as follows: The *Culex* hang at the surface head downward while breathing. Sometimes the *Psorophora* floats along in similar position toward it, sometimes remains motionless till *Culex* comes within reach. When they have reached a position so that *Culex* hangs almost directly over the head of *Psorophora*, like a flash, before *Culex* has time to move, the *Psorophora* turns its head (its mouth is on under side) and seizes *Culex* by the head in a fatal grasp, pulling it under and, in spite of its victim's struggles, quickly swallowing it whole.

" I examined some excrement just as it came from one larva and found that it was composed of the breathing tube and the two main tracheal tubes from the body of the victim passed whole through the alimentary canal of the cannibal. From these observations on eating whole larvæ it may be inferred that practically all the heads and breathing tubes which strew the bottom of my jars by hundreds, yes thousands, have passed through the alimentary canals of the *Psorophora* larvæ.

" In the case of the *Psorophora* eating each other, the strongly chitinized breathing tubes and the cylinder around the last segment are rejected as too tough, but in the case previously observed this day fully 1/2 the length of the body posteriorly has been thoroughly chewed up and the inner soft parts ab-



1 2 3

1, 2. Larva of Chaoborus.

3. Larva of Corethra.

stracted without swallowing the chitinous epidermis. This specimen was kept for hours in a few drops of water on a watchglass, for observation under the microscope, and was very lively when put back with the others."

The predaceous habits of *Megarhinus* larvæ have been noted by observers in both hemispheres. The feeding-habits of the larva of *Megarhinus septentrionalis*, have been studied by Morgan and Cotton. Twenty-four larvæ of this species were collected by Professor Morgan in a half-barrel of rain-water and carried to his laboratory, where they were placed in beakers containing tap-water, several larvæ in each beaker. They were fed upon the larvæ of smaller species, chiefly *Aëdes calopus* and *Culex sp.* The observers stated that the *Megarhinus* larvæ swallowed the smaller larvæ bodily, but when feeding upon one another the victim was beld in the strong mandibles and slowly devoured. They made no effort to pursue their prey but remained quietly near the bottom of the water until a smaller larva approached, when it was seized with a quick movement and speedily devoured. No effort was apparently made to change the hold, whether the prey was seized near the head, near the middle or posteriorly. One *Megarhinus* was seen to seize a nearly mature larva of *Culex salinarius* near the middle, and without loosening its hold to swallow it gradually, the head and tail disappearing together. When swallowing the prey head foremost, there was much difficulty, and in one instance it took an hour to swallow one in this way, whereas usually three or four minutes sufficed.

The larvæ of the culicid subfamily Corethinæ are predaceous and some of them feed extensively upon mosquito larvæ. In northerly regions the larvæ of *Corethra* (*Mochlonyx* auct.) appear simultaneously with those of *Aëdes* in the snow-water of early spring; they prey largely, if not altogether, on these and must act as a check to some extent. The larvæ of *Chaoborus* (*Corethra* auct., *Sayomyia* Coq.) occur under more varied conditions and their food appears to consist mostly of small crustacea; they do, however, feed upon mosquito larvæ to some extent. Thus one of us (Knab) has found the larvæ of *Chaoborus punctipennis* in a temporary puddle preying upon the larvæ of *Culex pipiens*. Plate VIII, figs. 1–3, shows the larvæ of *Chaoborus* and *Corethra*.

The larva of another non-biting mosquito of this subfamily, *Eucorethra underwoodi*, has been found by W. L. Underwood to feed upon the larvæ of other mosquitoes, and this has been abundantly confirmed by other observers. On one occasion Mr. Underwood found that fourteen of these larvæ ate over night sixty out of seventy mosquito larvæ that had been placed with them. He says (Popular Science Monthly, Sept., 1903, p. 466): "When eating the larvæ of mosquitoes smaller than themselves, the victim is caught, shaken violently a few times, and swallowed in a few seconds in very much the same way that a pickerel would catch and swallow a smaller fish."

The aquatic larvæ of many nemocerous Diptera are predaceous and doubtless many of these capture mosquito larvæ along with other prey. The larvæ of certain Chironomidæ, particularly those of the genus *Tanypus* and related genera, have long been known to be predaceous. The digestive tract of certain European species has been found to contain red coloring-matter, suggesting that these larvæ prey upon the small red worms known as *Tubifex* or upon the larvæ of *Chironomus*. One of us (Knab) found that larvæ of *Tanypus dyari*, accidentally introduced into breeding-jars, were very destructive to mosquito larvæ.

A remarkable case is that of an adult fly preying upon mosquito larvæ. J. Mitford Atkinson gives an account of *Lispa sinensis* Schiner, an Anthomyid fly, which at Kennedy Town, Hongkong, was seen to be eating the larvæ of mosquitoes. On stirring up the stagnant water crowds of larvæ were disturbed. "The flies pounced down upon them and rapidly devoured larvæ almost as long as their own bodies; at times they would fly away with the larvæ in their mouths." The flies were determined by Mr. E. E. Austen.

Dr. Paul Osterhout, of Bocas del Toro, Panama, has recently observed flies of the family Dolichopodidæ, well known for their predaceous habits, to attack mosquito larvæ in a similar manner. We quote the following from his letter to the Surgeon-General of the Public Health and Marine Hospital Service: "A short time ago, in passing through the outskirts of the town, I saw a large swarm of small flies seemingly very much occupied about a small pool of water standing in a wagon track (the track had been undisturbed for several days from the appearance), so I stooped to see what the commotion was about and I saw hundreds of these small flies and thousands of mosquito larvæ. I remained for some time watching the commotion and saw several of the flies catch the larvæ and drag them to the dry earth and devour them."

D'Emerez de Charmoy, the Director of the Museum in the Island of Mauritius, has made a study of the natural enemies of the malarial mosquitoes in Mauritius. He has drawn up the following interesting table showing at a glance the results of a series of experiments which he made to determine the relative effectiveness of certain species of insects and of a small fish in destroying mosquito larvæ:

Enemies.	Number of individuals.	Number of larvæ of Anopheles in the receptacle.	Least quantity of Anopheles larvæ eaten per hour.	Disappearance of larvæ after:	
				Hours.	
Dineutes indus	3	50	16	3	Quick destruction.
Cybister desjardinsi	2	50	..	72	Indifferent destruction.
Hydaticus exclamationis	1	..	3	72	Indifferent destruction.
Libellulid larvæ	4	80	..	60	Capture with difficulty.
Nepa larvæ	1	20	..	36	
Ranatra larvæ	3	30	..	48	
Larvæ of *Culex tigripes*	4	12	..	48	
Cyprin doré (3½ in. long)	1	30	15	2	Quick destruction.

Various adult insects have been found to prey upon adult mosquitoes. Dragon flies have already been mentioned and there is no doubt that mosquitoes furnish their quota of the food captured by these insects while on the wing. In this connection the crepuscular habits of certain species of dragon flies should be noted.

In the Diptera the Empididæ are well known to be predaceous, capturing other insects upon the wing. Wahlberg, in an interesting paper on the mosquitoes of northernmost Sweden, records two species of Empididæ (*Hormopeza obliterata* and *Tachydromia macula*), and a species of Scatophagidæ (*Cordilura hæmorrhoidalis*) as active enemies of mosquitoes. We give a free translation of his interesting account:

"It is well known that when animals collect in large numbers—as for example lemmings or grasshoppers migrating from one locality to another—they are attacked by numerous predaceous enemies; the lemmings by foxes and birds of prey—the grasshoppers by various birds. Similar conditions are found with the enormous swarms of *Culex*, as well as with those of *Simulia* and *Ceratopogon*.

"I have already communicated to this Academy my observations on one of the predaceous enemies of mosquitoes, *Tachydromia macula*, which catches its prey by the help of its specially adapted front legs.

"Not less agile and voracious enemies of the mosquitoes are two other small predaceous flies *Cordilura hæmorrhoidalis* and *Hormopeza obliterata*, which even come inside the tents of the Lapps in order to catch the mosquitoes there.

"Of the *Hormopeza*, which Prof. Zetterstedt only found in one example and of which Prof. Boheman has since found also but one male, I found in great numbers of both sexes near the river Sidosjocki on the Ounastunturi mountain while I visited a Lapp house there. I had first occasion to observe them inside the house, where they flew about catching such gnats as had gained entrance in spite of the continuous smoke. As I previously had noticed great swarms of gnats outside, over the top of the cabin, I went out to seek the *Hormopeza* there and found them in great numbers. They continued preying upon the gnats far into the night and were found in company with the above mentioned *Cordilura*."

Paul Combes has observed that in the island of Anticosti freshly emerged mosquitoes were attacked and killed by another blood-sucking dipteron, *Simulium*, which is a great plague in that region.

A male of a very common and widely distributed predaceous fly, *Scatophaga stercorarius* has been found by Claude Morley sucking one of the non-biting mosquitoes (Corethinæ) and presumably does not discriminate against the biting ones.

Two species of wasps have been observed to prey upon adult mosquitoes.

Charles Ferton, in the Annals of the Entomological Society of France for 1901 (p. 113), states that, at Bonifacio in Corsica, a specimen of *Crabro quadrimaculatus* was captured carrying an incompletely paralyzed male of *Culex* to its nest, and states that it is probable that this little wasp also captures *Anopheles*, and so merits esteem in a malarial country.

Mr. H. J. Browne, of Washington, at Calapatch Island, 70 miles south of Batabano, Cuba, and 30 miles east of the Isle of Pines, found the large wasp, *Monedula signata*, in great numbers. They seemed to make their practical diet on the yellow-fever mosquito, which they seized upon the wing and devoured in large numbers. Mr. Browne says that he has seen one of these wasps seize and devour upon the wing 20 mosquitoes in the space of five minutes. Bates, in his "Naturalist on the River Amazon," states that this particular wasp is an enemy of the motuca fly (a tabanid, *Lepiselaga*), and that one of the wasps captured a motuca from his (Bates') neck and carried it off to its burrow.

Recently Mr. W. L. McAtee, of the U. S. Biological Survey, while in Arkansas, found the curious "thread bug," which is often common about farm-houses, capturing mosquitoes and has furnished us the following note:

"There were 3 or 4 *Emesa longipes* on each window screen of the house in which I stayed at Big Lake, Ark. Mosquitoes would accumulate on these screens each evening and be eaten the next day by the *Emesa*. I picked up some *Anopheles quadrimaculatus* that had been sucked dry by the bugs."

Undoubtedly many other predaceous insects capture adult mosquitoes and Eysell mentions bugs (Hemiptera-heteroptera), locusts (Orthoptera), scorpion flies (Panorpidæ), wasps and robber flies (Asilidæ), but we have seen no exact observations on these forms in relation to mosquitoes.

MITES.

Certain acarids are frequently noticed attached to the bodies of adult mosquitoes. One of us (Howard) has quoted a letter from Mr. E. P. Salmon, of Beloit, Wisconsin, in which it was stated that one of these mites attacks the mosquitoes of Madeline Island a few weeks after their appearance in June, and that from the time the little red creature appears under the mosquito's wings the latter begins to lose its strength. "After a few weeks, along toward the end of July, the mosquito ceases to be very troublesome and seems to be fighting with his parasite for his life." The writer stated that the parasite is probably one of the red mites found upon flies and particularly upon the common house fly. Mosquitoes being aquatic insects, it was suggested that the mite observed by Mr. Salmon might be one of the little water mites of the family Hydrachnidæ, but that the mosquito issues from its pupa so rapidly that this was hardly likely to be the case. It was suggested that it might be one of the Trombidiidæ, the young of which may crawl upon the mosquito when it is at rest upon the plants (Howard's Mosquitoes, pp. 165–166).

Since that time a number of these mites have been sent in and others have been examined by other observers. All have been found to be hydrachnids and so far as known to us there is no exact record of the finding of a trombidiid on a mosquito. Specimens of these mites taken from a mosquito at Kanawha Station, W. Va., by Dr. A. D. Hopkins, have been determined by Mr. Nathan Banks as larvæ of the hydrachnid genus *Eylais*. Larvæ of an *Eylais* have also been determined by Mr. Banks upon mosquitoes from the Philippine Islands, sent in by Dr. Clara S. Ludlow. Other larval hydrachnids found upon mosquitoes have been sent to us from the Great Slave Lake by Ernest Thompson Seton. We have ourselves frequently found them and it may be stated, in a general way, that their presence on mosquitoes is a common occurrence. Dyé, previously cited, gives accounts of a number of instances in which larval hydrachnids have been found upon adult mosquitoes in different parts of the world. These larvæ, according to Blanchard, nourish themselves at the expense of the host, and in certain cases undoubtedly bring about its rapid death. Interesting observations upon one of these larval hydrachnids have been made by Sergent, in Algeria. There he found that *Anopheles maculipennis* carried these hydrachnids in the larval, pupal and adult condition. He showed that when the larva of *Anopheles* molts in its transformation to pupa, the mite passes to the pupa, and when the perfect insect is given out the hydrachnid leaves the skin of the pupa to attach itself to the adult.

Dr. Aubrey Hodges, in the "Journal of Tropical Medicine" (1902, p. 300), gives an interesting account of mites found upon *Mansonioides* and upon *Anopheles paludis* in Uganda. He states that in certain places quite 50 per cent of the mosquitoes were attacked and he found as many as nine parasites upon one mosquito. He asserts that the color of the parasite depends upon the nourishment of the host, and that they are red when attached to a mosquito which has sucked blood. He thought that the mites injure the mosquitoes, the latter becoming weakened and living only a few days in captivity.

It would seem from this statement by Doctor Hodges, as well as from the fact that so many mosquitoes coming from Madagascar were found by Blanchard to have mites attached to them, that in Africa there must be some genus or genera, of hydrachnid mites, that more commonly attach themselves in the larval condition to the larvæ of mosquitoes than is the case in temperate regions. This is the opinion of Mr. Banks, who thinks that the northern forms more commonly attach themselves to other aquatic insects.

In the course of his interesting observations on mosquitoes at Scott, Arkansas, Mr. James K. Thibault, Jr., has studied this question of parasitic mites. He writes as follows:

"More or less every adult specimen of certain species is found to be infested by a red mite very similar in general appearance to those occasionally found on house flies, though for the most part such will be the case only early in the season—spring. The proportion of infested individuals among the various species is very striking, *Anopheles* and *Mansonia* showing the greatest number of infested individuals, likewise the greatest number of mites per mosquito. The first *Anopheles* and *Mansonia* to hatch out show over ninety-five per cent of infested specimens, and indeed it is well-nigh impossible to find a single specimen that is not parasitized. *Culex abominator* D. & K. probably comes next, but in this case the mite is bluish-green—about the same shade as that seen in *Culex abominator* itself when first hatched. This probably accounts for the blue-green color of the otherwise red mite.

"I list the various species which I have found to be infested, placing those showing the greatest percentage of infested individuals first in the list, and so on in order:

"*Anopheles crucians* Wied.; *Anopheles quadrimaculatus* Say; *Anopheles punctipennis* Say; *Mansonia perturbans* Walk.; *Culex abominator* D. & K.; *Culex territans* Walk. (rarely); *Aëdes triseriatus* Say (only once); *Megarhinus septentrionalis* D. & K. (rarely).

"Nearly all of the above-named species hibernate as adults, and one might be led to believe that there was some connection between this and the fact that they are so often parasitized, but I do not think this is the case. I believe that it is more probable that the mites attach themselves to the mosquitoes when the latter are in the larval or pupal stage, perhaps both. I once found three larvæ of *Culex abominator* all having mites upon them. These mites were of the typical *red* color, whereas those found upon adult *Culex abominator* are invariably bluish green. This difference in color is, I believe, to be explained by the fact that the larvæ of this mosquito are not green, even when found among vegetation of that color until nearly full grown, after which, like the larvæ and pupæ of *Anopheles quadrimaculatus,* they may be bright grass-green. These mites lived for several days on the larvæ, but when removed from them and placed in water, they soon sank to the bottom and died.

"It is possible that the bluish green mite of *Culex abominator* is a different species, for I have never found them of this color on *Anopheles quadrimaculatus;* yet under similar circumstances the larvæ, pupæ and freshly emerged adults of this mosquito are also bright green. It is certainly very probable that this mite destroys quite a good many mosquitoes, and it is unfortunate that they do not extend their operations throughout the season instead of only the early part.

"A good many species seem to be for the most part never or only very rarely attacked at all."

In considering the whole question of the effect of these mites it seems doubtful whether they destroy adult mosquitoes. Mr. Banks gives as a result of his observations that mosquitoes that do carry mites do not seem to be inconvenienced by them. The mites, he states, can not live long out of the water, and can never complete their transformations. If extremely numerous their weight might hinder the flight of a mosquito, or they might take enough nourishment from the host to seriously weaken it. Mr. Banks's observations have been made for the most part in the vicinity of Washington, where this mite infestation is rare.

In their work on malaria in Algeria, the Sergents made a number of observations upon these parasitic mites. They found there that the mites seem to occur only on *Anopheles* and never upon *Culex* or any other genus of mosquitoes. Their specimens were examined by Trouessart, who found them to be hexapod larvæ of hydrachnids which could not be determined in the larval condition but which probably belonged to the genera *Eylais, Hydrodroma, Hydryphantes,* or *Diplodontus,* whose larvæ are known to have parasitic habits but whose distinctive characters are too slightly marked to connect them with the adult forms. Parasitized *Anopheles* were found by them from May to October, in the larval, pupal and adult condition. They found nine larvæ, two pupæ, twelve adult females and five adult males of *Anopheles maculipennis* so parasitized on the plain of Mitidja and in the valleys of Kabylia. They were able to follow in the laboratory the development of most of the parasitized larvæ and these underwent their metamorphoses normally and did not seem to be inconvenienced by the hydrachnids. When the larva transformed to pupa the hydrachnids passed from the larval skin onto the pupa, and when the adult issued the mites left the nymphal skin and attached themselves to the winged insect. In their experience these parasites are rarely single, and as many as ten were found upon the same insect. With the larvæ and adults they were found upon the abdomen; with the pupæ upon the dorsal portion, near the point where the skin splits to allow the adult to issue. They were attached to the host by their beaks and were observed to grow. The Sergents tried an experiment to see whether the larval hydrachnid can change its host. A female of *Anopheles algeriensis* was put into the same cage with two specimens of *Anopheles maculipennis* which carried numerous mites. The next day, upon the abdomen of the *Anopheles algeriensis,* found dead, they found a mite. From this experiment they concluded that these larval hydrachnids can change their host, but that the mites are not especially harmful to the mosquitoes. In their rearings, larvæ, pupæ and adults most abundantly parasitized did not die any more frequently than unparasitized individuals which they kept as checks. Doctor Trouessart informed them that he also believed that the well-known parasitization of aquatic insects in general by hydrachnids does not appear to be burdensome.

SPIDERS.

There is no doubt that many mosquitoes are destroyed by spiders. It is a matter of frequent observation to find mosquitoes in spider webs. Dr. H. C. McCook, a well-known writer on spiders, has written the following paragraph on this subject:

"But do the spiders have a special taste for mosquitoes? it may be asked. They take what comes to them, and when mosquitoes are abundant mosquitoes are taken. I have counted in an orb weaver's snare, spun upon the railing of the long bridge over Deal Lake, New Jersey, thirty-eight mosquitoes at one time hanging entangled upon the viscid spirals. Times without number have I seen like destruction wrought to mosquitoes by spiders' webs; for it is a fact that, even after the aranead has satisfied its appetite, its snare continues to capture insects. On one occasion I took the pains to count the number of insects of various species upon one large web, which was spread in a favorable position, and found that there were two hundred and thirty-six. It is a most common thing to observe three, four, or half a dozen flies or other insects trussed up upon the viscid orb of some of our orbweaving species. It is needless to add the conclusion from the above facts: if people would decrease the number of mosquitoes, let them encourage the multiplication of spiders."

The jumping spiders are probably more often an effective check upon the mosquitoes infesting houses than is generally realized. The commission of the Institute Pasteur, while engaged in their studies on yellow fever and the transmitting mosquito at Rio de Janeiro, found that their studies were seriously interfered with by spiders of the genus *Salticus*. They found that these jumping spiders were very common in houses in the tropics and that they are a valuable aid in the destruction of mosquitoes. In further praise of these spiders they state: "Not only do they reduce the large number of mosquitoes, which enter the houses, in a noticeable manner, but the flies as well contribute largely to satisfy the appetite of these voracious jumping spiders." It is probable that with us the mosquitoes which hibernate in cellars and similar situations are considerably reduced by the spiders which prowl about in these places.

Doctor John B. Smith seems to be impressed by the number of mosquitoes that are destroyed by spiders. He states that he has frequently looked over a series of webs in the morning and found only mosquitoes captured. Sometimes there would be only one or two, and sometimes there would be a great bunch of them—reduced to little balls or dry husks. He considers it probable that many spiders subsist largely upon mosquitoes, and that they are among the most effective mosquito checks.

In a recent article Doctor N. Leon, of the University of Jassy, shows that in the marshes of the delta of the Danube, and in other localities in Roumania, spiders are among the most important enemies of mosquitoes. Spiders are very abundant in these swamps and Doctor Leon states that enormous numbers of mosquitoes are caught in their nets and killed. Different species of spiders weave their webs on sedges, reeds and willows and it is not rare to find as many as twenty webs on one willow. Sometimes the number of webs is so great that they become continuous and completely enwrap the tree and one can conceive the large numbers of mosquitoes that can be caught in such webs.

Mr. W. L. McAtee recently made an observation in Arkansas which is at variance with those already given and which indicates the necessity for more careful observations.

"On a rainy day a large number of *Anopheles quadrimaculatus* were found sitting on a spider web in a hollow tree. Thinking they must be at least slightly entangled, I counted on capturing them easily. Upon putting my cyanide bottle near one, the whole swarm rose lightly on the wing, not sticking to the web at all. By further tests I found that they were perfectly at home on the web."

OTHER ARTHROPODS.

Doctor Dupree once stated in a letter that he was satisfied that small crayfish and fresh-water shrimps kill the larvæ of mosquitoes. Britton has shown that salt-water shrimps (species not mentioned) will eat the larvæ of the salt-marsh mosquitoes but thinks that their structure and small capacity prevent them from consuming any great numbers.

BATRACHIANS.

It appears from the observations and experiments of Galli-Valerio and Rochaz de Jongh that frogs and toads will not capture mosquito larvæ or pupæ. No observations appear to have been made with reference to frogs and toads as destroyers of adult mosquitoes but there can be no doubt that they capture mosquitoes along with other insects. The above-mentioned observers found that the north African *Discoglossus pictus*, a frog-like batrachian, is an efficient destroyer of mosquito larvæ. This animal has the habit of capturing its prey under water while the frogs and toads do not do so. The same observers found that in Switzerland *Triton cristatus* and *Triton alpestris* are effective destroyers of mosquito larvæ. They observed that a certain puddle which in past years was inhabited by *Triton cristatus* at that time contained no mosquito larvæ; during two subsequent years, when the tritons were absent, this same puddle harbored great numbers of mosquito larvæ. They found that the larva of this triton, as well as the adult, destroyed mosquito larvæ.

In the section on "Remedies" under the head of the "Practical use of natural enemies of mosquitoes," mention is made of the importation into Hawaii of the western salamander or newt (*Diemyctylus tortosus*) which has been kept for several weeks in an open tank by Mr. Albert Koebele, with the result that they devoured all of the mosquito larvæ in the tank.

The aquatic larvæ of our terrestrial salamanders are predaceous and feed on mosquito larvæ as well as other aquatic insects. Mr. W. L. McAtee of the Biological Survey has fed the larvæ of *Amblystoma opacum* with larvæ of *Chaoborus* and of mosquitoes and found that they captured them very promptly. In Europe the larva of *Salamandra maculosa* is known to destroy mosquito larvæ.

Tadpoles, or pollywogs, are so frequently found in stagnant ponds that the question has often arisen as to whether they destroy mosquito larvæ. In our experience tadpoles and mosquito larvæ do not occur together; we have found mosquito larvæ invariably absent from water inhabited by tadpoles. This may, however, be purely a coincidence and not due to any effect from the tadpoles themselves. As the tadpoles are wholly vegetable feeders their influence, if any, upon the mosquitoes must be a purely mechanical one; their violent movements might cause a contant disturbance which would interfere with the mosquito larvæ. It must also be remembered that, at least in temperate regions, the tadpoles appear when the great wave of mosquito larvæ has already passed and when, in fact, very few mosquito larvæ are to be found. Doctor Smith records some experiments made by Mr. W. P. Seal, of Delair, N. J., with the tadpoles of the bullfrog (*Rana pipiens*) which resulted negatively. Even when the tadpoles had been deprived of all food for several weeks they would not eat mosquito larvæ.

REPTILES.

In the tropics insectivorous lizards undoubtedly destroy mosquitoes along with other insects. Giles states that the bright little gecko lizard, commonly found in bungalows in India, is a valuable destroyer of mosquitoes in houses. He considers an individual gecko "at least equal in mosquito destroying efficiency to a fly paper of the largest size, and their company should be encouraged accordingly." There must be other species having similar habits, but as far as we are aware specific mention has not been made of their mosquito diet.

BIRDS.

As a matter of course, many insectivorous birds which feed while on the wing destroy mosquitoes in great numbers. This is especially true of the goatsuckers (Caprimulgidæ), to which belong our night-hawks and whip-poor-wills, as they are mostly active at twilight when mosquitoes are most in evidence. An observation is on record by the late Professor F. L. Harvey, in which he states that he found over 600 insects, largely gnats and flies, in the crop of a single night-hawk (*Chordeiles virginianus*).

Mr. Allan H. Jennings, formerly entomologist of the Isthmian Canal Commission, has published an interesting note in the Proceedings of the Entomological Society of Washington, vol. 10, pp. 61–62, on the mosquito-eating habit of the Cuban night-hawk (*Chordeiles virginianus minor*). He states that while collecting birds on the island of New Providenee, Bahamas, in May, 1887, he had an opportunity of observing the effectiveness of this bird as a mosquito destroyer.

"One afternoon about 4 o'clock a heavy thunderstorm came up from the west accompanied by much rain. When the storm passed by, about an hour before sunset, it was followed by large numbers of birds of many species, but mainly the smaller insectivorous birds, warblers, etc. They were moving in the direction the storm had taken and were evidently feeding as they went, though passing quite rapidly. Accompanying them was a number of Cuban night-hawks flying rather low at about the level of the tops of the somewhat low trees fringing the coast at this point, or, in other words, at a height of 25 or 30 feet.

"Two of these were taken and on preparing the skins were found to be exceedingly fat while the stomachs were distended with mosquitoes, apparently a small species of *Culex* and resembling the species that was most abundant in the locality.

"The stomachs of a few warblers taken at the time were also full of mosquitoes. Unfortunately I made no note of stomach contents of other specimens of the species taken at other times and points in the island."

The whip-poor-will (*Antrostomus vociferus*) has also been mentioned as a mosquito destroyer but the food of this goatsucker is known to consist largely of nocturnal moths.

In an interesting letter from Doctor John B. Fort, of Athens, Georgia, dated February 4, 1909, the statement is made that in his opinion the most useful bird in the destruction of the mosquito is the chimney-swallow or American swift (*Chætura pelagica*). He states that he once examined the stomach of a newly killed bird of this species, and estimated more than 600 insects of the order Diptera in its stomach. They were nearly all mosquitoes. Doctor C. Hart Merriam also gives this bird first place in the list of mosquito destroyers. It should be noted that this bird is crepuscular in habits.

The true swallows (Hirundinidæ) are often mentioned as mosquito destroyers. It is obvious that this must be so where mosquitoes are present when one considers their habit of feeding upon the wing and being most active in quest of food towards evening. Florence A. Merriam, in "Birds of Village and Field," states that the eaves- or cliff-swallow (*Petrochelidon lunifrons*) "eats enormous quantities of winged ants, mosquitoes, injurious wheat midgets, spotted squash beetles, and beetles that work under the bark of trees." Forbush enumerates mosquitoes as part of the food of the white-bellied swallow (*Iridoprocne bicolor*) and the barn swallow (*Hirundo erythrogastra*). W. L. McAtee gives the purple martin (*Progne subis*), bank swallow (*Riparia riparia*) and northern violet-green swallow (*Tachycineta thalassina lepida*) as mosquito feeders.

The tyrant flycatchers (Tyrannidæ) feed mostly upon insects which they capture upon the wing, watching for them from some prominent perch. Mosquitoes also make up part of the food of the birds of this family. Forbush specifies mosquitoes as part of the food of the wood pewee (*Myiochanes virens*), phœbe (*Sayornis phœbe*) and kingbird (*Tyrannus tyrannus*).

Aside from the work of birds against adult mosquitoes, it is certain that aquatic birds must destroy many larvæ and eggs. Mr. Wm. Beutenmüller, in the essay previously cited, is of opinion that aquatic birds could be used for the purpose of destroying mosquito larvæ, in rain-pools, ponds, and other waters near houses; also in ponds in well-cleared fields and cultivated land where there is no extent of woods. He thinks that the management of aquatic birds under such conditions can be made simple, and their breeding profitable. Some years ago, Mr. Wilton Lockwood, of Boston, an artist, who had at that time, and perhaps still has, a fad for raising aquatic fowls, told one of us that in his opinion they are great destroyers of mosquito larvæ. He was particularly impressed by the favorable work of the spoon-bill duck, which he thought is particularly adapted to the destruction of mosquito larvæ resting at the surface of the water. Mr. McAtee, of the Biological Survey, has recently found mosquitoes in the gizzard of the Mallard (*Anas platyrhynchos*).

Doctor Smith has recorded the fact that some of the shore birds eat mosquito larvæ in considerable numbers. He examined the stomachs of a ring-necked plover (*Ægialitis semipalmata*), of a least sandpiper (*Pisobia minutilla*), and of a semipalmated sandpiper (*Ereunetes pusillus*), and all of these had eaten the larva of *Aëdes sollicitans* in some numbers, the ring-necked plover having eaten the most. He states, and this has also been our experience, that there was no especial difficulty in identifying the larvæ from the remains, the head and breathing-tube are so strongly chitinous that they are not digested.

W. L. McAtee, in a recent circular of the Biological Survey, sums up our knowledge of the office of shorebirds in the control of mosquitoes as follows:

"Shorebirds perform an important service by their inroads upon mosquitoes, some of which play so conspicuous a part in the dissemination of diseases. Thus, nine species are known to feed upon mosquitoes, and hundreds of the larvæ or 'wigglers' were found in several stomachs. Fifty-three per cent of the food of 28 northern phalaropes from one locality consisted of mosquito larvæ. The insects eaten include the salt-marsh mosquito (*Aëdes sollicitans*), for the suppression of which the State of New Jersey has gone to great expense. The nine species of shorebirds known to eat mosquitoes are:

"Northern phalarope (*Lobipes lobatus*).
Wilson phalarope (*Steganopus tricolor*).
Stilt saudpiper (*Micropalama himantopus*).
Pectoral sandpiper (*Pisobia maculata*).
Baird sandpiper (*Pisobia bairdi*).
Least sandpiper (*Pisobia minutilla*).
Semipalmated sandpiper (*Ereunetes pusillus*).
Killdeer (*Oxyechus vociferus*).
Semipalmated plover (*Aegialitis semipalmata*)."

BATS.

Bats are important mosquito-destroying animals. Flying at dusk and after dark, and capturing all flying insects upon the wing, they devour large numbers of adult mosquitoes in times of mosquito prevalence. Mr. C. Few Seiss, at a meeting of the Feldman Collecting Social, in Philadelphia, June 19, 1901, stated that he had dissected a specimen of the common brown bat (*Eptesicus fuscus*), and had found its stomach full of mosquitoes. The suggestion has been made by Mr. A. C. Weeks, of Brooklyn, that an attempt be made to breed bats artificially on account of their importance as mosquito destroyers, but until recently no one seems to have taken the matter up.

Greatly impressed with the value of bats as mosquito destroyers, Dr. Chas. A. R. Campbell, formerly city bacteriologist of San Antonio, Texas, has erected a novel bat breeding-house six miles south of that city. His idea is that the bats will rapidly become sufficiently numerous, with this admirably adapted nesting place, to rid the neighborhood of night-flying mosquitoes, and at the same time the entire expense will be more than paid by having the structure built in such a manner that the bat-guano can be readily collected and taken away.

COLLECTING, MOUNTING AND REARING MOSQUITOES.

COLLECTING ADULTS.

In flight, adult mosquitoes may be captured with a net. A small, light, silken net is preferable, though an ordinary insect net will serve, if care be taken to let the insects settle before inserting the bottle. The chloroform killing bottle is the best, as the insects die more quickly and are thus less liable to injure themselves. A satisfactory bottle may be made by placing a rubber stopper in the bottom of a test-tube and pouring chloroform upon it. The chloroform is absorbed by the rubber, which swells to fill the tube, and a supply of vapor is subsequently given off without a residue of liquid to wet the captures. An ordinary cyanide bottle will serve, but it is necessary with this to wait a longer time until the insects are quiet before reopening it to admit others. Cotton should be placed in the bottom of the tube or jar to keep the mosquitoes from becoming abraded by sliding about as the jar is carried, or in the case of a small jar, narrow strips of absorbent paper. On no account should any other insects be killed in the same jar with mosquitoes.

The female adults of many species are readily captured as they come to bite, when they can generally be taken by placing the collecting bottle over them. Horses or other animals may be used as bait, or the person of some obliging friend. The collector can often attract specimens in some numbers by sitting in the woods or open, evenings after dark or by day, according to the species sought, and may collect them as they come. All males and those females that do not bite may be taken by beating bushes and low vegetation, especially in damp situations along streams and marshes. Some species frequent trunks of trees, hiding in the crevices of the bark, and may be searched for in the daytime. Outhouses, cellars and caves should be searched for the species which seek shelter in such situations.

MOUNTING ADULTS.

In mounting the adults for the cabinet a double mount should always be used. The insects are too small to admit of pinning them directly upon ordinary insect pins, except those of the smallest calibre. These can only be handled with forceps and this is very inconvenient in ordinary work. The specimens should be mounted upon card-points, small triangular pieces of card, the insect glued upon the small end, an insect pin passed through the larger end. The specimens should be attached by the ventral surface of the thorax, so that the upper side will be free for examination. We find shellac dissolved in alcohol the best adhesive. The pins carrying the card-points should be stout enough to be handled easily. Large specimens, like *Megarhinus*, may be pinned with the small pins used for Microlepidoptera upon narrow strips of cork. The method of pinning on pins run through card-board disks, in use among British collectors, we find objectionable, as the disk interferes with the proper examination of the specimen, and it is impossible to remove the insect from the mount without relaxing and remounting it. Furthermore, the specimens very often get broken by the disks becoming loose upon the pin. Labels, giving the exact locality and date of capture and the name of the collector, should be pinned upon the larger pin of every mount.

SENDING BY MAIL OR EXPRESS.

Specimens which are to be sent to a distance, should be placed while still soft in pill boxes between two layers of cotton, packed loosely and not again opened until they reach their destination. Tin boxes and glass vials should be avoided, as the retained moisture causes the specimens to mould. Collections made in moist climates must be well disinfected with creosote or some similar substance. The pill boxes to be sent by mail, should be securely packed in a stout outer wooden box that will not be crushed in transit. Considerable risk always attends sending pinned specimens by mail or express. This can be minimized by proper packing. The pins should be firmly set in a cork-bottomed box over which a thin layer of loose cotton has first been spread. This box should then be packed in a stout outer box, at least four inches larger than the inner box in all dimensions, the space between loosely packed with excelsior or other elastic packing material.

REARING.

Captured adult mosquitoes, even when most carefully collected, are liable to be more or less damaged, often unrecognizable, since the insects lose their scales easily even when living in a state of nature. It is therefore desirable to breed specimens from the larvæ as far as possible. It is still important to collect the adults, as many species may be thus taken which would be overlooked if only bred specimens were retained. Some species are not infrequent as adults, the larvæ of which are very difficult to obtain, if they are not entirely unknown. The larvæ of mosquitoes are of great importance in specific determination. Many species of *Culex* are of uncertain determination without the associated larvæ, while some *Aëdes* have identical adults, yet dissimilar larvæ. The characters of the larvæ reside in the modifications of the chitinous appendages of the skin and the arrangement of the hairs. As these are fully retained by the cast skins, it is possible to preserve both the larva and the adult of the same identical specimen, thus assuring absolutely correct associations. This should be done wherever possible. To secure it, the mosquito larvæ to be reared should be isolated in separate tubes. We find flat-bottomed glass tubes about one inch in diameter to be suitable. They should be loosely stoppered with cotton. Having obtained a culture of mosquito larvæ, the collector pours the liquid and contained larvæ into a shallow dish, one of white material preferred, and with a pipette or spoon places one larva in each tube. Care should be exercised to introduce no predaceous enemy with the larva. The tube is then filled two-thirds full with the original liquor and the cotton stopper inserted. As any given culture is apt to contain a mixture of species, it is well to use care to select those larvæ that appear to be of different kinds. A culture may contain hundreds or thousands of individuals, and it is seldom feasible to isolate them all. The rest may be bred in common to secure a supply of adults; but the jar should be kept under daily observation to see if any different species at first unnoticed appear.

The isolation made, each individual should be given a double number, one for the original entire culture as reference to the notes of locality and date, the other a serial number for the identification of the individual isolation. These numbers should be attached to the tube so that they are not liable to get mixed. All the isolations should be viewed at least once a day, and as soon as the larva has pupated the cast skin should be removed with a pipette and put in a small vial with alcohol containing a little glycerine and stoppered with cork. A small label bearing the locality and isolation numbers should be inserted in the bottle, and the bottle kept with the isolation until the adult has emerged. On the issuance of the adult, the pupa skin may be added to the same bottle. Finally, the small bottles of skins should be stored in a larger jar containing alcohol, to keep them from drying.

The adult should rest at least twenty-four hours after emergence for its chitin to harden and become perfectly dried. If killed too soon the specimens will shrink and collapse and be rendered unfit for study. When sufficiently hardened, the mosquito can be removed, killed by chloroform, mounted and given the locality and isolation numbers in addition to the usual data of locality, date and collector. The locality note-book should be kept as fully as possible, giving not only locality and date, but the character of the water in which the larvæ occurred and in what it was retained. There is no danger of recording too many data; the recording of too few is a common failing.

The food of mosquito larvæ consists of the organic matter in suspension in the water, or floating upon the surface, or settled or growing upon the bottom. It varies with the different species, so that the safest rule for general use is to keep a supply of the original water together with the detritus at the bottom and change the water in the isolation tubes occasionally. Experience will often show the nature of the food of a given species, and in such cases artificial food can be supplied, on which the larvæ will thrive even better than in their natural environment; but such an experiment may have a fatal termination. Doctor John B. Smith, who was familiar with the habits of *Culex pipiens* and *Culex restuans,* which live in foul water containing decaying organic matter, fed pieces of meat to larvæ of *Wyeomyia smithii,* that live in water in pitcher-plant leaves, and the resulting fermentation killed them all. Some mosquito larvæ are cannibalistic and must be supplied with the larvæ of other species for food, preferably of the same species with which they were found associated. No general rules can be given, as each species is a law unto itself; but the collector who desires the quickest results will isolate the largest, or most nearly fully grown larvæ, which will generally successfully complete their transformations upon the food material collected with them. It must not, however, be forgotten that the small larvæ may belong to another species, and they should not be neglected. *Anopheles* larvæ, which are surface-feeders, will not thrive in the isolation tubes above described. They must be isolated in broad dishes or saucers, which should be kept uncovered, in order that the dust from the air may settle continuously upon the water. By properly watching the cultures daily, the skin can be preserved at pupation and the pupa transferred to a cotton-stoppered isolation tube for the emergence of the adult.

SLIDE MOUNTS.

The above method of preserving the larval skins suffices for temporary purposes, and the skins when destined for dissection of the mouth-parts should be kept in the alcohol and glycerine mixture. For examination the skins may be placed on slides in a drop of glycerine; but for permanent preservation they should be mounted in balsam. The skin should be treated with weak alcohol to remove the glycerine, then in strong alcohol, absolute alcohol, oil of cloves and finally Canada balsam, which should be heated after the cover glass has been applied. Often sufficiently satisfactory results may be obtained by drying the skin on a slide and applying balsam directly; but if glycerine has been used this must first be removed. Skins thus mounted are liable to become distorted, but the method is more rapid and often suffices for ordinary determination.

The male genitalia are important not only for specific identification, but also for general study of systematic relations. For proper examination, the genitalia must be mounted on a slide as microscopic objects. The tip of the abdomen with the male organs attached can be readily broken off from a dried specimen by the use of a pair of fine forceps. They are then placed in a solution of caustic potash; about one part of the saturated solution to ten parts of water will give satisfactory results. The genitalia are left in this solution until only the chitinous parts remain and all the details are readily visible. The time required will vary with the temperature and with the size and chitinization of the specimen, very fresh specimens requiring much less time than old ones. The specimen should be examined from time to time while in the potash, as, if left too long, it will become too soft and transparent and the details will then be very difficult to see. Usually, if put in the potash late in the afternoon, the specimens will be ready to mount on the following morning. If one desires to study a specimen immediately, it should be boiled in the potash over an alcohol lamp or Bunsen burner. In this case, care must be taken, as the potash in boiling is likely to spatter and the specimen thus be lost. Moreover the specimens treated by the slower process make better mounts.

When sufficiently cleared the specimens must be thoroughly washed with water to remove all traces of the potash, then dehydrated with absolute alcohol, cleared with oil of cloves and finally mounted in balsam. Before placing the cover glass, the specimen should be examined to see that it is in the proper position for study. Sometimes, when the parts are folded together, they can be spread by pressure on the cover glass directly over them. This is especially true of those forms in which the abdomen is depressed and the claspers prominently exserted, such as the species of *Aëdes* and *Anopheles*. In those forms in which the abdomen is compressed or wedge-shaped, it is often very difficult to get the parts into position for a dorsal view. It is then necessary to press the tip of the abdomen with forceps until the parts lie flat, and this is best done while the specimen is in the oil of cloves. Sometimes the end pieces of the claspers are folded under, and then it requires careful manipulation to bring them into view without injury. In certain cases, where the genitalia are very compact, and in others where they are very complicated, it becomes necessary to break them up in order that the details may be brought into view. This must be done carefully under a dissecting microscope or a good lens, and requires skill and practice.

The slides should be numbered and the data entered in a book. The mosquito from which the genitalia were taken should receive a pin-label referring to the number which has been given to the slide.

Whole adults or portions of them or entire larvæ which it is wished to mount can be treated with caustic potash in the manner above described.

COLLECTING LARVÆ.

All mosquito larvæ are aquatic, and all sorts of water should be examined to collect them. In general, lakes, ponds and streams are not suitable breeding-places, for these larger bodies of water contain insufficient nourishment for the larvæ, and generally do contain fish, which would devour any larvæ that happened to appear. It is exceptional for mosquito larvæ to be found in large, or running bodies of water, though there are such exceptions. *Anopheles* larvæ not infrequently breed along the margins of swiftly running streams, and large ponds may harbor *Culex* larvæ in their grassy edges. *Mansonia* larvæ live in the mud at the bottoms of the sedgy swamps, attached by their air-tubes to the vascular roots of the aquatic vegetation. In the tropics, almost any water may contain larvæ. The collector will, however, find the best results in small stagnant collections of water, particularly those of a transient character. The different genera will be found to occur in different situations. For example, *Aëdes*, with the *Psorophora* that prey upon them, in temporary ground pools, some species in tree-holes; *Culex*, with the predaceous *Lutzia*, in permanent or semipermanent ground pools; a few species in tree-holes; *Bancroftia*, with their enemy *Megarhinus*, in tree-holes, some species in bromeliaceous plants; *Deinocerites* and allies in crab-holes; all the sabethids in water in the leaves or flower-sheaths of plants, some species in tree-holes, etc. The sabethid larvæ, in the tropics, require especially careful search, as they occur in such peculiar locations, while every different plant harboring them will be found to have its own fauna both of *Wyeomyia*, etc., and the predaceous *Lesticocampa* and others. This fauna is especially characteristic of the tropics, where many plants are water-bearing; but in our temperate region only a single sabethid occurs. It has, however, the normal habits of its tribe, living in the water in the leaves of the pitcher-plant, *Sarracenia purpurea*, the only water-bearing plant of temperate distribution.

The season of the year is an important factor in the occurrence of species, rains being essential to the development of perhaps the majority of larvæ. Especially is this true of *Aëdes*. Many species of this genus develop only in the water formed by melting snows and are to be found only in early spring, while others, are partial to tree-holes or rock-pools. The species of *Psorophora* breed with astonishing rapidity in the temporary puddles following showers, in which they hatch and pass the four larval stages in a scarcely greater number of days.

To follow the complete life-history of any species and to breed it from egg to adult will require special experiment in each case. Many species have never been thus bred. In fact, our collectors have all been too much hurried, and in endeavoring to breed as many isolated examples as possible in a limited time, have been obliged to omit the full and careful study of individual species, so much to be desired. Especially are we lacking in knowledge of the habits of the adults, their ordinary length of life, dispersal, swarming habits, etc., and these can only be discovered by careful, unhurried observations in the field.

COLLECTING EGGS.

Eggs of many mosquitoes may readily be obtained by confining captured females over water. *Aëdes* will generally oviposit readily, but *Culex* less readily. Bred specimens can not often be mated in captivity, on account of the peculiar swarming habits, which seem essential to copulation, and which can not be executed in a confined space. Doctor Dyar, however, bred two generations of *Aëdes atropalpus* in a quart jar. Adults confined for oviposition require food. All will eat sugared water, preferably soaked into cotton, or they may be fed with raisins or figs. Many thrive best on mammalian blood. There are, however, few species that absolutely require that article of diet. Speaking broadly, mosquitoes are flower-insects, living upon honey. The habit of taking mammalian blood, while common, is not universal, and seems to be obligatory only in the case of a few species. The group in general suffers in reputation from the vicious habits of a minority of its members. We are far, however, from wishing to imply that mosquitoes are negligible or harmless to man; only we can not emphasize too strongly the need of specific study of the different forms in order to direct our efforts against the dangerous or noxious species only, and not waste time and labor in destroying harmless or even beneficial forms.

THE RELATION OF MOSQUITOES TO MAN.

THE CARRIAGE OF DISEASE BY MOSQUITOES.

That certain mosquitoes are an essential factor in the propagation of certain diseases is now well demonstrated and generally accepted. In every case where such relation of the mosquito has been proved the rôle of the insect is not that of a purely mechanical carrier or transmitter, as is, for example, the conveyance of typhoid fever by the house fly. The diseases in question are caused by organisms which have a complex life-cycle, part of which is passed in man and part in the mosquito, and in the absence of one or the other of the hosts their existence or continuance is impossible. In other words, the causative organisms of these diseases, as far as we know them, are animal parasites. These parasites can exist only in definite hosts. This restriction goes so far that a given parasite is restricted, on the one hand to a certain vertebrate host (for example, man, the dog, the sparrow), on the other to a certain species of mosquito. It is the full recognition of these facts that has made the thorough investigation of mosquitoes, systematically and biologically, such an important study.

In the following, the causative organisms, their life-cycles, and the mosquitoes concerned in each case, are discussed under the heading of the respective diseases.

EARLY IDEAS.

The idea that mosquitoes carry disease is not only very old historically, but occurs among primitive nations in various parts of the world. References have been found in the very early literature of India, in writings that are practically prehistoric, that indicate that the idea was held in those early days, especially with reference to malaria. The natives of different parts of Africa and in Assam are said to hold the same idea, and it has been pointed out that the belief has long been prevalent among the Italian peasants and among those in the southern Tyrol. According to Humboldt the inhabitants of the upper Orinoco at the time of his visit accused the mosquitoes of being the cause of the febrile maladies from which they suffered. Koch points out that the negroes of the Mschamba tribe on Mount Usambara in Africa do not descend into the lower regions on account of fear of fever. Fever in their language is called *mbú* and *mbú* is also their name for mosquito, indicating that they understand the connection between the two so perfectly that they have but one name for both.

Dr. A. F. A. King, of Washington, in an important paper published in 1883, called attention to an article by John Crawford entitled: "Mosquital Origin of Malarial Diseases," said to have been published in the Baltimore Observer in 1807, but subsequent investigations by Dr. King and Dr. W. S. Thayer, of Baltimore, have failed to find the article, either in the newspaper itself, or in a review of Crawford's papers published in the Baltimore Medical and Physiological Recorder, 1809.

In 1848 Dr. J. C. Nott published a paper on the origin of yellow fever in the New Orleans Medical and Surgical Journal, in which he expressed his belief in the insect transmission of yellow fever and malaria. He called attention to the fact that yellow fever occurs under conditions and in places favoring the development of insects, and he thought it was spread from one locality to another by them. He thought it likely that the disease itself is produced by micro-organisms.

Recently Dr. A. Agramonte, in an article in the Crónica Médico-Quirúrgica de la Habana, and quoted by the British Medical Journal, calls attention to the pioneer suggestions of Louis Daniel Beauperthuy, born in Guadeloupe in 1808. Writing in the Gaceta Official de Cumaná (Venezuela), in May, 1853, Beauperthuy says that yellow fever is due to the same cause as that producing intermittent fever, and that it is by no means to be regarded as a contagions disease. It develops under conditions favoring the development of mosquitoes. The mosquito introduces into the circulation of a person bitten a poison which softens the red blood corpuscles, causes their rupture, and facilitates the mixing of the coloring matter with the serum. There are many mosquitoes but not all are equally dangerous; most so are those with legs striped with white and partly a household kind. He further states that remittent, intermittent and pernicious fevers, like yellow fever, have as their cause an animal or vegeto-animal virus which is inoculated into the human body. He supposed that this poison was sucked up by the mosquitoes from decomposing substances, exposed at low tide, on the seashore and in the mangrove swamps and pointed out that yellow fever invariably breaks out in such places. These fevers are grave in proportion to the abundance of mosquitoes. It is not the air from marshes, nor stagnant water, that makes such regions unhealthy, but the presence of mosquitoes. Beauperthuy wrote most fully to the journal above mentioned, but he made more than one communication to the Academie des Sciences, of Paris. We have seen one of his communications, dated January 18, 1856, entitled: "Researches into the cause of Asiatic cholera, into that of yellow fever and of marsh fever," in which he states that as early as 1839 his investigations in unhealthy localities in South America convinced him that the intermittent or so-called marsh fevers are due to a vegeto-animal virus inoculated into man by mosquitoes. His idea, however, was that this virus was extracted by the mosquitoes from decomposing substances.

Dr. Oswaldo Cruz, director of the Public Health Service of Brazil, in a recent paper (Public Health Reports, U. S. P. H. and M. H. Service, Nov. 19, 1909) calls attention to the fact that in Brazil, before the American experiments, Dr. Utingguassú and afterwards Dr. Stapler, of São Paulo, also made references to the transmission of yellow fever by mosquitoes. It is probable that there were other physicians in advance of their times who, like Nott and Beauperthuy, held similar ideas, but if they expressed them, or if they wrote about them, their words have not been preserved.

Many curious ideas about the possible relation between mosquitoes and disease have been published. For example, in a paper entitled "Curions Facts Concerning Man and Nature With a Few Practical Suggestions on Other Subjects," Dr. Samuel W. Francis, in 1874, made the following statement, which, in the light of recent developments, is a very curious instance of a conclusion diametrically opposed to the right one having been drawn from practically the same premises:

"It is my firm conviction that the mosquito was created for the purpose of driving man from malarial districts; for I do not believe that in nature any region where a chill and fever prevail can be free from this little animal. Now if man will not go, after warning is given in humming accents, then the mosquito injects hypodermically a little liquid which answers two purposes—first to render the blood thin enough to be drawn up through its tube, and secondly in order to inject that which possesses the principles of Quinine! This idea I published in a work entitled 'Life and Death,' p. 210, March, 1871; a few lines will suffice. 'The time will come when it will be publicly acknowledged that the little fluid they (mosquitoes) inject into your blood contains certain specific properties for different diseases. To prove that I am right, let any skillful chemist test the powerful drop contained in a mosquito's sack, and he will find many of the properties of Quinine.'"

A curious old account of the value of measures undertaken with the idea of preventing malaria, and which at the same time were incidentally antimosquito measures (although cause and effect were not in the least recognized), is given in the 15th Annual Report of the American Society for Colonizing the Free People of Color of the United States, Washington, 1832, p. 51.

Joseph Reynolds, of Bristol, writing to Elliot Cresson, in the United States, gives an account of the measures adopted to preserve the health of the crew of the ship *Cambridge* during the period of about ninety days when she lay in the river above Sierra Leone. None of the crew were suffered under any consideration to be out of the ship at sunset or after. A sail was stretched on the windward side of the vessel and an awning was also provided which extended over the poop and the whole of the main-deck "to defend the crew from the night air." "The night watch was encouraged to smoke tobacco." Incidentally, the hull of the vessel was kept pure by the constant use of chloride of lime. The crew were given a tonic treatment of strong coffee and French brandy. "The result was, that the ships on each side of the Cambridge, lost the greater part of their crews: not one man of the Cambridge was seriously unwell, during the whole time they lay in the River, and it was remarked that the ship was so clear of musquitoes, that the Captain threw aside the curtains which he had provided for his defence against them." Mr. Reynolds remarks that the instructions given to the commander were derived from reading Dr. Macculloch's "Essay on Malaria," a work which advocated protection against the exhalations of malarial localities.

MALARIA.

THE MALARIAL ORGANISMS.

The disease known as malaria is caused by parasites in the blood which feed upon the red blood-cells. They are unicellular animals, belonging to the Sporozoa. They have been classified in the sub-order Hæmosporidia and genus

Plasmodium of Marchiafava and Celli. Recently, as the result of more exact studies of blood parasites, Max Hartmann and Victor Jollos have worked out a new classification. They have created a new order, Binucleata, in which are united the various blood parasites, it being shown that the trypanosomes and other forms living free in the blood-fluid are related to the plasmodii and connected by intermediate forms. The malarial parasites are grouped in the family Plasmodiidæ and four genera are recognized. The genera *Achromaticus* and *Polychromophilus* of Dionisi are parasites of bats, the genus *Proteosoma* Labbé is parasitic in birds and the genus *Plasmodium* infests man, monkeys and squirrels. All the Plasmodiidæ require two hosts to complete their life-cycles and one of these hosts acts as the transmitting agent. Three species of *Plasmodium* are generally recognized as affecting man, but some investigators believe that more species are concerned in producing the various types of malarial fevers. The nomenclature of the malarial parasites is a most confusing one, hardly two authors agreeing in the specific names applied to the different parasites. We follow here the nomenclature of Blanchard who has carefully worked out the synonymy according to the rules of zoological nomenclature.

Plasmodium vivax (Grassi & Feletti).—This parasite produces the benign tertian fever, simple or double. The period of schizogony is 48 hours and may sink to 44 hours. It is the most widely spread and commonest of the species.

Plasmodium malariæ (Laveran).—This parasite produces the regular quartan fever. The period of schizogony is 72 hours. It is more prevalent in temperate and subtropical regions, but appears to be rare everywhere. It resembles the *Plasmodium vivax* in its appearance and development, but can be distinguished readily by morphological differences, besides the different type of fever that it produces in man.

Plasmodium falciparum (Welch).—This is the parasite of pernicious, tropical or æstivo-autumnal malaria. It is most frequently termed *Plasmodium præcox* or *Laverania malariæ*. The genus *Laverania* is based on the crescent-shaped stage but has been generally abandoned. The opinion has been expressed by various investigators that there is more than one species of organism accountable for the various forms of pernicious or quotidian fever. Schizogony usually occurs in the internal organs, particularly the spleen, instead of in the peripheral circulation, as is the case with the tertian and quartan forms. The fever produced is of an irregular type and the period of schizogony, as it does not occur in the periphery, has not been definitely determined. Most observations indicate a period of about 48 hours, others one of 24 hours.

THE LIFE-CYCLE OF THE MALARIAL ORGANISMS.

There are two cycles in the evolution of the malarial parasites. One takes place in the blood, is asexual, and is designated the schizogonic cycle; the other is the sexual cycle which develops within the transmitter and is called the sporogonic cycle.* The continuous existence of the parasites depends upon the trans-

* The cycle in the blood is sometimes called endogenous, or cycle of Golgi, that in the mosquito exogenous, or cycle of Ross.

fer from one host to the other. When a mosquito sucks the blood of an individual harboring gametes in a state of complete maturity, these, finding themselves in a temperature favorable to their further development, copulate. The male gamete or *microgametocyte* throws off prolongations in the form of flagella, called *microgametes,* and these seek to unite with the female gametes or *macrogametes.* Upon contact with the microgamete the macrogamete prolongs its protoplasm, forming the so-called cone of attraction. This first stage, brought about by the union of microgamete and macrogamete, is designated as the *oökinete* and can be easily observed in any mosquito, or even in blood transferred from the human body directly to the microscope slide. However, the succeeding stages can only take place in the stomach-wall of an *Anopheles,* as demonstrated by Grassi. The oökinete, to undergo further development, penetrates into a cell of the stomach-wall of the transmitting insect and there transforms to the *oöcyst.* In the process of growth of the oöcyst further stages occur, first, by its division the *sporoblasts,* and from these, by further division, the *sporozoits.* When the oöcyst is mature it bursts, liberating the sporozoits which thus pass into the general body-cavity of the host. The sporozoits now find their way into the salivary glands of the host and there they remain until the mosquito, in biting, forces them, along with the saliva, through its proboscis into a human being. Then the other, sporogonic, or asexual, cycle begins.

The sporozoits when introduced into the blood at once enter the red blood-corpuscles and are now called *schizonts.* The schizont grows within the blood-cell and finally undergoes a process of division. The products of this division are called *merozoits.* These merozoits are liberated but at once enter another blood-cell where they again go through the stages of schizonts and merozoits. Parallel with this development the schizonts begin also to produce *gametes* or sexual elements. These sexual elements, however, can not copulate within the human organism on account of the unfavorable temperature. To enable them to carry out this function, and to develop further, they require the intervention of an intermediary host, as already described.

In the macrogametes there is furthermore to be observed a curious phenomenon first determined by Schaudinn; we refer to the *parthenogenesis* which is nothing less than a stage which insures the survival of the plasmodium. The macrogamete when mature, in order not to disappear from the organism, as happens with the microgametocyte, divides in the same manner as the schizonts. Probably each product of this division then again becomes a macrogamete. In this parthenogenesis of the macrogametes lies the explanation of the cases of malaria with periodical attacks recurring at great intervals of time. This phenomenon has already been determined for *Plasmodium vivax* and *Plasmodium falciparum,* and there is every reason to believe that the same occurs with *Plasmodium malariæ.* An ancient Roman imprecation "*Quartana te teneat*" is significant in this connection as it can be given no other interpretation.

As already stated there exist three well-defined species of *Plasmodium* which cause human malaria: *Plasmodium malariæ, P. vivax* and *P. falciparum.* For the diagnosis of the species two methods are employed. One is to examine a drop of fresh blood, unstained, placed upon a slide and under cover-glass. It is the method least employed because it requires greater technical skill; it permits, however, all the details to be seen, as Schaudinn has shown. Among other notable achievements he succeeded with this method in following clearly the penetration of the sporozoit into the blood-cell. The second method consists in staining the blood which has been spread in a very thin layer upon a microscope-slide. There are various methods of staining which all have as a basis more or less the same color substances. That most in actual use, because it is the simplest and the one which enables all the details of the parasite to be distinguished, is the process of Giemsa.

Plasmodium malariæ (the organism of quartan malaria).—When one examines with the microscope a slide with live parasites of quartan fever one sees that their movements are much weaker than those of *Plasmodium vivax*. The black pigment-granules appear early; the parasitized red blood-cell shrinks a little, and in stained preparations this can be seen readily. The quartan parasite sometimes also produces a heavier coloration; however it does not possess granulations like those of Schüffner (seen in stained preparations as small red dots) in *Plasmodium vivax*, or of Maurer (a very few dots) in *P. falciparum*. Schizogony takes place only in the peripheral circulation. The parasite divides into from 8 to 14 merozoits arranged with great regularity, hence this phase is sometimes called the "rosette," "daisy," or "marguerite" form. The evolution takes longer than in any other plasmodium, 72 hours being consumed from one schizogony to the next. There is a characteristic appearance which this parasite assumes during growth, that of a more or less broad band across the corpuscle which is by many called the *æquatorial band*. The gametes are round, not only when inside of the corpuscle, but also when free in the blood-plasm.

Plasmodium falciparum.—The disease caused by this parasite goes under several names: *quotidian, malignant tertian, atypical, irregular, æstivo-autumnal, pernicious,* or *tropical fever*. The Germans follow Koch and use the term "tropical fever" but this expression is not in accord with the geographic distribution of the parasite. The differentiation of this parasite is based more on clinical data than on the structure and biology of the organism. When alive the schizont is very active. Schizogony takes place in less regular periods than in the other parasites, fluctuating between 24 and 48 hours. Doflein states that there may be a prolonged period of 72 hours. Also the number of merozoits is variable and may range from 4 to 30, although commonly between 6 and 14. The division always occurs in the internal organs; in acute cases it can, however, also be found in the periphery. In this parasite there is commonly formed a precocious division in the young forms, a fact which explains the rapid progress which pernicious attacks make. Besides the habitual cycle, then, the parasite can subdivide before it has completed it. It is quite common to find blood-cells containing more than two schizonts; there have already been found as many as 6 or 7 in a single corpuscle. A peculiarity of this parasite is its retreat to the internal organs after 30–36 hours; after having divided the parasites reappear in the periphery, generally two or three hours after this process. To this phenomenon is due the fact that blood examinations made just before a fever-paroxysm may be negative, the parasite not having yet reached the periphery. In the greatest part of the cases there can only be observed annular parasites, generally situated close to the margin of the blood-cell. Rarely there can be found adults and schizonts in process of division. The proportion of parasitized corpuscles is variable and in acute cases can reach an enormously high number, far beyond what is known to occur in the other two species.

The gametes have a form characteristic of the species. They were the first malarial organisms to be observed. In 1843 Klencke found them but it was Laveran who, in November of 1880, in Algeria, recognized them as the causative agents of malaria, calling them *crescentic bodies* or *half-moon bodies*. On account of this very characteristic form of the gametes certain authors have placed the organism in a genus by itself, under the name *Laverania,* in spite of the fact that this form is transient and changes to a spherical shape when it becomes free in the blood-plasm.

Ziemann described a form of *Plasmodium falciparum* which he found in Africa, founding it on the more pronounced roundness of the crescents and the rarity of their appearance in the peripheral blood. This rarity of the crescents is, however, everywhere a frequent occurrence with the pernicious parasite and it is particularly accentuated during the epidemic months. This variety, as also various species indicated by certain investigators, have not been accepted by the majority of good workers. Withal it seems nearly certain that still another species of *Plasmodium* exists, characterized by annular forms identical with those of *P. falciparum,* but developing without provoking the acute attacks characteristic of this species.

Plasmodium vivax.—This species is responsible for the benign tertian malaria. It is the best studied of all the species, being the one used by Schaudinn in his famous researches which have thrown so much light on the biology of the malarial parasite. Seen fresh the schizont appears endowed with lively movements. Schizogony takes place in periods of 48 hours, each parasite liberating from 12 to 24 merozoits. It is this species which produces the greatest change in the blood-corpuscle. After 16 hours it already presents the characteristic granulations of Schüffner. The parasite, 24 hours after having invaded the corpuscle, begins to produce an hypertrophy of the blood-cell which becomes more accentuated with the growth of the parasite. Parallel with this change the granulations of Schüffner increase in number and the anemia of the corpuscle, which begins with its hypertrophy, continues to grow more pronounced. In stained preparations these changes can be very distinctly perceived. The gametes are spherical. The macrogametes when fully developed are about 1 1/2 times as large as the normal red blood-cells; the microgametocytes are very slightly larger than the corpuscles.

The human organism can be parasitized at the same time by more than one generation of parasites, either of the same species or of different species. These evolve independently of each other and therefore also produce separate fever-paroxysms. The "double benign tertian" is an example which can be cited;

here there are two generations of the same *Plasmodium*, which, developing alternately, produce an attack every 24 hours. The double and the triple quartan are rare forms; the first is marked by two successive days of fever, followed by a day of repose, while in the second the attacks are daily. The explanation is the same, the presence in the same individual of two or three generations of *Plasmodium malariæ* which alternately undergo schizogony.

In acute cases of malignant tertian the attacks are prolonged and another attack begins before the previous one has ended; such attacks are called *subintrant*. There are cases in which a continuous fever appears. As there are diverse generations of the parasite, whenever any one of them enters into schizogony this is indicated by a fever-paroxysm, generally preceded by a chill which *coincides exactly with the schizogony. The initial chill can be absent in malignant-tertian fever*; it is, however, always present in benign tertian and in quartan fever.

When more than one species of *Plasmodium* is found in the blood this association is called a *mixed infection*. These are most frequently produced by the parasites of benign tertian and malignant tertian fevers and it is very rarely that one of these forms has been reported as associated with the quartan parasite.

In these cases not only does each *Plasmodium* develop in the most complete independence, without the development of one affecting that of the other, but also the two species can grow and develop within the same blood-corpuscle without interfering with each other. The same thing happens with like or unlike elements of the same species. For example one corpuscle can be infested by various schizonts, each one of which goes through its evolution without disturbing the others; or, the same may occur with schizont and gamete, male or female, when they happen to be found together in the same corpuscle.

The mixed infections have contributed much to furnish arguments for the unicists who believed in the existence of only a single species of *Plasmodium* and that this was capable of transforming into varieties, according to temperature, the transmitting species, the climate, etc. Kinoshita has demonstrated that from the oöcyst onward the species of parasites can be differentiated. These differences become more marked, both morphologically and biologically, in the different stages of schizogonic development and moreover produce different organic reactions. The specific identity of all the parasites is a point now disposed of. Few still defend this extravagance and among these there is only one of universal renown.

Another hypothesis, formulated by some authors, is in a similar position. This is the hypothesis of the possible transmission to man of the *Plasmodium* of monkeys, and, more startling, of other similar parasites of various animals.

Some points in relation to the malarial parasites still await future research to better elucidate them. The hereditary *transmission of the sporozoit to the* egg of the mosquito is a possibility indicated by Schaudinn. This investigator also believed in a differentiation of the sporozoits into males, females and undifferentiated. The belief in the possibility that another cycle may occur in the mosquito, different from that already known and perhaps more rapid, can not be summarily dismissed. The suspicion of such a possibility must occur to anyone who has experience with the subject and who has observed that when in the months of epidemic malaria the carriers of gametes, who serve as the means of infecting mosquitoes for experimental research, are in very small proportion and that nevertheless the epidemic increases with great rapidity. Withal it will be futile to seek the explanation of this phenomenon outside of the mosquito, where alone, sooner or later, it will be found.

Practically an *Anopheles* can become a transmitter in 10 to 12 days after having fed. This period may be diminished under optimum conditions for the vitality of the *Plasmodium*. It would appear from the few experiments in this direction made with each species of *Plasmodium* that this period is variable. The most favorable temperature appears to lie between 22° and 28° Centigrade. Beyond these conditions the development of the parasite goes forward more slowly and there are observations which show a period of more than 50 days. In hot countries, during the months of greatest heat, the proportion of malignant tertian to the entire number of cases of malaria may reach as high as 96 per cent. After this epoch the malignant tertian decreases and is replaced in proportion by the benign tertian. The quartan malaria is generally everywhere much the rarest form.

It is not rare in malarial countries to find children harboring ring-forms of the parasites which are indistinguishable from *Plasmodium falciparum* and yet these children present no symptoms of abnormal health except splenomegaly. They are typical cases of *imunitas non sterilans*—immunes who, nevertheless, are bearers of the parasites and therefore sources of infection. Do the parasites lose their virulence, or are they a different species? We have already mentioned that parasites exist in every way like those of malignant tertian but which in their development produce attacks of a very benign character. Some authors also report two clinical types of quartan malaria, one benign, the other malignant; however it has been impossible to differentiate the parasites microscopically.

Spontaneous recoveries from malaria can be observed with a certain frequency. It is to this circumstance that the supposed efficacy of remedies other than quinine is to be attributed. Of such remedies the only one of any value is methylene blue which acts destructively upon the plasmodia, but its effect is slow and in cases of acute malignant tertian it does not act with the necessary rapidity and energy, as does quinine. Under certain conditions there may come about the formation of races of *Plasmodium* resistant to quinine.

THE SCIENTIFIC DEMONSTRATION OF THE CARRIAGE OF MALARIA.

Before the actual demonstration of the carriage of malaria by mosquitoes of the genus *Anopheles*, a number of observers in different parts of the world, in addition to those already stated, had announced their belief in the relation between mosquitoes and the malady. By far the most forcible argument, however, was presented by Dr. A. F. A. King, of Washington, in a paper read before the Philosophical Society of Washington in 1882 and subsequently published in the Popular Science Monthly for September, 1883 (vol. 23, pp. 644–658). This paper attracted much attention in this country, but the author himself realized that the arguments brought forth could not be held to prove the theory. He said, however, "they may go so far as to initiate and encourage experiments and observations by which the truth or fallacy of the views held may be demonstrated." The main arguments used by King were substantially as follows:

1. The malarial season corresponds to the season of mosquito abundance.
2. Malarial country is suitable for mosquito breeding.
3. Similar conditions afford protection against malaria and against mosquitoes.
4. Exposure to night air means exposure to mosquitoes.
5. Influence of occupation. Soldiers, tramps and fishermen are particularly susceptible to malaria and are especially exposed to mosquitoes at night.
6. Turning up the soil or making excavations in previously healthy districts is often followed by malaria, but this turning up of the soil gives opportunities for water to accumulate and for mosquitoes to breed.
7. Coincidence of malaria and mosquitoes.

The scientific study of malaria may be said to begin with the far-reaching discovery of the malarial parasite. Laveran, on November 6, 1880, first recognized the organisms as minute protozoan parasites of the red blood-corpuscles. He furthermore discovered the flagellate and crescent forms of the parasites which were afterwards shown to be sexual phases of it. The idea that the infection was brought about through mosquitoes was suggested by Laveran in 1884; by Robert Koch in 1892; and by Sir Patrick Manson in 1894. The Italians Bignami and Mendini mentioned it in 1896, and Grassi in 1898. Bignami and Dionisi are said to have conducted mosquito experiments which, however, turned out negative, in 1893 and 1894. Manson, who had already proved that mosquitoes acted as the transmitters in filariasis, pointed out that there was probably a similar relation in malaria. He expressed his belief that the flagellæ were spores and that they underwent further development in the mosquito.

Following the publication by Manson, in 1894, of his theoretical induction that the gametes of malaria undergo further development in mosquitoes, Dr. Ronald Ross, of the Indian Medical Service, commenced, in May, 1895, certain researches in the hope of demonstrating this hypothesis by practical experiment. He was then stationed in India, and almost immediately proof that the gametes undergo their peculiar changes more readily in the stomach of mosquitoes than elsewhere was obtained. Then followed two years of arduous work with mosquitoes of the genus *Culex* without the desired results. In August and September, 1897, however, in Secunderabad, he succeeded in following the development of the parasites in *Anopheles* mosquitoes, and his results were published in the British Medical Journal for December 18, 1897, and February 26, 1898. The following year he was unable to work with human malaria on account of the public agitation against plague inoculation in Bengal, so he determined to

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study the malaria of birds. As the result of work carried on from March to August, 1898, he completely demonstrated the life-history of a malarial organism in birds. He succeeded in infecting healthy birds by the bites of infected mosquitoes, the species being identified as *Culex fatigans*.* Before this (in 1897) MacCallum of Baltimore had found that with *Halteridium* of birds the flagella and the pigmented spheres represented sexual forms of the parasite, the flagella impregnating the spheres. He was able to observe this process with malarial parasites of human blood. Thus the general law of infection and of the development of the malarial parasites was established.

Grassi, approaching the subject from another viewpoint, conceived the idea that the disease and its transmitter must be coincident and that therefore the host relation of the malarial parasite is restricted to definite mosquitoes. He carried out most careful studies, which proved this to be the fact and showed that mosquitoes of the genus *Anopheles* alone are concerned in the transmission of malaria in man. In 1898 Grassi, together with Bignami and Bastianelli, was working in Italy upon the malarial problem; on November 28 they reported finding developmental stages of the malarial parasite in the stomachs of two *Anopheles claviger*, fed on patients with malarial crescents in their blood. On December 3, in the London *Lancet*, Bignami described the first successful infection (of a man named Sola) by an infected *Anopheles*. Later numerous valuable publications by the Italian investigators followed. Ross's finding of the pigmented cells in *Anopheles* mosquitoes, in August, 1897, and his complete demonstration of the life-cycle of a malarial organism of birds, entitles him to the credit of the complete scientific demonstration of the relation between mosquitoes and malaria, a fact which, though still disputed by certain of the Italian school, has been recognized by most writers and has brought him the Nobel prize in medical discovery. To Grassi belongs the credit of the discovery that human malaria is only transmitted hy *Anopheles* mosquitoes. Later work by investigators of many nations has resulted in an extensive knowledge of the life-history of the causative organisms of malaria, and a number of species belonging to *Anopheles* have been proved to be secondary hosts of the malarial parasites of man. The Italian workers, Machiafava and Celli, and those above mentioned, Koch, and above all Schaudinn, of Germany, Laveran and Marchoux, of France, Manson, Ross, Daniels, and others, of England, have all contributed to the final results. It is perfectly demonstrated that the full development of the malarial parasite can not take place within the human body, and that certain species of *Anopheles* mosquitoes are the necessary secondary hosts, the sexual generation of the parasite taking place only in these mosquitoes.

Some especial attention must be give to the work of Robert Koch on account of his large share in malarial investigation, not only from the scientific, but also from the practical side. In Italy, in the autumn of 1898, he was able to find the various stages of *Proteosoma* in birds and in mosquitoes. He succeeded in infecting mosquitoes by allowing them to feed on birds harboring the parasites. Koch continued the investigation in Berlin, and in the middle of November fol-

* = *Culex quinquefasciatus* Say.

lowed the developmental stages of the parasite to the end, thus verifying the discoveries of Ross. He had in June of the same year, without knowledge of MacCallum's investigation, detected the process of fertilization and the function of the flagella as spermatozoa.

In the course of his malarial investigations in Java, late in 1899, Koch discovered that when malaria is endemic it is often confined almost entirely to the children, a fact which he had already noted previously in East Africa; the adults, therefore, that have survived have acquired a certain degree of immunity. Koch found that very little malaria was in evidence in localities which seemed to be favorable in every way. He therefore sought a native village, which was situated in the midst of swamps and offered optimum malarial conditions, for the purpose of making blood examinations of the natives. He found that the adults did not suffer from malaria while a large percentage of the children did, the youngest ones being worst infected. Koch's discovery of the frequent infection of naked children in the tropics, Ross considers to be one of the highest importance. It indicates the possibility of the disappearance of the effects of malaria, and that such apparently immune individuals, harboring the malarial parasites, are the source of most malarial infections in the tropics.

Large scale practical demonstrations were soon made. One of the most interesting was that carried on in Italy by Professor Grassi during the summer of 1900 in the Plain of Cappacio near Salerno. The objects of this experiment were: (1) To afford an absolute proof of the fact that malaria is transmitted exclusively by the bite of mosquitoes; (2) To formulate, in accordance with the results, a code of rules to be adopted to free Italy from malaria within a few years. The experiment consisted in protecting from mosquitoes railway employés and their families along about 12 kilometers of railway in an intensely malarious region. These people lived in ten cottages and two stations at St. Nicolo, Varco, and Albanella, situated along the Battipaglia-Reggio Railway. They numbered 104 persons, including thirty-three children under ten years of age. Of these 104 individuals, at least eleven, including four children, had never suffered from the disease, not having previously lived in a malarious district; a certain number, it appeared, had not suffered from it in two or three years, and all tbe others, that is to say, the large majority, had suffered from it during the previous malarial season, some of them even in the winter. During the malarial season, the health of the protected individuals was exceptionally good; there were a few cases of bronchitis and one of acute gastro-enteritis, and none of these cases were treated with quinine. Among these 104 persons, only three cases of malaria appeared and these were clearly relapses from malaria acquired the previous year. The unprotected neighbors, however, without exception, contracted malaria.

Another very striking experiment which, during the autumn of 1900, was mentioned in newspapers all over the world, was that performed by Doctors Sambon and Low, of the London School of Tropical Medicine, in the Roman Campagna, reputed for its malaria, during more than three months of the late summer and early autumn of 1900. They had constructed a comfortable little five-roomed wooden house about three hours drive from Ostia, in one of the most malarious portions of the Campagna. The house was tightly built and was thoroughly screened. The experimenters, together with a Signor Terzi and two Italian servants, lived in this house through the period when malaria is most prevalent. They took no quinine and no health precautions beyond the fact that at sundown each day they entered the house and remained there until daylight the next morning. Dr. Rees, of the London School, visited them and occupied the house with them for a portion of the time, and all three conducted laboratory work in one of the rooms, which was fully equipped for such a purpose, and led a busy and contented life. They explored the neighboring swamps and woodlands and visited the neighboring villages. They received and entertained many visitors who were interested in the experiment. They always turned indoors before sunset and then stood at the windows and timed the first appearance of *Anopheles,* which would come at a certain hour each evening and try to enter the screened windows and doors. As Dr. Rees expressed it, "It must have been very tantalizing for them to be unable to get at us." When the rains set in, everyone said that that was the critical time of the experiment. The people in the surrounding country became ill generally with malaria, the chilling caused by the rain having brought about an explosion of the fever. The experimenters, however, went out into the rain and got soaked to the skin, but their health remained perfect. Not the slightest trace of malaria developed in any of them. As above stated, the spot where the house was built was probably the most malarious one in the whole Campagna, and it was situated on the banks of one of the canals, which literally swarmed with *Anopheles* larvæ. The prevalent idea that the night air of the Campagna is in itself so dangerous was included in the experiments and the windows were always left open at night, so that if the marsh air had anything to do with malaria they would have contracted it.

A check experiment was carried on at the same time. *Anopheles* mosquitoes, which, under the direction of the Italian doctors Bignami and Bastianelli, had been fed on the blood of a sufferer from malaria in Rome, were sent to London early in July. A son of Sir Patrick Manson offered himself as a subject for experiment and allowed himself to be bitten by the mosquitoes. He had never been in a malarious country since he was a child and was in perfect health, but in due time he was taken with a well-marked malarial attack of the benign tertian type; microscopical examination showed the presence of the parasites in his blood. Later a second subject, also an Englishman, who had never suffered from malaria, submitted to the experiment, allowing himself to be bitten by infected mosquitoes sent from Rome. He also developed malaria after two weeks and the parasites were demonstrated in his blood.

Another early experiment on a large scale, to control malaria through protection from mosquitoes, was carried on in 1900 by Fermi and Tonsini on the Island of Asinara. This island is north of Sardinia, and inhabited only by convicts and their guards. After a close study of the malarious localities, and mapping of the mosquito breeding places, measures were taken for (1) destruction of mosquito larvæ (petrolizing pools and emptying tanks and tubs completely twice a month); (2) destruction of adult mosquitoes in the convict dormitories with pyrethrum powder, 'zanzolina,' chlorine gas, etc.; (3) protection of habitations against mosquitoes by screening doors and windows. The results in one season were: *Anopheles* almost never found (and other mosquitoes much more rarely than formerly) in dormitories. Not a single primary case of malaria developed, the new cases, nine in number, were all importations or relapses. The previous year there had been ninety-nine cases, of which about forty-four originated on the island.

Since that time the relation of the mosquito to malaria has become the common knowledge of the civilized world, and many regions have been freed from the disease by anti-mosquito work. Some of these have been mentioned in other sections of this work.

Koch, in 1900, at Stephansort, in German New Guinea, conducted a vigorous anti-malaria campaign to determine if malaria could be eradicated from a given locality. His work was based on the idea of destroying the parasites in the blood of man by means of quinine and thus depriving the mosquitoes of the source of infection. In the first place, by the microscopic examination of the blood, all the persons of the community in whom malaria was latent were discovered These potential transmitters of the disease were treated with quinine, administered methodically at regular intervals until the parasites had disappeared from the blood. Every one of these, at intervals of ten or eleven days, was given one gram of quinine on two successive mornings. When necessary the intervals were shortened and the doses of quinine increased. In this manner Koch succeeded, in the space of a few months, in almost wholly eradicating malaria from Stephansort. The results of Koch's experiments indicated that this method of destroying malaria, so that there is no disease for the *Anopheles* to transmit, may be most useful under certain conditions. Koch protests that his method differs radically from the so-called quinine prophylaxis with which it has been frequently confused. This latter method aims to prevent the infection of man and, to be effective, would have to be applied to all the inhabitants of a malarial region.

Dempwolff later continued the work of Koch in German New Guinea. He found, when he tried to apply the Koch method on a large scale, that the method has its limitations. He found much difficulty in making the necessary blood and spleen diagnoses, not only in the prejudice and superstition of the natives, the shifting character of the population, but often in the indifference of the European settlers as well. Dempwolff points out that the prospects are much more hopeful when the *Anopheles* appear only at a certain season and one can hope to break the chain of the malarial organisms from one season to another. He points to the results, under such conditions, of Vagedes in Franzfontein (German South-west Africa), Frosch in Brioni (Istria) and Ollwig in Dar-es-Salaam (East Africa).

It should be here stated that cinchonization was tried in 1903 by Edmond and Etienne Sergent in France at Saint-Philbert de Grand-Lieu, but their effort, based exclusively upon Koch's method, did not give good results. They found it difficult to make exact microscopic diagnoses, and also found it impossible to give agricultural laborers the doses of quinine prescribed by Koch, since such doses incapacitated them from work and made them refuse subsequent treatment. Giving the doses recommended did not in two cases prevent the reappearance of the fever. They concluded that, if the results obtained by them in this test are compared with the results which they obtained in Algeria by mechanical defense against mosquito bites and the use of petroleum against their larvæ, there can be no doubt about the superiority of the latter methods. The theoretical idea of the disinfection of the blood of malarious patients is very logical, provided that the quinine actually kills the parasite in all its stages.

Quininization has been used in many of the British colonies, not entirely on the Koch plan to use it as the sole means of doing away with malaria, but as an auxiliary, and with considerable success. In British Guiana, as pointed out by Boyce, the government gives out quinine at the postoffices to laborers, and he states that it is sought after and does good.

In Italy very marked results have followed the general use of quinine, introduced by the government and encouraged in every possible way. There was already a very marked reduction of malaria in the first years following the discovery of the transmission of the disease by mosquitoes, when many efforts were made to control malaria through the mosquito. Further improvement was brought about by extensive drainage operations, but the statistics show that with the introduction of the free use of quinine there was a great reduction in the, until then still high, malarial rate. Professor Celli is the strongest advocate of the extensive use of quinine. He believes that by this means alone malaria can be controlled in Italy and that other measures are negligible. There has been much opposition to his view, but he argues that drainage measures, while theoretically the ideal method of malaria control, can not be carried out in a sufficiently perfect manner to insure results. He points out that drainage can never be perfect and that tbe smallest collections of water will furnish breeding places for *Anopheles*. Furthermore, agricultural irrigation works, established on the reclaimed lands, have unavoidably established new breeding places for *Anopheles*. It seems to us that neither method alone would have given the results now obtained, but just what share should be credited to the different methods would be difficult to determine. Certainly in Italy the general use of quinine appears to have very materially reduced malaria. The accompanying maps, from Professor Celli's paper in the Atti della Società per gli Studi della Malaria, vol. xi, 1910, show the wonderful improvement which has been brought about in malarial conditions in Italy through the modern ideas.

Stephens and Christophers state that a prophylactic method was tried with considerable success at one point in Africa. This consisted in removing the residences of the Europeans to a distance from the native town, and thus, from the source of infection. "Several years ago at Accra, Gold Coast, the residences of the officials were removed from Accra town to an unoccupied site about half a mile from any native dwellings, since called Victoriaborg. This is almost the

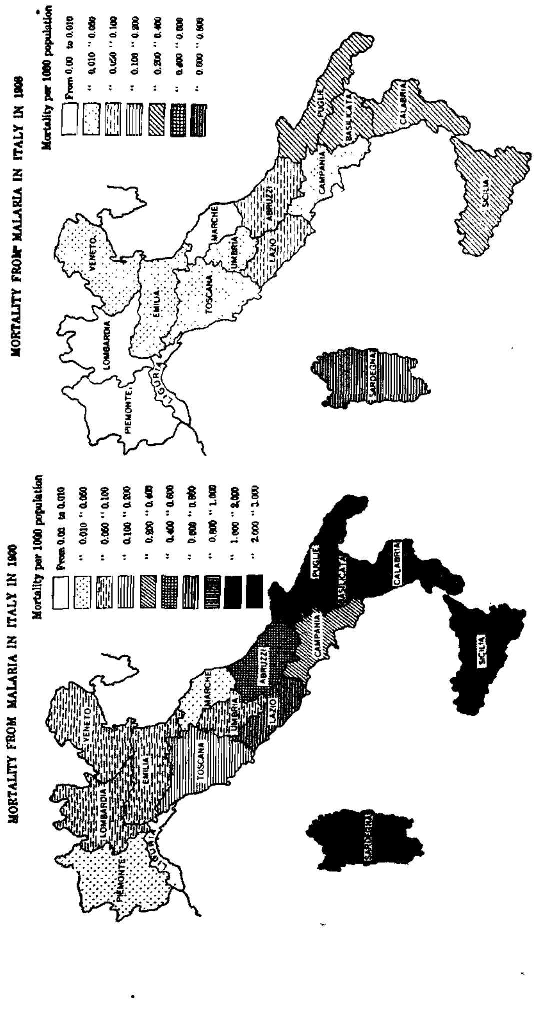


FIG. 5.—Showing comparative mortality from malaria in Italy in 1900 and 1908.

only case we have seen where in Africa a scheme of segregation has been carried out. The result has been to make Victoriaborg reputedly the most healthy European settlement on the West Coast of Africa."

THE MOSQUITOES THAT CARRY MALARIA.

No mosquitoes belonging to genera other than *Anopheles* have been shown to carry malarial diseases of human beings. *Culex quinquefasciatus* has been shown by Ross to be the necessary secondary host for a closely allied malarial disease of birds, and other mosquitoes have been shown to carry malarial diseases of other animals. At present our knowledge of malarial diseases in wild animals is very slight. With the human species it will probably be ascertained that many, though by no means all, of the species of the genus *Anopheles*, in its broader sense, transmit malaria. Grassi, Bignami and Bastianelli have proved that in Italy *Anopheles maculipennis, A. bifurcatus* and *A. superpictus* transmit the various types of malaria. In Japan and Formosa, Tsuzuki determined that *Anopheles jesoënsis, A. formosaënsis* and *A. cohæsa* are responsible for tertian and æstivo-autumnal malaria.* Dr. W. S. Thayer, in his chapter on malaria, vol. 2, part 2, Allbutt & Rolleston's System of Medicine, London, 1909, indicates the following species as having been shown to carry malarial infection: *Anopheles bifurcatus* (Europe); *A. maculipennis* (Europe); *A. quadrimaculatus* (North America); *A. jesoënsis* (Japan); *A. martini, A. pursati* (Cambodia); *A. vincenti* (Tonkin); *A. listoni, A. culicifacies* (India); *A. funesta, A. superpicta, A. paludis* (West Africa); *A. coustani* (Madagascar and Reunion); *A. costalis* (Africa); *A. cruzii* (Brazil); *A. albimanus* (Panama). According to Stephens and Christophers *Anopheles listoni, A. culicifacies* and *A. fuliginosus* are the species principally concerned in India, and to these *A. turkhudi* has been added and *A. jeyporensis* is suspected. Kinoshita reports *Anopheles annulipes* as transmitter of pernicious malaria in Formosa. Dr. Arthur Neiva states that in Brazil *Anopheles albimanus, A. argyritarsis, A. pseudomaculipes,* and *A. intermedium* have been proved malaria carriers. Experimental work with *Anopheles punctipennis* in the United States was begun in 1902. Smith in New Jersey, on the 24th of September, caused a number of specimens of the females of this species to bite a patient suffering with malaria. These specimens were later examined by Dr. W. N. Berkeley, of New York City, but without any definite result. Hirschberg reports the result of comparative experiments with *Anopheles quadrimaculatus* and *Anopheles punctipennis* conducted by feeding them with the blood of patients known to contain the parasite of æstivo-autumnal malaria. The results were that of 58 specimens of *Anopheles punctipennis* fed, none were found to be infected, whereas of 48 *A. quadrimaculatus* fed, 8 were found to be infected. The same writer pointed out that the distribution of the latter species in the vicinity of Baltimore coincided in a general way with the occurrence of malaria-infected districts. The disease prevailed

* According to Kinoshita *Anopheles jesoënsis* = *A. sinensis*, *A. formosaënsis* and *A. cohæsa* = *A. listoni*.

where *Anopheles quadrimaculatus* had its breeding-places, but was absent from districts where *A. punctipennis* abounded. Smith, in his report of the New Jersey State Agricultural Experiment Station upon the mosquitoes occurring within the State (1904, page 158), discusses the relation of *Anopheles* to malaria in New Jersey. Where *Anopheles punctipennis* is the abundant species malaria is practically unknown; while within the range of *A. crucians* malaria does occur, it is by no means prevalent and *A. quadrimaculatus* is also found there and is considered by him the responsible species. Dr. J. W. Dupree, however, has recorded the fact that the malarial relation has been established for *Anopheles punctipennis* by himself. He further states that it has been established for *Anopheles crucians* by Pothier and Beyer.

The discrepancies in the results of different investigators, which are particularly obvious in the above-mentioned experiments with *Anopheles punctipennis,* may find an explanation in facts brought out by Professor Beyer and his collaborators (Prof. George E. Beyer, Dr. O. L. Pothier, Dr. M. Couret and Dr. I. I. Lemann: Bionomics, experimental investigations with Bacillus sanarelli, and experimental investigations with malaria, in connection with the mosquitoes of New Orleans. N. Orl. Med. & Surg. Journ., Jan., 1902). These investigators show that a definite species of *Anopheles* can be the host of a certain type of malaria while other types of malaria can not develop within it. In a series of careful experiments it was found by these students that *Anopheles quadrimaculatus* became infected with the parasites of tertian and quartan, but not of æstivo-autumnal fever. On the other hand *Anopheles crucians* proved to be the bearer of æstivo-autumnal malaria while it remained wholly negative to the other types of parasites. The results were obtained by feeding mosquitoes of both species upon humans in whose blood the malarial parasites were found to be present, and, after a suitable interval, examining the mosquito for the parasite. These experiments were repeated a sufficient number of times with the different types of malaria and the two species of *Anopheles* to be conclusive. They found further that the distribution of *Anopheles crucians* about the city of New Orleans corresponded very closely with the distribution of the cases of æstivo-autumnal fever.

Kinoshita, in his studies in Formosa and Japan, found that the type of malaria depends upon the species of *Anopheles,* and that, while in Europe *Anopheles maculipennis* appears to be capable of transmitting all three forms of malaria, this is not true of any of the *Anopheles* studied by him. In Formosa the occurrence of pernicious malaria corresponds, both geographically and in time, with the occurrence of *A. listoni.* "Every epidemic of *malaria tropica* depends upon the increase and decrease of *A. listoni,* of which, as determined above, more than 50 per cent can transmit tropical malaria. This mosquito develops very abundantly between the months of April and October. The new infections of tropical malaria begin also about the end of April and reach the highest number between June and July. *Anopheles listoni* is generally more abundant in mountainous regions than on the coast and the distribution of tropical malaria corresponds. Taihoku, where *A. listoni* does not occur, is therefore free from the tropical malaria."

Kinoshita states further that *Anopheles listoni* does not occur in Japan and that the country has always been free from pernicious malaria in spite of the fact that persons suffering with pernicious malaria frequently come to Japan. On the other hand, Kinoshita found that both in Formosa and Japan *Anopheles sinensis* is the principal transmitter of tertian malaria. By experimentation he found that about 50 per cent of this species became infected with tertian parasites; quartan parasites developed in this mosquito only at low temperatures and the parasites of pernicious malaria never. Another interesting point in this connection is that he not rarely found new infections of tertian malaria in winter, while this was not the case with pernicious malaria. The explanation lies in the fact that in Formosa *Anopheles sinensis* is active throughout the winter.

It will thus be seen that negative results with a given species of *Anopheles* are not conclusive unless the experiments are conducted with all types of malaria and under the most favorable conditions. Furthermore it would appear that different species of *Anopheles,* where susceptible to the same types of malaria, may be so in different degrees. Grassi, Bignami and Bastianelli, in their early experiments, had found that a certain proportion of the *Anopheles* appeared to be naturally immune and failed to develop the malaria parasite, even under the most favorable conditions. This proved to be the case with all the species of *Anopheles* and of parasites experimented upon by them.

In a recent paper Dr. Samuel T. Darling discusses the relation of the various species of *Anopheles* to malaria in the Panama Canal Zone. His careful studies show that *Anopheles albimanus* is the principal transmitter of malaria, both æstivo-autumnal and tertian, in that region. He found that 70.8 per cent of the individuals of this species which he induced to bite malarial patients became infected. He also found that this was the species which frequented houses most, constituting in Ancon, during October, 1908, 72.5 per cent of the *Anopheles* found, and in some villages being the only species present. Of *Anopheles pseudopunctipennis* it was found that 12.9 per cent of the individuals experimented with became infected, while of 17 *A. malefactor* none became infected. *Anopheles argyritarsis* and *A. tarsimaculata* were later found by him to be malaria transmitters.

The brothers Sergent have recently found sporozoits, probably malarial, in the salivary glands of *Anopheles algeriensis* and *A. hispaniola* in Algeria. In addition to the malaria-bearing forms above mentioned, Theobald in the fourth volume of his monograph lists *Anopheles barbirostris, A. pseudopictus* and *A. theobaldi* as transmitters of the malarial parasites.

THE HABITS OF ANOPHELES MOSQUITOES.

The general points of difference between adults of this group and those of other mosquitoes are very well understood, the long palpi of the female as contrasted with the short palpi of the females of most other mosquitoes, for example. The other points of difference will appear from the systematic descriptions.

While full descriptions, not only of the adults, but of the early stages of the different species of malaria-bearing mosquitoes, together with some remarks concerning the geographical distribution and habits, will be found in their appropriate places under the systematic consideration of the genus *Anopheles*, later in this work, some general consideration of their habits will be given here. The general question of distribution is briefly mentioned under the head of geographical distribution of malaria.

RESTING POSITION OF ADULTS.

Much has been said concerning the resting position of *Anopheles* as compared with that of other mosquitoes. It has been held that *Anopheles* always sits with its body-axis at a considerable angle to the surface upon which it rests. This, however, can not be relied upon for identification. When *Anopheles* rests upon a surface, such as the wall of a room, the body is frequently held at only a comparatively small angle to the surface; in fact, it is sometimes held parallel, but more often at a considerable angle. The angle at which the body is held differs with the species and is characteristic for it. The hind legs are frequently in motion but as a rule hang down with more or less of a bend at the knee joint. In whatever position *Anopheles* rests, the beak and the rest of the body are practically in the same plane, whereas with other mosquitoes the beak and the abdomen are by no means in the same plane. In *Culex* and *Aëdes*, for example, the appearance is that of being humpbacked. During hibernation, the hind legs are drawn in, and, for the most part, the body is brought close to the wall, as observed by one of the writers (Howard) upon *Anopheles quadrimaculatus* hibernating in barns in southern Idaho.

Giles has found an Indian *Anopheles*, which he claims has exactly the resting attitude of a *Culex*. This caused him to give it the specific name *culicifacies*. Grassi states that *Anopheles superpictus* holds itself rigidly perpendicular to the wall, and the Sergents state that *Anopheles hispaniola* rests in the same perpendicular attitude. Schüffner has observed the same habit in a Sumatran species. Peryassú states that *Anopheles nimba* rests and flies like a *Wyeomyia*, with the hind legs raised and curved forward over the body.

SEMI-DOMESTIC AND WILD SPECIES.

Several of the species of *Anopheles* seem to be on the verge of becoming domesticated, like *Culex pipiens*, and the yellow-fever mosquito, and are commonly found about houses. They attempt to enter houses at the times during which they are active and, once inside, remain there. They seek cellars, attics, barns, and outhouses for hibernation purposes. They often find shelter elsewhere, as under culverts and other protected places, but they seem to prefer to get into buildings if possible.

Mr. A. H. Jennings has pointed out that, in the Canal Zone, *Anopheles albimanus* is the semi-domesticated form and occurs everywhere about houses and villages. This species, in fact, is the great carrier of malaria in the American tropics. Away from civilization, in Panama and the neighboring countries, Mr. Jennings states that this species is very rare or can not be found at all, but *Anopheles eiseni* takes its place as a wild, undomesticated species.

James and Liston have a significant statement which bears upon this differentiation in regard to domesticity among the different species of *Anopheles* in India.

"It is a well recognised fact that some species of 'anopheles' are more commonly found near villages and dwellings than others. We may, in fact, divide these insects broadly into two classes: the 'domestic' species, which are usually found near human dwellings, and the 'wild' species, which are rarely found in houses. Of the first class, *A. rossi* is a typical example, and of the second *A. barbirostris*. Some species would appear, as regards this habit, to occupy a place intermediate between the typically domestic and the typically wild species. *A. fuliginosus,* for example, may, in certain parts of India, be found in enormous numbers in the sheds and outhouses on the outskirts of a village, while in other parts, though large numbers may be caught in tents pitched at some distance from a village, few or none will be found in the houses of the village itself.

"It is usual to say that the greater the number of 'anopheles' there are in a place, the greater will be the prevalence of malaria. This is not by any means borne out by experience. We have already mentioned that some species of 'anopheles' are better malaria-carriers than others, and apart altogether from the fact that 'anopheles' may be abundant in a place without there being any malaria there at all, it often happens that the species which is present most abundantly is not the one which is carrying malaria at the time. It is, however, a difficult matter to estimate the relative abundance of different species in any place, for some are much more easily seen than others, and the habits which some species have of secreting themselves among the straw of a thatched roof and of resting only upon objects which are as nearly as possible the same colour as they are themselves, are very important. In order to exemplify this, it seems worth while to recount an instance which happened in our experience. In the malarious village of Ennur in the Madras Presidency, *A. rossi* was so abundant that on almost every straw of the thatched roof of every house three or four specimens of this species were resting. A careful search in the ordinary way did not reveal the presence of any other species, and it is certain that, had there been no other object in the search than the mere determination of the species of 'anopheles' present in the village, the observer would have gone away quite satisfied that *A. rossi* was alone present. But the village was an extremely malarious one, and knowing that *A. rossi* was an inefficient carrier of malaria in nature, he was unwilling to believe that no other species was present in the houses. Fixing his mind, therefore, upon the thought that he was looking for *A. culicifacies* and not for *A. rossi,* he again commenced the search with great care, and was rewarded not only by detecting the presence of *A. culicifacies,* but by catching a sufficient number of this species during several days' work, to prove that it was the species responsible for the prevalence of malaria in the place and not the very much more abundant species *A. rossi.*"

HIBERNATION AND ÆSTIVATION.

Anopheles pass the winter, for the most part, in the adult condition. In regions with a rigorous climate the fecundated female is the only form that survives the winter and starts a fresh generation with the return of mild weather. Smith has shown that in New Jersey they begin to seek winter quarters in September. He dissected specimens during the winter and found the alimentary canal empty and the ovaries undeveloped. In the early winter he found the abdomen filled with a fatty mass, but in the early spring the fatty mass had disappeared. In cellars and in attics they remain motionless on the walls, or under shelves in pantries. Professor Hodge, of Worcester, Massachusetts, has found them resting under such pantry shelves in winter literally by thousands. This points out the great desirability of cellar fumigation in winter in malarial regions, as will be shown under the head of remedies. In Washington, adults often appear in houses during the winter when stimulated by high temperature. Under such circumstances they have been known to bite even in midwinter, although it would seem that it is only a small proportion of the hibernating individuals that become active. Giles has found that in the colder portions of northern India, *Anopheles* hibernate, and he points out that they pass the intense dry heat of the early summer in much the same condition. Grassi found that *Anopheles* can not withstand the same amount of desiccating heat as other mosquitoes. Stephens and Christophers state that in India the *Anopheles* pass the hot, dry season in houses, and although they feed at intervals they will not lay eggs even if artificial breeding-places become available. James and Liston, in India, found eggs, young larvæ, and pupæ of two species during the winter in newly made breeding-places and another species was able to hibernate in the larval condition. Giles on the other hand shows that in many localities in India *Anopheles* may be found in all stages practically every month in the year, decreasing in numbers in the hot weather and increasing in the rainy season, the determining factor undoubtedly being the moisture conditions. Hibernating larvæ have been found in Italy and Galli-Valerio and Rochaz de Jongh have demonstrated that the larvæ of *Anopheles bifurcatus* hibernate normally in Switzerland.

FEEDING HABITS OF ANOPHELES.

The feeding habits of the female *Anopheles* have an important bearing on the malarial relations of these mosquitoes. It has already been pointed out that certain species of *Anopheles* occur more or less in association with man and these species are the important malaria carriers. Other species show, at least, no preference for man. Thus, for example, Jennings has observed that, in Panama, *Anopheles eiseni* is the abundant species in regions uninhabited by man, while *A. albimanus*, which is the chief malarial agent in the American tropics, is absent from such localities. The *Anopheles* found in localities uninhabited by man must have recourse to other animals to procure blood. Schüffner asserts that a species of *Anopheles* found by him in Sumatra could not be induced to suck blood. On the other hand, he remarks on the extreme voracity of another species, and this last species proved to be instrumental in the transmission of malaria. "When the animals have an empty stomach it is sufficient, in order to feed them, to put the hand into the cage. Instantly this is covered with them, and one feels, from the slight burning sensation which follows immediately, how rapidly they can sting. When they have once begun to suck they do not easily allow themselves to be disturbed; one can touch and shake them without succeeding in driving them away. Therefore there is no trouble in capturing them while feeding. The voracity of the animals is incredible. An ordinary *Culex*, after it has sucked its fill, flies away. These *Anopheles*, however, are not satisfied with this but continue to suck, making more room by discharging the surplus through the anus. At first they discharge the fæces and intestinal liquid, but afterwards, drop by drop, pure blood follows. So, before it chooses to fly away, it flushes its digestive tract with three to four times the amount of bood which would have been necessary to fill its stomach."

Grassi, in Italy, was the first to study carefully the habits of *Anopheles* and his observations still stand unsurpassed. He believes that the normal food of *Anopheles* is blood, and, if they can find it, exclusively that of warm-blooded animals. They prefer the blood of mammals, but he found that sometimes they would, as it seemed with some reluctance, suck the blood of birds (poultry, sparrows and hawks). Grassi does not believe that there is a predilection for particular mammals, but that they are attracted in proportion to the size of the animal, the larger animals appealing more strongly to the olfactory sense of the mosquitoes. He found that frequently, when a man and horse were near each other, the horse would be bitten many times before the man was bitten at all. On the other hand, in the case of a man and rabbit, the man is generally attacked first.

Grassi found that under proper conditions *Anopheles* will bite in the open, in houses and in stables. He states that in malarial regions it very often happens that, in the evening, when persons are sitting at their doors, they are attacked by great clouds of *Anopheles*. He found that in the summer the *Anopheles*, after having procured a blood-meal within the house, seeks a hiding place outside where it can digest the food. It does not fly far but hides in the foliage near by and returns to the same place to obtain another meal of blood. During the day they remain quiescent among the herbage, upon the under side of leaves, selecting a spot where they are best protected from sun, rain and wind.

Grassi found that in the winter the *Anopheles* sought shelter in houses and particularly in stables, and that, while with low temperatures they remained quiescent, if the temperature rose they would suck blood. The preference of *Anopheles* for stables has been repeatedly observed. Kinoshita, in Formosa, found *Anopheles* abundant in stables and he utilized these in his studies on malaria, for it proved that such *Anopheles* were all free of malarial parasites. Mühlens, in his studies of some malarial epidemics in northern Germany, made some interesting observations on the preference of *Anopheles* for stables. In the spring of 1907 and 1908, at Bant in the vicinity of Wilhelmshaven, he found the *Anopheles* preponderatingly in the warm stables of cattle and hogs, where they had hibernated. They were rare in the cellars of houses, while, on the contrary, *Culex* were abundant in the cellars but rare in the stables. The *Anopheles* fed through the winter and showed a preference for the animals over man. The stomach contents of the *Anopheles* from stables were tested by the Uhlenhut process and it was found that they consisted of the blood of cattle or hogs, according to whichever animal they happened to have been associated with. As already pointed out by Grassi, two factors probably determine the preference of

Anopheles for stables. The size and number of animals exercise a strong attraction upon the *Anopheles*, and the even warm temperature within the stables is probably another influence.

Anopheles females will feed upon other substances when they can not obtain blood. Grassi states that Ficalbi has seen them sucking the juices of fruits and the filth in out-houses. Grassi and Noé have surprised *Anopheles* feeding upon unripe ears of Indian corn and sucking green grasses; they have noted that they would, in time of need, absorb dirty water and they have seen them attracted to sweetened water.

Grassi states that *Anopheles* first sucks blood two or three days after emerging from the pupa and that in cool weather a longer time passes. Darling, in Panama, found that they would bite after 24 or 48 hours. Peryassú states that *Anopheles argyritarsis* and *A. albimanus* will sometimes suck blood ten hours after emergence. Many observations show that *Anopheles* suck blood frequently under favorable conditions. Neiva made careful experiments on this point and found that the various Brazilian species would suck blood at intervals of 24 hours or even more frequently. In Italy it has been observed that the *Anopheles* fed upon successive days even when they had not fully digested the previous meal. Neiva noted that weather conditions had a marked effect on the activity of *Anopheles*. When there is a change of weather and rain threatens the *Anopheles* are numerous and bloodthirsty. During rain they remain quiescent but become active afterwards, even if a heavy rain has fallen for some hours. Neiva found that on very hot days the *Anopheles* also attacked with great ferocity.

Little is known of the feeding habits of the male *Anopheles*. Grassi thought that the males normally feed on the juices of fruits and he has kept them alive on this food for 25 days. It is probable that the males of *Anopheles* suck the honey of flowers, as do those of other mosquitoes. There are several records of *Anopheles* visiting flowers but the sex is not mentioned and it is probable that the females also resort to flowers when their normal food fails them.

NOCTURNAL AND DIURNAL HABITS.

Most of the *Anopheles* fly preferably at twilight. This fact was turned to practical account in the first anti-malarial work in Italy. Grassi found that, while occasionally *Anopheles* will bite during the day, their time of normal activity is at twilight, and in reality very short. He observed that on unclouded days, during June, July and August, the period of greatest activity lasted from 30 to 40 minutes and they would disappear before the obscurity became complete. At first they would come in small numbers and these increased until the maximum was reached after about 20 minutes; then they would again decrease in numbers. On cloudy days they would come earlier and remain longer, the governing factor being the amount of light. The *Anopheles* would appear when it was still light enough so that one could read easily, and when it became so dark that it was hardly possible to read the *Anopheles* disappeared. The *Anopheles* were active both during the evening and morning twilight but their number was much greater in the evening. In some cases a certain number of *Anopheles* remained on the window screens from evening until the following morning.

Grassi found that *Anopheles* will bite even at night if the temperature is high. He found them very troublesome on a calm night when the moon was shining brightly. They proved very annoying up to 2 a. m., but after that the temperature fell and none were felt up to 4 a. m.; between 4 and 6 a. m. they again bit in the fiercest manner. The above observations apply to the hot plains of central and southern Italy. In northern Italy the time during which *Anopheles* bites is much restricted on account of the low night temperature.

When it is windy no *Anopheles* are seen or felt. On calm evenings they come in clouds and it may happen that on the next evening none appear. In sufficiently shaded localities it is not rare to have *Anopheles* bite out of doors during the day and this is also the case in houses which are not well lighted or when the day is cloudy. Cases of *Anopheles* biting in sunlight are very rare. During the day *Anopheles*, when hungry, will bite if a victim happens to be near, but they will not go far to obtain food.

Grassi further states that *Anopheles* do not come directly to artificial light, but they are attracted to the edge of the illuminated zone. A method of getting rid of the *Anopheles* and other mosquitoes in a room, indicated by Grassi, is based upon their preference for a certain amount of light. In the evening the room is closed and the light allowed to enter only through a single aperture; the mosquitoes will then leave by this opening. This expedient is only successful at twilight; during full daylight the mosquitoes can not be induced to leave in this manner.

Careful observations in Brazil, by Doctors Chagas and Neiva, show that the different species of *Anopheles* follow each other in regular sequence in the evening and morning twilight. Thus Neiva found that, at Xerém, *Anopheles pseudomaculipes* appeared first, later *Anopheles intermedium*, and last, when it is already quite dark, *Anopheles mediopunctatum*. *Anopheles albimanus* and *argyritarsis* appear together as soon as the twilight begins and remain until dark. Apparently the activity of each species is governed by a definite amount of light and on this account the time of appearance and disappearance of a species varies with the season and with the weather conditions. Generally the time for biting lasted but thirty minutes but this was extended on moonlight nights. These observers found that with artificial light the *Anopheles* bite at all hours of the night but they doubt that they bite in absolute darkness. In the morning the *Anopheles* appear when it is already much lighter and remain longer, but they appear in much smaller numbers. In the forest every species of *Anopheles* comes to bite during the daytime but not in such numbers as in the evening. Dr. Neiva found that *Anopheles brasiliensis* attacked man and animals in open fields in the hot sunshine, and immediately after a rain it appeared in true swarms, characteristic for this species.

Anopheles crucians, according to Smith, bites during the day, and the same authority has upon rare occasions seen *Anopheles punctipennis* bite in the afternoon on porches in New Jersey. One of us (Knab) has been attacked by this species in full sunlight, early in the spring, in Massachusetts. Smith states that *Anopheles crucians* bites readily from sunrise until 11 a. m., and from 3 p. m. until after dark. In his opinion it will bite any time during the day, provided the victim is in a cool and sheltered location. Captain Fernside, I. M. S., according to Giles, has seen an Indian *Anopheles* (presumably undetermined) "feed greedily in the daytime," and a number of similar observations might be quoted.

Rev. James Aiken, in his "Notes on the Mosquitoes of British Guiana" (5th Series), in the British Guiana Medical Annual for 1908, shows that at least one species of *Anopheles* bites during the day in British Guiana. His statement is as follows:

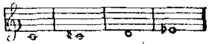
"Anopheles during the day never by any chance attack in front, but invariably settle on some part of the anatomy invisible to the eyes of the subject to be bled. I have often experimented with a hungry albipes, turning round and following her with my eye as she vainly endeavored to lodge on the back of my neck. As I am still somewhat sensitive I have sometimes occasion when seated on a cane chair to rise and interpose a sheet of newspaper or some such protection from the subtle attack of this troublesome gnat."

THE NOTE OF ANOPHELES.

The senior author pointed out in 1900 that there is a distinct difference between the buzzing sound or hum of *Anopheles quadrimaculatus* and that of *Culex pipiens*, in that the former is indisputably lower in tone. His attention was called to this by Mr. F. C. Pratt, who believed that he could at once distinguish the two insects from the pitch of the hum as he was sitting reading in his house in Virginia. The note of *Culex*, as it approaches the ear, is higher in pitch and that of *Anopheles* is certainly several tones lower and not so clear. This difference becomes at once perceptible by confining the respective insects under gauze in a breeding-jar.

Some interesting experiments on the sounds produced by *Anopheles* were made by Nuttall and Shipley, who found that by cutting off more and more of the wing the sonnd decreases in volume, the pitch rising progressively.

"When the wing was cut off quite closely, a very high-pitched note of slight intensity remained, this as we supposed being produced by an internal apparatus such as Howard indicates. It may however be due to respiratory movements which are exaggerated through the efforts at flight, the sound is not produced by the insect in repose. We found that the males gave a higher-pitched note than the females, and that the note was higher in both sexes when they had fed; the greater the meal, the higher the note. Of four unfed females three gave notes within a quarter of a tone of 264 (*i. e.*, of 240 to 270 vibrations), the fourth female gave an abnormally low note of about 175 vibrations. Four other females were arranged in the order of the distension of the abdomen by food, the last being largely distended, these gave notes corresponding roughly to 264—281—297—317 vibrations or according to the musical scales, the notes:



"Three unfed males gave exactly the same note, viz. corresponding to 880 vibrations  immediately after feeding one gave the note A ♯, another which had fed well B♮. The unfed males were more closely concordant than the unfed females, the latter varying over about a semitone. Mr. J. W. Capstick, M. A., Fellow of Trinity College, Cambridge, to whom we are greatly indebted for making these ear determinations for us by means of tuning-forks, was not certain that the note given by the males was not one of 440 vibrations. Overtones were obviously strong and it sounded at times as if there were a faint note of 440 vibrations overshadowed by a strong one of 880.

"The obvious explanation of the higher note given off by the males is that their wings are markedly narrower and shorter than those of the females. Although a female *Culex pipiens* gave a higher pitched note than a female *A. maculipennis*, we are not at all sure that it was not simply due to the smaller size of the former insect. The male of this species of *Culex* certainly gave a higher pitched note than the female."

DISTANCE OF FLIGHT.

Distances to which malarial mosquitoes will fly is a very important point in the consideration of malarial prophylaxis. It seems reasonably sure that they are much less capable of extended flight than many other mosquitoes and that ordinarily they travel but a very limited distance. Statements that *Anopheles* fly a long distance may be set down as based upon faulty observations. Thus Craig has recently stated that he determined a flight of *Anopheles* of two and a half miles in the Philippines. The difficulty of determining, in a tropical region, that no breeding-places are present within a radius of two and one-half miles must be obvious. When we consider that *Anopheles* larvæ may exist in the water-filled foot-prints of animals, and that these may be hidden by vegetation, that furthermore they may breed in hollows in trees, or in water-bearing epiphytic plants, the task of determining with absolute certainty the absence of breeding-places over a large area will be clearly seen to be impossible. Grassi already pointed out that on account of the absence of scaly covering these mosquitoes are less able to withstand desiccation than others and that, therefore, they can not cross large areas which afford them no shelter from the direct rays of the sun.

Pressat, who made careful studies at Ismaïlia in Egypt, objects to the statement of certain authors that *Anopheles* fly very long distances and points out that they are not capable of sustained flight. He affirms that, when *Anopheles* are present, careful search will reveal breeding-places within a distance of a few hundred yards. Pressat admits that under certain conditions *Anopheles*, progressing by stages, travel considerable distances. When they are found at great distances from their breeding-grounds they have reached the place in a passive manner, transported by wagon, by railway or by boat. They may travel with a caravan, as he determined by actual observation at Ismaïlia, by resting upon the animals, the baggage or clothing. Pressat believes that *Anopheles* can not cross a region denuded of vegetation, or a considerable expanse of water. On the other hand wooded country affords them the necessary shelter and the animals found there furnish them food.

Celli has concluded, from his observations in Italy, that *Anopheles* do not fly farther than from 200 to 350 meters. When at greater distances from their breeding-places they have traveled passively. They may be carried by a light wind but in that case the limit is two kilometers. Dr. J. M. Young, of the British Army, after extensive observations in China, came to the conclusion that as a rule malarial mosquitoes will not fly over two hundred yards.

Stephens and Christophers, however, in their reports on the malaria expedition to Sierra Leone, state that under some conditions *Anopheles* may fly much greater distances than has been supposed. In one small inland house which had been occupied by one old man, five and six *Anopheles* were to be caught each morning. These were fresh from pupæ and could only be derived from the breeding-place three to four hundred yards away. The same writers have also demonstrated a flight of six hundred yards. The Royal Society's malarial commission in India found that, in certain villages in the central provinces, *Anopheles culicifacies*, *A. stephensi*, and *A. fuliginosus* were always present if there were extensive breeding-places within a quarter of a mile, but that villages which were distant half a mile from these breeding-places contained few or no malarial mosquitoes. The obvious conclusion is that half a mile was beyond the normal flight. James and Liston point out that in Mian Mir three groups of rain-pools gave an opportunity to make fresh observations upon this question of flight. The first group was four hundred and fifty yards distant from any house; the second seven hundred and fifty yards distant; and the third upwards of three-quarters of a mile. "On repeated occasions the pools of the first group were found to contain larvæ within a week of a shower of rain, on three out of four occasions the pools of the second group contained larvæ, but on no occasion were larvæ found in the pools of the third group. These experiments appeared to show that *A. rossi,* which was the species concerned, would readily fly to a breeding place a quarter of a mile away, that it would less readily fly to a breeding-place 750 yards away, and that it would never fly to breeding places three-quarters of a mile away. It is obvious, however, that from none of these experiments can any knowledge of the *maximum flight* of 'anopheles' be obtained; they prove only that when these insects are once established in a village they naturally select the nearer breeding places in preference to those which are further away. But in their search for food adult 'anopheles' often become attracted to villages which have no breeding places near at hand, and recent observations have shown that they may be abundant in a place even when there are no breeding grounds within a very long distance. Captain James, I. M. S., in the operations at Mian Mir already referred to, found on one occasion that numerous adult *A. fuliginosus* were present in the bazaars and houses when no larvæ of this species were to be found nearer than two and a quarter miles, and Dr. Christophers, during the same operations, found that the limit of flight of *A. rossi* had not been reached at three-quarters of a mile, and that although all breeding places of this species had been obliterated up to this distance, it still appeared in increasing numbers in the houses. The latter observer draws the following conclusions from his experiments:—

"(1) In every case where an abundant food supply existed, anopheles travelled long distances (half a mile or more) to reach it, and traversed an equal distance, if necessary, to lay their eggs. Where, however, a suitable breeding place lay near at hand they did not appear to pass it over.

"(2) *The maximum distance of flight of A. rossi is not known with certainty*, but under the conditions at Mian Mir the experiments showed that they flew to and fro a distance of more than half a mile.

"(3) The breeding places of *A. fuliginosus* were in no case nearer than 1000 yards from the situation where the adults were captured.

"(4) In the later part of the season it was difficult to understand where adult *A. culicifacies* came from unless distances of half a mile or more were traversed by this species.

"It is obvious that in any attempt to estimate the probable efficacy and practicability of efforts at destruction of 'anopheles,' these conclusions are extremely important." *

The Sergents in Algeria found that the breeding-places are generally to be found from 100 to 300 meters from infested houses, but in the case of the railway station of Ighzer-Amokran, absolutely isolated in the Valley of the Soumman, the station contained adult *Anopheles* while the nearest breeding-place was distant one kilometer. The mosquitoes found in the station were in good condition. The authors do not mention the possibility that they were brought there in the railway coaches. Further observations by these authors, at Mondovi, showed adult *Anopheles* at a distance of two kilometers from breeding-places but they ascertained that this distance was traversed by successive short flights.

It is obvious, then, that these mosquitoes do not progress by direct flight for considerable distances but usually spread by other means. A succession of short flights, *e. g.*, from areas in which they are abundant, will carry them farther than by any single direct flight. Moreover, the adults are frequently carried by railroad trains and in other conveyances for long distances. This question we have considered in regard to mosquitoes in general in another section.

That *Anopheles* perhaps may be carried, exceptionally, for considerable distances by winds is indicated by the observation of Surgeon A. C. H. Russell, U. S. N.; he sent us a specimen of *A. annulipalpis* Arribálzaga, with the statement that it was one of a considerable number of mosquitoes blown aboard the U. S. S. Newark in June, 1903, at anchor off Montevideo, more than two miles from the shore. Carter credits Goldberger with the observation that *Anopheles albimanus* appeared on board a ship, at Vera Cruz, anchored half a mile from shore.

In a most suggestive address, delivered before the Section of Preventive Medicine of the Congress of Arts and Sciences at the St. Louis Exposition in 1904, entitled "The Logical Basis of the Sanitary Policy of Mosquito-Reduction," Dr. Ronald Ross considers the whole question of the spread of mosquitoes from their breeding-places, both in communities in which anti-mosquito work is being carried on and from outside breeding-places from which cleared areas may be restocked. He states that the problem which governs the prophylaxis of malaria through mosquito control may be stated in the following words: "Suppose that a mosquito is born at a given point, and that during its life it wanders

* A Monograph of the Anopheles Mosquitoes of India. S. P. James and W. Glen Liston; Calcutta, 1904.

about, to and fro, to left or right, where it wills in search of food or of mating, over a country which is uniformly attractive and favorable to it. After a time it will die. What are the probabilities that its dead body will be found at a given distance from its birth-place?" Doctor Ross attacks the problem from the mathematical standpoint. His address as a whole is full of interest, and may be consulted on pages 89 to 102 of volume VI of the published report of the Congress. We may, to advantage, quote his conclusions:

"I will now endeavor to sum up the arguments which I have laid before you—I fear very cursorily and inadequately. First I suggested that there must be for every living unit a certain distance which that unit may possibly cover if it continues to move all its life, with such capacity for movement as nature has given it, always in the same direction. I called this distance the limit of migration. It should, perhaps, be called the ideal limit of migration, because scarcely one in many billions of living units is ever likely to reach it—not because the units do not possess the capacity for covering the distance, but because the laws of chance ordain that they shall scarcely ever continue to move always in the same direction. Next I endeavored to show that, owing to the constant changes of direction which must take place in all random migration, the large majority of units must tend to remain in or near the neighborhood where they were born. Thus, though they may really possess the power to wander much further away, right up to the ideal limit, yet actually they always find themselves confined by the impalpable but no less impassable walls of chance within a much more circumscribed area, which we may call the practical limit of migration—that is, a limit beyond which any given percentage of units which we like to select do not generally pass. Lastly I tried to apply this reasoning to the important particular case of the immigration of mosquitoes into an area in which their propagation had been arrested by drainage and other suitable means. My conclusions are:

"1. The mosquito-density will always be reduced, not only within the area of operations, but to a distance equal to the ideal limit of migration beyond it.

"2. On the boundary of operations the mosquito-density should always be reduced to about one-half the normal density.

"3. The curve of density will rise rapidly outside the boundary and will fall rapidly inside it.

"4. As immigration into an area of operation must always be at the expense of the mosquito population immediately outside it, the average density of the whole area affected by the operations must be the same as if no immigration at all has taken place.

"5. As a general rule for practical purposes, if the area of operations be of any considerable size, immigration will not very materially affect the result.

"In conclusion, it must be repeated that the whole subject of mosquito-reduction can not be scientifically examined without mathematical analysis. The subject is really a part of the mathematical theory of migration—a theory which, so far as I know, has not yet been discussed. It is not possible to make satisfactory experiments on the influx, efflux, and varying density of mosquitoes without such an analysis—and one, I may add, far more minute than has been attempted here. The subject has suffered much at the hands of those who have attempted ill-devised experiments without adequate preliminary consideration, and whose opinions or results have seriously impeded the obviously useful and practical sanitary policy referred to. The statement, so frequently made, that local anti-propagation measures must always be useless, owing to immigration from outside, is equivalent to saying that the population of the United States would remain the same, even if the birth rate were to be reduced to zero. In a recent experiment at Mian Mir in India the astounding result was obtained that the mosquito-density was, if anything, increased by the anti-propagation measures—which is equivalent to saying that the population of the United States would be increased by the abolition of the birth-rate. It is to be hoped that if such experiments are to be repeated they will be conducted by observers who have considered the subject. In the meantime, I for one must continue to believe the somewhat self-evident theory that anti-propagation measures must always reduce the mosquito density—even if the results at Havana, Ismaïlia, Klang, Port Swettenham and other places are not accepted as irrefragable experimental proof of it."

THE BEHAVIOR OF ANOPHELES TOWARDS CERTAIN COLORS.

As is pointed out with relation to the yellow-fever mosquito, persons dressed in white are less liable to be bitten than those dressed in black. It was early found that *Anopheles*, like many other mosquitoes, seeks dark places to rest during the day and alights by preference upon dark objects. A study of the behavior of *Anopheles* towards different colors has been made by Nuttall and Shipley, which is of sufficient interest to quote in full:

"The behavior of the insects towards various colours has not as yet received sufficient attention. Whilst engaged with experiments upon the influence of shade and colour we came upon a few data cited in the recent literature.

"Austen (March 1901, p. 341) writes, 'If the walls of the room be whitewashed, with a dark dado, it is interesting to note that the insects will always be found upon the dark strips, and never on the white portions of the wall.' Buchanan (April 1901), in India, notes that 'The men who collect the living *Anopheles* say that the *Anopheles* hide in a black coat, but avoid a white coat, so they hang up one or two black coats in the Hospital Ward' when they desire to catch the imago. Neither Austen nor Buchanan say anything about the influence of colour. The first as far as we know to refer directly to the influence of colour is Joly (May 1901, p. 259) who made observations on mosquitoes in Madagascar. He states, without saying what genus, that mosquitoes there were more attracted to black than to red soil, or to white sand. Persons wearing black shoes and socks were more bitten than when these articles of apparel were white. Brown clothes protected less than those of white or blue. He states that the natives of Madagascar know the attraction black offers to mosquitoes and for this reason hang up a black cloth on the rafters of the room for the insects to collect upon. Joly observed that a yellow haired dog was very much less bitten than a black one. For the same reason the natives are more bitten than the whites, although they suffer less from the after effects.

"It seemed to us to be a matter of considerable practical utility to determine what influence, if any, colour exerted upon a known malaria-bearing species of mosquito. And we deem our results sufficiently striking to make it worth the while for those who are engaged in similar studies abroad to take the matter up systematically. Our experiments certainly indicate that *Anopheles maculipennis* is attracted by some colours and repelled by others, a matter which would have its *practical application in the choice of the colour of clothing and the interior of rooms* in malarious districts. We are moreover inclined to believe that suitably constructed coloured boxes, or *colour-traps,* might be of practical utility in and about houses infested with mosquitoes. By periodically closing the boxes and sweeping out the contained insects into a receptacle, or, possibly by rendering the interior of the boxes sticky a considerable number of mosquitoes might be destroyed.

"Our experiments were made in a large gauze tent which had been erected within a disused photographic establishment, the one end of the tent ending against large windows into which the sunlight poured on bright days. Large stone basins were placed on the floor for the *Anopheles* to breed in, the stock being renewed from time to time.

"It was noticed at the beginning that when one entered the tent in dark grey clothes, that the imagos frequently flew up and settled on the dark cloth, but that they never did this when the person entering the tent was clothed in white flannels. To test the influence of colour, a number of pasteboard boxes were taken which measured 20 by 16 cm. and had a depth of 10 cm. The boxes were lined with cloth, having a slightly roughened surface, to which the insects could comfortably cling. All of the fabrics had a dull—not shiny—surface, and each box was lined with a cloth of different colour. The boxes were placed in rows upon the floor and upon each other in tiers, the order being changed each day after the observations had been made. The interior of the boxes was moderately illuminated by light reflected from the surface of the white tent. On 17 days during a month beginning with the middle of June, we counted the number of flies which had accumulated in the boxes. Counts were actually made on 17 sunny and cloudy days, and with the following result:

Colour of Box	Number of *A. maculipennis* counted in each box during 17 days.
Navy blue	108
Dark red	90
Brown (Reddish)	81
Scarlet	59
Black	49
Slate grey	31
Dark green (olive)	24
Violet	18
Leaf green	17
Blue	14
Pearl grey	9
Pale green	4
Light blue (forget-me-not)	3
Ochre	2
White	2
Orange	1
Yellow	0
	512

"We see from the above table that dark blue was most attractive, the other colours being less and less attractive in the order of numbers given. A marked fall in the number of insects resting in the boxes begins with the 'pearl grey' box. Pale green, light blue, ochre, orange, and yellow, especially the last two colours seemed to repel the insects. The karki-coloured uniform at present in vogue should offer advantages besides invisibility to human foes! These observations on colour were described by one of us in a short note which appeared in the *British Medical Journal* (14 Sept., 1901).

"Mr. J. Cropper, of Mount Ballan, Chepstow, who read the above note wrote to us (17 Sept., 1901): 'Seeing your article on Colour Selection by *Anopheles* reminds me that I found the dark navy-blue lining of my tent this summer (in Palestine) extremely attractive to mosquitoes, almost entirely *Anopheles*—and when the sun got hot I always noticed an increase in their numbers, presumably as they came from the herbage and trees near by. No one ever slept in the tent, and I never found *Anopheles* bite in the day time.'

"Moreover Dr. H. E. Durham has since informed us that whilst he was studying yellow fever at Parà, Brazil, he was much less bitten about the feet than was his late companion Dr. Myers. Dr. Durham wore ochre coloured socks, Dr. Myers black ones."

Further experiments upon color preferences have been made by Jordan and Hefferan ("Observations on the Bionomics of Anopheles," Journal of Infectious Diseases, vol. ii, No. 1, January 12, 1905). Their results are as follows:

"Experiments were made to determine the color preference of adult A. punctipennis. The conditions of the experiment were substantially the same as those in a similar series of observations made by Nuttall upon A. maculipennis. The mosquitoes were confined under a large hood with glass sides and front. Boxes covered with different colored cloths of similar texture were placed under the hood, and every day at a fixed hour during a week the number of mosquitoes that had settled on each color was counted. The position of the boxes was changed every day after counting to eliminate possible influences of light and shade and other factors. The results were as follows:

Number of Mosquitoes.	On
61	Dark red
57	Dark blue
41	Black
8	Dark pink
6	Dark green
5	Lavender
5	Purple
4	White
2	Light blue
2	Pale green
1	Light pink
0	Yellow

"These results with A. punctipennis are very much like those obtained by Nuttall with A. maculipennis, dark red and dark blue proving the most attractive in both cases."

BREEDING-PLACES OF ANOPHELES.

Some observations bearing on this question will be found under the genus *Anopheles* in the systematic portion of this work. In the early investigations in America the larvæ were found in more or less permanent pools of water in the bed of an old canal, in the side pools of spring-fed woodland streams, in the side pools or shallows of field springs, or in artificial excavations filled with surface water. In such places, especially when supplied with a certain amount of green scum, the little larvæ were often found resting at the surface of the water, occasionally darting from one spot to another. They were also found in water contained in barrels and troughs, in fountain basins, but comparatively rarely found in the same water with the larvæ of *Culex*. Austen, in the report of the proceedings of the expedition for the study of the causes of malaria at Sierra Leone, states that on August 26, 1899, Doctor Prout and Doctor Berkeley found *Anopheles* larvæ mingled with those of *Culex* in a tub of water in a yard at the Sanitary Office. Aside from this and one other instance, *Anopheles* were always found breeding in roadside puddles and ditches. Nuttall, Cobbet, and Strangeways-Pigg, in England, found *Anopheles* larvæ nine times with *Culex* in ponds, and also took them with *Culex* in ditches in which the water scarcely flowed, in water-logged boats, and in stone troughs, and in fact found them fourteen times altogether with *Culex* and ten times with fish. Grassi and Ficalbi state that *Anopheles maculipennis* is most frequently found in flat land in Italy, the larvæ requiring clear water rich in vegetable food. Austen found in Freetown that *Anopheles* larvæ occurred in stagnant puddles varying from a foot to several feet at the sides of the streets, but many were met in the still water in little bays at the side of slowly running shallow ditches. Whether the water was clear or muddy seemed to make no difference, but green algæ were nearly always present, and in some puddles tadpoles were numerous. Veazie, of New Orleans, finds *Anopheles* larvæ in the ponds out in the suburbs and in the swamps back of the city. Colonel Gorgas, in the Havana campaign, found that the most efficient work was done by his malaria brigade along the small streams, the irrigated gardens and similar places in the suburbs. *Anopheles* bred principally in the pools and puddles well protected with grass, and were abundantly found in the small holes made by the footsteps of cattle and horses, which observation has been frequently repeated elsewhere. F. C. Pratt, of the Bureau of Entomology, has found them breeding in temporary standing water between rows of corn in lowlands in North Carolina.

As a matter of fact *Anopheles* larvæ may breed in almost any standing water. Smith, in answer to his own question "where does *Anopheles* breed?" says "Everywhere." He has found the larvæ in trap-pails in his back yard, and states that he has found no pool so insignificant and no stream so rapid but that somewhere in it *Anopheles* can breed. He has found the larvæ of *A. quadrimaculatus* on the salt marsh, and he has taken a larva of *A. punctipennis* in a stream that was so foul that it resembled an open sewer. He says:

"Small creeks through meadow land, the ditches and gutters or drains along railroad and other embankments, and the shallow overgrown edges of ponds or swamp areas are favorite breeding places. Pools containing grassy or other vegetation are nearly always infested, and ponds with lily pads, dock, saggittaria and other plants of a similar character, are danger points. The larvæ need only a mere film of water, and this being found over a leaf or at a grassy edge, protects them from the usual natural enemies. . . . no other mosquito has as wide a range of breeding places as have the species of *Anopheles*."

James and Liston, in their admirable study of *Anopheles* in India, state also that it is almost impossible to find a collection of water in which *Anopheles* may not occasionally be found. Unless every collection of water is systematically searched, important breeding-places may be overlooked. It is the opinion of these writers that each species has a particular kind of breeding-ground that it prefers above any other, a fact which has been noted by other observers in other parts of the world. *Cœlodiazesis barberi*, for example, in the United States, and *Anopheles eiseni* in Central America, breed in collections of water in tree-holes, frequently far away from human habitations. James and Liston point out that at Jalpaiguri two species of *Anopheles* were common; *A. rossi* bred in the small shallow, muddy puddles and pools near and among the native huts; *A. nigerrimus* bred at some distance from the village in the deep natural pools of a swampy marsh. Neither of these larvæ was found in the breeding-places of the other.

This principle, they state, extends to all the species of Indian *Anopheles*, and they point out an excellent example in three species found in an isolated bazaar at Mian Mir. Here there were three species, *A. culicifacies*, *A. fuliginosus*, and *A. rossi*. "This bazaar is surrounded by an irrigation channel about four feet wide and three feet deep. At the upper end of this water-course and about ten yards from it are a number of broad shallow muddy pools. At the lower end of the water-course and about thirty yards from the bazaar is a swampy piece of land covered with thick trees and shrubs, and containing a number of deep clear pools in which water plants and weed had grown." The adults of all three species were present in the houses of the bazaar, but in the irrigation channel only the larvæ of *A. culicifacies* were found, while in the shallow, muddy pools only the larvæ of *A. rossi*, and in the deep, clear pools under the trees only the larvæ of *A. fuliginosus*. Each of these species, therefore, had selected a particular kind of breeding-place. In another part of Mian Mir still another species of *Anopheles* was found breeding in the earthenware vessels of water. This species was *A. stephensi*, and it was not found breeding elsewhere.

The Sergents in Algeria studied with great care the subject of breeding-places, but there is little to add to what is given above. They call attention to the fact that in this country of the Arabs the spring, without which a community of people can not exist, is at the same time the indirect cause of the unhealthiness of the region in serving as a breeding-place of *Anopheles*.

We have mentioned the breeding of two species in collections of water in tree-holes, frequently far away from human habitations, but have not mentioned in this connection the accumulations of rain-water at the bases of the leaves of certain bromeliaceous plants in the tropics. A number of species of mosquitoes breed in such accumulations, and among them there is at least one *Anopheles*. In a suggestive paper entitled "Waldmosquitos und Waldmalaria," Dr. A. Lutz, formerly Director of the Bacteriological Institute of São Paulo, gives an account of the possible influence of such an *Anopheles* upon the construction of a railway. This railway was being built from São Paulo to Santos in Brazil, through an elevated well-wooded and wild region in which there were many mountain streams. Stagnant pools did not occur. During the construction of an adjoining railway intermittent fever had prevailed among the laborers, but after the line was completed it disappeared. During the construction of the new line many laborers were lodged in clearings in the forest along the line. Intermittent fever soon appeared, especially in the lower portions, but in the hot seasons rising to the top of the mountain. The fever was mild, but relapses were frequent. Doctor Lutz personally investigated the conditions, and himself spent a few nights on the spot. The first night he found an *Anopheles* mosquito, afterwards described by Theobald as *Anopheles lutzii*.* He found it abundantly in the mountain forest near the coast, but never far inland. He made a careful search for the breeding-places, and by a process of elimination finally focused his attention upon the epiphytic Bromeliaceæ. These were very

* A species was previously given the same specific name by Dr. Cruz, the present one was changed to *A. cruzii* by Dyar & Knab.

difficult of examination, since the plants for the most part grew upon the forest trees thirty feet above the ground. Those that had fallen with the trees had lost their water. Later, however, many plants were found in places which could be reached, and in the water accumulations of their leaves were found breeding a number of species of mosquitoes, and among these the larvæ of *Anopheles cruzii*. He considers the species to be a typical forest insect breeding only in such places, and that it is responsible for the malarial attack of a mild type from which the railway constructionists had suffered. The genera of Bromeliaceæ most commonly met with are said to be *Bresia*, *Nidularium*, *Billbergia*, *Æchmea* and *Bromelia*. In the water in these plants, he found bits of vegetation and a humus formed from them, and living in it small crustaceans, tadpoles, larvæ of Culicidæ and Chironomidæ. Among the other mosquitoes inhabiting this bromelia-water he found *Megarhinus violaceus* which was feeding upon the other culicid larvæ. The relation of *Anopheles cruzii* to this outbreak of malaria was not positively established.

On the supposition that *Anopheles punctipennis* is not a carrier of malaria, the control of malaria in certain regions of the United States, through the destruction of the *Anopheles* larvæ or breeding-places, may be simplified if a difference in the character of the breeding-places of *A. punctipennis* and *A. quadrimaculatus* (the only other common inland species in the more northern United States) can be ascertained. This consideration led Jordan and Hefferan (*loc. cit.*) to carry out the following observations:

"In the present instance it was found that the favorite breeding-places of A. maculipennis * and A. punctipennis, although close together, were of quite different character, as shown by the following facts relating to the distribution in Western Michigan.

"Dipping for mosquito larvæ was carried out in the springs and spring-fed pools of the northern ravines, along the river shore, in the bayou, and in rain-water barrels of the village. In all of these places, with the exception of the bayou, Anopheles larvæ were found in abundance at some time during three consecutive summers. The distribution was more extensive in 1902, merely because the early part of the summer was wet, and water stood longer in the springs and ravines. In 1903 the early part of the summer was dry, so that by the middle of August two springs and the river shore only were left as breeding-places in the immediate vicinity of the village. In the river the larvæ of A. maculipennis * are found regularly at certain places along the north shore, where abundant food and quiet are ensured by the wreckage and masses of river weed which lie a few inches below the surface of the water. Here, with the river running almost due west, the larvæ are exposed to direct sunlight. They were not found along the more shaded south shore. A curious instance of choice of breeding-places occurred in the summer of 1904. A small stream running to the river had, during the spring, a course of a mile or so down the ravine, but by August 1 it had dried to a few pools of the following character: (a) River inlet, 40 feet long and 7 feet wide, shaded by willows, bottom sand and mud, no larvæ; (b) Ten feet above this inlet a pool 40 feet by 4 feet in area, some 15 inches deep, entirely without shade or vegetation, no larvæ; (c) Only three feet from this second pool another pool of clear water, 5 feet by 3 feet in size, and 6

* = *Anopheles quadrimaculatus* of this work.

inches deep, shaded in the morning. Duckweed abounds here, and a quantity of green algæ cover the sticks and stone of the bottom; the pool swarms with Culex and Anopheles punctipennis larvæ; (d) Thirty-five feet above (c) is an 'iron' pool with a deposit of iron; it is about 9 feet by 9 feet, 10 inches deep, partly shaded by bushes and a huge log. It contains no vegetation and no larvæ. Of these four pools the smallest one, in the center of the row, is the only one containing Anopheles larvæ. *These larvæ are exclusively those of A. punctipennis, while in the river only a few feet from here, A. maculipennis is abundant.*

"Another noticeable feature of the distribution is the entire absence of all mosquito larvæ from the bayou, although the water is currentless, the vegetation abundant, and the light and shade favorable. It is probable that the duckweed and lily pads cover the surface too closely in the shallow water near the shore. As pool (c) above described became choked with duckweed later in the season, the larvæ disappeared.

"The following table shows the undoubted selection of different breeding-places by A. maculipennis and A. punctipennis:

ANOPHELES BRED FROM LARVÆ AND PUPÆ.

	A. maculipennis.		A. punctipennis.	
	Males.	Females.	Males.	Females.
Collected from spring-fed pools..........	0	0	30	35
Collected from river....................	46	47	1	4

"The fact that the breeding-places are only a few feet apart renders especially remarkable the specific preference displayed. The predominance of A. punctipennis in the other two regions that were examined is in accord with the observations in Michigan. A. punctipennis shows a predilection for spring-fed pools, and, in localities where these abound, is the chief species. Hirschberg and Dohme observed a rather definite geographical distribution of the two species in the vicinity of Baltimore, A. maculipennis being found on low ground in or near large bodies of water, while A. punctipennis was found in small, clear streams or springs on higher ground."

Smith in New Jersey says of *A. punctipennis,* "On the whole it breeds most abundantly in clean water along the edges of ponds or swamp areas or in the eddies of shallow streams." Concerning *A. quadrimaculatus,* he says, "The breeding places are similar, but this form also occurs in brackish water on the salt marshes, hence has a somewhat wider range and adds the positive danger of disease to the disadvantages of an undrained marsh."

J. K. Thibault, Jr. (*in litt.*) states that at Little Rock, Arkansas, *Anopheles punctipennis* is the most abundant species in the city and that it is scarce in the country; but that *A. quadrimaculatus* is the more abundant mosquito in the river-bottoms but is scarce in the city.

An interesting point has been brought out by Dutton in his report of the malaria expedition to the Gambia (Liverpool School of Tropical Medicine—Memoir X), to the effect that the number of mosquito breeding-places present in compounds was found to vary with the social position of the occupier, and in this statement he includes *Anopheles* mosquitoes. The following is taken from his report:

"In small compounds of the poorer natives, where one or two huts were present, no breeding-places were found. These natives had no discarded bottles, etc., in which water could collect, nor were wells or tubs or any article for the storage of water present, sufficient water for the day being drawn from one of the public wells. These compounds were exceedingly clean and tidy, and no mosquitoes were found breeding in them. Excepting these, breeding-places were found and increased in extent and number in proportion to the wealth and position of the occupier of the compound, reaching a maximum on the premises of the larger traders (natives and white), where innumerable facilities for the development of mosquitoes were afforded. These breeding places included all those domestic articles which are capable of containing a small quantity of water after showers lasting over a week without being dried up, or are not dried up between the frequent showers in the wet season. Such articles found were broken bottles, either stuck on a wall or scattered over the compounds, iron pots, old calabashes, tin-lined packing cases, cocoanut husks, fowl troughs, and old tins of all sorts. There was found an extraordinary amount of such-like rubbish in some of the factory compounds, the more specialized breeding-places included tubs, used for the storage of rain-water or as wash tubs for bottles, or in which water was placed for the preservation of the tub. Large barrels in which fibres were soaked, garden tubs in which water was stored for gardening purposes, old iron boilers for the collection of rain-water, improperly covered rain-tanks formed other breeding-places. In some of the factories a small gutter six inches across by four feet deep is let into the cemented floor of the yard around the ground-nut store house. This gutter is kept full of water to prevent the entrance of the ground-nut insect into the store. These gutters swarmed with mosquito larvæ. In some yards a small channel runs down the centre to drain off rain water, and is generally covered over with a board. It was found that some of these had become clogged up at intervals with sand and rubbish, so that small pools of water collected along their course; these pools acted as breeding-places for mosquitoes. An account of an examination of one of the larger European factories will illustrate to what extent mosquitoes are bred by the white man in the tropics on his own premises. In the factory yard were six barrels containing water, in some the water was very foul; in the garden were seventeen tubs containing water for gardening purposes, and besides this number of tubs there were eight wells, all uncovered. In all these articles mosquito larvæ were present; in the barrels in the yard the water swarmed with *Culex* and *Stegomyia* larvæ, and in the wells and tubs in the garden the larvæ of *Anopheles* and *Culex* were found in all of them in good numbers. Besides these breeding-places there were many domestic articles scattered about in odd corners of the yard, which in the wet season would also have acted as breeding-places.

"It was observed that larvæ of *A. costalis* were frequently found in rain-tubs and smaller articles containing water. Though many of these larvæ may have been originally transferred to some of these articles along with the water drawn from the well, yet the occurrence of batches of larvæ of the same age and in fair numbers would tend to show that this species of mosquito avails itself of these small collections of water in which to breed.

Stegomyia fasciata, in tubs and old bottles, etc.
Culex fatigans, " " and especially when the water was foul
A. costalis, tubs and barrels
Culex duttoni
Culex hirsutipalpis
Stegomyia pagens (rare), in ground-nut gutters.

"The wash-tubs, garden-tubs, wells, and rain-barrels occurring in compounds form the chief source of mosquito in Bathurst for at least six months of the dry season, when all other breeding-places, artificial and natural, have ceased to exist."

ANOPHELES BREEDING IN SEA-WATER.

We have mentioned above a statement by Smith that *Anopheles* has been found in the salt marshes, and this observation has been repeated by others. *Anopheles* have been found breeding in salt or brackish water in many parts of the world; in every case the habit has been found restricted to certain species. An article was published by Dr. W. T. de Vogel, health officer of Samarang, Java, in the *Atti della Societa per gli Studi della Malaria* for 1907, bearing upon upon this question, and his observations are so important that we devote considerable attention to them. De Vogel found that the investigations of several Italian workers have negatived the idea that *Anopheles* can multiply in pure sea-water and that they have shown that the maximum proportion of sodium chloride in the water which *Anopheles* larvæ can stand is 1.87 per cent according to Perrone, and 1.75 per cent according to Vivante. De Vogel, having made some elaborate studies in regard to malaria at Samarang, found as early as 1902 that *Anopheles* was breeding in a certain pool containing 2.8 per cent of chloride of sodium. Later he verified these results in several interesting cases. One of these was the island of Onrust, a small coral island situated two thousand meters from the mainland, and which contains no fresh water whatever. The distance from the mainland is such that even if *Anopheles* were brought from the mainland by winds they would not be numerous enough to cause trouble. Nevertheless a marine station established on the island had to be abandoned on account of the ravages of malaria among the workmen and Dr. de Vogel believed that this was due to *Anopheles* breeding in the sea-water upon the island itself.

De Vogel studied also the conditions in the Karimon Islands, a little archipelago in the Java Sea, sixty-five kilometers from the coast. The first colonists in this archipelago were convicts and were sent there to cut down the forests of rhizopores. There were no buildings, and the convicts were forced to sleep on the earth. The mortality was between two and three thousand in two years. Later one of the officers named von Michalofski—a plain man but full of good sense—succeeded in putting a stop to the excessive mortality by drying the sea-water pools, removing a part of the forest, and raising the ground on which the men slept. The success which followed these measures leads de Vogel to suppose that the mortality had been caused by malaria, and this supposition is all the more probable since, as he himself has verified, malaria is today rife among the population of the islands.

There is on the island of Grand Marimon only a single permanent source of fresh water which has only one restricted outlet. During the dry season there is no mingling of fresh water with sea-water, so there exist during that season many pools of dead sea-water peopled with *Anopheles* larvæ; these pools contain not less than three per cent of sodium chloride and must then be considered as concentrated sea-water.

Continuing his researches at Samarang, de Vogel found other pools of water inhabited by *Anopheles* larvæ, in proximity to the sea. One of these places had a surface of 20 to 30 square meters and a depth of from 10 to 30 centimeters. It was connected with a pool of sea-water by a bamboo-pipe crossing the dike. The pool is thus invaded by seaweeds, but the fish can not enter. This place swarms with *Anopheles* larvæ, while *Culex* larvæ are not found there. In this pool the percentage of sodium chloride is about 2.88, while in the water of the neighboring swamps it varies between 2.44 and 2.76.

Other instances of the occurrence of *Anopheles* larvæ in concentrated sea-water are given with careful descriptions and the author finally draws the following conclusions:

"1. There are species of *Anopheles* which can live very well in sea-water.

"2. These mosquitoes lay eggs which develop even in sea-water which has been evaporated to half its original quantity.

"3. These larvæ in the gradually evaporating pools of sea-water can stand an evaporation of the water to one-third of its bulk, but do not appear to transform to adults if the concentration be greater than this.

"4. The larvæ coming from eggs laid in sea-water of high concentration can accomplish their entire metamorphoses in almost the normal time. This is true even when the water has such concentration that the development of larvæ originally hatching in unconcentrated sea-water would be retarded by this salt water."

In the opinion of de Vogel the bad reputation which the coral islands of the East Indies have, is explained by his observations, since so many cases of malaria are observed along the coast during the dry season when all the rivers and fresh-water streams are dried up. Villages near the sea, in the middle of tidal pools, have had during a period of ten years an average mortality of from 1 to 4 per cent each year. In villages further away from the sea, where the ponds have been abandoned or neglected and the sea-water, therefore, is isolated, there is a mortality which varies from 8 to 10 per cent each year. The pools in these regions during the dry season have a proportion of sea salt equal to that of the ocean. In this dry season the death rate is greatest, and this is exclusively due to the *Anopheles* breeding in the sea-water ponds.

"The great mortality is surely due to malaria, since almost without exception the cases of pernicious malaria or hæmoglobinuria which are treated at Samarang come from the south border of tidal pools. A quarter of Samarang called Zeestrand was inhabited by well-to-do citizens of the city who had good health, although surrounded by pools. Then, when on account of the banking of the coast, these pools were left further from the sea, the locality became unhealthy and the inhabitants were forced to quit the quarter because the death rate from malaria reached terrible proportions. The empty houses of this quarter still bear witness to past grandeur. The mortality of the indigenous population which still remains there has been on the average during the last ten years 9.7 per cent per year."

The difference in the malarial rate is not due to any change in the character of the water itself. When the pools were tide-water pools fish and other life had access and kept the mosquito larvæ in check, while in the now isolated pools the *Anopheles* larvæ can develop unhindered.

De Vogel's paper has been criticised in that he produced no direct proof that the *Anopheles* breeding in the sea-water pools are the ones responsible for the malaria attributed to them. Furthermore, the species indicated, *Anopheles rossii*, has been shown repeatedly to be incapable of transmitting malaria, the parasites failing to develop within it. But recent investigations by Major Carruthers in the Andaman Islands confirm de Vogel's conclusion that the *Anopheles* breeding in the sea-water pools are responsible for malaria. The species, however, is not *Anopheles rossii*, but *A. ludlowii* which greatly resembles it. The question is clearly presented in a recent address by Surgeon-General C. P. Lukis, Acting Sanitary Commissioner with the government of India, at Bombay, before the General Malaria Committee. Speaking of the results of Major Carruthers, he says:

"The first thing that struck him was the remarkable fact that a large number of villages were quite free from malaria, in spite of the fact that many of them were surrounded by riceland, swamp or jungle, whereas others showed a considerable amount of malaria, the spleen rate varying from 25 per cent. to 50 per cent. Eventually it was noted that what determined the healthiness or unhealthiness of a village was its proximity to the sea. Villages near the sea were invariably malarious; those remote from the sea healthy. Even a distance of half a mile from the sea was sufficient to insure the endemic index being 0 per cent. This distribution of malaria was shown by actual measurement to be exactly coincident with the occurrence of a particular species of anopheles, namely *Pseudomyzomyia Ludlowii*, which appeared to breed chiefly in salt swamps and brackish water, and which was undoubtedly the chief malaria carrier in the Port Blair Settlement.

"Now so closely does this mosquito, on casual examination, resemble *M. Rossii* that, with reference to these two species, Professor Eysel has remarked upon the folly of too nice distinctions in regard to the species of anopheles and the transmission of malaria. Yet the existence of two distinct, though closely related species of anopheles is the explanation why, in the Andamans, the proximity to ricelands and swamps is innocuous, provided that these are at a distance from the sea."

According to these observations, the proposed destruction of *Anopheles* by the introduction of sea-water does not seem to be rational, at least with certain species. At all events the specific identity of the *Anopheles* concerned must be taken into account. It appears certain that while some species may breed either in fresh or brackish water others occur exclusively in saline water. In certain regions good tidal ponds prevent the breeding of *Anopheles* to some extent and may in that affect the malarial rate. In others, where the species which breed in salt or sea-water are present, and there are isolated stagnant pools, as has been observed at Samarang and in the Andamans, such measures would have little effect unless fish were admitted with the sea-water.

According to C. S. Banks *Anopheles ludlowii* in the Philippines breeds in both salt and fresh water. Banks gives an account of his observations in the Philippine Journal of Science. In an earlier publication he had shown that this species breeds in sea-water and claimed that it is a transmitter of malaria. In his first paper he stated that this mosquito had never been found in the Philippine Islands breeding in fresh water. Later, however, he took a trip to the mountain province of Lepanto-Bontoc for the purpose of investigating an epidemic of malarial fever. He fully expected to find that the responsible mosquito would prove to be a different species, but during his first stay in the province he found what he considered *Anopheles ludlowii* in the dwellings, while later he also found their larvæ breeding in greatest abundance in the rivers and smaller streams of the vicinity. He spent over two weeks in the neighborhood, and made a search for larvæ which included the rice fields (flooded at that time of the year), the water tanks near the buildings, and all probable breeding-places. He states that he found no other species of *Anopheles*.

It is evident that the observations of Mr. Banks are faulty and inconclusive. From the observations previously cited it is to be seen that *Anopheles ludlowii* breeds exclusively in saline water. The species which he found at Lepanto-Bontoc and so identified was in all probability *Anopheles rossii*. However, as this latter species is known to be ineffective as a malaria transmitter, and as other species of *Anopheles* have a wide distribution in the Philippines, it is obvious that his methods were inadequate. Moreover, it appears that many of the determinations were made from larvæ and were therefore unreliable, as the *Anopheles* larvæ are very similar and much more difficult to distinguish than the adults.

Some interesting observations on the existence of *Anopheles* larvæ in sea-water were made by Dutton in his malaria expedition to the Gambia in 1902 (Liverpool School of Tropical Medicine, Memoir X). The following account is taken from pages 29 to 30 of his report:

"A garden tub in which mosquitoes had been breeding was emptied and cleaned, and sea water, taken as the tide was coming in, placed in it, the other tubs in the garden being covered with mosquito netting. In four days afterwards a batch of small *Anopheles* larvæ was discovered in the water, which subsequently hatched out into adult mosquitoes (*A. costalis*) seven days later. This experiment was repeated with the result that first eggs of *Anopheles* and also *Culex* appeared in one or two days after the tidal water had been placed in the tub, and subsequently adult insects hatched out from them. From these experiments it would thus appear that certain kinds of mosquitoes can breed in tidal water if it is not disturbed, and subsequently when the dry season had fully set in, I found larvæ in suitable tidal pools, namely, as I have already mentioned, in the drains near the sluice gates in which tidal water had soaked in through the gates. In this water, which contained 1038.5 parts of chlorine per 100,000 parts, I found a few larvæ of *A. costalis* and large numbers of *Culex halassios*. On another occasion, in December, I found these mosquitoes breeding in a small hole from which shells had been taken, close to the edge of the water at the mouth of Oyster Creek. The *Culex* were subsequently hatched out from this tidal water, but the *Anopheles* larvæ were nearly all infested with a fungus (not identified) which gave them a woolly appearance, and I failed to hatch out any of them. I observed *A. costalis* breeding in a similar salt-water pool during a period in which neap tides occurred. The tidal water in an arm of the central channel in Box Bar, running from the sluice gates to the cemetery, had become converted into a series of small pools by partial evaporation of the water, though at every tide some water leaks through the sluice gates into this channel, but during this period it was not sufficient to replenish this small branch drain. *Anopheles* larvæ were found in great numbers in these pools. It is interesting to note, also, that at this time two of the largest pools which were situated close by, and have been described as swarming with mosquito larvæ, had been filled in with sand. Samples of water taken from various parts of the town were examined for the amount of chlorine present in them, the result is given in the following table.

"Sample of water.	Chlorine per 100,000 parts.	Chlorine expressed as percentage of NaCl.
1. Public well, New Town, no mosquitoes present in water	161.2	.265
2. Public well, Lancaster Street, water rather foul, *Anopheles* larvæ present in numbers	1148.0	1.89
3. Public well in Clifton Road, behind Hospital, no larvæ present	186.0	0.3
4. Water (tidal) found in drain near sluice gate, Blucher Street, *A. costalis* and large quantities of *C. halassios* present	1038.5	1.71
5. Small well in private garden, *Culex* present, few only	27.9	0.04
6. Small well in native compound, Victoria Street, *Culex* larvæ present	1145.0	1.88"

To refer briefly to the other records of *Anopheles* breeding in sea-water, this habit was probably first mentioned by Grassi, who observed it at Metaponto, Italy. Nuttall, Cobbet and Strangeways-Pigg captured larvæ six times in brackish water. A. Clerc has experimented with larvæ of *Anopheles maculipennis;* he found that larvæ placed in water with 44–46 grammes of salt to the liter would die if very young, but the older larvæ developed and produced imagos. Christophers and Stephens found *Anopheles* larvæ to occur at Accra in brackish pools 0.6 per cent salt. Foley and Yvernault found that in Algeria *Anopheles chaudoyei* breeds in saline water containing 40 grammes of salt to the liter. Chatterjee found larvæ of what he called *Anopheles rossi,* but which it would now seem were *A. ludlowii,* in brackish water in India. Gholap found another Indian species, *Anopheles stephensi,* breeding in salt water.

In America several species of *Anopheles* have been found to breed in brackish water, but none of them exclusively so. Chapin, in Rhode Island, found *Anopheles* larvæ living in brackish water on the coast. *Anopheles crucians* has been found to breed in brackish water in New Jersey and Louisiana, and we have already mentioned that Smith has found larvæ of *A. quadrimaculatus* in New Jersey under similar circumstances. It is worthy of note in this connection that *Anopheles crucians* seems to thrive best in the vicinity of tide water and to occur much less abundantly inland.

Anopheles albimanus, of tropical America, according to information furnished by Mr. A. H. Jennings of the Isthmian Canal Commission, breeds in strongly brackish water as well as in fresh water. The same may be said of *Anopheles tarsimaculata,* a geographic form of *A. albimanus,* and of *A. argyritarsis.* This last statement is made on the authority of Peryassú. The Brazilian observers made a series of laboratory experiments to determine the degree of salinity in which these larvæ could develop to imagos. They found that in slightly brackish water imagos were produced in a normal manner. In a mixture of 19 per cent of sea-water with fresh water only a very small proportion of larvæ transformed to imagos. Beyond this the larvæ failed to pupate; with 20 per cent sea-water some of the larvæ survived three days; with 30 per cent all died after one day.

HABITS AND FOOD OF THE LARVÆ OF ANOPHELES.

The early stages of *Anopheles* were first studied in the United States by the senior author in 1899. Eggs were secured from gravid females captured, and the full life round was studied and first described in an article entitled "The Differences between Malarial and Non-malarial Mosquitoes" in the Scientific American for July 7, 1900, pages 8–9, and subsequently in a bulletin of the U. S. Department of Agriculture. About the same time he found larvæ of *Anopheles* along the borders of a small stream in Roland Park near Baltimore, Maryland, and was under the impression at the time that he was the first American entomologist to find this peculiar larva; but it seems that 25 years earlier the larva had been found by Dr. Charles Sedgwick Minot, of Boston, and the adult was reared at that time. The identity of the insect was not suspected, however, but Doctor Minot had preserved the early notes, and after the appearance of Bulletin 25 recognized the larva and published an account of his early observations in the Journal of the Boston Society of Medical Sciences, volume v, January, 1901.

The first reference to the early stages of *Anopheles* to be found in the literature is a paper by Joblot, published in Paris in 1754 under the title (translated) "Description of a New Fish which I found in the Water of the Basin of St. Magloire of the Fauxbourg Saint-Jaques at Paris, which can be called an Aquatic Caterpillar." He figures the larva, which is recognizable as that of *Anopheles.* Brauer gave a good figure and description of the larva as that of *Dixa* in 1883. F. Meinert next published accurate descriptions and figures of the larvæ of two European species in 1886. Other descriptions and figures were published by Ficalbi in 1899 and Giles in 1900. The different stages were described and figured in 1900 by Grassi.

The eggs, elsewhere described, are laid loosely upon the surface of the water, each egg lying upon its side, from forty to a hundred of them as a rule floating rather close to one another.

The larva, also described in the systematic consideration of the genus, is markedly peculiar in its structure. It habitually remains at the surface of the water. It is without the breathing-tube so characteristic of the other mosquito larvæ, and its body is held practically parallel with the surface and immediately below the surface film, while portions of its head as well as its breathing apparatus are practically out of the water. In addition to the protruding head and the mechanism surrounding the spiracles the larva is held at the surface by means of rosettes of scales, the so-called "stellate hairs," upon some of the abdominal segments. These protruding parts interlock with the surface film, hence the larva can not descend without an effort and it only does so to escape danger. The larva's head rotates upon its neck in a most extraordinary way, so that the larva can turn it completely around with the utmost ease; it feeds habitually with the under side of the head towards the surface of the water whereas the upper side of the body is towards the surface. In this customary *feeding position*, the mouth-parts are working violently; the long fringes of the mouth-parts cause a constant current towards the mouth and the particles floating on the surface of the water in the neighborhood thus gradually converge to the mouth opening and enter the alimentary canal. The spores of algæ, bits of dust, minute sticks, bits of cast larval skins, everything in fact which floats, follow this course, and, watching the larva under the microscope, they can plainly be seen to pass through the head into the thorax until they are obscured by the opaque color of the larva's back. This is the common method of feeding when full grown; however, the larva will descend in the shallow water and mouth over the slime on pebbles at the bottom. Occasionally a fragment, too large to be swallowed with ease, clogs the mouth. Sometimes it enters the mouth and sticks. In such cases the head of the larva revolves with lightning-like rapidity until the top of the head is upwards, and the fragment is nearly always disgorged, although sometimes it is swallowed with an evident effort.

As indicated, the larva feeds upon everything that floats. It is especially often found in stagnant water on which there is more or less of an algal scum; therefore a very frequent food consists of algal spores, and the color of the larva is influenced more or less by the character of the food, green algæ making it green. Daniels, in his African investigations found that the contents of the intestines of the larvæ are mainly vegetable matter, in some cases entirely so. "Occasionally limbs of minute insects or crustaceans are found as well as scales of mosquitoes or other insects. On watching them feeding, it is seen that all minute particles are drawn to the mouth, but many of them are rejected. This rejection is somewhat arbitrary, as a particle at first rejected is often subsequently swallowed. Amongst the bodies seen to be swallowed I have seen living minute crustaceans and young larvæ, both of anopheles and culices, but, as a rule, living animal bodies either escape or are rejected." Christophers and Stephens state that in their observations in Sierra Leone the food of the *Anopheles* larvæ seemed to be an unicellular organism. James and Liston state that the food of *Anopheles* larvæ consists chiefly of minute water animals which abound among algæ and other water plants. They believe that the larvæ can not subsist upon vegetable diet alone and that the duration of the larval stage depends chiefly upon the supply of animal food. When this is small in proportion to the number of larvæ, they state, the stronger larvæ kill and eat the weaker. The cause for the discrepancies in these observations undoubtedly lies, at least in part, in the fact that different species were under observation. Thus we have found that the tree-hole inhabiting larvæ of our *Cœlodiazesis barberi* are very largely predaceous and prey upon other culicid larvæ associated with them. The species inhabiting bromeliads have similar habits, as has been recorded for *Anopheles cruzii* by Peryassú.

RESISTANCE TO DESICCATION.

One of the points of importance in considering the eggs and larvæ of the malarial mosquitoes is their possible resistance of desiccation. Exact observations on this point are still needed. Instances of supposed resistance on the part of larvæ must be studied from every side with care before forming conclusions. Nuttall and Shipley give an account of two observations made at Gainsborough, where many fully developed larvæ and pupæ were encountered in ditches which, according to persons living in the vicinity, had been filled with river water after having been dry from four to seven days. It seemed to the authors at first that the larvæ might have been carried in with the water from the river, as larvæ were also found there, but the larvæ in the ditches were so numerous as to render this explanation incompetent for a large part of them. In all probability the ditches in question had not been completely dried out. The authors call attention to the fact that Christophers and Stephens in Africa found that no large larvæ reappeared in a pool which had been dried up for two days and then refilled with rain-water. The larvæ which did appear were very small, and issued from eggs which apparently had resisted desiccation for the two days in question.

James and Liston point out that when *Anopheles* eggs are laid on water they almost invariably hatch in 48 hours, but that when laid upon damp mud the development of the embryo goes on and when water is added the larvæ hatch out almost immediately. They point out that in Mian Mir Christophers found that after the water in an irrigation canal or pool had been emptied out the *Anopheles* still laid their eggs on the soft mud and that if water entered before the mud had become completely dry young larvæ would almost immediately be found. After giving the details of his observations, James and Liston state, "It will be seen therefore, that pools which are, to all intents and purposes, quite dry, may contain numerous larvæ almost immediately after a shower of rain." Christophers also found that larvæ may remain alive on soft mud even after exposure to the sun for several hours, but were killed when the mud had so far dried as to lose its glistening surface.

The observers of the Instituto Oswaldo Cruz at Rio de Janeiro made experiments with *Anopheles albimanus* and *A. argyritarsis*, the two species of greatest economic importance in tropical America. When the larvæ were dried on filter paper, in the laboratory, they were still alive after six hours. On moist mud they remained alive six days.

LENGTH OF EARLY STAGES.

The duration of the early stages of *Anopheles* varies according to the temperature and food-conditions. With the heat the growth is faster; food supply also governs the duration of the larval stage. In India Liston found that the larval state might last but a week, but with a deficient food supply it might last for a month. Foley and Yvernault record the development of *Anopheles chaudoyei* from egg to imago within 13 days. The early observations made by one of us (Howard) on *Anopheles quadrimaculatus* at Washington showed a minimum larval period, in May and June, of sixteen days, and a pupal period of five days; eggs, three days—these periods undoubtedly being reduced later in the summer.

NUMBER OF GENERATIONS.

The general impression is that, in temperate regions, there are several generations of *Anopheles* during a season and that they continue to reproduce while conditions are favorable. Kulagin, in Russia, appears to have been the only one who has investigated the question carefully and after observations through several years he concluded that there is but a single generation annually, the imagos issuing from pupæ not laying eggs until the following year. It is well known that the female *Anopheles* do not lay all their eggs at one time. According to Kulagin the egg-laying period is extended over the entire summer through the fact that some of the *Anopheles* do not leave their hibernation quarters until well into the summer. He points out that in the female *Anopheles* examined by Koschewnikow late in July all showed a strongly developed fat supply and undeveloped ova and that the presence of the fat was a preparation for hibernation. We have already mentioned that in this country Smith has found the hibernating *Anopheles* in similar condition.

The observations made by Kulagin in 1906 are very convincing. In that year there was a very early spring in the province of Moscow; the temperature rose very high in April and there were no cold days. As a result of these early favorable conditions the hibernating mosquitoes left their shelters very promptly. Oviposition followed with the same promptness. He found great numbers of larvæ about the middle of April and these developed rapidly. The imagos issued from the pupæ during the last half of May, within a very short period. From the end of May on, throughout June and July no *Anopheles* larvæ could be found in spite of the most thorough search. Kulagin then points out that the conclusion is inevitable that in that year the females which issued from pupæ about the middle of May were the ones to hibernate.

Observations made by one of us (Knab) on the mating habits of *Anopheles punctipennis* are significant in this connection. This species has been observed repeatedly, swarming in the manner described on another page, but in every case observed this occurred well towards the end of the season.

Further observations are necessary to determine if all the species of *Anopheles* of the temperate regions agree in the number of generations. As to the tropical species, practically nothing is known as to the number of generations. Quite probably in certain regions, where there is an abundance of water throughout the year, breeding is continuous. In parts of India, where there is a long, well-marked dry season, the behavior of the *Anopheles* appears to be much as in colder climates, only that in this case the dry time is the resting period. Stephens and Christophers state that in India æstivating *Anopheles*, although they feed at intervals, will not deposit eggs even if suitable deposits of water are present.

GEOGRAPHIC DISTRIBUTION OF MALARIA.

The distribution of malaria coincides in a way with the distribution of the mosquitoes of the genus *Anopheles;* that is to say malaria does not originate in localities where *Anopheles* does not exist; but on the other hand there exist many localities where there are *Anopheles* where malaria is not to be found.

Such localities or such regions are either those into which malaria has never been introduced or those in which it has been absolutely stamped out. Also the species of *Anopheles* present may be such as do not act as efficient hosts for the malarial parasites, or, as has been already indicated on a previous page, the proper species of *Anopheles* and of malarial organisms may not coincide. A general consideration of the geographic distribution of the disease is given by Shipley as follows:

"Roughly speaking, malaria is confined to a broad irregular belt running round the world between the 4th isothermal line north of the Equator and the 16th line south. It is, however, said to occur occasionally outside these limits—for instance, in Southern Greenland and at Irkutsk in Siberia; but until recently the accurate diagnosis of the disease has been difficult, and too much reliance must not be placed on these statements. The chief endemic foci of the disease are along the banks and deltas of large rivers, on low coasts, and around inland lakes and marshes. Malaria is common all round the Mediterranean region: it was well known to, and its symptoms were clearly noted by, the early physicians since the time of Hippocrates. They even recognized the difference between the mild spring and summer attacks and the more pernicious effects of the autumnal fever. In France there are several prominent malarial districts: the valley of the Loire and its tributary the Indre, and the valley of the Rhone; also the sea-coast stretching from the mouth of the Loire to the Pyrenees, and again the Mediterranean sea-board. It occurs in Switzerland, and is found in Germany along the Baltic coasts, and on the banks of the Rhine, the Elbe, and other rivers, and in many other parts. Scarcely a province in Holland is quite free from it, and it is found in Belgium and around Lake Wener, in Sweden. It extends along the Lower Danube and around the Black Sea, and spreads across Russia, being especially prevalent along the course of the Volga and around the Caspian. From Europe it spreads over Asia Minor, and affects all Southern Asia as far as the East Indies, but in Japan it is curiously rare. It is also infrequent in Australia—where it is confined to the northern half of the continent—and in many of the Pacific Islands; and it is unknown in the Sandwich Islands, New Zealand, Tasmania, and Samoa. In America it is more common, and of a more severe type on the Atlantic sea-board than on the Pacific; in the last hundred years its northern limit is said to have retreated in the centre of the continent, though some observers think it is creeping further north in the Eastern States. In a mild form it is known around the Great Lakes, and in Canada and in New England; but it reaches a high degree of intensity in the Southern States, Mexico, Cuba, and Central America, where it probably played a greater part in ruining the projected Panama Canal than all the corrupt financing of the speculators in Paris. It extends throughout the warmer parts of South America, and is known in a virulent form all over Africa except the extreme south.

"In Great Britain it used to flourish. The following extract from Graham's 'Social Life of Scotland in the Eighteenth Century' shows what a part it played in the life of the Scottish peasant:

"'The one ailment to which they were most liable, and in which dirt had no share, was ague. This was due to the undrained land, which retained wet like a sponge, and was full of swamps and bogs and morasses in which "green grew the rushes." Terribly prevalent and harassing this malady proved to the rural classes, for every year a vast proportion of the people were prostrated by it, so that it was often extremely difficult to get the necessary work of the fields performed in many districts. In localities like the Carse of Gowrie, which in those days abounded in morasses and deep pools, amongst whose rushes the lapwings had their haunt, the whole population was every year stricken more or less with the trouble, until the days came when drainage dried the soil, and ague and lapwings disappeared.'

"In England it was once very prevalent. James I. died of 'a tertian ague' at Theobalds, near London, and Cromwell succumbed at Whitehall to a 'bastard tertian ague' in 1658, a year in which malaria was very widely spread and very malignant; and it is only within recent memory that the fen districts in Cambridgeshire and Lincolnshire, Romney Marsh in Kent, and the marshy districts of Somerset, have lost their evil reputation for ague. The older chemists in the towns in the fen districts still recall the lucrative trade their fathers carried on in opium and preparations of quinine with the fenmen during the first half of last century; but with the improved drainage of the fens this has all disappeared, and at present cases of endemic malaria appear to be unknown in England, though sporadic cases turn up at rare intervals. It was also very prevalent along the estuary of the Thames, both on the Essex and Kentish marshes. Pip in 'Great Expectations' says to his convict:

"'I think you have got the ague.' 'I'm much of your opinion, boy,' said he. 'It's bad about here,' I told him. 'You've been lying out on the meshes, and they're dreadful aguish.'

"Ireland, which appears at first sight peculiarly adapted for the disease, seems to have been remarkably free from it. It may be that the strong antiseptic quality of the peaty bog-water hinders the development of the larval mosquito." *

According to Hirsch malaria in Europe extends northward to between 63° and 69° north latitude. In the western hemisphere it is rarely found above 45° north latitude. It is most common and severe in low-lying coast regions and the deltas of large rivers, the rivers of tropical countries especially, are hot-beds; and this is true also of all bodies of water in such localities. As we approach the equator we meet more rarely with the milder forms and more frequently with the severe and often fatal æstivo-autumnal variety. Craig gives a more detailed consideration to America than does Shipley, and his paragraphs on North and South America, Asia, and Africa are quoted:

"*North America.*—In North America, malaria occurs rarely above the forty-fifth parallel, but is often frequent and fatal in the Southern states and in the West Indies, especially in Cuba, as well as in Central America. In the New England and Middle Atlantic states the benign forms are present, but are comparatively rare. The severe forms prevail along the low regions of the southern coast line, and especially in the swampy regions of the Gulf states. These infections are common and severe along the Mississippi River and its southern branches, and they are present in many of the Western states, especially in the river valleys of California where severe and fatal æstivo-autumnal infections are not uncommon. The regions about the Great Lakes are almost free from malaria except in certain localities about Lake Michigan. Canada is the only country in North America which appears to be almost entirely free from malaria.

"*South America.*—In South America, severe types of the disease are common, especially along the coast regions of Colombia, Venezuela, Guiana, Brazil, Eucador, Peru and Chile. The whole Atlantic coast line of Central America is severely infected with æstivo-autumnal malaria, and in this region the most pernicious forms are common.

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* ***Anopheles*** **is prevalent in parts of Ireland. It is worthy of remark that as early as 1828 Haliday, in his paper entitled "On some insects taken in the north of Ireland" (Zoological Journal, iii, 1828, pp. 500-504), states that *A. maculipennis* occurs in profusion in the neighborhood of Belfast throughout the summer and autumn.—H., D. and K.**

"*Asia.*—India, Ceylon, portions of China and Arabia, and the Islands of the Malay Archipelago are infected with the malarial fevers. This is also true of Asia Minor and the valleys of almost all the great rivers, such as the Indus and Ganges. In Japan the benign infections are common, and even upon the lofty table lands near the Himalayas malarial infections are often met with. The Philippine Islands, until very recently considered as comparatively free from malarial diseases, have been proved to be badly infected, a large percentage of our soldiers returning from there showing infection with the tertian and æstivo-autumnal parasites.

"*Africa.*—In Africa are some of the most dangerous lurking places of malarial infections, the worst areas being those along the west coast and the Senegal, Congo, and Niger Rivers, as well as the regions around the great lakes and the jungles, and lake shores of Abyssinia. Madagascar, Reunion, and Mauritius Islands present the pernicious varieties of the disease. Around Delagoa Bay and along the east coast of Africa, æstivo-autumnal fever is prevalent. Lower Egypt, the Soudan, the Nile delta, Tripoli, Tunis and Algeria, all harbor these infections."

Regarding the vertical distribution of malaria it may be said in a general way that malaria decreases with the increased altitude above sea level. The governing factors are, on the one hand, the unfavorable effect of low temperatures on the development of the malarial organisms, on the other hand, the absence in many mountainous regions of conditions upon which the abundance of *Anopheles* depends. Nevertheless malaria does occur at considerable altitudes in various parts of the world, apparently going highest in the Andes of South America. According to Treutlein, at La Paz, Bolivia, it reaches an altitude of 2564 meters. This author states that while endemic malaria, on account of the conditions, unfavorable to mosquitoes, does not occur at La Paz it exists on the plain of Potopoto, 100 meters lower, where *Anopheles* breed in some numbers. Ziemann gives the following summary of the occurrence of malaria at high altitudes:

"While, for example, in Ceylon malaria no longer occurs at 500 meters above sea level, the writer still found malaria in Cameroon and also in the Manenguba mountains at about 900 meters altitude; however no longer from 1200 meters on in the grass land, and the distribution of malaria and of anophelines seemed to agree pretty closely. Steuber still found malaria in German East-Africa at Lake Nyassa at an elevation of 1560 meters. In the mountainous regions of Usambara the conditions appeared to be similar to those of Cameroon in that malaria there still occurred at 800 meters altitude. In the Himalaya mountains it is said that malaria is still found at a height of 2000 meters, in the Andes of Peru even to 2500 meters, in the high lands of Persia, on the other hand, only to 1500 meters. In the German mountains malaria rises to 400–500 meters, in Italy to 600–1000 meters. Recently Grassi even found there an endemic malarial focus, in the vicinity of Colico, at an altitude 2500 meters. In malarial regions comparatively slight elevations above the malaria-infected plain are often sheltered, which one can easily explain, with our present knowledge, by the relatively small height of the flight of anophelines. Therefore the inhabitants of malarial regions always withdrew by preference to the surrounding hills. It is known that the shepherds of the Campagna about Rome passed the nights on scaffoldings which were several meters above the ground."

Edmond Sergent states that in Algeria, while *Anopheles* abound at all times in altitudes of from 1600 to 1800 meters, malaria occurs in those altitudes only in certain years. In these years of malaria it was found that the sirocco, a hot wind from the desert, blew continuously for nine or ten days. Sergent reaches the conclusion that usually the very low night temperatures in these localities *inhibit* the development of the malarial plasmodii within the mosquito; the continuous high temperature during the sirocco, however, brings about the development of the parasites.

Recently Hehir, in India, has confirmed the observations of Hirsch that in India and Ceylon malaria occurs up to altitudes of 2000 meters.

Referring again to the United States, it may briefly be stated that malaria rarely exists in this country above an elevation of one thousand feet or in the dry climates of certain of the western and southwestern States, except where irrigation has been introduced. This is quite to be expected, from the well-known habits of the species of *Anopheles* that carry the disease in this country. There seems to be little doubt, moreover, that malaria has practically died out in many localities where once it was rife. In the early settling of the Central and Western States, malaria was one of the most serious obstacles in the path of the pioneers, but with the gradual improvement of agriculture, with the cutting down of the trees in swampy forests, increased value of land for agriculture and the consequent reclamation of swamps, the disease has disappeared in many wide-spread regions; yet *Anopheles* still retains its foothold in many of these regions, although in vastly smaller numbers than in former years. Over other large regions the disease, while vastly less in relation to the population, still exists and is carried from one person to another by the reduced supply of *Anopheles*. In such large regions there are often smaller areas, where, through local breeding-places, a large supply of *Anopheles* is kept up and the disease maintained at a higher rate through their instrumentality.

THE APPEARANCE AND DISAPPEARANCE OF MALARIA.

In the section on economic loss from mosquitoes we have referred to the fact that the development of the United States in many sections has been retarded for years by the prevalence of malaria. The army of pioneers pushing west, stopping at various apparently favorable spots, clearing farms and settling for a time at least to build homes, encountered malaria in many places. Some of them were killed off or disabled by this disease, others, discouraged, were driven back east, while others pushed further west. But in very many of the localities where malaria was once existent in severe form, it has gradually lessened more and more, until localities once extremely unhealthy are now among the healthiest regions of the country. This means the gradual disappearance of malaria under the influence of civilization. We shall briefly discuss this class of phenomena from the viewpoint of the breeding places of malarial mosquitoes, and will show by contrast that under other conditions advanced civilization may bring malaria into localities in which it formerly did not exist.

DECREASE OF MALARIA FOLLOWING SETTLEMENT AND CIVILIZATION.

It has been shown in our discussion of the geographic distribution of malaria that the disease formerly flourished in Great Britain, and it is well known that its disappearance in that country had been due entirely to the improved drainage of the marshes or fens. It is comparatively recently that the marshy and fen districts have lost their malarious reputation. At present, however, cases of endemic malaria appear to be unknown in England, although sporadic cases are met with rarely.

The early conditions in certain of the United States were very similar, and the improved conditions are due to the same cause. In the great agricultural middle western States of Ohio, Indiana, Illinois, Michigan, and Wisconsin, where malaria played such great havoc during their settlement through more than the first half of the nineteenth century, there were great areas of swamp land, and it is in those states that swamp reclamation as a whole has been carried out on the largest scale. At the present time these great areas, once breeders of *Anopheles* in extraordinary numbers, constitute the most fertile and productive land in the whole region. How recently and how rapidly the change has come about is indicated, for one locality in Michigan, by Jordan and Hefferan (*loc. cit.*), and may be quoted:

"A. *The Locality.*—The observations were made in and about the village of Eastmanville, in western Michigan, during the summers of 1902, 1903 and 1904. A white settlement has existed at this point, upon the north bank of the Grand River, twenty miles (river measurement) from its debouchement into Lake Michigan, since about 1840. Prior to that date, and for some time afterward, Indians of the Ottawa and Pottawatomie tribes had villages near this part of the river. The population of the village, never more than a few hundreds, is at present about 150.

"The soil of the district is clay, covered by a few feet of sand for the most part, but occasionally cropping out. The country-side is almost entirely under cultivation or in pasture land; little or nothing remains of the marshes or of the heavy timber which formerly covered the area. The north bank of the river, upon which the village lies, rises with somewhat more marked declivity than the south, which is sandy, the channel being here, for two miles, on the north shore. The stream is at this point thirty rods wide; the vegetation of the shores is characterized by low willows and wild rice. North from the river run several ravines, dry in summer except for occasional spring-fed pools. Opposite the village, and separated from the river by a strip fifteen rods wide, part sand and part marshland, is a deep currentless bayou, mud-bottomed, spring-fed, ten rods wide and two miles long. With the exception of a few rods, its shores are timbered; the vegetation is that of a spring-fed lake.

"B. *Malarial History.*—This part of Michigan was in earlier times, according to tradition, one of the worst malarial districts in a highly malarial state. No records except the general State Reports for western Michigan are available to show the former prevalence of malaria in Eastmanville, but the testimony of all the older settlers is unanimous. Everyone in the district was a sufferer, and everyone who came to the district expected to contract the disease. From the strongest of the laboring men to the infant born on the mother's ague day, the entire population was subject to chills and fever.

"Such conditions do not now exist. The Michigan State Board of Health Reports contain interesting statistics regarding the decrease of malaria in Michigan during twenty-three years:

"WEEKLY REPORTS OF DISEASES IN MICHIGAN.

"PER CENT. OF REPORTS WHICH SHOWED INTERMITTENT FEVER.

"1877	75%	1884	65%	1891	36%	1898	19%
1878	82	1885	59	1892	27	1899	17
1879	82	1886	54	1893	24	1900	16
1880	82	1887	48	1894	24	1901	14
1881	82	1888	45	1895	22		
1882	71	1889	43	1896	19		
1883	69	1890	41	1897	17		

"In 1879, 1880 and 1881, intermittent fever was the most prevalent of all diseases in Michigan; in 1881 the western division of the State, including the locality described above, showed a greater prevalence of malaria than other parts of the State, 90 per cent. of all weekly reports recording the disease as under the observation of the physician making the report. But according to the statements of local physicians the disease has been very infrequent in and about Eastmanville for the last few years. One physician had observed during six years but three cases presenting a typical malarial history; one of these occurred in the summer of 1889, one in 1902, and one in 1904. All three patients lived on the bank of the river, at distances of several miles from one another.

"The question of course arises whether this decrease in malaria has been paralleled by a decrease in the number of the malaria-carrying mosquitoes. In the absence of data, no definite statement can be made regarding the number and virulence of mosquitoes in the earlier years of the settlement, except the very general one that they were much 'more numerous' than at present, and that they were very large. They were felt as so real a pest that the farmers would often leave the unscreened houses to sleep in the barns and haylofts, which were not frequented by mosquitoes."

The effect of drainage as a corrective of malaria was naturally noticed long before the fact that *Anopheles* is the carrier of the disease was discovered, and in the earlier works a number of such instances have been pointed out. We have already referred to the extensive drainage of the fens in England, and of course the sanitary benefit arising from this drainage was at once perceived. In his excellent work on malaria and malarious diseases (New York, 1884), Sternberg refers to the case of Boufaric in Algeria which was noted for its unhealthiness. Successive importations of soldiers and colonists died off from malaria. Deep drainage was resorted to, and the level of the ground-water was lowered less than two feet. To this measure was attributed the reduction of the mortality to about one-third. He points out that the completion of the system of drainage in the towns of Fairfield and New Milford, Connecticut, resulted in the steady and rapid decrease of malarial diseases. He further shows that, according to Colin, while the laborers engaged in drainage measures often suffer very severely from malaria, the subsequent effect is to greatly increase the health of the locality. He cites the instance of Staouëli in Algeria, where the reclamation by drainage of the lands belonging to a Trappist convent cost, during the first years, the lives of eight monks out of twenty-eight and of 27 soldiers out of 150 who were placed at their disposal. The improvement in the health following the drainage, however, was very great, and in eighteen months there were but two deaths out of a population of 152.

It will be seen that these beneficial results—and the same experience has been repeated in many other parts of the world—have been brought about through the swamp drainage necessitated by the demand for more and richer agricultural land and without regard to health conditions, except possibly incidentally in a few instances. In this way, then, the improvement by agriculture has worked towards the arrest of malaria and the improvement of health. There still remain in portions of the United States many very fertile regions the agricultural and industrial development of which is only beginning or has not yet been touched. We have pointed out that the tide marshes around Puget Sound in Washington, which have been lying untouched until within the last few years, are now about to be reclaimed through great immigrations of new and desirable settlers, while in California, in the Sacramento-San Joaquin delta, the same work is beginning; also that the immensely fertile delta regions in Mississippi are attracting the attention of the government, and that it is probable that this land, the most fertile land in the world, with possibly the exception of the delta of the Nile, will not only be reclaimed for agricultural purposes, but that incidentally these operations will change a malaria-ridden area into healthy farms.

INCREASE OF MALARIA DUE TO CIVILIZATION AND ITS CONCOMITANTS.

But the advance of civilization does not always bring about these results. It is obvious that extensive irrigation of desert lands will bring about conditions allowing the breeding of enormous numbers of *Anopheles* mosquitoes, and will ultimately result in the introduction of malaria into portions of the country where it has not previously existed. This has been shown again and again in some of the western States. The irrigation ditches of portions of California breed *Anopheles* in great numbers. Into some of these localities malaria has entered and has been rapidly spread by these pernicious insects. Expert horticulturists from the U. S. Department of Agriculture going into these regions in the course of their scientific investigations, and others, have been forced to consult the Bureau of Entomology on the subject of anti-malarial measures.

Dr. J. P. Widney, a member of the California State Board of Health, gives an acconnt of the results of the introduction of irrigation into parts of California (Report, Cal. State Board of Health, 1881). Doctor Widney divides the lands under irrigation at that time into four general classes: (1) Uplands, like those of San Gabriel, Pomona and Riverside, which have a firm soil, rather a gravelly clay which remains moist but not water-soaked after irrigation; (2) river bottoms of sand or alluvium, as those of the Los Angeles and lower Santa Ana, with a fair slope so that the water does not remain in pools and with a substratum making under-drainage thorough; (3) the sandy bottoms of the San Gabriel River, of much the same character as No. 2, but with a much less rapid surface slope and much less thorough under-drainage; (4) the Cienaga lands, having a heavy soil of the adobe type, occasionally springs and bogs, with natural ponds of water, very wet in the winter. Doctor Widney discussed specifically the relation of malaria to these four types of irrigated lands, and found that the lands of the first-class are almost entirely free from even the slightest trace of malaria and that the lands of the second class show its existence but not to a sufficient degree to form a marked feature in the endemic causes of the disease; the lands of the third class he states showed the presence of malaria in a notably active form, giving a well-marked type to the summer diseases, while those of the fourth class developed with irrigation a very active form of malaria, the diseases as a whole being largely of a pronounced malarial type and running often a very severe course. While naturally totally unsuspicious, at that time, of the connection of mosquito-breeding places with the case, Doctor Widney comes to a very just conclusion, as follows:

"The conclusion seems to be fairly just and legitimate, then, in the absence of any other apparent cause, and from what we know of the close connection between defective drainage and malaria, that in this case the relationship is that of cause and effect. With thorough drainage, the places which, by all other rules, should develop malaria, escape it almost entirely; without drainage, the places which, by all other rules, should be free from it, develop it constantly and actively. The whole history of irrigation in southern California goes to impress this lesson: that, to escape malaria, drainage must go hand in hand with irrigation; that unless it does, the water which brings wealth brings also disease and death."

We have already pointed out that in tropical Africa, as shown by Dutton in his investigations in Gambia, the number of mosquito breeding-places in compounds varies with the social position of the occupier, and that civilized methods of life are apt to increase the number of breeding-places of those species of *Anopheles* most nearly domesticated. While with us *Anopheles* does not breed to any appreciable extent in small receptacles, yet the activities of civilized life increase the breeding facilities of mosquitoes in many ways. This helps in some cases to account for the rapid spread of malaria in regions where it was before unknown. For example the well-known malarial outbreak in Brookline, Massachusetts, following the employment on the reservoirs of Italian laborers, some of whom undoubtedly brought the malarial organisms in their systems into a region where *Anopheles quadrimaculatus* was breeding. It is altogether likely that the epidemic which spread through a large part of New England in the latter portion of the last century can be accounted for in a similar way. Dependent as this disease is upon the *Anopheles* mosquitoes, the number of breeding-places determines the spread of the disease when once introduced. It should be remembered that the breeding-places brought about in increased numbers by civilization include, in addition to irrigation, not only the purposely prepared water receptacles and those accidentally brought about by domestic life, but collections of water brought about by different industrial operations. We may mention mill ponds which, where they have grassy borders and cause the backing up of rapid streams for a long distance into fishless shallows and swampy pools form admirable breeding-places for *Anopheles*. We may mention abandoned stone quarries and even those in active operation, which nearly always cause considerable accumulations of fishless water, and soon, as we have often seen, become inhabited by large numbers of *Anopheles* larvæ as well as the larvæ of other mosquitoes. The borrow-pits along the right-of-way of railroads furnish ideal facilities, in many cases, for the breeding of mosquitoes including *Anopheles*. We may mention also the numerous excavations large and small made for one purpose or another which, if they have a firm soil, will accumulate water and form breeding-places (artificial pools for watering stock are examples), and of course stagnant street and roadside gutters and the footprints of cattle and horses in moist land and the plow furrows in clayey corn land in wet seasons are *Anopheles'* breeding-places, dependent absolutely upon civilization. And we must not forget railroad embankments as obstructions to very small streams of running water and as the cause of very extensive accumulations of fishless waters often swarming with mosquito larvæ. Thus in very many localities it is not surprising that, with an entire lack of anti-mosquito measures, the conditions of civilization have greatly increased the possibilities of serious malarial troubles when the disease is once introduced.

With these facts in view, it is interesting to read such a paper as that by Dr. C. V. Chapin on " The Origin and Progress of the Malarial Fever now Prevalent in New England " (Providence, R. I., 1884), in which he traces the spread of the disease from shore towns in Connecticut in 1860 gradually over a large part of New England, long before the true method of spread was known. Here was a typical case of a non-malarious region in which the *Anopheles* breeding conditions described above had been continually increasing for years until, the disease once introduced into those Connecticut shore towns, found malaria-carriers everywhere and its spread was thus assured. Some of these breeding-places are even mentioned by Dr. Chapin without a realization of their true significance, and in fact the first outbreak in Connecticut occurred near dams and millponds.

YELLOW FEVER.

THE SCIENTIFIC DEMONSTRATION OF THE CARRIAGE OF YELLOW FEVER BY MOSQUITOES.

Physicians had been theorizing about the cause of yellow fever from the time when they began to treat it. It was thought by many that it was carried in the air; by others that it was conveyed by the clothing, bedding, or other articles which had come in contact with a yellow-fever patient. There were one or two early suggestions of the agency of mosquitoes, but practically no attention was paid to them, and they have been resurrected and considered significant only since the beginning of the present century. With the discovery of the agency of micro-organisms in the causation of disease, a search soon began for some causative germ of yellow fever. Many micro-organisms were found in the course of the autopsies, and many claims were put forth by investigators. All of these, however, were virtually set at rest by Sternberg in his " Report on the Etiology and Prevention of Yellow Fever," published in 1890. But a claim made by Sanarelli in June, 1897, for a bacillus, which he found in 58 per cent of yellow-fever cases and which he called *Bacillus icteroides*, received considerable credence. Wasdin and Geddings, of the United States Marine-Hospital Service, in 1899, reported that they had found this bacillus in a large percentage of yellow-fever patients in the city of Havana. Their work, however, was not carried to a satisfactory end and they stated that they had found no conclusive evidence that this bacillus was responsible for yellow fever. About the same time Archinard and Woodson, at New Orleans, obtained results which they considered confirmatory of Sanarelli's claim. Afterwards it was shown by Reed and Carroll that the organism in question was identical with the bacillus of hog cholera and in no way concerned with yellow fever.

FINLAY'S WORK.

In 1881 Dr. Cárlos Finlay, of Havana, proposed the theory that yellow fever, whatever its cause may be, is conveyed by means of a certain mosquito (*Culex mosquito* = *Aëdes calopus*) from man to man, and not in the manner of ordinary contagious or infectious diseases. His paper, published in the "Anales de la Real Academia de Ciencias médicas, físicas y naturales de la Habana," shows that he had carefully studied the habits of house mosquitoes and had determined all the factors in the life-history of *Aëdes calopus* which have since been shown to be essential in its rôle of transmitter of the disease. It was this careful study of the mosquito and the disease, conducted through many years in the most favorable locality, in the city of Havana, that gave him a firm conviction that the two were interdependent. On this account his theory has true scientific merit, it was based on intensive study, and not, as had been the case with his predecessors, on vague suspicions or flights of the imagination.

Subsequently Finlay published a number of important papers, in which his views were modified from time to time. He thought out carefully the question of immunization and concluded that this was brought about by mild infection, through the bite of single mosquitoes. In one of his papers he published experiments with 100 individuals, producing 3 cases of mild fever. None of the cases, however, was under his full control, and as the possibility of other methods of contracting the disease was not excluded his claims were not accepted. Therefore, his theory, while it was received with interest, was not considered to be proved.

DR. A. C. SMITH'S EXPERIMENT.

An interesting experiment, generally overlooked, was tried, based on the ideas of Finlay of the mosquito dissemination of yellow fever, in the summer of 1897 and prior to the exact work of the United States Army Board in Havana, shown in the following paragraph, by Past Surgeon A. C. Smith, of the then U. S. Marine-Hospital Service (now the U. S. Public Health and Marine-Hospital Service). Doctor Smith screened all the windows and doors of the National Quarantine Station on Ship Island, Gulf of Mexico, and no case of yellow fever developed at the station, although he treated some thirty cases of the disease brought there by infected vessels. We take this statement from a paper by Dr. P. H. Bailhache, Surgeon U. S. Public Health and Marine-Hospital Service, read before the first anti-mosquito convention in New York, in 1903.

DEMONSTRATION BY THE UNITED STATES ARMY COMMISSION.

In 1900 the facts were determined by scientific methods. An American army being at that time stationed in Cuba, a medical board was appointed by Surgeon-General Sternberg for the purpose of investigating the acute infectious diseases prevailing in the Island. The Board consisted of Walter Reed, James Carroll, Jesse W. Lazear and Aristides Agramonte. Dr. Reed was the chairman of the Board. In the course of the work yellow fever naturally received the main share of attention. The claims of Sanarelli's *Bacillus icteroides* were disproved, and Reed and his associates began a careful and thoroughly scientific investigation of the possibilities of mosquito carriage of the disease. The experiments carried on by the Board were as perfect in their methods as it was possible for scientific acumen and hard common sense to make them. Every possible element of error seems to have been guarded against. The final aud conclusive tests, made during the autumn of 1900, were conducted with a spirit of earnestness, self-sacrifice and enthusiasm, which affected every one connected with the work, even in the most subordinate positions, private soldiers not only offering themselves for the presumably dangerous test, but insisting that they should be accepted as subjects for experimentation. Dr. Reed, the master spirit of the investigation, was, moreover, the man above all men for this work, no less in his ability to compel the greatest confidence and enthusiasm, than in the absolutely complete manner in which the experiments were conducted. While the work was going on, criticism was invited and urged from Havana physicians, from visiting surgeons, and from every one interested, but so perfect were the plans that it seems impossible that any criticism could have been made.

An experimental sanitary station was established in the open, a mile from Quemados. Two houses were built, tightly constructed, with windows and doors protected by wire screens. In one of these houses soiled sheets, pillow-cases, and blankets were used as bedding, and this bedding was brought straight from the beds of patients sick with yellow fever at Havana. For sixty-three days these beds were occupied by members of the hospital corps for periods varying from twenty to twenty-one days. At the end of this occupation the men, who were all non-immunes, were taken to quarantine for five days and then released. Not one of them was taken ill. All were released in excellent health. This experiment is of the greatest importance, as it demonstrates that the disease is not conveyed by fomites. Hence the disinfection of clothing, bedding, or merchandise, formerly supposed to have been contaminated by contact with yellow-fever patients, is unnecessary; the disinfection work, which has been carried to the extreme in cases of yellow-fever epidemics in our southern States, has been perfectly useless.

In the other house, which was known as the "infected mosquito building," were no articles which had not been carefully disinfected. The house contained two rooms, and non-immunes were placed in both rooms. In one room, separated from the other by wire-screen partitions only, mosquitoes which had bitten yellow-fever patients were introduced. In the other room they were excluded. In the latter room the men remained in perfect health; in the mosquito room

50 per cent of the persons bitten by infected mosquitoes (that had been kept twelve days or more after biting yellow-fever patients) were taken with the disease, and the yellow-fever diagnosis was confirmed by resident physicians in Havana who were above all others familiar with the disease in every form. Persons bitten by mosquitoes which had bitten a yellow-fever patient within less than twelve days did not contract the disease. In another series of experiments, seven persons were bitten by infected mosquitoes by placing the hand in a jar containing the insects, and five of them, or 71 per cent, contracted the disease.

It was also found that yellow fever was produced by the injection of blood from the general circulation of a patient. Subcutaneous injections of two cubic centimeters of blood were followed by the disease, and the definite conclusion was reached that the parasite of yellow fever must be present in the general circulation, at least during the early stages of the disease, and that yellow fever may be produced, like malarial fever, either by the bite of the mosquito or by the injection of the blood taken from the general circulation. From these results this important corollary was reached, to quote Dr. Reed's own words: "The spread of yellow fever can be most effectually controlled by measures directed *to the destruction of the mosquitoes and the protection of the sick against the* bites of these insects."

One must be struck with the modesty of the men composing the Commission when, without a single symptom of self-laudation, the results of this remarkable experimental work, destined to revolutionize former ideas, were published under the simple title, "The Etiology of Yellow Fever; An Additional Note." Referring again to the experimental patients it must be conceded that the heroism exhibited by these persons is beyond praise. Speaking of John R. Kissinger, a young Ohio soldier who was the first person bitten by infected mosquitoes, Dr. Reed says:

"I can not let this opportunity pass without expressing my admiration of the conduct of this young Ohio soldier who volunteered for this experiment as he expressed it 'solely in the interest of humanity and the cause of science,' and with the only proviso that he should receive no pecuniary reward. In my opinion, this exhibition of moral courage has never been surpassed in the annals of the Army of the United States."

The next three cases were Spaniards, and all of these first four contracted the fever. After that, no more Spanish subjects could be secured. They had allowed themselves to be bitten largely through incredulity and for a money reward. After the fever appeared they lost their interest in the cause of science and preferred safety to money. Other Americans, however, immediately volunteered, and, while praising their courage in the highest degree, we must not fail to point out here that the inspiration was derived from Dr. Reed himself. Nothing but the most absolute confidence in this remarkable man could have gained his subjects; and the confidence was justified, since this series of experiments, the results of which has already been of inestimable value to humanity, was completed without the loss of a single life as the direct result of the strictly experimental work. It is true that Dr. Lazear died of yellow fever during the course of the investigation, but the bite by which he was inoculated was not given in the course of the experimental work. Dr. Reed himself died three years later; his death having been indirectly the result of his arduous labors on the Board. Dr. Carroll died still four years later and his death, too, was probably caused indirectly by the yellow fever which he contracted in 1900 in the course of the experiments. Kissinger is reported, at the time of the present writing, to be living in the State of Washington, and in very enfeebled health. Efforts are being made to secure for him a well-deserved pension.

After the publication of the first note by the Board some incredulity was expressed, and the British Medical Journal stated of the experiments, "At the most they are suggestive." After the publication of the additional note, however, the medical profession accepted the conclusion of the Commission more generally. During this work, and for months subsequently, continued investigations were carried on by members of the Board, searching for the causative organism of yellow fever, but it has not yet been found. It was discovered that the disease could be conveyed not only by the puncture of the mosquito, but by the injection of the blood serum of a yellow-fever patient into the system of a non-immune. It was further discovered that this blood serum could be filtered through a porcelain filter and yet retain its power to convey the disease. It was Dr. Carroll's theory that the cause of the disease is some micro-organism so excessively small as to fail to reveal itself to the highest powers of the microscope, and this view has generally been accepted.

LATER WORK IN CUBA BY GUITERAS AND JOHN W. ROSS.

Additional experiments were carried on in 1901 by the Havana Board of Health, under Dr. Juan Guiteras. In a number of cases the disease was experimentally conveyed by the bites of infected mosquitoes. Later in the autumn and winter of 1901, very careful experiments were carried on at Las Animas Hospital by the Director of the Hospital, Surgeon John W. Ross, of the U. S. Navy, and these experiments were made for the purpose of setting at rest the theory still adhered to, by many, of the transmission of the disease by fomites. Certain rooms in the hospital were made mosquito-proof and numerous bundles of bedclothes and bedding, which had recently been used in sickrooms and on the persons of people ill with yellow fever, were placed in these rooms. Eight men, recently arrived on the Island, 5 Spanish, 2 Italian and 1 English, were taken as subjects for experimentation. They were placed under observation for 7 days, then transferred to the experiment room, where they were kept for 7 days. They were then kept under observation for 7 days longer, with the result that all emerged from the experiment in good health.

WORK DONE IN BRAZIL BY THE SÃO PAULO AND THE FRENCH COMMISSIONS.

In spite of the perfect scientific character and convincing nature of the work done at Havana, the medical world was by no means unanimous in accepting the conclusions. Among the first countries to take up the work was Brazil. Dr.

Emilio Ribas, Director of the Health Service of São Paulo, and Dr. Adolfo Lutz, Chief of the Bacteriological Institute of the same city, repeated the experiments in yellow-fever inoculation by means of the yellow-fever mosquito. A commission, composed of Doctors L. Barreto, A. G. da Silva Rodrigues, and A. J. de Barros, was created to carry on the work. Doctor Ribas and Doctor Lutz were the first who were pierced by infected mosquitoes, but the results were negative, undoubtedely because both men had lived for many years in the midst of yellow fever and had become immune. With three other persons, however, the Brazilian commission succeeded in January, 1903, in producing characteristic yellow fever by having them bitten by infected *Aëdes calopus*. These mosquitoes came from the town of São Simão, situated several hundred kilometers away from São Paulo, and had been allowed to bite yellow-fever patients in that town where there was at the time an epidemic of the disease. This experiment was a strongly convincing one, for the reason that at the time there were absolutely no cases of yellow fever in São Paulo and no one could point out any other method of contagion than by the bite of these mosquitoes brought from the yellow-fever locality.

In addition to these Brazilian results, the French government, in 1901, sent a mission to Rio de Janeiro, composed of Messrs. Marchoux, Salimbeni and Simond, under the scientific direction of the Pasteur Institute. This Commission brought about some very exact confirmatory results, and in the months of May and June, 1903, succeeded in producing yellow fever in three cases by inoculation by infected *Aëdes calopus*. The report of the Commission and the subsequent papers by Marchoux and Simond, published by the Pasteur Institute in several parts extending down to 1906, form a notable contribution to the history of yellow fever. Their opportunities were great, their methods were most exact, and they confirmed in every respect the results obtained by the American commission. Their conclusions, as published in the Annals of the Pasteur Institute, in November, 1903, are sufficiently important to quote:

"(1) The serum of a patient is virulent on the third day of the illness.

"(2) On the fourth day the blood of a yellow-fever patient no longer contains the virus, even when the fever is higher.

"(3) One-tenth cc. of virulent serum injected under tbe skin is sufficient to produce yellow fever.

"(4) The virus of yellow fever placed upon an abrasion of the skin does not give the fever.

"(5) In the serum of a patient the virus of yellow fever passes through a Chamberland F filter without dilution.

"(6) Under the same conditions, it does not appear to pass through filter B.

"(7) The virulent serum kept from air at a temperature of from 24 to 30 degrees C. is inactive at the end of 48 hours.

"(8) In defibrinated blood kept under vaseline oil at temperature from 24 to 30, the microbe of yellow fever is still living at the end of five days.

"(9) At the end of eight days defibrinated blood kept under the same conditions no longer contains the active virus.

"(10) The virulent serum becomes inoffensive after a heating for 5′ to 55° C.

"(11) A preventive injection of serum heated for 5′ to 55° gives relative immunity, which, followed by inoculation with a very small quantity of virus, can become complete.

"(12) The injection of defibrinated blood, kept in the laboratory under vaseline oil for eight days at least, gives a relative immunity.

"(13) The serum of convalescents is endowed with clearly preventive properties.

"(14) The immunity given by the serum of a convalescent is still appreciable at the end of 26 days.

"(15) The serum of the convalescent appears to have therapeutic properties.

"(16) As proved by Reed, Carroll and Agramonte, yellow fever is produced by the puncture of *Stegomyia fasciata* [= *Aëdes calopus*].

"(17) To be able to produce the illness with man, this mosquito must be infected, previously, by absorbing the blood of a yellow-fever patient during the first three days of the sickness.

"(18) The infected mosquito is dangerous only after an interval of at least 12 days after it has sucked virulent blood.

"(19) The punctures of two infected mosquitoes may bring about a very severe case.

"(20) The mosquito appears to be more dangerous in proportion with the length of time which has elapsed after infection.

"(21) The puncture of infected mosquitoes does not invariably give yellow fever.

"(22) When the bite of infected mosquitoes is ineffective this does not give immunity against a virulent injection.

"(23) In the region of Rio de Janeiro, as in Cuba, no other mosquito than *Stegomyia fasciata* is connected with the transmission of yellow fever.

"(24) Contact with a yellow-fever patient, with his belongings or his excretions is incapable of producing yellow fever.

"(25) Aside from the bite of infected Stegomyias, the only known method of conveying the malady is the injection, into the system of a susceptible subject, of blood coming from a patient and taken during the first three days of the malady.

"(26) Yellow fever can assume a dangerous character only in regions in which *Stegomyia fasciata* exists.

"(27) The prophylaxis of yellow fever depends entirely upon the measures taken to prevent *Stegomyia fasciata* from puncturing the sick man and the healthy man.

"(28) It is necessary to remember that the period of incubation of yellow fever may be prolonged to thirteen days.

"(29) *Stegomyia fasciata* is frequently parasitized by fungi, by yeasts and by Sporozoa. None of the parasites so far found have any relation to yellow fever.

"(30) We have not been able to find, either in the mosquito or in the blood, the causative organism of yellow fever."

Two years later Marchoux and Simond published a brief note in the Comptes Rendus des Séances de la Société de Biologie (1905), on a possible hereditary transmission of the virus of yellow fever in the yellow-fever mosquito. This note, which created a great sensation at the time, and which still suggests a very important factor in the possibilities connected with *Aëdes calopus* and with yellow fever, is here given in full. Similar results have never since been obtained, and the observation must be deemed inconclusive to a certain degree until verified by a series of similar experiments with similar results.

"Since 1903 our attention has been directed to the fact that, in certain portions of an endemic zone, it is sometimes difficult to find a case of recent date as the origin of the new cases which appear at the time. No doubt existed that such outbreaks were due to the presence of infected Stegomyias, and we were obliged to admit that one or several of these mosquitoes had been carried in some way from a distant point where patients existed and from whom they had taken the virus. It is certain that this happened in a number of cases. Nevertheless we asked ourselves whether, under certain circumstances, eggs from infected Stegomyias, in a locality where there had been an epidemic some months previously, could not give birth to mosquitoes hereditarily infected.

"Various experiments were made in 1903 to verify this hypothesis. We got the eggs of Stegomyia which had punctured sick people in the first stage of the disease. We raised the larvæ, and as soon as the perfect insect issued we made it puncture a human subject.

"These experiments did not give us at that time any positive result. The subjects who were pierced by such mosquitoes were susceptible to the disease, for it could be given to them later by injections of fresh virulent serum.

"We began these experiments again in the month of February, 1905. Eggs coming from a Stegomyia twenty days old, which we had caused to puncture several of our patients in order to secure an intense infection, were collected and the larvæ, issuing the fourth of February, were placed in a jar for rearing. From the 16th of February the perfect insects began to emerge. These, isolated in tubes from the time of emergence, were fed with glucose up to the second of March. At this date, 14 days after the metamorphosis, two of these Stegomyias punctured subject 'A,' a Portuguese only a few days in Brazil and non-immune. The subject showed no reaction following these punctures.

"He was punctured again by one of these two mosquitoes (the second had died in the interval) on the 10th of March, eight days after the first puncture. Four days later, the 14th of March, he showed a typical attack, moderately severe, of yellow fever. The character of the onset, the vomiting, the pains, the progress of the temperature, the jaundice, the manner of convalescence, permitted no doubt of the nature of the disease. Nevertheless, we tried to confirm our diagnosis experimentally. After the attack we had this subject punctured on two occasions by series of infected Stegomyias. He was absolutely immune to these inoculations, as are all individuals recently immunized by a former attack. Let us add that he was watched by us from his arrival in Brazil, and that the conditions did not permit any contamination other than that through the hereditarily infected mosquito which must have, by its bite, caused the attack of yellow fever which he showed.

"This experiment seems to indicate that, in the conditions indicated, the *Stegomyia fasciata* coming from a mother directly infected by a fever patient are themselves hereditarily infected. It results from the different experiments carried out on this subject, that the lapse of time necessary before the hereditarily infected mosquito may be capable of emitting the virus with its saliva is longer than in the case where the virus has been taken directly by the mosquito from the blood of a yellow-fever patient. This lapse of time was 22 days in our experiment.

"It results, likewise, from the experiments as well as from the epidemiological facts, that this hereditary transmission can not be considered common, but rather as an exceptional occurrence.

"The mildness of the attack in this case leads one to believe that the passage of the virus through a generation of Stegomyia is accompanied by a certain degree of attenuation. It opens a new path towards researches in the direction of vaccination against yellow fever.

"The knowledge of this method of propagation clears up one of the most obscure points in the history of yellow-fever—that of the return of certain epidemics where no previous case sufficiently recent can be found to explain the inoculation of the existing mosquitoes. Finally, the importance of the experiments from the point of view of prophylaxis can not be disregarded."

This case is so extremely important that more space must be devoted to it. The year following the first announcement just quoted, fuller details were given in the Annals of the Pasteur Institute for January, 1906, in which the symptoms of the infected patient are carefully given, day by day, and the daily temperature is charted, leaving the case fairly open to the inspection and possible criticism of yellow-fever experts. The investigators consider a light attack of yellow fever as perfectly proved, and state that the absence of albumen, the lowering of the temperature after forty-eight hours, and the rapidity of the convalescence particularly show the mildness of the case. They consider that the immunity to a subsequent attack, which they tested by later inoculations with infected mosquitoes, is also strong evidence of the validity of the first attack, and in fact confirms it rigorously. They call especial attention also to the fact that the interval between the time of the first infective bite, 4 o'clock in the afternoon on the 10th of March, and the appearance of the first symptoms of yellow fever at midday on the 14th of March, being three days and twenty hours, or ninety-two hours, is exactly the interval most commonly observed in experiments in the transmission of yellow fever by the bite of *Aëdes calopus*. They point out that in the twenty-six experimental cases followed by positive results at Havana and in Brazil eighteen cases showed symptoms of the fever in the course of the fourth day following the bite.

They considered the possibility whether, in spite of their careful watch over the subject, who as a matter of fact lived with one of them in the laboratory, some chance circumstance had perhaps exposed him to inoculation other than the experimental puncture of the hereditarily infected mosquito. But they think that there was no chance that this could have occurred under the precise conditions.

In the article just cited the French writers admit that it is impossible to draw unassailable conclusions from an isolated case. However they elaborate upon the importance of this discovery as accounting for the return of recently stamped-out epidemics at a period which may be comparatively short but too long to permit of its direct carriage by adult mosquitoes infected before the epidemic was stamped out. They cite the return of the 1889 epidemic at Campinas as a possible example. Reverting again to the benignity of the case produced by the hereditarily infected mosquito, they ask if this was not due to an attenuation of the virus which had passed through the egg and larval stages of the insect. They state that among their experimental cases bitten by directly infected mosquitoes they found a certain proportion which were benign, and concluded that, aside from individual resistance to the disease, there are conditions as yet unknown which bring about an increase or an attenuation of the virus in the mosquito. They argued further that it is known that in countries where yellow fever occasionally exists there are false epidemics—an illness known under the name of inflammatory fever. It differs from yellow fever by the mildness of its attack and by the absence of mortalities. One of these writers studied in 1882 a slight epidemic of this affection among the soldiers in garrison in the island of Salut in French Guiana. In a space of eight or ten days a third of the effective force of this little garrison was attacked by the fever, which caused no deaths and disappeared as suddenly as it came. The writers were struck with the analogy existing between that outbreak and the case of yellow fever which they had produced by an hereditarily infected mosquito. This inflammatory fever is unknown except in countries in which yellow fever is endemic. Its epidemic appearances have been often preceded or followed by certain and severe cases of yellow fever. They think that if it shall be shown by future experiments that the yellow-fever mosquito hereditarily infected is capable only of producing light cases, it will be important to consider whether the so-called inflammatory fever does not differ from yellow fever simply by this mode of infection.

The final conclusions of the French commisssion are published in their second and third Memoirs, issued by the Pasteur Institute of Paris in January and February, 1906. The conclusions of the second Memoir include the observations just recorded, but the conclusions as a whole are so important that they may be stated in detail:

"(1) The transmission of the virus of yellow fever is possible hereditarily in *Stegomyia fasciata*. In the case, unique up to the present, in which this has been observed, the eggs which gave birth to the hereditarily infected individuals of the first generation had been laid by a mosquito which had been infected a sufficiently long time previously from a yellow-fever patient.

"(2) The infection of *Stegomyia fasciata* hereditarily does not appear to play a considerable part in the propagation of yellow fever. It is capable, nevertheless, of causing a recurrence of a recently stamped out epidemic, and it is therefore very important to take it into consideration in prophylactic organization.

"(3) It is possible that the passage of the yellow-fever virus from one generation of the mosquito to another, through the egg, causes the attenuation of the virus.

"(4) The mosquito does not become infected by absorbing either the blood coming from the hemorrhages common to patients in the second stage of yellow fever or from the black vomit or from the dejections of the patients. The mosquito, even in captivity, absorbs these substances only when it is compelled by hunger.

"(5) The larvæ of *Stegomyia fasciata* reared in water containing fresh bodies of infected mosquitoes do not contract the infection and the adults which issue from them are not virulent.

"(6) The infected mosquito kept at a temperature near 20° C. does not appear to possess the infecting power.

"(7) We have not succeeded in infecting mosquitoes from subjects during the period of incubation of yellow fever.

"(8) The virus of yellow fever can be artificially transmitted from mosquito to mosquito. We have not succeeded in causing several successive passages of this kind.

"(9) This mode of transmission is possible only under laboratory conditions. It does not exist in nature. Healthy adult mosquitoes kept in contact with the bodies of infected mosquitoes do not contract the infection and are incapable of transmitting yellow fever.

"(10) Experiments in the endeavor to transmit the fever by other mosquitoes than *Stegomyia fasciata* have uniformly given negative results.* It is very probable that the yellow fever virus is adapted to the organization of this single species to the exclusion of all other culicids.

"Were this not so, a biological phenomenon which is observed with most of the species, the death of the female after the first egg-laying, would prevent the virus absorbed by the individuals of these species, after piercing a patient, from having the time to develop in their bodies in such a way as to render them infectious.†

"(11) *Stegomyia fasciata* escapes this rule. It is because the female is capable of laying several successive batches of eggs that she acts as the intermediary host of the fever. If she were to die regularly after her first laying, as do so many other female Culicidæ, yellow fever would be unknown."

Conclusion No. 8, which reads, "The virus of yellow fever can be artificially transmitted from mosquito to mosquito," and the conclusion following it, indicating that this method of transmission is possible only under laboratory conditions, needs further explanation to those not familiar with the original paper.

A number of unsuccessful experiments in the transmission of yellow fever to monkeys and other animals were tried in the search for an inoculation serum, and for this purpose they carried 124 infected mosquitoes to France, 57 arriving in living condition in Paris. They caused the mosquitoes to puncture an orang-utan and a young chimpanzee, bringing about some elevation of temperature, but they were unable to determine that this was due to a yellow-fever infection. After having given periodically abundant injections of virulent human blood to a horse, and finding difficulties in the way of preparing an active serum which would not be dangerous, they attempted to cultivate a serum in the mosquito. They considered that if the germ which causes yellow fever issues from the mosquito in the form in which it enters it, it was a legitimate hope that a direct transmission from one mosquito to another might be secured. They took living mosquitoes, infected the 12th of February, 1904, pulverized them with glucose added to a little physiological water. This mixture, rapidly prepared on the 10th of March, was immediately offered to a certain number of young *Aëdes calopus* which had fasted for two days. The insects immediately took this nourishment. Sixteen days later, the 26th of March, three of these mosquitoes bit a man. The same individual was bitten by two more of these mosquitoes on the 28th. The 7th of April the patient felt uneasy; the 8th he had a chill with pain in the limbs and in the lumbar region; the thermometer, after having shown 39° the 8th of April, 39.8° the 9th of April, returned to the normal on the 11th. On the 13th there was a slight jaundice, with albumen in the urine—in fact, the man had shown a clear case of yellow fever. The virus had then passed from one mosquito to another. The experimenters considered the significance of this experiment as considerable, and believed that nothing would be easier than to procure the virus in abundance in this way. They continued the work, starting with a

* The species experimented with in this way were *Culex quinquefasciatus*, *Aëdes scapularis*, *Aëdes tæniorhynchus*, *Psorophora posticatus*, and *Psorophora ciliata*.—H., D. & K.

† The French investigators still adhered to the belief that most mosquitoes deposit all their eggs at once. We now know that a large proportion of mosquitoes lay their eggs in incomplete batches at intervals and that, therefore, the yellow fever mosquito is by no means exceptional in this respect.—H., D. & K.

single infected mosquito. They crushed it up and fed it to 25 new insects, and these latter, ground up in their turn, were distributed among 200 others. Of these, 25 were devoted to a fourth experiment, while the major part of the others were ground up in physiological water, and the liquid injected, after filtration through a metallic sieve, into the veins of a kid. The result was negative. Ten more were allowed to puncture a man, but without result. This lack of success did not discourage them. They continued the work, and repeated the injections into the kid, which thus received the extract of about two thousand mosquitoes. Serum from this kid, tried fifteen days after the last inoculation, was shown to be inactive. After the second passage the cultures were without doubt sterile, but unfortunately without the investigators having perceived it, and this is, in fact, the most serious obstacle to this kind of culture. With each passage it is necessary to experiment with a man in order to determine the success or non-success.

Very great praise is due to the French investigators for the care, persistence and ingenuity of their experimental work. They made important discoveries, strengthened and helped to fix the belief of the advanced medical profession, and indicated important lines of work for future research.

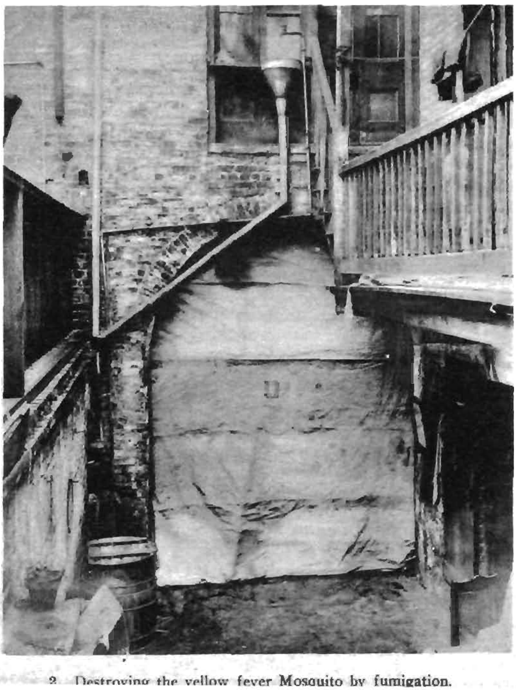
THE LAREDO OUTBREAK OF 1903.

The establishment of the fact that yellow fever is transmitted by *Aëdes calopus* was followed by admirable mosquito extermination work in the city of Havana by the United States Army authorities. The work was put in charge of Dr. W. C. Gorgas, of the Army, and quickly produced the most beneficial results. Some details concerning this work are given later in this volume among the examples of successful anti-mosquito work.

In 1903 it became evident that yellow fever was epidemic in the town of Laredo, Texas, and in the city of Nuevo Laredo, Mexico, immediately across the Rio Grande from Laredo. It was not until the end of September that the disease was definitely ascertained to be yellow fever, having been reported up to that time to be dengue; but upon September 25 the public health officials took charge of the situation and immediately began work based upon anti-mosquito measures. From September 25 to November 30 there were 1050 cases of yellow fever, of which 691 were Mexicans and 359 Americans. The number of deaths was 103, 95 being Mexicans and 8 Americans. The measures adopted and at once put into effect were practically those which had been instituted in Cuba, and which consisted in isolation of patients, protection by mosquito bars, fumigation of houses, and the oiling of water receptacles. We mention this Laredo work as a demonstration additional to those of the mosquito results in Cuba and Brazil, and as nothing else. Some of the conclusions reached by Surgeon G. M. Guiteras in his report to Surgeon-General Wyman may be mentioned:

"1. The results obtained through the efforts to combat the yellow fever epidemic at Laredo go to demonstrate that the mosquito (*Stegomyia fasciata*) is the only means of transmitting yellow fever and that the efforts to destroy the same were productive of much good, greatly limiting the number of cases.

1 Crane Lake, Saskatchewan, June, 1907.
Mosquito net for protection of face.



2 Destroying the yellow fever Mosquito by fumigation.

"2. The measure taken to prevent the reproduction of the *Stegomyia fasciata* or other mosquitoes by oiling all water containers and deposits of stagnant water were completely successful.

"3. It was demonstrated that to control an epidemic of yellow fever which has gained considerable headway (and such is the condition usually met with) it is necessary to have absolute power to enforce sanitary measures until such time as the people are educated up to the importance of such measures.

"4. Inasmuch as the *Stegomyia fasciata* can only become infected by biting the patient during the first three days of the disease it is of vital importance that cases of fever be reported at the earliest possible moment so that they may be screened and the mosquito prevented from biting them. Such being the case, an efficient system of inspection is necessary, especially where there is a tendency to hide cases.

"5. It is impossible to obtain good results without a mosquito-proof yellow-fever hospital.

"6. The difficulties of handling an epidemic are increased when such outbreak occurs on the frontier. Arrangements should, therefore, be entered into by treaty with contiguous foreign countries, so that under such circumstances sanitary measures may be carried out jointly by the countries interested for mutual protection.

"7. Insistent and continued efforts should be made through the public press and other available means, to educate the people within the sphere of influence of the *Stegomyia fasciata*, so that they will learn to protect themselves against the invasion or possible spread of yellow fever in their midst by destroying the means for the propagation of said mosquito, and by protecting themselves against the mosquito by efficient screening.

"Above all, to eradicate the existing fear in the medical profession, as well as among the laity, of declaring the existence of yellow fever. If the first case presenting the slightest suspicious symptoms of that disease were promptly made public and the proper modern precautions taken there would be no danger of the disease spreading. In fact, the public should be taught to acknowledge the existence of yellow fever in their midst with the same equanimity as in the case of measles or scarlatina."

The last of Guiteras's conclusions was an exceptionally important one. All through southern Texas that year the existence of yellow fever was systematically hushed up, and it must be said, to the shame of the medical profession, that members of that profession were concerned in the blinding of the public eye to the existence of the disease.

An interesting fact concerning the Laredo outbreak is that at Fort McIntosh, with a command of 111 officers and men, there were only five cases of yellow fever, while in the town beside them over one thousand cases occurred. The force was protected by leather helmets and leggings and mosquito head-nets, and it was found that the five men who became infected had violated orders by visiting the town without this protection.

THE NEW ORLEANS EPIDEMIC OF 1905.

In 1905 occurred the first opportunity (and let us hope it will be the last) to demonstrate in the United States on a large scale the efficacy of anti-mosquito work in the face of an epidemic of yellow fever. The disease was recognized and acknowledged at a sufficiently early date to permit of much more satisfactory results than had been obtained at Laredo, the scale of operations at the same time being very much greater. The presence of yellow fever in the city of New Orleans was first recognized about the 12th of July, 1905. The plan of campaign, adopted by the Board of Health under Dr. Quitman Kohnke from the beginning, was based on the recognition of the mosquito conveyance of the disease and was directed against *Aëdes calopus*. Dr. Kohnke had, in fact, for some time previously, been one of the foremost physicians in the South to preach mosquito destruction. For more than two years he had been doing everything in his power to secure the screening of the numerous cisterns, and to induce the city to adopt other necessary measures, but without success. Available funds to combat the epidemic were rapidly exhausted, and on the 12th of August the Public Health and Marine-Hospital Service was put in charge of the situation and provided with means. Dr. J. H. White, of the service, had complete command. By that time the increase in the new cases and deaths rendered it practically certain that the disease was as wide-spread as during the terrible epidemic of 1878. There had been up to that time 142 deaths from a total of 913 cases, as against 152 deaths from a total of 519 cases in 1878. The work for the rest of the summer was continued with great energy under Dr. J. H. White, and the measures were based almost entirely upon a warfare against the yellow-fever mosquito. The disease began almost immediately to abate, and the result at the close of the season indicated 460 deaths, as against 4046 in 1878, a virtual saving of over 3500 lives.

The following table of deaths from yellow fever in New Orleans from 1847 to 1905 points out strikingly the value of this anti-mosquito work:

Comparative table of deaths from yellow fever in New Orleans during various years.

Month.	Year.								
	1847.	1848.	1853.	1854.	1855.	1858.	1867.	1878.	1905.
May	......	......	2	......	......	......	......	......	......
June	......	4	31	2	5	2	3	......	......
July	74	33	1,521	29	382	132	11	26	35
August	965	200	5,133	532	1,286	1,140	255	1,025	236
September	1,100	467	982	1,234	874	2,204	1,637	1,780	107
October	198	126	147	490	97	1,137	1,072	1,065	59
November	12	20	28	131	19	224	103	147	23
December	10	......	4	7	7	15	26	3	......
Months unknown	445	22	......	......	......	......	......	......	......
Total	2,804	872	7,848	2,425	2,670	4,854	3,107	4,046	460

The epidemics of 1848, 1854, and 1855 are least comparable with that of 1905 because they immediately succeeded severe epidemics to which were due very many immunes.

The population of New Orleans by the United States Census was 130,565 in 1850; 168,675 in 1860; 191,418 in 1870; 216,090 in 1880, and 287,104 in 1900.

Quite as conclusive as the New Orleans experience has been the result of the work on the Isthmus of Panama. This work is also described in some detail among the examples of remedial work.

THE DEATHS OF REED, CARROLL, AND LAZEAR.

The deaths of Lazear, Reed and Carroll, following the brilliant results of their work, are inexpressibly sad. Dr. Lazear was a young man of great ability, admirably trained, whose work, as Dr. Reed says, was characterized by "a manly and fearless devotion to duty such as I have never seen equaled." He "seemed absolutely tireless and quite oblivious of self. Filled with an earnest enthusiasm for the advancement of his profession and for the cause of science, he let no opportunity pass unimproved. Although the evening might find him discouraged over the difficult problem at hand, with the morning's return he again took up the task, full of eagerness and hope." His death was due to accidental inoculation, by an infected mosquito, in the course of his researches at Havana. When the Board resumed its work after his death in November, 1900, and established the experiment station at Quemados, they named it in honor of their comrade, Camp Lazear. Dr. Walter Reed, the inspiring genius of the investigation, died suddenly November 23, 1902, with his health impaired by his strenuous labors. He had reaped some of the honors following his monumental work, but by no means all. His name will live as that of one of the great benefactors of the human race. Dr. Carroll, although he lived for a few years longer, died September 16, 1907. At Havana, in 1900, he suffered the first experimentally produced attack of yellow fever and it proved a severe one. His early death was undoubtedly due to the effect of the disease. He lived just long enough to see the substantial results which followed the great work with which he had been so prominently connected. Personally, all three were of the highest type, and each is mourned by a host of warm friends, as well as by the world at large.

THE SEARCH FOR THE CAUSATIVE ORGANISM.

The experiments just recorded demonstrate beyond all doubt that the specific agent of yellow fever inhabits the blood. A most prolonged microscopic search was made, not only by Reed and Carroll, but by many other investigators, with fresh and stained preparations of blood, taken at various stages of the disease and during early convalescence. But all of this search was negative. Further search was made in the bodies of infected mosquitoes dissected fresh, and also by means of serial sections of the hardened insect, and no results worthy of mention were obtained. The attention of Reed and Carroll was soon called by Welch to the important observations of Loeffler and Frosch on the etiology of the foot-and-mouth disease of cattle. In this disease the lymph, collected from the blebs present in the mouth and feet of sick cattle, had been diluted and passed several times through a porcelain filter, with the result that this strained and diluted lymph injected into calves produced the disease as promptly as with others that had been injected with the same quantity of unfiltered lymph. The German authors decided that there were two possible explanations of this result: either that the filtered lymph held in solution an extremely active toxin, or that the causative organism of the disease was so small as to pass through the pores of a filter through which even the smallest known bacteria could not pass. The latter explanation was accepted. Reed and Carroll decided to make similar experiments with yellow fever, and Carroll, returning to Havana in August, 1901, succeeded in carrying out some very interesting experiments; in the course of these it was shown that the filtered blood serum from a yellow-fever patient carried the disease to non-immunes. The serum used for the inoculations had been slowly filtered through a new Berkefeld laboratory filter. As soon as possible thereafter the filter was sterilized by steam and tested as to its effectiveness in preventing the passage of bacteria, with the result that it was found to intercept *Staphylococcus*. The opinion of Reed and Carroll, after these experiments, coincided with those of Loeffler and Frosch in the case of the foot-and-mouth disease, and they were inclined to believe that the causative organism of yellow fever is of extremely minute size (ultra-microscopic).

In 1902 a working party of the Yellow Fever Institute of the U. S. Public Health and Marine-Hospital Service worked for some time at Vera Cruz, Mexico, in the effort to find the causative organism of yellow fever. In their report, published in March, 1903, they describe a protozoan parasite by the name of *Myxococcidium stegomyiæ* which they stated was found with regularity in the appropriate mosquitoes that had bitten patients affected with yellow fever. These mosquitoes, after different periods of infection, had been killed, sectioned and stained. It was the belief of certain members of the party that in this organism they had found the cause of the disease. This conclusion was opposed by Carroll in a paper read at the Thirty-first Annual Meeting of the American Public Health Association, held at Washington, October 26–30, 1903, after examination of much material. His conclusions were as follows:

"1. The fusiform stage of the so-called *Myxococcidium stegomyiæ* of Parker, Beyer and Pothier (1903), is not connected in any way with the transmission of yellow fever.

"2. This organism appears to be not a protozoan parasite, but a yeast fungus. In its fusiform stage, the only form in which it was constantly present, it shows the characteristic budding, staining affinities and vacuolation or spore formation of a blastomycete, and it is found with considerable regularity in both male and female mosquitoes that have purposely been fed on overripe banana to which a pure culture of a wild yeast had been added in the laboratory.

"3. The organism has not hitherto been found in repeated examinations of mosquitoes of the genus *Stegomyia* that have bitten yellow fever patients in the early stages of the disease, when such insects had been fed only on blood, dry sugar and water. This statement applies also to mosquitoes that are known to have reproduced the disease in human beings."

A second working party, sent out by the Public Health and Marine-Hospital Service, went to Vera Cruz in April, 1903, and published its report in May, 1904. In the meantime the French commission had endorsed Carroll's conclusion. The conclusions, bearing upon the subject, reached by the second expedition to Vera Cruz, are as follows:

"The cause of yellow fever is not known.

"The *Myxococcidium stegomyiæ* is not an animal parasite. Yeast cells sometimes simulate the coccidia in form and staining reaction.

"The infection of yellow fever is in the blood serum early in the disease. No abnormal elements that bear a causal relation to the disease can be detected in the serum or in the corpuscles with the best lenses at our command.

"The infective principle of yellow fever may pass the pores of a Pasteur-Chamberland B filter.

"Particles of carbon visible with Zeiss lenses pass through both the Berkefeld and Pasteur-Chamberland B filters.

"Because the virus of an infectious disease passes a Berkefeld or Pasteur-Chamberland B filter it does not necessarily follow that the parasite which passed the filter is 'ultramicroscopic,' or that it may not have elsewhere another phase in its life cycle of large size.

"The filtration of viruses may succeed or fail, depending upon the character of the filter, the diluting fluid, the pressure, time, temperature, motility of the particles, and other factors.

"The period of incubation of yellow fever caused by the bites of infected mosquitoes is usually three days, sometimes five days, and in one authentic instance six days and two hours; but when the disease is transmitted by such artificial means as the inoculation of blood or blood serum the period of incubation shows less regularity.

"Yellow fever may be conveyed to a nonimmune by the bite of an infected *Stegomyia fasciata*; but the bites of *Stegomyia* which have previously (over twelve days) bitten cases of yellow fever do not always convey the disease.

"Fomites play no part in the transmission of the disease.

"The tertian and æstivo-autumnal malarial parasites will not pass the pores of a Berkefeld filter."

The causative organism of yellow fever still remains unknown.*

Carroll, of the American commission, in almost the last paper before his lamented death, and which forms the chapter entitled "Yellow fever" in volume ii of Osler's Modern Medicine, summarizes, on page 747, the arguments which favor the protozoal character of the organism presumed to cause the disease:

"Notwithstanding all the efforts that have been put forth in that direction, the specific organism of yellow fever still awaits recognition. The arguments opposed to the idea that the invisible causative agent of yellow fever is a bacterium are: (1) it has never been recognized nor cultivated; (2) according to the French Commission the blood of a patient loses its power to infect within two days if exposed to the air, and within five days if air be excluded; (3) the absolutely non-contagious and even non-infectious character of the disease under conditions otherwise favorable but in the absence of the mosquito. The arguments in favor of its being a member of the animal kingdom are: (1) its obligatory parasitic existence in man and the mosquito, alternately; (2) the necessity for the lapse of a definite period, two weeks or more after the ingestion of the blood, before the mosquito becomes capable of infecting; (3) the restriction of the hosts to a single vertebrate and a single genus of invertebrates which points to a definite cycle of development; (4) the rapidity of development of the parasite within its invertebrate host is governed by conditions of external tempera-

* Quite recently, claims of the discovery of the causative organism of yellow fever have been published by Dr. Harald Seidelin (Zur Aetiologie des gelben Fiebers. Berl. klin. Wochenschr., no. 18, pp. 821-823, 1909; Protozoon-like bodies in the blood and organs of yellow-fever patients. Journ. Pathol. & Bacteriol., vol. 15, pp. 282-288, 1911; The etiology of yellow fever. Yell. Fever Bull., vol. 1, no. 7, pp. 229-258, plate. 1911).

ture in the same way as the rate of development of the malarial parasite in the anopheles mosquito."

The view of Carroll, that the causative organism of yellow fever is a protozoan, ultra-microscopic in size and with its life-cycle partly in man and partly in the mosquito, has been generally accepted by students of the disease.

THE YELLOW-FEVER MOSQUITO.

DOMESTICITY OF THE YELLOW-FEVER MOSQUITO.

Aëdes calopus is inseparably associated with man in the tropics. It is essentially a town mosquito and it is never found at a great distance from habitations. It shows a very decided preference for human blood and must have blood for the development of its eggs. These points were very clearly brought out by Marchoux, Salimbeni and Simond, of the French commission to Rio de Janeiro, and they have since been verified by many observers. Both sexes inhabit houses and when the requisite conditions obtain the entire life-cycle takes place indoors. This is the only species of mosquito in which the male is attracted to man. Finlay's paper of 1881 shows that he already clearly understood the domestic character of *calopus*. Ficalbi, in 1896, noted the domesticity and diurnal habits of this mosquito, and that it does not bite at night. Goeldi states that in Pará it bites from sunrise until dark. A significant fact is the stealthiness of its attack, always approaching from behind. It retreats upon the slightest alarm but does not relinquish its efforts until it has accomplished its purpose. The ankles and, when one is sitting at a table or desk, the under side of the hands and wrists are the favorite points of attack. Of further significance is the fact that it attacks silently while other mosquitoes announce their presence with the piping or humming note. Doubtless sonifaction has been suppressed in this species in the evolutionary process of adaptation to man.

On their 1905 journies many notes were made by both Busck and Knab bearing upon the fact that the yellow-fever mosquito has become a strictly domesticated species. The hiding habits of the adult, its general air of familiarity with man, its habit of approaching from behind instead of from the front, its extreme wariness, its habit of concealment in garments, working into the pockets and under the coat lapels and collars and of crawling up under the clothes to bite the legs rather than the exposed ankles, are all indications of familiarity with the human species for many generations.

The habit of hiding, which has just been mentioned, seems very characteristic of this species. It was already noted by Finlay in 1881 and its bearing upon the dissemination of the species pointed out. In houses they will hide in dark corners, under picture moldings, behind the heads of old-fashioned bedsteads and in similar places. They will enter clothes closets and hide in the folds of garments. From this habit, as Finlay states, they are especially apt to be packed with clothing into trunks and carried on journeys. They have been known to emerge alive after some days' confinement of this character. Just how long *calopus* will live under these conditions has not been determined.

The domesticity of this mosquito will be apparent from the detailed account of habits which follows. Nearly always it is found in houses or in their immediate vicinity. Durham, at Pará and at Manaos, on the Amazon, found it a house mosquito. He says of it: "Never seen out in forest away from houses, or in isolated huts situated away in forest. Not seen at Santa Anna, some twenty-five miles north of Pará, or Fazenda Natal, in Marajo."

However, upon a number of occasions it has been found established at a distance from habitations. The Brazilian observers at Rio de Janeiro have paid special attention to this question and Peryassú records its occurrence in the forest at a distance of 500 meters from the nearest habitation. In the vicinity of Rio de Janeiro both males and females of *calopus* were found in the woods, away from houses, at Gavea, Corcovado, Paineiras, Furnas da Tijuca, Sylvestre, and in some woods near Lagoinha. Once the larvæ were found in a pool at Furnas da Tijuca, at a great distance from habitations, and on another occasion at 100 meters from the Hotel do Sylvestre which is situated in an uninhabited region. Such occurrences must nevertheless be considered rare, even under the most favorable circumstances, such as those observed about Rio de Janeiro undoubtedly were.

The only other instance known to us in which *calopus* has been found at a distance from human habitation, except on trains, ships and other conveyances, is told by Mr. Herbert S. Barber, of the Bureau of Entomology. On July 30, 1904, while making a trip along the supposed northern boundary of the distribution of the yellow-fever mosquito, after dinner at Helena, Arkansas, he took a walk into the wooded hills in the suburbs, a hundred feet above the river. Rather more than a quarter of a mile after leaving the last house, in a sunny opening in the woods, he was kneeling down and sifting the earth for small insects, when a single female of *calopus* alighted on his hand and pierced his skin. He captured the specimen. He searched and could find no house within a quarter of a mile, and there was no indication of any building having existed there before. He himself is sure that the mosquito was there before he arrived. Could the mosquito have flown this distance from the nearest house (there was no neighboring breeding-place, so far as Mr. Barber could find)? Mr. Barber thinks there was no possibility that the insect had come out from the town with him, although he was perfectly aware of the propensity of this species to hide under folds of garments, such as coat lapels.

The French investigators state that sleeping rooms are the preferred habitat of *calopus*. They determined that this mosquito very rarely attempts to leave a room and that it does so only when in search of a suitable place to deposit its eggs.

FEEDING HABITS.

The French commission found that both sexes normally frequent human habitations and that they obtain the necessary food inside the house. The female sucks blood when it is available, and, as will be shown further on, needs blood to develop her eggs. In captivity the female has been kept alive a long time on a diet of honey or other sweet substances. Ficalbi makes the following statement which has been widely quoted: "A most remarkable peculiarity of this species is that *the male stings* as well as the female and sucks the blood, producing a puncture equally painful with that produced by the female." It now seems well established that the male does not suck blood. Taylor in referring to this point states that "after a daily experience of over two years, with thousands of *Stegomyia fasciata,* we are in a position to state positively that the Havana male of this species does not bite the human skin." However it seeks the exposed portions of one's person, apparently to lap the perspiration, and produces a certain amount of irritation. The male also feeds upon sugar and upon various liquids, such as wine, beer or syrup.

Goeldi has observed an apparent connection between the existence of perspiration and the attraction of the yellow-fever mosquito. He says that when one perspires lightly on the neck, the ears, the face, and the hands *calopus* is attracted very greatly. He states that the males are also attracted to any exposed portion of the body covered with perspiration. He thinks that they come to drink the perspiration, and if they do not actually puncture the skin it is simply because they are unable to do so. He is inclined to think that their efforts to perforate the skin produce some irritation.

The French investigators found that a female will bite 24 hours after emergence from the pupa; Peryassú states that both fertilized and virgin females have been induced to suck blood after 18 hours. Under natural conditions it is rare that the female has not been fertilized before this time and it appears that copulation stimulates the desire for blood. Finlay tried to induce females captured fresh from the pupa to bite, but in trials during two and three days he was unsuccessful. The French commission determined that, nevertheless, virgin females will bite. In an experiment with eight virgin females the first one sucked blood after 54 hours. Finlay already noted that the fertilized females are very greedy for blood and this observation has been confirmed by others.

Finlay observed that after a meal of blood *calopus* is very sluggish and flies with difficulty; it seeks a hiding place where it remains quiescent during the process of digestion. During this period the female often, for hours at a time, moves its hind legs in a curious manner and Finlay supposed that during this operation it anointed its body with a secretion from the anus. If the mosquito has sucked enough blood for a full meal it will not return to bite for some time but, on the contrary, will avoid the bare skin, as Finlay thinks, because the warmth is disagreeable to it. He found that from two to four days were consumed in the process of digestion and that afterwards the female again became greedy for blood.

Peryassú records a minimum period of 24 hours for the digestion of a blood meal. Finlay called attention to the important bearing on the transmission of yellow fever of the fact that *calopus* normally sucks blood repeatedly. Thus a female which he kept alive for 31 days sucked blood 12 times. By biting a number of different individuals the chances of becoming itself infected and of transmitting the disease are greatly increased. Finlay further thought that the higher temperature of persons stricken with fever might be an additional attraction for the mosquito.

The French commission found that *calopus* has a decided predilection for the blood of man. It can, however, subsist upon the blood of any warm-blooded animal, but it shows a more or less pronounced repugnance for any other warm-blooded animal than man. Durham states that at Pará he has observed *calopus* feeding upon "dogs, on an agouti, and a bat," but he does not indicate whether this was in freedom or with mosquitoes in captivity. Neumann, in his experiments on the transmission of *Plasmodium præcox* to canary birds by means of *calopus,* found that this mosquito showed a decided preference for mammalian blood. In his experiments, conducted under the most favorable conditions, from a total of 2573 female *calopus,* he was only able to induce 789 to suck blood of canaries, or 30.7 per cent. With *Culex,* on the contrary, 64 per cent of the females attacked the birds. When the experiment was made with rats the results were reversed and the *calopus* attacked at once while the *Culex* showed repugnance.

It appears also that *calopus* discriminates between races and individuals. This was already discussed by Finlay in the following manner:

"Finally, should be taken into account the preferences which mosquitoes manifest towards certain races and individuals; one notes that the least tormented race appears to be the African and the individuals most persecuted by them are those of northern races who have recently come to the tropical regions of America. It appears probable that this depends upon the thickness of the skin and upon the condition of the capillary circulation of the skin; it is to be assumed that these circumstances will affect the facility with which the female mosquito can obtain the blood which it needs to complete its life-cycle."

The French investigators made a number of experiments to show whether *calopus* bites indifferently people of different races. They concluded that it easily bites both the negro and the red-skinned races, but that it has a marked predilection for the white race. If mosquitoes of the same age and at the same temperature are placed upon individuals of the black-skinned, red-skinned and white-skinned races, the white will be bitten most quickly. The red-skin is also quickly attacked. Towards the negro, *calopus* shows some repugnance, and almost never in the course of their observations did it decide to bite immediately, and often a contact of ten to fifteen minutes was necessary before the proboscis was inserted. They show also that among the individuals of the white race, this mosquito has preferences, and attacks with the greatest avidity young, vigorous individuals of fine skin and good color rather than anæmic or aged persons. When it is hungry, however, the mosquito will bite the first human being it meets.

The stealthiness of attack has already been mentioned as a peculiarity of the yellow-fever mosquito. This is brought out in an interesting manner by Parker, Beyer and Pothier in the results of their investigations at Vera Cruz (Report of Working Party No. 1, Yellow fever Institute, Bulletin 13, March, 1903):

"The approach to attack of *Stegomyia* is extremely insidious, usually approaching an individual on the shady side and without warning. The pertinacity of this mosquito in returning to its victim after it has been repeatedly driven off is almost characteristic. It has been noted repeatedly by us that females escaping while being transferred from one jar to another would almost unfailingly return after a few minutes and attempt to secure food from one of us. On one occasion a marked female was driven off five times during one forenoon; once she remained away nearly an hour, when her intended victim becoming tired of further timekeeping, finally recaptured her. Having satisfied its desire for food it gives vent to a triumphant note and goes in search of a resting place."

The French investigators determined that *calopus* would only drink blood that it could itself extract from the body. When females were placed upon a patient who was wet with a hæmorrhage from the mouth they refused to feed upon this blood and in case the mosquito was hungry it sought a place that was not daubed with blood and fed by piercing the skin. When given the choice of cold blood and sweet substances they preferred the latter. Otto and Neumann were able to feed female *calopus* on a mixture of blood and salt solution; the French investigators think that this must have been done under very favorable conditions and that it does not invalidate their own observations.

TIME OF ACTIVITY.

The yellow-fever mosquito in the West Indies is known often as "the day mosquito." It is usually active and bites only during the daytime, although where there is a light in the room it may also bite at night. Finlay, in his paper of 1881, already called attention to the strictly diurnal habits of this species and contrasted it with the exclusively nocturnal habits of the other house mosquito of Havana, *Culex quinquefasciatus*. He thought that there must be a constitutional difference in the two mosquitoes which accounted for the different habits and this he concluded to be the greater resistance of *calopus* to heat. He placed females of the two species in glass tubes and exposed them at midday to the direct rays of the sun under identical conditions, the thermometer marking 42.25° centigrade, the relative humidity 31.75. The *Culex* died after five minutes while the *calopus* remained unharmed after 15 minutes and continued alive in its tube through a further 24 hours.

Working Party No. 1 of the U. S. Public Health and Marine-Hospital Service at Vera Cruz in 1902, found that the greatest activity of this mosquito is during the daytime. They also observed them feeding upon members of the party at night by artificial light. They found them to be especially voracious early in the morning, about sunrise, and again late in the afternoon. Durham, in his studies at Pará, Brazil, was also struck with the diurnal habits of *calopus* and calls it "solely a day gnat."

"It is on the wing and will bite shortly after sunrise (about six a. m.); again a few have been observed biting about eight to nine a. m., after which there is a pause till about eleven a. m., when again a few may be feeding. The time of chief activity is in the middle of the day, from about twelve to two p. m., they then bite freely, and are seen to copulate on the wing in numbers; another pause follows, though there may be a few about, but they do not cause trouble when one is sitting at the microscope until about half-past three till about five p. m

After dusk or dark I have only once met with a specimen; this was a male, feeding in a sugar-basin rather before seven p. m. These statements are derived from observations whilst working in the laboratory, and during a residence for a week in the house of a gentleman, whose garden was liberally supplied with ant-guards (perforated troughs filled with water, for preventing the access of the destructive 'Saüba' to the plants), each of which was full of developing larvæ and pupæ. Sitting in the verandah of this house it was easy to catch fifty to eighty specimens without moving from one's chair, in the early hours of the afternoon, yet after sundown, not a single individual was met with."

Dutton, in the malaria expedition to the Gambia, observed *calopus* and found it strictly diurnal.

"The observation of Durham and others with regard to *Stegomyia fasciata* was fully confirmed at Bathurst; these mosquitoes only bite during the day, more especially in the early part of the afternoon. None of this species were collected in mosquito nets during the night."

It has been the experience of one of the writers (Howard), sleeping in hotels in the Southern States where the mosquito canopies were faulty, that when other species of mosquitoes were not in the room he was undisturbed until the room was lighted by the rising sun; then *Aëdes calopus* began to bite furiously. According to E. G. Hinds, at Victoria, Texas, they seem most active from eight to ten in the morning and from four to six in the afternoon, and are very active just before a storm.

Carter states that *calopus* has not been found to feed in the dark nor in a strong light, and that its feeding seems to depend more on the degree of light than on the time of day. He says that if the place be fairly light, it approaches its victim on the shadow side, thus especially attacking the ankles under a writing table, or the hands under the head during a siesta. It does not bite out of doors in ordinary bright daylight. Knowledge of these points is of much practical value. Carter points out that by these habits is explained the comparative safety of daylight communication with towns infected with yellow fever; that is to say, entering a town only after ten a. m. and leaving by four p. m. under pledge to go in only on sunny days and to enter no residence. The danger of staying all night, he points out, is really the danger of the late afternoon, early evening and morning hours, spent, of course, in houses.

Veazie, of New Orleans, in an early paper (New Orleans Medical and Surgical Journal, 1901) says that this mosquito "usually flies and bites in the daytime; if a light is burning at night you will find an occasional one . . . [It] is quite cunning in selecting the dark side of a person away from the light, and especially likes persons in dark clothing; old people, as they usually sit quiet, are greatly annoyed in the daytime by them." Taylor, of Havana, says of *calopus*, "If hungry, it will bite freely at any hour of the day or night."

Charles S. Banks has observed *Aëdes calopus* in the Philippines and says: "It is altogether a day flier, individuals being seen after dark only on the very rarest occasions."

Goeldi, originally of the opinion that *calopus* does not bite during the night, was obliged after cumulative instances to admit that it may do so. Writing between eight and eleven o'clock at night, in a room in his house or in his office at the Museum at Pará, with electric light, the windows open, he caught mosquitoes that settled upon his hands, biting him. Generally those which came at these hours, certainly those from outside through the windows, were other species, but from time to time, each time causing him a certain surprise, there appeared also a female of *calopus*. In Rio de Janeiro he also noticed nocturnal bites by this species, in a library on the lower floor of a house illuminated by gas, at about the same hours. He noted that the room was papered with dark paper, and he had always noticed that during the day he was more persecuted by *calopus* in that room than in any other. He soon learned that the deep moldings of the furniture were the chosen hiding places for a large number of *calopus*. He also ascertained that females in captivity could easily be induced to bite at night. He asserts, however, that the yellow-fever mosquito is a diurnal species, but admits that it may happen that hunger drives some females, who during the day have not succeeded in obtaining their meal of blood, to prolong their hunt to unusual hours, especially when guided by a bright light in the room. Biting at night is therefore an exception, and they bite only in the presence of artificial light.

The French commission (Annales de l'Institut Pasteur, vol. 17, 1903, p. 691) assert that *Aëdes calopus* is essentially a nocturnal mosquito. According to their deductions *calopus* will only bite in the daytime within the first few days after leaving the pupa, and then only when driven by hunger. They maintain that when the female has reached a certain age, at the most two weeks, it will under no circumstances bite in the daytime. They say that the belief of other authors, that this mosquito is diurnal and hardly ever bites at night, is an error which must be destroyed. Still stronger than this categorical statement is the third of their conclusions (*l. c.*, p. 705), where, concerning the transmission of yellow fever by *calopus*, they say: "Que cette transmission n'a pas lieu en plein jour pendant que le soleil est sur l'horizon." * This expression is preceded by another, equally dogmatic: "dans la nature la transmission s'effectue ordinairement la nuit. Peut-être même cette règle est-elle absolue." †

In these assertions the French commission have made a complete inversion of values; their "rule" is certainly the exception. The conclusions of the French investigators are based upon insufficient and faulty data, as will be shown in the following. Furthermore, it appears that they were influenced in formulating their conclusions by the often repeated assertion that, at Rio de Janeiro, persons who visited the yellow-fever zone in the daytime only, remained free from infection.

The assertions of the French investigators were discussed and fairly refuted by Dr. Ivo Bandi, of São Paulo, immediately after their publication. Nevertheless, they have been widely accepted and in view of their great importance in connection with yellow fever we are under the necessity of thoroughly analyzing the French observations.

* "That this transmission does not occur during the daytime while the sun is above the horizon."

† "Under natural conditions transmission ordinarily occurs at night. It may be that this rule is absolute."

The conclusions of the commission rest, at least in the main, upon the observations of one of the members who was detailed for this work. A room was prepared to serve as both laboratory and sleeping room, arrangements made to prevent the escape of mosquitoes, and here the observations were to be made under the most natural conditions possible. "L'un de nous s'est astreint à habiter cette pièce pendant la journée et la nuit, afin d'observer les *Stegomyia fasciata* qui, soit isolément, soit par séries, y ont été introduits au cours des saisons chaudes de 1904 et 1905, dans un but expérimental." * (Ann. Inst. Pasteur, vol. 20, 1906, p. 105.) We are further informed that the observer absented himself from the room at meal-time only and that the observations were continued day and night, the first time during 18 days, the second time during 28 days. Clearly a continuous effort for such periods is beyond the power of the ordinary man and the excessive fatigue resulting from such an attempt must, as we shall see, seriously affect the character of the observations.

Seven separate experiments were made. Five of these were with series of from 6 to 8 mosquitoes and two of them were with single mosquitoes. Thus 42 is the *maximum that we can assume* of mosquitoes used *in these experiments*. Five of these experiments were cut short before the sixteenth day by the accidental death of the mosquitoes. In the two remaining experiments, which were carried beyond the sixteenth day, nine mosquitoes were employed. The results of these two experiments are given in detail; of the others we are briefly told that the results were similar, as far as the biting habits are concerned. "Nous rapporterons en détail les deux dernières comme étant les plus complètes." (We report in detail the two last as being the most complete.)

Experience I.

Un lot de 8 *Stegomyia fasciata* femelles, nées et élevées au laboratoire, sont mises en liberté dans la chambre à expérience, 24 heures après leur passage à l'état parfait. Pendant ces 24 heures elles sont restées enfermées en compagnie de mâles et ont été vraisemblablement fécondées.

1e jour: piqûres nombreuses entre 9 heures du matin et 5 heures du soir.

2e jour: piqûres (1 ou 2 seulement) entre 3 et 6 heures du matin, a l'obscurité. Piqûres nombreuses de 10 à 11 heures du matin.

3e jour: piqûres entre 1 et 5 heures du matin.

4e jour: piqûres entre 9 et 10 heures du matin. Piqûres entre 4 et 5 heures du soir.

5e jour: piqûres à 5 heures du soir. Piqûres à 10 heures et ½ du soir.

6e jour: piqûres entre minuit et 5 heures du matin. Une piqûre à 3 heures du soir.

7e jour: piqûres à 5 heures ½ du soir. Piqûres à 10 heures du soir.

8e jour: piqûres à 2 heures du matin, a l'obscurité.

9e et 10e jour: pendant ces 2 jours, on a laissé les moustiques seuls dans la chambre à expérience.

11e jour: piqûres entre 6 heures et 6 heures ½ du soir. Piqûres entre 10 et 11 heures du soir.

* "One of us was obliged to inhabit this room day and night in order to observe *Stegomyia fasciata* which, sometimes singly, sometimes in series, were introduced, during the hot seasons of 1904 and 1905, for experimental purposes."

12e jour: pas de piqûres.
13e jour: piqûres entre 10 et 11 heures du soir.
14e jour: piqûres entre 4 et 5 heures du matin.
15e jour: pas de piqûres.
16e jour: piqûres dans la nuit, entre 1 et 6 heures du matin. Il parait ne ıbsister que 2 moustiques du lot mis en expérience.
17e jour: piqûres à 9 heures ½ du soir.
18e jour: on a vu ce jour-là un seul moustique voler dans la pièce sans essayer : piquer. Depuis ce moment, aucun des moustiques n'a été revu.

EXPERIENCE II.

Un *Stegomyia fasciata* femelle a été laissé en liberté dans la chambre à ex-ıriences le lendemain de son passage à l'état parfait. En même temps, on a troduit dans la chambre 2 *St. f.* mâles.
1e jour: piqûres à 2 heures ½ du soir.
2e jour: piqûres le matin entre 4 et 6 heures.
3e jour: pas de piqûre.
4e jour: pas de piqûre.
5e jour: pas de piqûre.
6e jour: piqûre le matin entre 1 et 6 heures, à l'obscurité. Piqûre le soir 11 heures ½, à la lumière.
7e jour: pas de piqûre.
8e jour: pas de piqûre.
9e jour: pas de piqûre.
10e jour: piqûres le matin entre 1 et 2 heures, à l'obscurité.
11e jour: pas de piqûre.
12e jour: piqûre dans la nuit entre 2 et 5 heures du matin, à l'obscurité.
13e jour: pas de piqûre.
14e jour: piqûre le matin, entre 4 et 6 heures.
15e jour: pas de piqûre.
16e jour: piqûre entre 5 et 6 heures du matin.
17e jour: piqûre à 1 heure du matin.
18e jour: piqûre entre minuit et 6 heures du matin.
19e jour: pas de piqûre.
20e jour: pas de piqûre.
21e jour: pas de piqûre.
22e jour: piqûre à 11 heures du soir, à la lumière.
23e jour: pas de piqûre.
24e jour: piqûre à 10 heures du soir, à la lumière.
25e jour: pas de piqûre.
26e jour: pas de piqûre.
27e jour: piqûre dans la nuit, entre minuit et 6 heures du matin.
28e jour: pas de piqûre.
Le moustique a été vu le 28e jour pour le dernière fois.

These two experiments were begun with nine mosquitoes. In Experiment No. ye find this statement:

"16th day: bites during the night, between one and six o'clock in the morn-g. It appears that there still exist two of the mosquitoes employed in the ex-riment." It is thus clear that the investigator, beyond the sixteenth day, rked wih a maximum of three female *Aëdes calopus*. Furthermore, soon er, in experiment no. 1, we read: "18th day: one could see on this day but ingle mosquito flying in the room without attempting to bite. After this nt not one of the mosquitoes was seen."

Accordingly, from the eighteenth to the twenty-eighth day the observer draws his conclusions from a single mosquito.

It appears necessary to deal with this subject in detail, for it involves questions of methods of prophylaxis of yellow fever. Wrong deductions, based upon inconclusive experiments, not alone because of the few mosquitoes employed but also on account of the faultiness of the experiments themselves, can produce the most serious consequences. The absence of accuracy in indicating the exact time of biting, in the above experiments, is most regrettable and invalidates them. This becomes at once apparent from the following extracts: Experiment I. "2d day: bites (1 or 2 only) between 3 and 6 o'clock in the morning, in darkness." "3d day: bites between 1 and 5 o'clock in the morning." "6th day: bites between *midnight and 5 o'clock in the morning*." "*16th* day: bites in the night, between 1 and 6 o'clock in the morning." Experiment II. "6th day: bite in the morning between 1 and 6 o'clock, in darkness." "12th day: bite at night between 2 and 5 o'clock in the morning, in darkness." "18th day: bite between midnight and 6 o'clock in the morning." "27th day: bite in the night, between midnight and 6 o'clock in the morning."

In the second experiment the mosquito bit twelve times, but, as the experimenter wishes us to believe that *Aëdes calopus* becomes nocturnal after the sixth to eighth day, we need consider only the bites from the sixth day on. In this time the mosquito fed ten times. Five of these bites are indefinitely placed *between midnight and* 5 or 6 *o'clock* in the morning; in other words the investigator was asleep during those hours. In the summer, at Rio de Janeiro, it is already daylight at 5 o'clock, and from what we know of the habits of *calopus* we do not hesitate in asserting that these bites were inflicted at daybreak. This leaves five credibly nocturnal bites and four of these admittedly took place with artificial light. Viewed in this manner the experiments may be said to be in accordance with the general impression of the habits of *calopus*.

Goeldi devotes a special chapter to this subject and hotly attacks the assertions of the French commission. "How can the most illustrious doctors of the French medical commission of the Institute Pasteur in Paris wish to prove, through their faith in their full scientific responsibility, that these Stegomyias in Rio de Janeiro 'ont pique *pendant la nuit*,' when here in Pará, we, conscious of the same full responsibility, in view of our positive assertions for years, must declare the nocturnal bite as an exception?" The idea that *calopus* should change its habits after the first blood meal Goeldi characterizes as an absurdity. All the responsible investigators who have worked with mosquitoes in recent years disagree with the point of view of the French investigators.

We must insist on this point on account of the danger which the French doctrine carries with it. It may lead those entrusted with yellow-fever prophylaxis to abandon the safe methods and place their whole reliance upon protection against nocturnal bites.*

* The Public Health and Marine Hospital Service of the United States has published quarantine regulations, for fruit vessels visiting ports at which yellow fever exists, which appear to reflect the dogma of the French commission. These regulations were first published as Circular No. 27, Bureau of P. H. and M. H. S. in 1907, but they have been recently newly promulgated (Public Health Report, Washington, May 6, 1910, vol. 25, no. 18, pp. 604-607) and given still wider publicity through the Journal of Tropical Medicine and Hygiene (August 15,

Simond, Aubert and Noc, in their work on the epidemic of yellow fever in Martinique in 1908, carried away by this idea, insinuate at frequent intervals that the transmission of yellow fever takes place only at night. At a certain point, where they discuss the abundance of *calopus* during the hot months, they formulate this doctrine as follows: "C'est en se basant sur cette considération que la mission estima dangereux, au mois de janvier, le retour des fonctionnaires européens dans la ville, à moins qu'ils ne fussent astreints à se protéger la nuit d'une manière efficace contre les piqûres de Stégomyias." * This is a complete inversion of biological facts. *Aëdes calopus* is a diurnal mosquito and nocturnal bites, if they occur in darkness at all, are certainly rare exceptions. The erroneousness of the views of the French investigators is clearly brought out in their remarks on the copulation of *calopus*. "Deux fois seulement nous avons eu l'occasion d'observer l'accouplement: il a lieu presque toujours dans la nuit et à l'obscurité, d'où la rareté des observations de ce genre." † The testimony of many good observers is that where *calopus* is abundant copulation can be frequently observed in the daytime. Goeldi, for example, says: "teml-a visto milhares de vezes e a vêmos todos os dias" ("we have seen it thousands of times and we see it every day").

1910, vol. 13, p. 253). Under "Regulations to be enforced at foreign ports infected with yellow fever" we read the following:

"The vessel shall not lie where her crew will be exposed to the danger of contracting yellow fever, and at ports where the vessels lie at wharves the vessel must be moved into the stream or at least 200 meters from the wharf before sunset, and not returned to the wharf before sunrise the following day. . . . ."

It was difficult to believe that an American medical department which had been in close touch with the work of our Army surgeons in Cuba, and afterwards conducted investigations on its own account which were entirely confirmatory, should accept the French contention that *Aëdes calopus* bites only at night. It was therefore decided to make inquiry of the head of the Public Health and Marine Hospital Service and in reply we received the following letter:

Treasury Department, Washington, January 26, 1911.

Dr. L. O. Howard,
Chief of the Bureau of Entomology,
Department of Agriculture,
Washington, D. C.

My dear Dr. Howard:

I have been unable before this time to answer your letters of January 14 and 16, owing to the extreme pressure of official business.

In regard to the activity at night of the yellow fever mosquito, and the idea as to this activity, conveyed by the phraseology of paragraph 9 of the foreign fruit regulations, I have to say that it is necessary for quarantine administrative reasons that some measure be devised to hold on board between the hours of sunset and sunrise, the crews of vessels which are lying in ports infected with yellow fever. In the day time the crew is under control while the vessel is alongside the wharf. If the vessel should be allowed to remain at the wharf at night the sailor man would be free to visit such dangerous surroundings as lighted music halls, saloons, and other resorts, but removed to mid-stream, between the hours of sunset and sunrise, he cannot conveniently reach such points. It is impossible to control the mosquito problem in any foreign port, and therefore the only recourse is to attempt to control the man.

In regard to the activity of the mosquito at night, for the quarantine purpose above outlined, I have to say that in the report dated May, 1904, of the Yellow Fever Working Party, Part 2 of the Yellow Fever Institute the statement is made (on page 100) in their summary and conclusions that "Stegomyia fasciata is a domestic insect. It is most active during the day but will bite at night under artificial light." In another part of this report it is stated that the working party noticed that these mosquitoes were especially voracious in the morning about sunrise. An officer of the service who has had large experience in localities infected with yellow fever, and especially in the work of eradicating mosquitoes, states that the yellow fever mosquito is very active during the twilight.

As a general rule, the majority of sailors on shore liberty will spend the greater part of their time in presumably well lighted rooms, and if their shore liberty should start at sunset and end at sunrise, which times are specified in paragraph 9 of the fruit regulations, as the time when shore liberty should be denied, said sailors would, in addition to the time above stated, be ashore during twilight and sunrise, the times during which the mosquito is active without artificial light. In other words paragraph 9 of the fruit regulations does not conflict with the opinions that the stegomyia is inactive in the darkness.

Respectfully,
Walter Wyman,
Surgeon-General.

* "The mission bases itself upon this consideration when it judges it dangerous, in the month of January, for the European officials to return to the town, at least if they are not compelled to protect themselves at night in an efficient manner against the bites of the *Stegomyias*."

† "Twice only we have had occasion to observe copulation: it occurs nearly always at night and in darkness, hence the rarity of observations of this character."

Furthermore the French commission admit that in capturing mosquitoes that came to bite in the daytime they obtained "un nombre très considérable" (a great number) of *Aëdes calopus*. However they try to demonstrate, in accordance with their contention, that these female *calopus* coming to bite in the daytime were all individuals but a few days old. They adopt as a criterion of age the condition of the vestiture and state that it is rare that a *calopus* more than 15 days old is not much denuded. In fact, under normal conditions, *calopus* frequently retains its vestiture a long time. Denudation depends upon circumsances in the insect's life and we can not accept it as a criterion of age.

We have already referred to the case of Petropolis, the inhabitants of which were said to escape yellow fever in their diurnal visits to Rio de Janeiro. It may almost be said that the French commission obliged the mosquitoes to respect the itinerary of the boats to Petropolis and abstain from the molestation of the passengers between their arrival at 9 a. m. and their departure at 4 p. m. We see the case of Petropolis in an entirely different light. There have been no epidemics of yellow fever at Petropolis for the simple reason that the average night temperature is unfavorable to the development of *calopus*, as the French commission themselves have shown. On this account Petropolis has been a health resort of the wealthy, native and foreign, during the hot months.

As to the apparent impunity with which the inhabitants of Petropolis could visit Rio de Janeiro during yellow-fever epidemics, this was probably due to a variety of circumstances, not evident, but acting together. It will be safe to say that most of the inhabitants of Petropolis who spent the business hours at Rio, whether natives or foreigners, had previously lived elsewhere in Brazil. In the course of such residence they could not have failed to have had yellow fever and thus acquired immunity. On the other hand a large proportion of the employees of the business houses at Rio were non-immune foreigners who were obliged to live in the city for pecuniary reasons. It was among these that yellow fever was most in evidence. With the immunes, as the French commission have shown, immunity is strengthened and prolonged by the bites of infected mosquitoes and there is no reason to doubt that this process was in operation with the business men from Petropolis. That those who spent a single night in Rio became infected was not the rule. The notoriety of such cases is to be explained by the circumstance that the person attacked was generally a member of the foreign diplomatic service. Customarily the diplomatic corps did not leave Petropolis during the months of yellow-fever epidemic; if, by chance, one of them was obliged to visit Rio and remain over a single night he probably became infected in the early morning when *calopus* is most aggressive.

The fact seems to be well established that non-immunes from Petropolis, when visiting Rio de Janeiro in the daytime, escaped infection. This is easily explainable in that most of the mosquitoes would already have obtained their meal of blood before the arrival of the visitors from Petropolis, having had fully five hours of daylight to accomplish their purpose. Such mosquitoes as would bite later in the day would be mostly fresh individuals that had not obtained their first meal and were therefore harmless. The members of the second American commission to Vera Cruz, without mentioning the case of Petropolis, make some remarks which are significant in this connection. "We have noticed on several occasions that they [*Aëdes calopus*] are especially voracious early in the morning, about sunrise. On several occasions a number of non-infected insects were let loose in the laboratory and we observed that upon rising at sunrise they attacked us viciously. It may be noted that this fact apparently explains the danger to persons sleeping in an infected house and the comparative freedom from danger in daylight communication with an infected town." (Yellow Fever Institute, Bull. 14, p. 92.)

LENGTH OF LIFE OF IMAGO.

In the course of laboratory experiments, it has been necessary for medical experimenters to keep the females of *calopus*, alive for a certain length of time and they have been tried with different foods, just as were the females of *Anopheles* at an earlier date. They have been fed upon bananas and upon other fruit, upon honey, and upon molasses, and in this way have been kept alive for long periods.

The French investigators found that it was easy to keep *calopus* alive for two months; however, beyond the fortieth day the mortality was considerable, regardless of the method of feeding employed. This mortality was greater among the males than among the females. Among the females kept in confinement those that lived longest reached the age of 89, 90, 93, 97, 105 and 106 days. These females had been first allowed to bite a person and were afterwards fed with honey. They point out that *calopus* will die very quickly in a dry atmosphere. Guiteras, at Las Animas Hospital, kept five infected adults alive for 101 days, and one for 154 days. Goeldi has kept a female alive 102 days, feeding her with blood and obtaining several deposits of eggs. He believes that the female will live longer if fed only upon sweet substances. Theobald kept specimens reared from the larva alive without food for two months.

The male is much shorter lived than the female. The French commission did not succeed in keeping males alive more than 50 days. Goeldi has kept the males alive, feeding them upon honey, for periods of from 28 to 72 days, the longest lived one escaping at the end of 72 days. Undoubtedly life was prolonged in these cases beyond the normal span by withholding the opportunity for the male to perform its natural function, the fertilization of the female.

This brings us to the important question as to how long an infected yellow-fever mosquito may be capable of conveying the disease. This point has not yet been accurately determined. Reed and Carroll reported cases of yellow fever caused by the bites of this mosquito at intervals varying from 12 to 57 days after infection; they are dangerous after the twelfth day, and thus for at least 45 days. Another insect under their examination lived until 71 days after biting a yellow-fever patient, the dangerous interval in this case being 59 days or over eight weeks.

Reed and Carroll dismiss the fear that the infected insects are likely to be carried in boxes of clothing or trunks, as groundless, since their observations indicate that when mosquitoes are deprived of moisture they die within a few days and that even when allowed to suck blood they will still die in a few days if deprived of water.

INFLUENCE OF TEMPERATURE.

The French investigators pointed out that one of the most striking characteristics of *calopus* is its extreme sensibility to differences in temperature and this has been confirmed by many observations. They were impressed by the great activity which the insect showed when the thermometer ranged in the vicinity of 28° Centigrade (82° Fahrenheit), the temperature at which it displayed the greatest energy. In contrast with this was the markedly reduced activity when the temperature rose or fell a few degrees above or below that point. Beyond 39° C. (102° F.) the heat is fatal to it. If the thermometer goes below 15° or 16° C. (59° or 61° F.) it becomes sluggish and will not feed. At 12° to 14° C. (54° to 57° F.) it becomes torpid, flies with difficulty and no longer stands firmly on its legs. At temperatures of from 14° to 18° C. (57° to 64° F.) *calopus* not only does not bite in freedom but refuses to bite when put in a glass tube and placed in contact with the skin. Only when the temperature inside the tube is raised sufficiently by the heat of the hand does the mosquito bite. At a temperature of 14° C. twelve mosquitoes in tubes were placed in contact with the arm and kept there for 15 minutes without showing any willingness to bite. At 17° C. the result was the same. At 18° C. nine of these same mosquitoes bit, one after five minutes, the remainder after seven and eight minutes. These investigators do not believe that in nature *calopus* will bite below 17° C.; they found that it would bite readily between 22° and 25° C. (72° and 77° F.) but that the temperature which suits it best is between 27° and 30° C. (81°–86° F.). Reed and Carroll made some interesting observations on the effect of temperature on biting with the yellow-fever mosquito. They may be quoted as follows:

"As regards the effect of temperature on the stinging of *stegomyia fasciata*, the results of a number of observations made by us show that this mosquito will bite at temperatures of 62° F. and above. At temperatures below this point, we have not, as yet, succeeded in inducing even very hungry females to suck blood. We may, therefore, say that observations thus far made appear to show that *stegomyia fasciata*, while not breeding at temperatures below 68° F., will still bite at a temperature as low as 62° F., but probably not at lower temperatures.

"If this insect is concerned in the propagation of yellow fever, it is now quite apparent why an epidemic of this disease should fall to a low ebb in the city of New Orleans during the month of November, with a mean temperature of 61.8° F., and practically cease in December, with a mean temperature of 55.3° F. A careful study of the charts herewith submitted, showing the monthly mean temperatures of the cities of Havana and New Orleans and Havana and Rio de Janeiro, together with the relative monthly mortality from yellow fever in these cities, will prove of interest, we think, as showing better than laboratory observations the general effect of temperature upon the breeding and biting of *stegomyia fasciata*. In the light of recent researches, we can now understand that while yellow fever can, and does, prevail during the entire year in Havana and Rio de Janeiro—although at a comparatively low ebb during the winter months—it cannot propagate itself in New Orleans from December to May."

Otto and Neumann have made experiments on the resistance of the adult *Aëdes calopus* to cold. These were made in Germany, with imagos bred in confinement. When *calopus* were placed outside the window with the temperature at the freezing point they died very quickly. When exposed to a temperature of 4° C. (39° F.) for one hour and then returned to the warm room they could still be revived, but longer exposure killed them. However, *calopus* can survive cool temperatures for a considerable time. Carter states that "Guiteras placed thirty-three mosquitoes in an ice-box at 46.5° to 50° F., without food or water; three of them survived to the eighty-seventh day, when they were eaten by ants." Otto and Neumann, in a similar experiment, with a constant temperature of 7° to 9° C. (45.5°–48° F.) kept *calopus* alive to the eighty-second day. In this experiment they employed 25 male and 25 female mosquitoes; they were fed with sugar, honey and water, and part of the females had sucked blood. In a short time the insects became stiff and only moved very slowly; they nearly always sat on the bottom of the jar, as if they could no longer retain their hold on the glass sides. After three days four of the males died and none of the remaining 21 males survived the fifteenth day. On the contrary but very few of the females died in the first two weeks and after 30 days about half of them still remained alive; on the fiftieth day three were alive; after 61 days but two, and after 71 days only one remained.

THE BITING OF CADAVERS.

An interesting observation made by Rosenau, Francis and Goldberger (Report of Working Party No. 2) indicates that the yellow-fever mosquito may bite a cadaver, and, if on a dependent portion, can draw blood. The two observations made on this point were as follows:

"Narciso Nadal (Case XX). A number of *Stegomyiæ* were applied twelve hours after death, only one of which apparently obtained blood.

"Trinidad Martinez (Case XXII). A number of female *Stegomyiæ fasciatæ* were applied one-half hour after death, and three insects succeeded in feeding with blood."

These authors point out that, as the work of the French commission has shown that the blood of yellow-fever patients is not infective after the third day, the danger of the carriage of infection by mosquitoes which have fed upon cadavers must be very remote. The only chance of infection from such a source would be in the case of the death of the patient within the first three days.

DISTANCE OF FLIGHT.

The distance of flight of the adult is a very important question. *Calopus* seems to be a strong flier, as is evidenced by a series of experiments carried on by Goeldi on the effect of a strong current of wind between two open windows, or by air currents produced by a mechanical ventilator. He found that *calopus* pays absolutely no attention to such currents, continuing its evolutions about him and stinging precisely as though the air current made no difference to it. This indicates that *calopus* would not easily be carried involuntarily by the wind. Opposed to these assertions of Goeldi are the observations of Otto and

Neumann at Rio de Janeiro. They state that a draft is undoubtedly disagreeable to *calopus*. On this account they searched for it in vain in exposed situations accessible to wind, as for example the Monte da Providencia within the city.

It would seem that the yellow-fever mosquito does not fly very far and the fact that it is very rarely found away from houses supports this view. Carter points out that it probably never flies high, and that it is found by preference in the lower stories of houses. The same writer in 1904 suggested that the problem of flight be investigated as of importance in determining the anchorage of vessels in yellow-fever ports. He say on this point:

"So far he knows of no direct observations on this subject, except those of Goldberger at Tampico, and of Grubbs at Ship Island Quarantine. The latter found Stegomyiæ aboard three vessels from Vera Cruz, two of which claim to have lain a half mile from shore. He believed they came aboard at Vera Cruz. The observations of Goldberger will be given later.

"Although direct observations on this problem are few, yet there are certain indirect ones, bearing, however, entirely on the aërial conveyance of the Stegomyia infected with yellow fever. It is notorious that yellow fever is usually conveyed but a short ways aërially, 'across the street,' or, more often 'to the house in the rear,' which is about as far as it was expected to be thus conveyed. This represents a maximum distance of about 75 yards. The two lougest distances recorded in recent times of aërial conveyance, one of 225 meters (Mèlier) and one of 76 fathoms—456 feet (the writer) are entirely exceptional. So much for the distances which the (infected) Stegomyia is conveyed—or rather usually conveyed—aërially.

"On the other hand it is known that vessels moored in certain districts of the Havana harbor did not develop yellow fever aboard, except in those who had been ashore, or unless they lay close to other vessels which were infected. This experiment has been made on so large a scale—with so many vessels and for so many years—that we must accept as a fact that an infected Stegomyia was not conveyed aërially from the Havana shore to those vessels, or, allowing for errors, was very rarely so conveyed. This distance which had been found safe was something over 200 fathoms—1200 feet. The prevailing wind was generally slightly on shore, but was not constantly blowing. Whether there is any difference in the distance to which infected or non-infected mosquitos are conveyed, is, of course, entirely a matter of surmise. There is no apparent reason why there should be. Yet the infected Stegomyiæ have almost certainly become so in a house; and with their very domestic habits must be found out of doors, where they would be subject to conveyance by the wind, in much smaller numbers than the uninfected insects, and consequently a lesser *number* of them would be conveyed aërially. Observation is needed on this subject—the distance (across water) that Stegomyiæ are aërially conveyed.

"Goldberger, very ingeniously, suggests that on account of its diurnal flight, the direction of the wind during the day only need be considered in estimating this factor in their aërial conveyance, and states that at Tampico he failed to find Stegomyiæ aboard vessels lying, for ten or fifteen days, about half a mile from a place on shore where they were abundant, while numbers of Anopheles albipes * and Culex pungens † were found. The wind was on shore during the day and calm or off shore during the night. The importance of this point is obvious, as on the coast, except when overborne by the trades, the direction of the wind is very generally different by day and night."

* *Anopheles albimanus* Wied.
† *Culex quinquefasciatus* Say.

It would seem as if in this discussion the possibility of the conveyance of mosquitoes to ships by means of lighters for the discharge of cargo could not be omitted. This is the common method of exchanging cargo in many tropical ports and furnishes a ready means of transferring mosquitoes from the shore to the ship.

At an earlier date this question of distance of flight was considered by one of us (Howard), and he endeavored to induce several surgeons in the U. S. Navy to make observations. A series of notes were sent in by Surgeon A. H. Russell of the Navy, who made some interesting observations. With a vessel anchored, say a mile from shore, and constant boat parties going to and fro between the vessel and the shore, there is always the chance that *Aëdes calopus* may be carried under the coat lapels or even in the pocket of passengers. Therefore the occurrence of a few individuals on shipboard at this distance, and with constant traffic going on, is inconclusive. Russell (in litt.) observed one instance, and investigated all factors carefully, in which he apparently proved a flight from shore to a vessel anchored a mile out, but it would be practically impossible to eliminate all chances of error in such a case.

Bearing upon the question of the origin of *calopus* on board ships the observations of Durham at Pará are significant.

"It is said by captains that mosquitoes only commence to come on board when the lighters which are used for the discharge of the cargo are brought alongside. Seeing that the anchorage for the large ships is some two miles below the city, and the lighters lying about the neighbourhood of the city are brought to wharfsides for discharge, they are a means of bringing city mosquitoes to the ships. On examination, several of the large barges (which are covered with a rainproof metal cover) were found to harbour a certain number of the insects, both *S. fasciata* and *C. fatigans* were found in the adult condition and a few larvæ of the former in the bilge water; but these lighters had recently been cleaned up and painted; open lighters are also used, these were seen to contain abundant rain water and tar and oily material from the coal for which they are used; no larvæ were found in them.

"During my trip up to Manáos, indiscriminate collection of all and any mosquitoes that could be found on board was made. Although a number were collected it was not until after anchoring at Manáos and the lighters came alongside that the species *S. fasciata* was taken. It appears that the method of discharge by means of lighters may be almost as risky for the importation of mosquitoes infected in the city, as if the vessel was actually brought to the wharfside."

Busck, on the occasion of his visit to Trinidad, made an observation which bears upon the distance of flight of *calopus*. He states that at La Brea there is a long pier, built by the asphalt company, near the end of which the superintendent erected his house in order to be free from mosquito molestation. The experiment was successful, and he lived in peace, until, later, another official, for similar purposes, built a house in the middle of the pier. This apparently afforded just the right interval for *calopus* to spread from the shore to the house in the middle of the pier, and from that house to the one on the end of the pier, and both houses became infested. The entire length of the pier was about 400 feet.

Assistant Surgeon Grubbs, of the Public Health and Marine-Hospital Service, in a paper entitled "Vessels as Carriers of Mosquitoes," published as Bulletin No. 11 of the Yellow Fever Institute, which has been mentioned more fully on another page of this volume, gives instances which seem to indicate that *calopus* came aboard a schooner at Vera Cruz, the vessel lying half a mile from the shore; that another vessel had the same experience. But the evidence is not analyzed and the probability of the mosquitoes being brought to the ship by lighters, which at that time were used at Vera Cruz for the interchange of cargo, is not taken into consideration. In the first of the instances mentioned it is stated that mosquitoes came aboard "*in large quantities.*" Some of these were said to be *calopus,* but it is not stated that all belonged to this species. It is possible that *Aëdes tæniorhynchus,* a common coast species, may have been mistaken for *Aëdes calopus.*

MATING.

E. G. Hinds, of Victoria, Texas, in a report submitted to one of the writers (Howard) in the autumn of 1903 shows that with this species mating begins when on the wing. It may, and usually is completed while still flying, but the female frequently alights during the act and before its completion. The complete act requires but the fraction of a minute. According to this observer, females partly or fully fed seem more attractive to males than those which have not fed at all. Copulation sometimes, perhaps usually, occurs before either sex has fed. Males often alight on the dark colored clothing of a person sitting quietly and watch their chance to pounce upon a female coming to feed. The time of the greatest activity of copulation seems to be between 4 and 6 p. m. A male may mate with several females. More than one batch of fertile eggs may be laid without intervening fertilization.

The French investigators found that temperature has a great influence on the sexual activity of *Aëdes calopus.* When the temperature rises above 25° C. (77° F.) the males become very active and the females but rarely escape fertilization. When the temperature ranges between 20° and 25° C. (68°–77° F.) fertilization is still the rule and the proportion of unfertilized females is very small, but below this the proportion of unfertilized females increases rapidly with the reduction in temperature.

Goeldi points out that wherever many of these mosquitoes are together, the males tend to congregate apart in little clouds of fifteen or twenty or more; they show a marked tendency to gather over prominent objects, as the corner of a table or other salient parts of furniture, while the females are flying all about the room. He has noticed that they will settle themselves on the upper parts of mosquito bars while the females are flying around under the bed or in the immediate vicinity. "These are lookouts, salient points for watching and observation, whence the males direct themselves against any female that happens to come into their area of dominion." When a female approaches one of these groups of males she is pounced upon, the male clasping the female from beneath. Goeldi says "He unites himself to her from the lower side and permits her to carry him with a slow heavy flight for a few seconds (two or three only), and then again separates himself." He stated that the act is so fleeting that people note it with difficulty, and he has always failed to kill specimens in the act except by smashing them between his hands. He also says that they will copulate within the narrow dimensions of a bottle or breeding cage, a fact that facilitates the fecundation of females bred in captivity and thus enables the breeding of the species for many successive generations. Goeldi confirms the observation of Hinds that the same male has frequent connections in rapid succession with various females which approach him. Peryassú also found that a male will copulate with more than one female in succession.

The copulation of *Aëdes calopus* has been observed by a number of other investigators. Nearly all of them agree that it takes place in the daytime, during flight, face to face, and that it is of very short duration. Both sexes are ready to mate soon after leaving the pupa.

One of us (Knab) has pointed out that Godeheu de Riville, a French naval commander, in the third volume of the Mémoires de Mathématique et de Physique, published in 1760, has described the copulation of what was with little doubt this species, since he states that the species of mosquito he observed was most active during the warmest hours of the day, that it was a domestic species, and united with the female face to face. The observations were made on board ship during a voyage from India. We quote from Knab's article:

"However, upon May 13, a lucky chance permitted him to observe what for more than two months had been the object of his research. Seeing a pair of mosquitoes united and hovering in a sun-beam, he gently approached them to obtain a better look. Escaping him they flew to the rear of the cabin where, after an irregular flight, they entered the canopy of the bed and alighting remained suspended from the under side of the canopy-top. Here the light yellow color of the cloth contrasted well with the dark bodies of the mosquitoes and this proved to be the long desired opportunity. Waiting until they had become well settled he approached cautiously. The female, recognized by the length and stoutness of her body, sat in the ordinary position of mosquitoes; she clung to the fabric with her front and middle legs, the two hind legs elevated in a half-circle above her wings. The male, on the contrary, had assumed a different attitude. The smaller size of his body and the necessity of obtaining union with the female, who did not seem inclined to incommode herself, left him apparently less at ease. His two greatly elongated front legs alone held him to the top of the canopy while with the other four legs he grasped the female. In spite of their movements, the commander was able to study them well and settle all doubts. An involuntary move on his part, caused by the rolling of the vessel, startled the pair from its resting-place. Still united they tried to obtain a new hold, but without success, and finally flew off and were lost to view, having probably separated.

"From his observations Godeheu de Riville concluded that copulation in mosquitoes does not last long, takes place very quickly in comparison with other flies, and appears to occur only in the air. He considers that the attitude assumed does not permit them to alight, and that the one couple thus observed was a rare exception. None of the many other couples which he attempted to observe more closely came to a resting position."

RELATION OF FOOD TO OVIPOSITION.

Finlay found that the female *Aëdes calopus* could not develop its eggs without having obtained blood. "Nearly all the females captured after having filled themselves with blood, at the end of a few days lay eggs, while those which are fertilized and have not been able to obtain blood die without ovipositing." He believed furthermore, as *calopus* does not lay all its eggs at once, that it needs several blood meals to dispose of all its eggs.

Reed and Carroll confirmed the observations of Finlay and found that the interval between a blood meal and oviposition may vary from two to thirty days. "As a rule, the eggs are laid within seven days; sometimes a second or third meal of blood is taken before any eggs are laid."

The French commission also found that in *calopus* blood food is indispensable for the reproduction of the species. They found that whether the female sucked blood before or after copulation the eggs would be deposited within a few days. If a fertilized female is fed on sweet substances the eggs will not develop; if afterwards, for example after 15 or 20 days, the female is fed blood the eggs will then develop. In the latter case the interval between the blood meal and oviposition will be about the same as when it has fed on blood soon after being fertilized. In one of their experiments 10 females and 15 males were placed together in a cage on the same day that they had issued from pupæ. Three of the females were taken out 48 hours afterward and induced to suck blood. Of these three females one deposited eggs after four days, the other two after six days. After 18 days three of the females which had been fed only upon honey, and which had not oviposited, were allowed to suck blood; they deposited eggs five days after the blood meal. The four remaining females which had not been allowed to suck blood died without depositing eggs. The French observers state that the result is the same whether the females are allowed to bite man or some other warm-blooded animal, but that it must be remembered that *calopus* shows more or less repugnance towards any other animal.

Goeldi, at Pará, made a series of experiments with similar results. One of his conclusions is that blood food, in hastening the development of the eggs, shortens the life of the mosquito. On the contrary a diet of honey prevents the development of the eggs and thus prolongs life. He found that by feeding the females with honey the power of depositing fertile eggs may be kept latent for long periods. He determined, also, that unfertilized females would lay eggs when fed with blood but that these eggs would not produce larvæ (pseudo-parthenogenesis). Goeldi found that the interval between the first blood meal and oviposition averaged 3.7 days = 88 4/5 hours. The female, after having deposited all her eggs, dies, either immediately afterward or at the most within a few days. The longest time that a female survived oviposition was 14 days.

Goeldi determined that the shortest interval between a blood meal and oviposition was two days, the longest interval seven days. He gives observations in which eggs were laid one day after a blood meal, but in these cases the females were captured and probably had already sucked blood. On one occasion, in an experiment with captured females, eggs were laid after blood had been withheld during an interval of 15 days or more. All 36 of the eggs deposited proved fertile and had produced larvæ five days later. Goeldi supposed that in this exceptional case oviposition resulted from the effect of a previous blood meal. In another experiment Goeldi fed a female exclusively with honey for 75 days without obtaining eggs; she was then fed blood for 20 days. On the 20th day of the blood diet a single egg appeared and six days later, or 102 days after the experiment was begun, 85 eggs were deposited. Goeldi calls this the first batch of eggs but it would seem as if there had been some oversight, for, 13 days after the female was put on a blood diet a larva was found in the breeding cage. Goeldi tried to determine the comparative effect of guinea-pig blood on oviposition. Of two females fed with guinea-pig blood one laid seven eggs three days after the first meal; the second female was given another ration and four days later had laid no eggs. Goeldi remarks that these data are too insufficient to be conclusive, but he expresses the belief that it will be found that human blood is much more effective than the blood of the guinea pig.

The French investigators pointed out that the ability of *calopus* to transmit yellow fever depends upon the fact that it needs several blood meals to develop all its eggs. The female continues to bite after having oviposited and, without being fertilized again, deposits more fertile eggs, and this may be repeated a number of times. They found that in captivity a single blood meal between ovipositions was effective. They state that in freedom *calopus*, after having deposited eggs, would often bite every 24 hours and sometimes even several times within that period, and they call attention to the significance of these frequent bites in the transmission of yellow fever. Among the females which have deposited eggs once there are some which survive a long time, and, while continuing to suck blood, do not lay more eggs. This, they think, is due to the fact that the supply of spermatozoa in the receptacula seminis has been exhausted. These females, in the opinion of the French investigators, are the most dangerous on account of the probability of their living a long time and biting many persons.

It has already been shown that *calopus* will only feed upon blood obtained by piercing the skin. Otto and Neumann claim that they were able to feed female *calopus* with a mixture of blood and salt solution placed upon cotton. The mosquitoes sucked the blood from the cotton without hesitation; afterwards eggs were laid in the normal manner and larvæ hatched from these, but it appeared that these larvæ lacked the usual vitality.

The French investigators made feeding experiments with human blood serum, with red blood corpuscles separted by centrifugal action, and with blood clots, and from none of the females so fed were they able to obtain eggs. When these same females were afterwards allowed to suck blood they laid eggs. They conclude from this that *calopus* must have fresh blood in order to lay eggs.

OVIPOSITION.

Aëdes calopus deposits its eggs separately in several lots, the separate lots being disposed of at intervals of several days or more. The eggs may be laid near the water, close to the edge, or upon the surface of the water. Finlay says they "lay their eggs singly or in rows of 9 to 15, separated or contiguous, sometimes upon the water at others upon adjoining objects very close to the water level so that a slight elevation of the water will submerge them."

The second commission to Vera Cruz state that "The eggs are sometimes laid on the water, sometimes on the side of the vessel above the water line, and sometimes on a leaf floating on the water."

The French commission state that the eggs are laid at the edge of the water or upon it and that the latter is the commoner method. In accordance with their assumption that *calopus* is nocturnal they assert that the eggs are generally laid at night, but they admit that "numerous" captive females oviposited in the daytime. They state that oviposition extends over several hours and that the time required depends upon the temperature. They found a night temperature of 27° to 28° C. (81°–82° F.) with a diurnal maximum of 29° to 30° C. (84°–86° F.) most favorable in hastening oviposition. Under these conditions the eggs may be laid 48 hours after a blood meal, while usually the interval is from three to four days. When the nocturnal temperature is between 25° and 27° C. (77°–81° F.) the eggs are deposited on the fourth or fifth day; when it ranges between 20° and 25° C. (68°–77° F.) oviposition occurs on the sixth day and sometimes not until the seventh or eighth day. When the temperature is below 20° C. at night and does not rise above 22° or 23° C. (72°–73° F.) in the daytime oviposition is retarded until the temperature rises to 26° or 27° C. (79°–81° F.) and sometimes it will be prevented altogether.

Durham says of the disposition of the eggs that they "are deposited close to the edge of the water, if not sometimes actually on the surface of the containing basin. At any rate, they readily adhere to this surface sufficiently firmly to prevent detachment by a stream of water; this is probably of use when the breeding places (*e. g.*, a small tin or a roof gutter) is exposed to tropical rain."

H. W. Henshaw, while living at Hilo, Hawaii, among other interesting observations made on this species, found that the females laid eggs every day around his cottage in vessels prepared for them and that they invariably deposited them upon the moist sides of the containers, perhaps a sixteenth of an inch above the surface, and never touching the water. Eggs removed from these moist spots hatched within 30 minutes after having been placed in water (in litt.).

This undoubtedly represents the mode of oviposition under natural conditions as it corresponds with that of the nearly related tree-hole inhabiting species of *Aëdes*. The impression that *calopus* lays its eggs upon the surface of the water appears to have been gained by observations with females in captivity. It is probable that the smooth sides of the glass receptacle in which such captives are kept is not a suitable surface for the attachment of the eggs.

The method of oviposition has been described by Agramonte:

"The mosquito alighted upon the water, which was in a small beaker inside the jar, with legs spread wide apart. The abdominal segments being bent forwards and downwards, she dipped her whole body until the last segment touched the surface of the water; then she rose, walked a few steps, and dipped again. This she would do repeatedly (14 to 22 times), when she would remain for a slightly longer time with the last abdominal segment touching the water, and would allow a minute white egg to issue forth upon the surface. In this way she laid at the rate of 3 eggs per minute, resting quietly after every sixth or eighth egg for about 30 seconds when she would resume the process."

There are many observations on the number of eggs deposited by one female. It has already been shown that in this species the eggs are not laid at once but in batches, at intervals, the last determined by the blood meals of the female. The French investigators found that about half the females died without depositing eggs a second time. Out of 100 females 30 laid eggs the second time and 21 laid eggs from three to seven times. This last was the largest number of ovipositions observed by them in a single female.

Taylor of Havana states that the number of eggs varies from 35 to 114; the first American commission to Vera Cruz gives the number of eggs as from 40 to 150, but in neither case are details given. Goeldi thought that the maximum number of eggs from one female ranges between 50 and 100 and on one occasion there were some in excess of the last number. The French commission found the maximum number of eggs from a single female 144.

Francis, in the report of the Working Party No. 2, records experiments with a number of females at Vera Cruz. In one of his experiments a female laid 51 eggs on October 25th, 24 on November 7th, and 26 on November 8th, a total of 101.

The French investigators found that generally the first batch of eggs is much the largest, between 70 and 95; sometimes there are less and very rarely more. The succeeding batches are smaller and do not go above a maximum of thirty.

Goeldi considered the death of the female after oviposition a certain index that all the eggs had been laid. The French investigators point out that the number of eggs varies considerably and that one can not draw conclusions with such certainty. They found, on the one hand, that females after having deposited from 70 to 95 eggs remained alive for several months; on the other hand, they noted that females which had deposited but 30 eggs refused all food and died after a few days or within a few hours. In one case a female which had deposited 82 eggs died three days later, after having been fed; dissection showed that 30 partly developed eggs were present.

The French investigators found that there were small females which laid but a small number of eggs. These females came from larvæ which had developed under unfavorable conditions. The number of eggs from such females did not exceed 50 or 60 and sometimes it was even less. The season has a certain influence in this connection. Thus it was found at Rio de Janeiro that the proportion of females which died after laying the first batch of eggs was considerably less during the warm months than in the cool season.

Peryassú determined that in order to obtain a full complement of eggs it is necessary to feed the female with blood repeatedly, at intervals of at least every two or three days.

BREEDING HABITS.

THE EGGS.

The different stages of this mosqui-o are carefully described in the systematic portion of this work. The eggs, as above described, are frequently laid in small, irregular groups some distance above the margin of the water, and may remain dry for long periods, hatching when reached by the water. They develop better after having been dry for a period. Reed and Carroll state:

"The resistance of stegomyia's eggs to external influences is worthy of note. Drying seems to be but little injurious to their subsequent fertility. We have found that eggs dried on filter paper, and kept for periods of from ten to ninety days, will promptly hatch when again submerged in water. Dried eggs brought with us from Havana, in February, were easily hatched during the month of May, in Washington, furnished about 60 per cent. of the usual number of larvæ hatched from fresh eggs. Freeziug does not destroy the fertility of the eggs. Although freezing with a mixture of salt and ice for thirty minutes has several times seemed to prevent subsequent hatching; on one occasion a batch of one hundred and fifty-five eggs, freshly deposited, which were frozen at a temperature of –17° C., for one hour, then thawed out at room temperature and placed in the incubator at 35° C., began to hatch on the sixth day, the majority furnishing active larvæ on the eighth day. In another observation, freshly deposited eggs, frozen at –17° C. for half an hour on two successive days, began to hatch on the third day as usual at incubator temperature. The resistance of stegomyia's eggs to drying for a period of three months would appear to demonstrate that this genus of mosquito could survive the winter in Havana, without the presence of hibernating females. Doubtless the genus is preserved in both ways. It is probable that the same could occur in our extreme southern latitudes."

The Brazilian investigators at Rio de Janeiro determined that the eggs will, when dry, preserve their vitality unimpaired for five months. Eggs placed on filter paper and kept in test-tubes developed after this period but beyond that period they failed to hatch. Francis asserts that eggs hatched which he had kept dry during six and a half months. Eggs sent to Theobald in England, from Cuba, hatched after two months and a half. It is to be supposed that under natural conditions the eggs of *calopus* will survive out of water even longer than the longest period achieved experimentally. It should be remembered that in the majority of the species of *Aëdes* the eggs do not hatch until the following year and that a percentage, with some, and we believe with many species, remains dormant until a second year.

Agramonte (a member of the American commission to Cuba), in a chapter on mosquitoes and yellow fever appended to Berkeley's "Laboratory Work with Mosquitoes" (New York, 1902), states that the duration of the egg-state varies according to the season of the year, the temperature of the water and the chemical conditions of the water. He shows that with the lye of wood-ashes, employed by laundresses in Cuba for the purpose of whitening the clothes, the eggs hatch more quickly than in the dirty water of overflows and gutters, and yet the latter contains more organic matter.

The duration of the egg-stage according to Agramonte is from fifteen hours to three days. J. R. Taylor, of Las Animas Hospital, Havana, gives the duration of the egg-stage as 12 to 24 hours. The first American commission to Vera

Cruz gives 10 to 24 hours as the duration of the egg-stage. Goeldi gives the minimum duration as three days. The French commission indicate a minimum period of two days.

It appears that eggs which have been deposited out of the water hatch very promptly when submerged, just as is the case with related species of *Aëdes*. When the eggs are deposited directly upon the water they require at least two days to hatch. The discrepancies in the data of different observers can probably be explained by these facts.

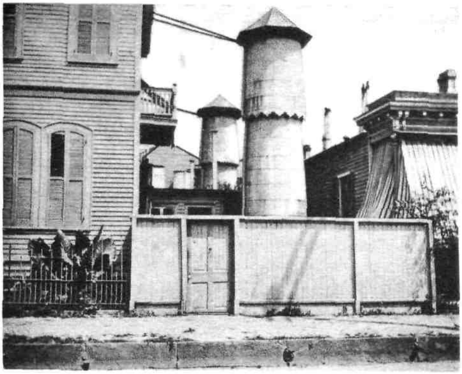
Eggs deposited on the surface of the water float, but they are easily sunk by disturbing the water. Goeldi states that eggs invariably perish when submerged. The investigations of the French commission show that this is not the case. They found that hatching is somewhat retarded by immersion and that sometimes some of the eggs do not hatch, particularly if the temperature of the water is rather low. Peryassú found that if eggs were submerged a day after being laid, and the temperature was not below 26° C. or above 29° C. (79°–84° F.) they would hatch at the same time with those that floated. It would seem however that the eggs which are submerged soon after being laid generally perish.

The French investigators found that the eggs suffered when immersed in water at low temperature for a considerable time. They were not only subject to the attacks of various organisms under these conditions but the egg-shell was also gradually softened and would finally allow the water to enter. Eggs which have perished by prolonged immersion do not remain intact but split open. While in hatching the egg splits transversely at about one-fourth from the larger end, the dead egg splits open longitudinally. The French investigators conclude that survival of the eggs is much more certain in a dry state than when submerged.

In Cuba, according to Reed and Carroll, the eggs begin to hatch in summer temperature, as a rule on the third day. They record two days as the shortest egg period. Presumably these observations were made with eggs deposited directly upon the water.

The French commission found that a temperature of 27° to 29° C. (81°–84° F.) was the most favorable and in it the eggs would hatch within two or three days. At a temperature of 25° to 26° C. (77°–79° F.) the eggs usually still hatched with considerable regularity after four or five days. At high temperatures the eggs from one batch hatch together, or at the most within a few hours of each other. Below 25° C. hatching is irregular and only part of the eggs hatch, and below 20° C. (68° F.) it ceases altogether. In temperatures between 25° to 20° C. but a few larvæ appear and generally all the eggs remain dormant until there is a rise of temperature.

The eggs will survive low temperatures down to the freezing point. While ordinarily the chilling of the eggs is not fatal it nevertheless has a bad effect on the entire development of the mosquito. In nature a drop of temperature to below 20° C. in a single night will not only retard the hatching of the eggs but also the development of the larvæ. The French investigators further determined that the eggs will withstand temperatures of from 20° C. to freezing for a considerable time; if then subjected to a suitable temperature the eggs will hatch.



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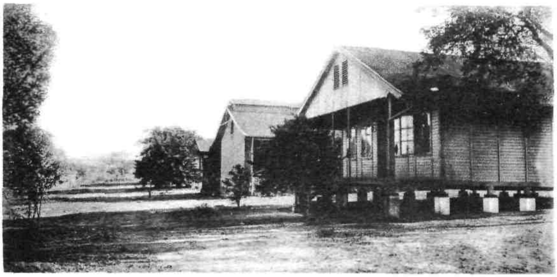

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However, if the eggs are kept in low temperatures for some months there will be a considerable loss. In one case eggs which had been exposed to night temperatures of from 10° to 20° C. (50°–68° F.) for 70 days were placed in a proper temperature for hatching and only one-twentieth of them produced larvæ. The French observers concluded from their results that eggs subjected to low temperatures for some months will perish.

The Brazilian investigators made careful experiments with high, as well as low, temperatures. Eggs taken from the water the day after they were laid were placed for five minutes in an oven regulated to temperatures of from 37° to 47° C. (99°–117° F.); when afterwards placed in water they hatched after 48 hours. The larvæ from these eggs developed in a normal manner and the first imago, a female, issued seven days after the hatching of the eggs. Exposed to a temperature above 48° C. (118° F.) for five minutes the eggs failed to hatch for the most part; the few that hatched only did so after from four to six days. At 49° C. (122° F.) and above the eggs would no longer develop.

Peryassú records the following experiments regarding the effect of cold on the eggs. Eggs frozen in a mixture of salt and ice for 30 minutes failed to develop. In another experiment 150 recently laid eggs were frozen for one hour, and then, after being allowed to thaw out, were placed in an oven at a temperature of 35° C. (95° F.); they began to hatch on the sixth day. In still another experiment eggs, also recently laid, were frozen for half an hour on two successive days; they hatched on the third day.

Experiments were further conducted on the effects of varying degrees of salinity of the water on the hatching of the eggs. Eggs would not hatch in pure sea-water. Female *calopus* were induced to lay their eggs in a mixture of fresh water with 30 to 35 per cent sea-water; these eggs hatched and the larvæ developed to imagos. With 40 per cent of sea-water the eggs hatched but the larvæ did not develop.

BREEDING-PLACES.

There seems to be a strong probability that *Aëdes calopus* was originally a tree-hole breeding mosquito. There are several arguments in favor of this conclusion. The mosquitoes which come closest to it in general habits are tree breeders. *Calopus* itself will breed in tree-holes when such happen to be near human habitations. Tree-hole breeding forms, like *Aëdes triseriatus*, will breed also, when there are human habitations near their original home, in rain-water barrels and other domestic accumulations of water such as seem now to be the normal breeding-places of *calopus*. The tree-hole breeding forms, like *triseriatus* and *mediovittata*, are continuous breeders just as is *calopus*, whereas the forms breeding in temporary puddles and swamps are more or less periodical in their occurrence, depending to a great extent upon rainfall. The egg-laying habits, as just described, are in accordance with this view. Originally, then, a tree-hole species, *calopus* has so perfectly adapted itself to human civilization that it has become a true domestic form and practically dependent for its existence upon the conditions that surround human habitations. This dependency upon the human species is undoubtedly of ancient development. The preference for human blood is well demonstrated, and, as has been pointed out, the work done by several investigators seems to prove that *calopus* does not oviposit until after having had a meal of human blood. Although Goeldi has shown oviposition after a meal of guinea-pig blood, he considers human blood more efficacious in bringing about ovulation.

We have already demonstrated that *calopus* is essentially a town mosquito. The larvæ are found practically exclusively in artificial receptacles about human habitations. It may be said that the larvæ of *calopus* are never found in swamps, in pools or in temporary puddles, even when these are in close proximity to houses. Durham, who studied the species at Pará, makes the following statement concerning the breeding-places. "Casual water in vessels, etc., in and about houses such as buckets, tins, washtubs, rain gutters, ant-guards (perforated troughs to protect plants in gardens, and sugar, etc. in houses), larger and deeper collections of water as casks or hogsheads full of rain water. Also in bilge water of barges, lighters, and S. S. Viking (Amazon Telegraph Co's ship, many years on the river). Not found in sewage collections as cesspools, stable runnings, etc., although found in neighbourhood in cleaner waters. Also not found in natural puddles in forest or streets, etc." We are well aware that there are a number of records of *calopus* larvæ occurring in street puddles and in swamps, but it would seem that in these cases the larvæ were not bred and most probably they were those of some other species of *Aëdes*, many of which greatly resemble *calopus* in general appearance.

In the tropics the large earthen jars in which drinking water is kept are the most frequent and unfailing habitat of the larvæ. Rain-water barrels are abundant breeding-places. In New Orleans and other southern cities, like Galveston and Mobile, rain-water tanks, so abundant behind the houses, are probably the source of the most abundant supplies of these mosquitoes. Reed and Carroll state that in their search for the larvæ of this insect in Cuba they found them in the following places: "(1) In rain-water barrels; (2) in sagging gutters containing rain water; (3) in tin cans that had been used for removing excreta and which still contained a small amount of fecal matter; (4) in cesspools; (5) in tin cans placed about table legs to prevent the inroads of red ants; (6) in the collection of water at the hase of the leaves of the *agave americana;* (7) in one end of a horse trough that was in daily use."

In New Orleans, in the epidemic of 1905, water-closet tanks were found to be abundant breeding-places, and Surgeon White suggested that an ordinance be made and enforced to cover these tanks with wire gauze. They were also found breeding in the accumulation of water in the drain traps of stationary washstands. Roof gutters, in New Orleans, were especially noticed on a number of occasions, where they sagged, to contain large numbers of *calopus* larvæ. Another interesting place where they were found breeding was in the urns in the cemeteries. In the autumn of 1905, at New Orleans, Surgeon Richardson, of the Public Health and Marine-Hospital Service, told one of the writers (Howard) that at Laredo, Texas, in the outbreak of 1903, *calopus* was found breeding in the lye barrels where ashes were mixed with water for the purpose of making lye. He also noticed them the same season in the holy-water fonts in churches. In New Orleans they were also noticed in the holy-water fonts, but here, after this had been pointed out, wet sponges were substituted for standing water. Moreover, in New Orleans it is the custom to keep wine cool by placing it in the pools of water accumulating under the water tanks, and in these pools the yellow-fever mosquito was found to breed extensively. In some houses in the low quarter of the city water was found to accumulate under the houses, and here also the yellow-fever mosquito bred. At San Antonio, Texas, in 1903, Surgeon Mason, of the U. S. Army, informed one of the writers (Howard) that he had found *calopus* breeding not only in such places as have just been mentioned, but in the water pans in the chicken yards and in the water receptacles of an old grindstone in a yard.

In 1905 Messrs. Busck and Knab, in their respective journeys to the West Indies and to Central America, made especial notes on the breeding-places of this species. Both of these observers stated that *calopus* nearly always breeds in clear water and very seldom in foul water. They always found it in artificial receptacles except a few times in tree-holes near houses and in one case where Mr. Knab, at Córdoba, Mexico, found a larva of this species in a street gutter. This larva probably came there by the emptying of some vessel. Goeldi was of the opinion that the larva of *calopus* could only develop in clear water. Busck has on two occasions found the larvæ in very foul water and the French commission noted that it thrives in filthy water. However, the breeding in clear water is the rule. Mr. Knab found that the house of the American Consul at San Salvador was especially infested by this species. The larvæ throve abundantly in the garden, in the small water-filled stone gutters which served to protect the plants from the leaf-cutting ants. In a church in Grenada Mr. Busck found *calopus* breeding abundantly in the holy-water font, and also in several other churches in different West Indian islands. This fact was mentioned in a paper presented by one of the writers (Howard) before the International Congress of Sanitarians of the American Republics held in Washington in the autumn of 1905, and was widely exploited by the newspapers. The matter was taken up by an ingenious resident of Boston who forthwith invented a holy-water font in which it is impossible for the yellow-fever mosquito to breed, the water being allowed to issue from the font drop by drop from a faucet. Adult mosquitoes were found to be abundant in churches where the larvæ were breeding in fonts, and under these conditions such churches must always be sources of great danger. In Trinidad Busck found that beer bottles were used as a border ornament for the flower beds; the necks of the bottles were stuck into the ground and in their slightly convex bottoms (turned upward) water had accumulated and *calopus* were breeding. In the broken bottles forming the cheval-de-frise on the stone wall around the jail, he found that water had accumulated and the yellow-fever mosquito was breeding. Knab, at Acapulco, found these mosquitoes especially abundant in his hotel. In the patio there were beautiful flowers protected from ants by water in shallow trenches; in this water *calopus* was breeding abundantly. Discarded bottles and tins about houses are favorite breeding-places. Dutton, at Bathurst in Gambia, found many boats lying on the beach containing collections of water, in some cases one or two feet deep. This water almost universally contained mosquito larvæ of five species, the most abundant being *Aëdes calopus.*

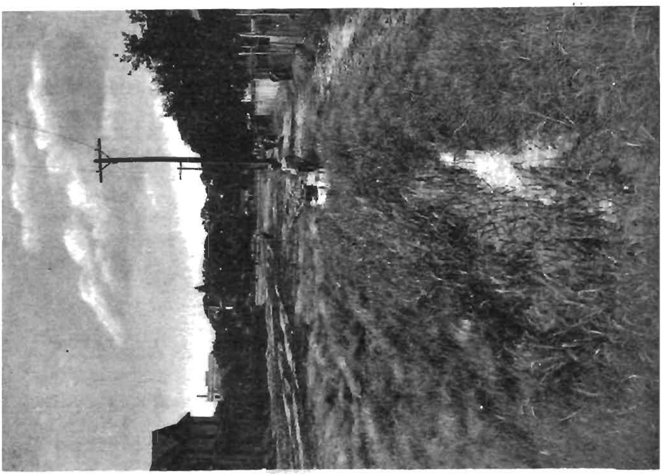
Occasionally the larvæ occur in water in holes of trees, but only when these are in close proximity to human habitations. In a small grove of fruit trees in the town of Tehuantepec, Mexico, Knab found the larvæ in water at the base of the branch of a mango tree; there were numerous larvæ in the water-filled holes of two other trees in the same grove. In the village of San Antonio, near Sonsonate, Salvador, Knab again found larvæ of *calopus* in a hole in a large mango tree. Jennings found larvæ of *calopus* in the hole of a tree, near buildings, at Ancon in the Panama Canal Zone.

Goeldi, at Pará, found the larvæ in water-bearing bromeliads, presumably near houses, and in the still folded leaves of banana plants. Peryassú also records the larvæ of *calopus* from bromeliads at Rio de Janeiro. H. W. B. Moore of the British Guiana Museum has sent us specimens of *calopus* bred from bromeliads at Georgetown. He has since found the larvæ again in similar situations and writes us in this connection: "The Bromelias from which I bred *calopus* were not very far from dwellings. On August Monday (Bank Holiday) I took a trip into a sparsely populated district where I have not yet collected, and got more *calopus* larvæ in Bromelias. Is it not likely that Bromelias and other such water-holding plants were the great natural breeding-places of *calopus* before it took seriously to breeding in man's receptacles? It is evident that it is still one of their natural breeding-places, but they do not succeed as well there as some other species." We are inclined to consider the conditions indicated by Mr. Moore as exceptional and due to the excessively moist climate of British Guiana. Our belief that *calopus* originally bred in tree-holes is supported by the fact that related species with similar habits breed mostly in holes in trees; moreover it is very rarely that species of the genus *Aëdes* resort to bromeliads.

The Brazilian observers have found the larvæ of *calopus* in brackish water on a wharf on the Ilha das Cobras in the bay of Rio de Janeiro, the water showing a salinity of 35 per cent of sea-water.

BEHAVIOR OF LARVÆ.

The larvæ of *calopus* when suspended from the surface film, to take in air, hang almost perpendicularly. They are very easily alarmed and then go quickly to the bottom where they remain a considerable time. They can live under water, without rising to the surface, for a long time and this is also true of many other tree-hole inhabiting species of *Aëdes.* When water is poured from a receptacle inhabited by *calopus* larvæ these quickly seek the bottom and their presence may not even be suspected although the vessels be in constant use. They cling so closely to the bottom that unless the jars are tipped up so as to empty them completely, which is not usually done, nearly all the larvæ remain in the jars.



The first yellow-fever commission to Vera Cruz found that, on account of this habit, the larvæ are not easily disposed of by pouring out the contents of a barrel. "When the barrel or other container with thousands of larvæ is approached and slightly agitated, the insects disappear rapidly to the very bottom, so that nearly all the water can be dipped from the barrel without removing more than a few of the larvæ. The barrel may be turned upon its side, and it will be found that about 80 per cent of the larvæ will stay in the few remaining ounces of water."

FOOD-HABITS OF THE LARVÆ.

It has been pointed out that the larvæ occur most frequently in the clear water in rain-water barrels or in drinking-water receptacles in houses. The water in such receptacles contains more or less animal matter, such as particles of human skin or remains of insects, as well as vegetable refuse, and such probably is generally the food of the larvæ. The larvæ feed at the bottom, where they mouth over the organic sediment, even when the water is very deep. Larvæ in confinement may be observed chewing vigorously at dead insects or larval and pupal exuviæ.

C. S. Banks has observed the larvæ in the Philippines and says: "They feed largely upon the sediment contained in the dregs, which may be both animal and vegetable in its character, but more frequently vegetable, as it is composed of the bits of decaying *nipa* forming the roofs from which the rain water is collected. The larvæ, in feeding, move forward over the bottom of the vessel, taking in the particles of food with great rapidity and rejecting tiny morsels of undesirable material in a constant stream."

Goeldi found that the larvæ of *calopus* are cannibalistic, and this has been confirmed by the Brazilian observers at Rio de Janeiro, who state that the larger larvæ devour the smaller ones. This habit probably accounts for the development of the larvæ in very clear water, which has been so frequently noted.

An interesting fact is that the growth of these larvæ is greatly hastened by the presence of a small amount of fecal matter in the water. Reed and Carroll, at Havana, found that *calopus* bred in the tin cans used for carrying away human excrement and throve remarkably under those circumstances.

Dupree and Morgan, of Baton Rouge, have also recorded the fact that by adding fecal matter to the water they hastened the development until the life-cycle was completed "in from six to eight days."

The French commission to Rio de Janeiro found that the larvæ develop in clear water, but also thrive in foul water. Water containing alimentary debris, amylaceous or fatty material seems to suit them perfectly. These investigators thought that rain water, on account of the microbes which it contains, seems to be more favorable to their development than spring water. In the laboratory the larvæ were easily reared in water in which had been placed excremental pellets, or grains of corn or wheat. They seemed to be less at ease in muddy water and in water containing macerated dead leaves and vegetable debris, but they found that the differences in the duration of the different stages of larval evolution in these different kinds of water were not ordinarily very marked. They decided, however, that the vigor and the strength and the size of the perfect insect which resulted was in distinct relation with the larval food. Reed and Carroll found that muddy water is unfavorable to the larvæ. "In water, however, which contains much suspended soil—muddy water—the larvæ, in our experience, do not flourish, but die off rather rapidly."

DURATION OF EARLY STAGES.

Temperature has the greatest influence, not only upon the hatching of the eggs, but also upon the subsequent development of the larvæ. The effects of various temperatures on the early stages of *calopus* were carefully investigated by the American commission in Cuba and by the French commission at Rio de Janeiro and the results of both agree very closely.

The shortest period of development to imago observed by Reed and Carroll during summer weather in Cuba was 9½ days, divided as follows: incubation 2 days; larval stage 6 days; pupal stage 36 hours; but they believed that this was quite exceptional. Their observations on the influence of temperature on development are as follows:

"We have just seen that at summer temperatures the time required for a complete generation of this insect is from eleven to eighteen days. We may say that at an average temperature of 75° F., or over, stegomyia multiplies abundantly. Exposure to a cooler temperature, even for a short time daily, much retards the development of this mosquito. Thus, a batch of fifty-one eggs kept at 35° C., but which were placed in a cool chamber at 20° C. for two hours daily during the whole process of development, although furnishing a few larvæ at the end of the third day, were not all hatched until the eleventh day. The first pupæ appeared on the fourteenth day and the first mosquito on the nineteenth day; the whole process being completed in twenty-seven days, instead of the usual fifteen or eighteen days. The loss of insects was about 50 per cent. Eggs kept at a temperature of 20° C. (68° F.) do not hatch, in our experience. Newly hatched larvæ kept at this temperature develop very slowly and require about twenty days to reach the pupal stage. Mosquitos developed under such conditions are feeble, and but few arrive at maturity. Young larvæ kept at 10° C. (50° F.) have failed to reach the pupal stage—although some growth takes place. In one experiment more than 50 per cent. were dead at the end of two weeks, and none survived the thirty-second day. Half grown larvæ and pupæ exposed to a temperature of 20° C., and even as low as 10° C., continue to develop slowly, but the few insects which escape drowning have, as a rule, been of feeble strength and have refused to bite. Although the reduction of the temperature to the freezing point, or below, would not necessarily destroy the vitality of the eggs of this genus of mosquito, it should be remembered that a reduction of temperature to 68° F., or below, for even a few hours of the twenty-four, will much retard the development of the generation. At a temperature less than 68° F. the eggs of this insect have ceased to hatch."

Under the most favorable conditions of food and temperature the larva develops with great rapidity. When the conditions are very unfavorable larval life may be prolonged indefinitely, the larvæ showing great resistance. Agramonte places the minimum period of development from egg to imago at ten days; Taylor of Havana places it at nine days. As already mentioned, Dupree and Morgan, succeeded in obtaining imagos after from six to eight days.

At Pará, Goeldi conducted a number of experiments on the rapidity of development of the yellow-fever mosquito. The duration of the entire cycle, from the date of oviposition to the emergence of the imagos, showed a minimum of twelve days and a maximum which was indefinite and almost unlimited, according to the season of the year and the dearth or abundance of food. He observed one case in which a male emerged only after fifty days, and other cases where with the same number of days there were still larvæ and pupæ.

The French observers determined a distinct relation between temperature and the rate of development. At Rio in the most favorable season, when the night temperatures were from 26° to 27° C. (79°–81° F.) and the day temperatures from 28° to 31° C. (82°–88° F.), they observed that some of the larvæ of *calopus* reached the pupal stage seven days after the hatching of the eggs, and the adult condition on the ninth day, and generally most of the larvæ from the same laying of eggs produced imagos about the tenth day. They found that when this rapid breeding occurred it was necessary that the egg as well as the larva should have had the right temperature and the egg a rapid incubation. The temperature being lower the evolution naturally becomes longer, and at Petropolis, with a night temperature lower than 22° C. (72° F.), they found the larvæ taking from forty to sixty days to reach the pupal state, and from three to five days longer before the perfect insect issued. Ordinarily, according to their observations, the pupal stages last only from thirty to fifty hours. They found that the larvæ do not perish at a temperature near the freezing point, but they grew very slowly and took an indeterminate time to become adults.

The French investigators showed that the development of this species is possible in brackish water, but that soapy water is very destructive to them. They proved that in sea-water they perish quickly; that this is not true when sea-water is mixed with fresh water. In one of their experiments a female, placed in a tube containing five-sixths fresh water and one-sixth sea-water, laid its eggs as under normal conditions. These eggs hatched at the end of four days, and the larvæ, reared in a jar containing the same water, reached the pupal condition on the eleventh day and the perfect condition on the thirteenth day. The same result was reached when larvæ were placed in brackish water containing one-fifth sea-water and four-fifths fresh water, but two young larvæ placed in brackish water containing one-third sea-water perished at the end of a few hours.

RESISTANCE OF LARVÆ TO ADVERSE CONDITIONS.

The Brazilian investigators made an extensive series of experiments to determine the effect of brackish water of different degrees of salinity. They found that in a mixture of 30 per cent sea-water with 70 per cent fresh water the larvæ transformed to imagos in a normal manner, although development was retarded. They found larvæ of *calopus* in nature in brackish water containing 35 per cent sea-water. With 40 per cent sea-water the larvæ still survived and a few produced imagos. With mixtures up to 8 and 9 per cent the larvæ developed normally but when the salinity was increased beyond this the larval period was greatly prolonged. Under these conditions larvæ lived for 50 days without transforming. One larva, in a mixture with 10 per cent sea-water, died without transforming after having lived 92 days. Larvæ well advanced are much more resistant and when nearly full grown would still transform in highly saline water. In a proportion of 50 per cent sea-water the larvæ generally survived 24 hours and those that were nearly full grown transformed to pupæ. Beyond this the larvæ only transformed when they were within one or two hours of the pupal stage and then only in mixtures up to 56 per cent sea-water. Of 50 larvæ placed in a mixture of 60 per cent sea-water three survived to the third day. The pupæ, when placed in pure sea-water, always produced imagos in a normal manner.

These experiments are of considerable economic importance, as they show that the larvæ of *calopus* may, in nature, survive in water which has, through evaporation, reached a high degree of salinity. If afterwards, through rains, the solution becomes again diluted the larvæ may then develop to imagos.

Experiments were also made with solutions of pure salt (NaCl) and it was found that the larvæ would not withstand solutions stronger than one per cent. Only once a larva transformed to pupa in a solution of 1.5 per cent, but in this case the larva was already full grown and ready to moult.

The Brazilian investigators also experimented with corrosive sublimate. In the presence of 1/1000 the larva of *calopus*, on the average, died after one and a half hours and the pupæ but rarely produced imagos. With 1/2000 the larvæ died, on the average, after 4½ hours and the pupæ produced imagos. With 1/10000 a very few larvæ developed to imagos, but this only happened when they were in the last stage.

At Rio de Janeiro it was found that the tanks used for washing clothes were favorite breeding-places of *Aëdes calopus*. Both the French commission and the Brazilian investigators experimented on the effect of soap in the water on the larvæ.

In their experiments with soap the French investigators found that larvæ of any age placed in a solution containing one-thousandth by weight Marseilles soap died in five minutes. In solutions of one to five thousand and one to ten thousand, they lived for a time but finally died. In solutions of one to two hundred thousand and one to two hundred and fifty thousand, they developed normally. The larvæ bred normally in basins and tubs in which linen is customarily washed, because, when the soapy water remains in the tubs for some days, its alkalinity is greatly diminished. Peryassú experimented with common Brazilian washing soap. He found that larvæ of any age, when placed in a solution of one-thousandth by weight died in from six to seven minutes. Only when the solution was weakened to 1/200000 or less did the larvæ develop in a normal manner.

In apparent contradiction to this extreme sensitiveness to alkalinity are the observations of Agramonte, already mentioned, that the presence of wood ashes hastens the hatching of the eggs, and of Jennings who has noted larvæ in water containing wood ashes. In this latter case, at Cartagena in Colombia, the larvæ were found in large numbers in an earthen pot containing a large quantity of wood ashes in brackish water from a shallow well near the sea-coast. None of the larvæ produced imagos. In such cases the potash contents, which are variable with different kinds of wood, must be taken into account and also the fact, already pointed out, that after some time the water loses its alkalinity.

The degree of resistance to desiccation of the larvæ and pupæ of *Aëdes calopus* is important from the practical standpoint. The first yellow-fever commission to Vera Cruz found that in that dry climate larvæ died very quickly when the water containing them was poured upon the ground. In moister climates the larvæ may, under favorable circumstances, live out of water a considerable time and the pupæ show great resistance to desiccation.

Peryassú records a series of experiments conducted on a large scale at Rio de Janeiro. Placed upon filter paper none of the larvæ lived nine hours. When placed upon the moist ground, according to temperature and evaporation, they survived as much as 13 days, and, when again put in water, developed to imagos. In the experiments with larvæ and pupæ the following method was employed. A determined number of larvæ or pupæ were put in a watch glass with a little water and then emptied upon a cone of filter paper; this latter was then placed upon two other layers of filter paper, to absorb all the water from the first; then, when the necessary time had passed, the paper with the larvæ was placed in a glass of water so that the number of dead or surviving larvæ could be determined, as well as the time they required to return to a normal state. Tabulations of the results are given and from these the following data are extracted.

Larvæ dried up to three hours developed normally when returned to the water and it is only beyond this that they began to suffer. In the course of the many experiments the longest periods during which *calopus* larvæ survived were in one case 8 hours and 20 minutes, and in another 8 hours and 55 minutes. It must be noted that on the day on which these results were obtained it rained copiously all day; the evaporation, in the shade, was 1.4 mm. and the relative humidity 86.1. These results are based upon 64 experiments with 3685 larvæ. The larvæ, when returned to the water, sometimes immediately resume their activity, but most of them remain immovable for from 5 to 15 minutes. Generally the larvæ that did not recover within this time would die. Drying during periods of from three hours to four hours and fifty minutes was survived by from 72 to 98 per cent of the larvæ, and the number of these that reached the imago state varied from 1.5 to 75 per cent. The time to transformation, after being returned to the water, varied from 3 to 41 days. Experiments with drying during 5 hours to 6 hours and 50 minutes gave the following results: The larvæ survived in the proportion of 7.5 to 95.5 per cent; they produced imagos in from 2.5 to 62.5 per cent. The period to transformation varied from 3 to 42 days. Experiments with drying for from 7 to 9 hours resulted as follows; the larvæ survived in the proportion of from 4 to 97.77 per cent and produced imagos in from 1.25 to 26.66 per cent; the variation in the time to transformation varied from 3 to 32 days. The meteorological factor which most influences the larva out of the water is evaporation; up to 2 mm. evaporation does little harm but becomes injurious in proportion to its increase. Pupæ dried upon filter paper survive up to 9 hours and 30 minutes. Advanced pupæ produce imagos after drying of from 5 to 8 hours, and they would issue even while upon the filter paper. Pupæ of any age produced imagos when placed upon the moist ground.

To determine the resistance of the larvæ upon moist earth 55 experiments with 3780 larvæ were made. The practical conclusions are that the larvæ, after being so kept for three days, will develop in a normal manner. One larva, kept on moist soil for 14 days, under natural conditions, when returned to the water transformed to imago after three days; this was the greatest endurance observed by the experimenter. As in the previous drying experiments, the time of transformation was affected, the larvæ producing imagos in from 3 to 39 days.

THE GEOGRAPHICAL DISTRIBUTION OF THE YELLOW-FEVER MOSQUITO.

As is pointed out incidentally in the consideration of the carriage of mosquitoes by conveyances, the yellow-fever mosquito, by reason of its habits, being a domestic species, having a fairly long life in the adult stage, and having the custom of hiding itself in the most ingenious ways, is particularly subject to carriage for long distances on board vessels, in railway trains, even packed securely away in baggage. It was in this way that the yellow-fever mosquito was carried from America to Africa, or vice versa, according to the view of the origin of the species which is adopted. It should be stated that in the old days of sailing vessels on very long voyages, it was not only quite possible for the yellow-fever mosquito to breed continuously in the more or less exposed water supply of the vessels, but undoubtedly this was a common occurrence.

By such means this mosquito is distributed far and wide and during warm summers is taken often far beyond the point where it is capable of maintaining itself permanently. Thus there are two distributions for this insect, one in which it is capable of breeding continuously, and another over which it spreads during warm weather, to be annually exterminated by the cold, after breeding for a certain number of generations. Owing to its domestic habits, the mosquito does not flourish except in the presence of fairly dense settlements. It can breed anywhere where man is congregated and the temperature is sufficiently high. Thus its permanent distribution is determined by the minimum temperatures and its temporary distribution by the maximum temperatures of any given region wherever it is sufficiently populated.

The permanent distribution is limited in a general way by the frost line. Where frost does not occur, the species generally may breed permanently. We have shown in the discussion of the influence of temperature that the species does not thrive below a temperature of 80° Fahr., so that in a uniform climate with a temperature much below 80° the species could not continue to exist. Such climates, however, are rare, and in general when frost never occurs the general temperature is high enough to permit the species to flourish. Besides this, the species no doubt continues in particularly favored locations north of this area, perhaps here and there and not always in the same place every winter. From these foci the summer dispersal is no doubt much facilitated.

The temporary distribution is determined by the means of carriage that happen to be available. The insects do not fly far, as we have shown, but are readily carried in conveyances. Thus the species may continue to exist for a time wherever it may be carried while the temperature remains about 80°.

These facts have not been generally taken into account in discussing the distribution of *Aëdes calopus,* and so the temporary and permanent habitats of this insect have not been separated. It is impossible to do so from records of captured specimens only, consequently these distributions can not be exactly mapped.

When Theobald published the first two volumes of his Monograph of the Culicidæ of the World, in 1901, he stated roughly that this insect, which at that time was not known to him as the yellow-fever mosquito, ranged from 38° south latitude to 38° north latitude, and his map upon page 292, vol. 1, indicated a general distribution throughout eastern Australia, western New Guinea, all of Celebes and farther India, southern Japan, eastern Hindostan, the Seychelles, southeastern Africa, the African west coast, including Senegambia and Lagos, Spain, southern Italy, the east coast of South America from British Guiana to the La Plata River, Panama, Belize, all of Cuba, Jamaica, Haiti, Bermuda, and all of the southern United States. In vol. iii of his monograph, published in 1903, he adds certain other localities.

In No. 46, vol. xviii, of the public health reports of the Public Health and Marine-Hospital Service, published November 13, 1903, and subsequently revised to September 10, 1905, one of the writers (Howard) published a long list of additional localities. All of these are covered by the general statement of the distribution given above. All the exact localities observed by us will be found under the heading of *Aëdes calopus* in the systematic part of this work.

The foregoing consideration of the temperature conditions governing the breeding of *Aëdes calopus* explain why epidemics of yellow fever have occurred on the Atlantic coast of North America even as far north as Montreal, and may again occur, whereas no epidemic has occurred on the Pacific coast, nor is it possible for one to occur. The summer temperature on the Atlantic coast is for long periods at or above 80° both day and night, so that the mosquito, once carried by ship or otherwise from regions of its permanent occurrence, may breed in large numbers in our cities. It needs then only the introduction of cases of yellow fever to start an epidemic.

On the Pacific coast, on the other hand, the nights are so cold that the mosquito can not survive. It is as regularly imported into Pacific coast ports as into Atlantic ones. We have records of specimens taken at San Diego and San Francisco. It breeds permanently in all the west coast Mexican seaports and must be frequently brought to the Californian coast. Yet it has never been known to breed there. This seems at first sight strange, since the mean annual temperature of southern California is much above that of eastern cities where epidemics have occurred. In San Diego and Los Angeles one sees tropical vegetation on every hand growing unprotected and severe cold is unknown. Yet the nights are cold, even in summer, and it is to this condition, the low minimum nightly temperatures, that the freedom from *Aëdes calopus,* and consequently from yellow-fever epidemics, is due.

ORIGINAL HOME OF AËDES CALOPUS.

The original habitat of this mosquito must clearly be identical with that of yellow fever, for it is inconceivable that this parasite would have developed in any other region than the original home of its obligatory host. Early history points very strongly to the West Indies and adjacent main-land as that home. Finlay, in a paper read February 19, 1902, before the Pan-American Sanitary Congress, gave good evidence that yellow fever was endemic in America before the arrival of the Spaniards. "As may be gathered from the contemporary chronicles of Las Casas, Oviedo and Herrera, such endemic foci did exist in the Island of Santo Domingo (Hispaniola) and on the coasts of Venezuela (Nueva Andalusia) and Colombia (Castilla de Oro) ever since settlements were made in those places by newly-arrived Spaniards." The data have been so well presented in small compass by Marchoux and Simond that we can do no better than quote them.

"It has been much discussed whether Christopher Columbus encountered yellow fever on his first or on his second voyage. But whether the 39 men left by the admiral in Santo Domingo fell victims to the disease during the summer or after the battle of Vega-Real, matters little for the history of this disease. It is certain that it existed in an endemic state in the Antilles and along the coasts of the Gulf of Mexico before the discovery of America. It is equally certain that if the Europeans did not bring yellow fever to the New Continent they are the ones who, from Central America, have distributed it over the world. There were amongst them the most numerous victims and the new towns which were founded in the vast territory which today is the Republic of the United States had to suffer attacks. In this country alone, more than 100 epidemics were studied at different points and at different times.

"From New Orleans the yellow fever spread over the entire lower basin of the Mississippi and Missouri, even reaching Gallipolis [now Pittsburgh] and Cincinnati on the Ohio. One can say that it touched all the towns of the east coast from Florida to the northern frontier, and even to Quebec in Canada. On the west coast it has been seen as far up as San Francisco. New York was attacked for the first time in 1688 and had to suffer some twenty great epidemics. The yellow fever remained in an endemic condition from 1740 to 1860, and this was the same with Philadelphia, Charleston and New Orleans. All the towns of Louisiana, Mobile, Pensacola, Key West, St. Augustine, Savannah, Baltimore, Norfolk and Boston were thus greatly tried. In fact, according to what is known, it is in the United States that the yellow fever made its most frequent incursions. If one estimates at 100,000 the number of deaths of which it was the cause, one certainly remains well below the truth.

"In South America it rapidly gained the Guianas and Brazil, and we see it there from 1640. The coast of this vast country, from the Amazons to Rio de Janeiro, constitutes a still persisting endemic center. From there it has made frequent incursions to Santos, and sometimes into the states to the southward, Santa Catharina, Rio Grande, reaching Montevideo and Buenos Ayres, and, going up the rivers of the La Plata to Assumption in Paraguay. On the west coast it has spread from Panama to Peru and even to Chili.

"Ships, particularly the ships loaded with sugar, have transported this terrible malady to Africa where we find it in the Canaries after 1701 and perhaps even after 1510. Besides the Canaries it touched Madeira, the Cape Verde Islands, Senegal, Gambia, the Bisoagos, Sierra Leone, the Ivory Coast, the Gold Coast, Benin, Fernando Po, the mouth of the Congo and Angola with Saint Paul de Loanda. It has caused several epidemics in the island of Ascension and from this it was carried to St. Helena but without attacking the population of the island. At this day it persists as an endemic center in the Sudanese region comprised between the Gold Coast, the Ivory Coast, the upper Senegal and the upper Niger."

After carefully considering the question of the original home of yellow fever, Sir Rubert Boyce concluded that the disease, and therefore the mosquito, is indigenous to America. His brief summary of the early history is given.

"There is every reason for supposing that yellow fever is one of the very old diseases of mankind in the New World. It is stated that it was known to the Aztecs under the name of *matlazahualt,* and according to Humboldt it existed as early as the eleventh century.

"Amongst old Spanish writers who refer to this disease may be mentioned Oviedo, who in his 'Historia General de las Indias' describes the great mortality among the followers of Columbus in 1494. This mortality he attributes to the humidity of St. Domingo, but in every probability it was yellow fever. So bad were the reports which reached Spain, that Ferdinand V. had to send out 300 convicts to the island as there were no volunteers.

"Columbus in 1498, in writing to the King of Spain upon the sickness of his men, attributed their illness to 'peculiarities in the air and water' in the new land. No doubt the peculiarity was the mosquito.

"In the sixteenth century yellow fever is said to have decimated the Mexicans. But the first authentic history of an epidemic of yellow fever was furnished by Jean Ferreyra de Rosa at Olinda * in Brazil in the year 1687.

"Père Dutertre, 1635, appears to have been the first to furnish details of the symptoms and progress of the disease in the West Indies. He regarded it as a new disease.

"Père Labat, whose name is well known in connection with yellow fever, found on landing in Martinique in the year 1649, the disease raging in the island, the monks of the religious order stationed there being severely afflicted. The learned father stated that the disease was called 'the Maladie de Siam,' because in Martinique they supposed that it was imported from Siam by the ship *Oriflamme.* As, however, this ship called at Brazilian ports on the voyage, it is much more probable that either the crew became infected there or that infected mosquitoes were carried away. According to Bancroft the disease existed in St. Domingo in 1731. Old writers upon yellow fever frequently refer to the West Coast of Africa as being the original source of the disease.

"Thus Dr. Chisholm believed that yellow fever was first introduced into the West Indies in 1793, when Grenada became infected from the remarkable ship *Hankey,* which had come from Bulam in West Africa. On account of this supposed origin of yellow fever it is sometimes called Bulam fever. Evidence, however, points the other way,—that in fact it was a very prevalent disease in the New World, stretching from Mexico down through Central America to Brazil. Brazil appears, then, to have been the centre from which it radiated out to the West Indies. As I have stated before, the early Conquistadores suffered from it, the Latin races of the Old World being therefore the first to make its acquaint-

* Now a suburb of Pernambuco.—Editors.

ance during the time they were occupied in pushing civilization into the then newly discovered continent.

"In Cuba yellow fever was probably known as the Pest or Epidemic of Havana as early as 1620. The first authentic description of the black vomit in Havana was furnished by Dr. Thomas Romay in the year 1761.

"In the beginning of the eighteenth century the disease, from its appearance in various parts of Spanish America under the name of *vomito prieto*, attracted much attention, and it is particularly referred to by the historian Ulloa, who resided for some years in that country. The word *prieto* appears to be the Portuguese or nearly obsolete Spanish term for black. In Spanish the word *negro* is now universally substituted. A small pamphlet of sixty-two pages by a Dr. Gastelbondo, written at Carthagena (S. A.) in 1753 and printed at Madrid in 1755, was probably the first work *ex professo* on the black vomit as it appeared in South America. He gives his experience of the disease during forty years. He says on the title page that he is about to write about a disease of frequent occurrence in that part of the world, mentions change of climate and mode of living among some of the causes of the disease in new-comers, and says that the natives of Carthagena, Vera Cruz, etc., were not subject to attacks of the true black vomit fever, though liable to the 'Chapetonada,' a disease resembling it in some respects."

It has been claimed by some that yellow fever is of African origin and was imported into America through the slave trade. The most comprehensive argument in favor of the African origin of the yellow-fever mosquito is given by Goeldi and on that account we give it here in full.

"I am well acquainted with the arguments of those authors who claim that stegomyia is of American origin. They are based chiefly on the story of the voyage of Christopher Columbus. Without disputing whether the disease which killed a part of the crew of the caravels of the conquerors was indeed identical with yellow fever, does this in itself amount to a positive proof that this disease did not previously exist on the coast of Africa? Most certainly not. At most it might be objected that no historical documents exist relating to the existence of stegomyia in Africa before Columbus. Further, from the absence of any historic document about any given fact there never can be deduced the non-existence of this fact. There are evidently many things which happened in this sublunary world of which no human historian has left us a story and which nevertheless are most certainly true.

"Let us examine this question a little more closely. *Stegomyia fasciata* is, as we know, a mosquito which affects great cities, populous centers of the shore and neighboring regions. Now, I ask where were these great cities which the European invaders should have found along the Atlantic coast from the Antilles even down to the Rio de la Plata? Where are those points where the indigenous Americans were found in populous permanent residences? There were none, and this in no wise surprises us, considering the habits and customs of the Indians. The indigenous American was at all times that which he is today; endowed with the love of liberty, he never had the habit or even the tendency to group and concentrate himself in really considerable collective residences. His village consisted of a few dozen houses—in most cases not even one hundred being found in a limited area. They were peasants rather than townspeople; as with ants and bees, an increase of numbers always produced for them as a consequence migration of groups, dismemberment—a new village was formed, half a day, a day, or two days further up the river, further down the river, further in the forest, and this in turn became disintegrated in view of the rest-less and nomadic character of the Indian long before it could have acquired any considerable increment or dimensions. They are not properly sociable in their dwelling places: if among them the social spirit exists it merely shows itself at the time of feasts, of warlike enterprises or of great migrations, etc. During transitory and passing occasions there are indeed agglomerations of people, but inchoate, ready to break up, and their camps can not even be called temporary. The occasion over, the multitude dissolves itself as by enchantment or before the breath of the wind. Now such conditions are not to the taste of *Stegomyia fasciata.*

"On the other hand, what do we find in Africa? One of the most striking ethnological characteristics of the black people is precisely the social spirit strongly developed. In the stories of all travelers we find at every moment expressions of surprise and admiration as to the grouping of houses, attaining numerical dimensions so great as to prevent a rapid census. In that country there are frequently found centers of ten, fifteen or twenty thousand inhabitants, and yet these are barely called villages; in Africa the idea of a city is only given consideration with such centers as possess a multiple of the above figures. Here we have the condition of affairs that admirably meets that which stegomyia wants and demands. It is the very best condition for its life requirements: a hot and humid climate and very large groups of human beings.

"All I wish to set down in brief words is that a careful comparison of the ethnological situation there and here—and this certainly constitutes a factor of the utmost importance in the matter—at once demonstrates the indubitable advantage on the side of the African origin of *Stegomyia fasciata.*

"Another series of considerations which in the highest degree tend to upset the theory, so weak in its basis, of the American origin of *Stegomyia fasciata*, are opened up as soon as we weigh the results obtained by a *critical examination of the partnership, Stegomyia fasciata—Culex fatigans.* In a previous essay I frequently and persistently pointed out that these two mosquitoes are inseparable companions all over the world, and I demonstrated that, one a diurnal and the other a nocturnal mosquito, they together formed a partnership admirably organized to take in daily cyclic rotation tribute from man in the tropical zone.

"Now it is worth while noting that the type specimen, the original which served for the first description of *Culex fatigans* by Wiedemann in 1828, came from the oriental Indies. This circumstance, if indeed by itself alone it does not amount to proof, is nevertheless of no small symptomatic importance.

"I ask this: Does this ominous partnership of *Stegomyia fasciata* and *Culex fatigans* date from yesterday? Is it perhaps an accidental result in the tropical part of the New World? I believe that it is of a date much further back, and that we must find the locality where the pact was celebrated in some part of the Old World, and that it was not accidental but the natural consequence of an almost identity of common interests.

"I believe that there are good arguments indicating an Ethiopic-Indian nativity of this alliance, and the more I examine it the more it seems desirable to me that there should be a conscientious and critical investigation undertaken into the question of an eventual parallelism between the distribution and dispersion in ancient and modern times, of the black human race on the one hand, and of the two mosquito partners in their damnable offensive alliance on the other hand.

"It is indispensable not to lose sight of the fact that he would be ill-advised who would permit himself to be impressed and influenced one-sidedly and partially by the aspect which things present today in this field. Do you wish an example? It is not necessary to go far to find a most drastic one. Brazil today is the greatest producer of coffee and undoubtedly is the country where the greatest number of coffee trees have been planted. Now suppose for a moment that there was a complete disappearance of all historical documents proving the Asiatic origin of the coffee plant and of its introduction into Brazil via Cayenne, who would imagine that the original country of this tree was Arabia? And is it not an absolute fact that this very historical remembrance is becoming weaker every day in popular knowledge here in Brazil with the increasing interval of time separating us from the moment of introduction which nevertheless was scarcely 200 years ago?"

One of the authors (Knab) has already pointed out some of the weaknesses in Goeldi's argument. He showed that Goeldi is in error where he denies the existence of large cities in America at the time of its discovery. The vast centers of population found by the Spanish conquerors in Mexico and Yucatan are too familiar to need discussion. Even the Amazons themselves, if we can believe the early explorers, had large towns upon their shores and supported a considerable population. Moreover it must be remembered that Africa is for the most part a dry, open country in which a mosquito with the habits of *Aëdes calopus* could hardly originate and find opportunities to adapt itself to man. On the other hand in tropical America the ideal conditions exist which would bring about the adjustment of such a mosquito to man. We find extensive forests and plenty of moisture to support tree-hole breeding mosquitoes and human settlements within these forests to furnish the blood supply. In fact we find in this region a great variety of mosquitoes which have the tree-hole breeding habit; among these are some which clearly show a predilection for the proximity of man and may thus be said to be in progress of developing domesticity in the manner it must have been done by *calopus*.

Had yellow fever existed in Africa prior to the discovery of America we would surely have had some indication of it through the earlier explorers, but nothing exists to warrant such a belief. The distribution of yellow fever in Africa, as has been recently set forth anew by Boyce, is in itself significant. It has there been confined to spots in a restricted area on the west coast, the part nearest America and formerly most in communication with it through the slave trade. This is well brought out by Prof. W. J. Simpson, in his discussion of the paper just mentioned, by Boyce. It is hardly conceivable, had yellow fever been endemic in Africa for a long time, that it could have failed to spread, not only over the hotter parts of the continent, but even to the East Indies. Finally the experiments of Marchoux and Simond, given on a previous page, which indicate a certain repugnance to the black race, while not in themselves conclusive, in connection with the foregoing, are at least significant.

DISTRIBUTION BY ARTIFICIAL MEANS.

It seems worth while to give some practical account, in the light of our present knowledge, of the way in which the yellow-fever mosquito is distributed by the presentation of specific cases. To illustrate shipboard carriage the story of the case of the steamer *Luxor* and its journey in the spring of 1906 may be described as follows:

In Public Health Reports, vol. 21, no. 23, published July 8, 1906, there is an interesting report from Surgeon Wightman, of the Public Health and Marine-Hospital Service, dated May 5th, in which he states that the steamer *Luxor* left San Francisco February 9th and proceeded to Guayaquil via Mexican and Central American ports, leaving Corinto, the last Central American port, on March 7th. She also called at four South American ports north of Guayaquil. No mosquitoes were seen on board in any of these ports except at Corinto, and these did not stay with the vessel after leaving port. The *Luxor* reached the quarantine station at Guayaquil at 9 a. m. on March 18th, passed inspection, and passed up the river, anchoring a few hundred yards from the city. She carried a cargo of lumber forward and aft; that aft was discharged, but forward, near the forecastle, it remained on deck, was wetted with rain and formed a hiding-place for mosquitoes. Large numbers of mosquitoes came on board. *Anopheles* was recognized, but not *Aëdes calopus.* The vessel remained four days and five nights, leaving March 23d. She arrived at Pieta, Peru, at 11 a. m., March 24th, and the holds were fumigated lightly. No mosquitoes came on board. She sailed that night for Callao, and a few active mosquitoes were seen on board. The steamer arrived at Callao at 4 a. m., March 27th. All the crew passed inspection, but were told to expect detention until the 29th. The work of discharging the cargo, including the lumber on the forward deck, was begun. March 27th, at 6 p. m., that is four days and fifteen minutes after leaving Guayaquil, a fireman was reported sick. The case was not reported to the authorities until the 29th, when yellow fever was diagnosed and the patient removed to a quarantine ship. The same night the second forecastle and second and third-class quarters were fumigated and kept closed for 24 hours. The next morning a second case developed, and April 1st the remaining portions of the vessel were fumigated. April 4th a third case was reported, and a fourth case developed April 7th. The whole vessel was fumigated throughout. April 8th the fifth case developed. The first, third and fifth cases died, the last death occurring April 11th. The vessel was ordered south to a colder climate by the Peruvian authorities, and the subsequent history was good. None of the people aft were infected.

Doctor Wightman concluded that the insects probably gained access to the vessel in the covered lighters rather than by flying; that the fire room, usually regarded by seafaring men as never infested with mosquitoes, is under grave suspicion; that the futility of partial fumigation is plain—even the life-boats should receive attention; that there is danger of harboring these insects in deck cargo, and that possibly *calopus* may be present on a ship without detection, even when carefully searched for.

We have indicated, in the section on the carriages of mosquitoes by railroads, ships and other conveyances, that the yellow-fever mosquito is frequently carried in the summer time by railway trains and ships far beyond its permanent habitat, and that even in these abnormal locations such mosquitoes escaping from trains or ships may, in the warm weather, find suitable breeding-places and produce one or more generations of adults. This process is going on every summer in the United States. Yellow-fever mosquitoes are being brought north of their normal range, escape from their conveyances, find breeding-places, and breed, and it is only necessary that a case of yellow fever be brought to them to enable them to become infected and to start an epidemic. Thus in St. Louis in the year of the Exposition (1904), train service from the south was especially efficient, and loaded cars came quite to the Exposition gates. Yellow-fever mosquitoes had probably escaped from these cars and bred on the Exposition grounds, as they were found there in August by Mr. A. Busck, of the Bureau of Entomology, who was stationed at the Exposition in charge of the exhibits of the Bureau.

As has also been pointed out in the section on carriage of mosquitoes by conveyances, the yellow-fever mosquito has actually extended its permanent range along the railroad running from Vera Cruz up to the City of Mexico by means of railway trains, establishing itself at places where it did not formerly occur, but in which, having the conditions of the moist tropical or moist Lower Austral Zone, it has succeeded in establishing itself in a permanent way. One of the writers' (Howard) observations in 1905, as mentioned in the previous section referred to, were confirmed by the Report of Working Party No. 1 of the Public Health and Marine-Hospital Service, and the following quotation is from this report:

"*Habitat.*—This mosquito is widely distributed, probably more so than any other species, being found throughout the tropical world and well up into the temperate zone. At one time it was supposed to be a coast mosquito, but now it is found to have spread along the commercial lines of communication to cities in the interior that furnish receptacles for breeding places. Its acclimation to the altitudes is gradual, as may be illustrated by the following example:

"About twenty-eight years ago a railroad was constructed connecting Vera Cruz with the City of Mexico. Some years later a competing line was built between these cities, but going through a different part of the country. Along the line of the Mexican Railroad yellow fever was unknown in the interior. During the construction of the railroad the disease prevailed among the employees until the road reached the foothills; it then disappeared. About nine years ago yellow fever appeared in Cordoba at about an altitude of 3000 feet, and has since been epidemic. Three years ago yellow fever appeared at Orizaba and this year (1902) there was a severe epidemic in that city. Since the construction of the railroad many cases of the disease had been received during sickness and convalescence, and many cases have developed among strangers going through Vera Cruz to that city without the disease in any way affecting the general health of the community, until three years ago.

"In the second instance, along the line of the Interoceanic Railroad we know by actual observation that the *Stegomyia fasciata* has been ascending from station to station until it has now reached Carasal at an altitude of about 3000 feet. Synchronously with the ascent of this mosquito yellow fever became epidemic in those places. El Palmar, the next station above Carasal, about 8 miles distant, does not harbor any of these insects at the present time, and though some cases were sent there from the latter station this last year, there was no spread of the infection. Jalapa, a city of about 35,000 inhabitants, at an altitude of about 4500 feet and about 20 miles above Carasal, does not harbor the *Stegomyia fasciata*, and though cases have been sent to that place for years from Vera Cruz and intermediate stations, there has never been any spread of the disease.

"It will be seen in these instances that the ascent of yellow fever and the advent of the *Stegomyia fasciata* have gone hand in hand until they have now reached an altitude of 4200 feet in the first instance and 3000 feet in the second. This is the first authentic record we have of yellow fever reaching such an altitude and is another proof that, the proper conditions supplied, the disease and the insect can be introduced and cause the same destruction of life as in more tropical regions. The distribution of this insect in our southern States has already been dwelt upon."

In an interesting article on mosquito work in Khartoum, published in the first report of the Wellcome Research Laboratories, Balfour states that *calopus* breeds in Khartoum though not to any great extent. He believes that its prevalence is due to the steamers on the Blue Nile. Together with *Culex quinquefasciatus,* it has been found breeding in large numbers in the bilge water, tank water and engine-room water of the river steamers. He believes that by this means these two species have been introduced into the towns along the upper Nile.

THE YELLOW-FEVER MOSQUITO IN EUROPE.

The yellow-fever mosquito appears to be well established in southern Europe. Meigen's description of *Culex calopus* was based on a specimen from Portugal—probably the city of Oporto—and shows that the species was established there before 1818. Ficalbi, who redescribed the insect under the name *Culex elegans* reports it from Pisa, Leghorn (Livorno), Florence and Naples, and the islands of Sicily and Sardinia. He was well aware of its habits and stated that it is not generally distributed and noted its absence from Sienna and Ravenna. Theobald reports it from Gibraltar, from Poros in Greece and Larnaka in Cyprus. We have specimens from Naples and Malaga. In Europe, as elsewhere, the climatic conditions previously set forth will limit its permanent habitat.

There can be little doubt that the yellow-fever mosquito was brought to Europe by the early Spanish conquerors, perhaps by Columbus himself. The long voyage, necessitating a large water supply, kept in a primitive way, gave ample opportunity for the mosquito to propagate en route. We have an excellent description of such a case in the account of Captain Godeheu de Riville, already mentioned on a previous page.

Under modern conditions the danger of introduction of the yellow-fever mosquito into other parts of Europe is very greatly reduced. The rapidity of the voyage is more than offset by the lack of breeding facilities on modern ships. Nevertheless the introduction of *Aëdes calopus,* and with it of yellow fever, into the more northerly portions of Europe, has occurred repeatedly within comparatively recent times. As recently as 1908 there was a small outbreak of yellow fever at the French port of Saint Nazaire with eleven cases, seven of which terminated fatally. The ship "La France" had been en route from Martinique from September 11 to 24 and no cases had developed on board. As the prescribed period of nine days since leaving port had been passed the ship was admitted without quarantine. Soon after unloading began yellow fever appeared among the crew; a journalist, who had visited the ship, and a seaman of a nearby ship were also stricken. Yellow-fever mosquitoes were found on the ship but apparently there were none on shore and the disease did not spread.

A short account of the importations and outbreaks of yellow fever which have occurred in past years in Europe is published by Dr. J. M. Eager in a series of pamphlets of the Yellow-Fever Institute (U. S. Marine-Hospital Service) Bulletins Nos. 3, 4, 5 and 8. All are traced to vessels coming directly from the West Indies or South America. In many instances (all of those in Great Britain) the cases were confined to members of the crews of the vessels, the climatic conditions having been unfavorable to the propagation of the disease and the necessary species of mosquito absent. In the cases where there was an outbreak, as in ports in Italy and southern France, these are exactly comparable to the outbreaks that have occurred in former years in the northern cities in the United States. They were summer outbreaks, ceasing on the appearance of winter, and started by the carriage of infected mosquitoes, or the arrival of persons in the infective stage of the disease at a suitable season from regions of permanent establishment.

Some recent very interesting observations have been made in the actual carrying of living *calopus* from Brazil to Europe, and the conditions under which they will exist in two portions of Europe have been studied.

Otto and Neumann, in their account of their expedition to Brazil under the auspices of Hamburg merchants, to study the sanitary conditions of the Brazilian ports, brought back with them to Hamburg living adults of *calopus* which they fed on the journey from a canary and from white rats. On arrival at Hamburg they found that even in the summer time *calopus* is not able to breed in the open air for a full generation, although they succeeded in breeding them at an artificial temperature of 27° C., and also in the ordinary temperature of the houses. They found that cold killed them rapidly. At zero (C.), they died instantly; at 4° they lived only an hour, and lived for 82 days at a temperature of from 7° to 9°. They found that eggs preserved dry did not hatch after eight days. When they were kept at 27° they would still, at the end of twelve days, give birth to larvæ. As with the eggs, the perfect insects live longest at an even temperature of about 27°.

Marchoux and Simond brought *calopus* adults with them from Brazil to France. They took 20 females and 20 males, isolating them in rearing tubes immediately after their transformations on the 15th of February some time before their departure from Rio. During the voyage they were fed on glucose. On arrival in France the 5th of May, 17 females and 9 males were alive. In France they reared five generations at the ordinary temperature, the eggs of the last hatching in September. The larvæ of this last generation lived until the middle of October without transforming. Some of them, however, gave perfect insects a little later, and these were kept until the 10th of November by feeding on glucose. One female of this generation, taking a meal of blood, laid 60 eggs which did not hatch. All adults died early in November.

This experiment, carried on through six months of the warm season of the French climate, showed that the yellow-fever mosquito can breed for four or five generations in France under conditions that exist about houses, but the German experiments show that it is unlikely that this species can produce even a generation under the natural conditions of the climate at Hamburg.

DENGUE.

This disease frequently appears in epidemic form throughout the tropics and subtropical regions. It is marked by sudden appearance, acute fever, short duration and comparative benignity, fatal cases being extremely rare. Dengue has been confused with influenza and various febrile diseases and its existence as a disease entity has even been denied. However, it is now generally recognized as a specific disease. Considering the fact that dengue has been comparatively little studied, its mosquito-born character may be said to be fairly well established. Ashburn and Craig point out that attention has been directed repeatedly to the resemblance between dengue and yellow fever, and that it is well founded in fact. Craig has recently shown, as will be seen in the following, that, like yellow fever, this disease is caused by an organism of ultra-microscopic size, almost certainly a protozoan and closely related to the causative organism of yellow fever.

Harris Graham, of Beirut, in 1902, was the first to point out that dengue is not contagious, but is due solely to the agency of mosquitoes. In a second paper, in 1903, he specified the common house-mosquito of the tropics (*Culex quinquefasciatus*) as the responsible species and this has been experimentally confirmed by some of the later investigators.

Graham was led to investigate the possibility of mosquito agency in the propagation of dengue through the fact that at Beirut, where there was a very extensive epidemic, mosquitoes were excessively abundant, while certain high and dry mountain villages where there were no mosquitoes remained free from the disease. From the previous history of the disease he made the following deductions:

"There is great multiplicity of evidence to show that it does not spread to any extent when carried away from certain low-lying regions, which are its favorite abode. Epidemics in Cuba, Jamaica, East Indies, Réunion, Martinique, and Madagascar, all seem to show that, in spite of the most active communication, dengue cannot spread to any extent when carried into dry and high places in the interior. These epidemics have shown time and again that people come down from these higher and drier places, contract the disease, and then have it break out on them in their homes to which they have returned, and there lie smitten with it for several days without the other inmates of the household catching it."

Graham went to work to prove experimentally the transfer of dengue by mosquitoes. A mother suckling her child became ill with dengue. As soon as the diagnosis was made, wire screens were put in all the windows of the house, and the mosquitoes in the interior were all destroyed. These precautions were continued until the 10th day after recovery. The infant did not cease to nurse and remained constantly in its mother's arms, yet it did not take the disease. In another case one of four children was attacked by the disease. The room was kept free from mosquitoes for 13 days. Its three brothers continued to play with it during the day and to sleep with it under the same bed-covering, and none of them contracted the sickness. In a third experiment the head of a family contracted the disease in the city and was willing to submit to Graham's instructions to protect his wife and children. The same method was followed as in the previous experiments. The rooms were kept as free from mosquitoes as possible for 17 days, and although the man had a severe attack, lasting five days, none of his family were taken ill. Several other experiments had to be abandoned because, through carelessness, mosquitoes had gained access to the rooms.

Graham then sought more positive proof and tried to inoculate the dengue fever by the bite of infected mosquitoes. Four persons volunteered for the experiment. "In each case several mosquitoes were taken from the netting of patients sick with the fever and put inside the netting of the candidate for the disease, he sleeping night after night with the mosquito in the netting." The four volunteers were placed in a house where, for a long time, there had been no sickness. They were forbidden to leave the house, or to receive any visitors. Three of them came down with the dengue in from 4 to 6 days. The fourth one passed about 15 nights with the infected mosquitoes without developing the disease; but three years before he had had a violent attack of dengue and it would seem had been thus made immune. Still Graham was not entirely satisfied that this experiment would be accepted as conclusive. He therefore conducted another experiment which eliminated as far as possible the chances of error.

"In a city where so infectious a disease was raging I still felt that these three men might have received the contagion in some other way. In order to avoid this objection mosquitoes were taken from inside the netting of a dengue patient and carried up to a village on the mountain slope where as yet no case had occurred. After visiting my patient for the infected mosquitoes I changed my clothing and took a bath before mounting my horse to ascend the mountain. In this village, about 3000 feet above the sea, there are *almost* no mosquitoes. It is dry and very healthy. I easily found two young men in different parts of the village who consented for a consideration to take their chances of having the dengue. One of them, after sleeping four nights under the netting with the mosquitoes, was taken with a severe typical attack of dengue. The other had his initial chill after having passed five nights in the company of the mosquitoes. These men continued to sleep under the mosquito nettings I had prepared for them until some time after they were well, all the mosquitoes in the netting having been killed to avoid infection of other people. No other cases of dengue occurred in this village during the summer that I could learn of, although I made the most careful inquiry."

Bancroft, in Australia, suspected the transmission of dengue by the yellow-fever mosquito, *Aëdes calopus.* Ashburn and Craig experimented on the mosquito-transmission of dengue at Fort William McKinley near Manila. Their experiments with *Aëdes calopus* resulted entirely negatively. With *Culex quinquefasciatus* they succeeded in producing a typical attack, the mosquitoes employed by them having been reared from the eggs and allowed to bite a patient with a well-marked case of dengue.

The idea that *Aëdes calopus* is concerned in the transmission of dengue has been revived again recently by J. Legendre. He describes an epidemic of dengue at Hanoï during July, August, and September, extending lightly into October, with an occasional isolated case in November. The rôle of *Aëdes calopus* in the transmission of dengue appeared justified to him, on account of the fact that the epidemiology is an exact reproduction of that of yellow fever. He states that *A. calopus* bit frequently during the duration of the epidemic and that other culicids were rare during the same period. He argued that the malady stopped at a time when the *Aëdes calopus* became rare. Moreover other biting insects, possibly capable of transmitting the disease, were absent. He offered no experimental evidence but the assemblage of facts appeared to him quite sufficient to attract serious attention. To the argument of Legendre the criticism must be made that his general observations can not be accepted against the positive work of Graham and of Ashburn and Craig. It must be pointed out that wherever *Aëdes calopus* is abundant *Culex quinquefasciatus* is nearly always equally so, relieving the former at night; it would be very strange if such a widely distributed mosquito were absent from Hanoï. Furthermore many of Legendre's observations on the habits of *Aëdes calopus* do not apply to that species and this makes it practically certain that most of the mosquitoes present belonged to other species, probably mostly *Culex quinquefasciatus*. The mosquitoes mentioned by him as being so abundant early in the season are undoubtedly species of *Aëdes*, similar in habits to those which develop with us in the snow water of early spring and which we have discussed in the chapter on habits of mosquitoes in general.

E. H. Ross gives convincing evidence that mosquitoes are a necessary factor in the transmission of dengue. He shows that in Egypt, since the towns of Port Said and Ismailia have been rid of mosquitoes they have escaped the epidemics of dengue which have invaded the rest of the country.

"Dengue fever used to be very prevalent in Port Said, as in other parts of Egypt, up to the year 1905. An epidemic of the disease occurred in the town during the summer of 1904, and in the spring of 1905. This epidemic was part of an infection of all the towns of Egypt, and was most severe. The hospitals were full of cases, and patients actually contracted the disease in them. In Port Said almost everyone suffered from an attack, and the place was regarded as fever-stricken and unhealthy. The town was full of mosquitoes, including two species of Anophelines, *Culex fatigans* and *Stegomyia* spp., in abundance. These mosquitoes were breeding in cess-pools under the houses, in basement cellars flooded with sewage, garden fountains, barrels containing water, and were a veritable pest day and night, summer and winter."

In May, 1906, a campaign against mosquitoes was launched and with the mosquitoes dengue has disappeared also.

"During the early part of that year, before the mosquito work began, dengue fever made its appearance as usual. Thirteen cases were treated in the hospital alone during April and May, and then as the mosquitoes disappeared the disease stopped and has not recurred since. In September, 1906, a severe epidemic raged throughout Egypt, beginning at Assouan and running rife in Cairo and Alexandria. It appeared in all the other towns, but Port Said and Ismailia remained free from it, no case occurring at either place. During the autumn of

1907 it again passed through Cairo and other parts of Egypt, but again Ismailia and Port Said escaped. Formerly the wards of the hospital in this town were full of cases of 'fever' during the summer months, but now the beds are used for other cases, which no longer contract fever although the mosquito nets have been removed."

Balfour shows that much the same conditions govern the spread of dengue in the Sudan. Thus an epidemic made its appearance in 1906 at Halfa, Port Sudan and elsewhere. Khartoum, however, did not have a single case of dengue and Balfour points to the scarcity of mosquitoes at this place, particularly of *Culex quinquefasciatus,* as the probable reason.

An hæmatozoan, which he compared to the *Plasmodium* of malaria, was found by Dr. Graham and considered by him to be the causative organism. Other observers have failed to find this organism and have on that account rejected his observations and conclusions. However, as we have seen above, his observations and deductions on the mosquito-transmission of the disease are confirmed by a number of workers. Bancroft considered that the causative organism of dengue is similar to that of yellow fever in respect to its ultramicroscopic size.

Craig has recently discussed dengue in connection with yellow fever and with the so-called pappataci fever, this last being transmitted by a minute biting fly of the genus *Flebotomus,* family Psychodidæ. He shows the close relationship of the three diseases and points out that they are most probably due to very similar organisms, ultra-microscopic in size and in all probability protozoan. The substance of Craig's discussion, based upon the investigation by Ashburn and himself, follows herewith.

"After a thorough examination of the blood of numerous patients with dengue we concluded that it did not contain any visible organism either bacterial or protozoal in nature, which could be considered as the cause of the disease. Our attempts at securing blood cultures also resulted negatively and in order to determine whether the cause of this fever was present in the blood we were forced to attempt the production of the disease by the inoculation of the blood from dengue patients into healthy individuals. As the disease is one which in the young and robust is not dangerous to life, we felt justified in making such experiments, and had no difficulty in procuring volunteers for this purpose.

"We first undertook to study the effect of the intravenous inoculation of unfiltered dengue blood. Eleven men were inoculated, and in seven a typical attack of the disease developed, while one case was doubtful. . . .

"These experiments proved beyond question that the cause of dengue is present in the blood of infected individuals, as the intravenous inoculation of such blood in healthy men is capable of producing a typical attack of the disease.

"As our examinations had proved that it was impossible to demonstrate a parasite in the blood we concluded that it must belong to the class of so-called ultramicroscopic organisms and in order to determine this point we inoculated two healthy individuals with filtered blood from dengue patients, with the result that severe attacks were produced in both men. In our filtration experiments we employed a Lilliput filter which was tested and controlled each time it was used, and the filtration was done under 730 millimetres pressure. After filtration a control test was made of the filter by using a bouillon suspension of *Micrococcus melitensis,* the filtrate then being incubated for two weeks, and examined every day. The filter we used retained this organism, so that it may be stated that the virus of dengue passed through the pores of a filter which prevented the passage of an organism measuring 0.4 micra in diameter. The blood from the dengue patients was defibrinated and diluted with an equal amount of normal salt solution, and the filtrate was introduced intravenously.

"In both of the men inoculated with the filtrate the attack was of severe character, and we regarded these two cases of dengue, produced by the intravenous injection of filtered dengue blood, as the most typical cases of the severe type of the disease which we observed. These experiments proved that the organism causing the disease is probably ultramicroscopic in size, and this conclusion explains the uniformly negative results obtained in the search for the parasite.

"We concluded that an organism was present in the filtrate, rather than a toxine, because of the length of the period intervening between inoculation and the appearance of clinical symptoms, and also because one of the men was inoculated with the filtered blood of an experimental case of dengue produced by the intravenous injection of unfiltered blood from a naturally infected dengue patient." . . .

"Owing to the subsidence of the epidemic we were unable to continue our mosquito experiments, which are therefore incomplete, but, taken in connection with those of Graham, prove that this disease may be transmitted by the mosquito. We felt justified in concluding that this method of transmission is the only natural one which has been proved by experiment, and which agrees with the epidemiology of the disease.

"We were further able to show experimentally that natural immunity exists against this disease, and that it is not contagious. We exposed eight healthy men to fomites, the men experimented with living in mosquito proof tents with patients suffering from dengue, throughout the entire course of the disease. They slept in their beds, wore their underclothing and pajamas, and ate and drank from the same table furniture, but none of them developed the disease.

"Our conclusions regarding the ætiology of dengue were partly to follows:

"1. No organism, either bacterium or protozoan, can be demonstrated in either fresh or stained specimens of dengue blood with the microscope.

"2. The intravenous inoculation of unfiltered dengue blood into healthy men is followed by a typical attack of the disease.

"3. The intravenous inoculation of filtered dengue blood into healthy men is followed by a typical attack of the disease.

"4. The cause of the disease is, therefore, probably ultramicroscopic.

"5. Dengue can be transmitted by the mosquito, *Culex fatigans* Wied. and this is probably the most common method of transmission.

"6. No organism of ætiological significance occurred in bouillon or citrated blood cultures.

"7. The period of incubation in experimental dengue averages three days and fourteen hours.

"8. Certain individuals are absolutely immune to dengue, as proved by our experiments.

"9. Dengue is not a contagious disease, but is infectious in the same manner as is yellow fever and malaria."

FILARIASIS.

Under this name is understood the presence in the blood or other body fluids (the lymph and urine) of nematode worms belonging to the family Filariidæ. These worms are present in man and in other vertebrates in two stages, as adult worms and as larvæ or so-called microfilariæ. The adult filariæ are found in the lymphatic vessels or in the connective tissues in various parts of the body. The two sexes are usually associated, coiled about each other, and sometimes several are coiled together. The larvæ to which the female worm gives birth find their way, in large numbers, into the blood and sometimes into the urine. Man is the host of several species of *Filaria*, and, as in the case of the malarial organisms, more than one of these may be present in the same individual.

Only one species of *Filaria* is of marked pathological importance. This is *Filaria bancrofti*, also frequently designated as *Filaria* (or *Microfilaria*) *nocturna* or *Filaria sanguinis-hominis*. The presence of this parasite does not necessarily produce sickness; in fact it is well known that the filariæ are often present without the host showing any symptoms and they are only detected when the blood is examined. However, a series of pathologic conditions are produced by the presence of filariæ in man, which, while they are seldom directly fatal, incapacitate to a greater or less degree. Manson, who is probably the best authority on filariasis, gives as the result of the parasitism of *Filaria bancrofti* in man the following filarial diseases:

"Abscess; lymphangitis; varicose groin glands; varicose axillary glands; lymph scrotum; cutaneous and deep lymphatic varix; orchitis; chyluria; elephantiasis of the leg, scrotum, vulva, arm, mamma, and elsewhere; chylous dropsy of the tunica vaginalis; chylous ascites; chylous diarrhœa, and probably other forms of disease depending on obstruction or varicosity of the lymphatics, or on death of the parent filariæ."

Filariasis is a widely distributed disease in tropical and subtropical regions and is especially common on the west coast of Africa, in South China, certain parts of India and some of the islands of the Pacific. In certain islands of the Society and Tonga groups, according to some observers, fully 70 per cent of the population are afflicted with filariasis. In America it is very prevalent in the West Indies. Dr. Mario G. Lebredo, in a recent paper, states that in the city of Havana he found 17.82 per cent of filaria infection. He points out its dangerous character and that there is reason to fear its general spread unless effective control measures are adopted. In the United States cases are occasionally found in the Southern States and isolated cases occur further north, but it can not be considered endemic. The forms of the disease appear to vary considerably according to locality and on this account the belief has been expressed that more than one species of *Filaria* is included under the name *Filaria bancrofti*.

TRANSMISSION BY MOSQUITOES.

The suggestion that mosquitoes are probably the carriers from man to man of at least one of the parasitic worms of the genus *Filaria*, in one stage or another, apparently was made about the same time by Bancroft, in Australia, and Manson, in China. The evidence was first gained by Manson about 1878, who thus became the discoverer of the first recognized transfer of a disease organism by mosquitoes. Manson found that mosquitoes which feed upon filarial blood become infected and that the filariæ undergo a metamorphosis within the body of the mosquito. The actual mode of transmission from the mosquito to man remained unknown for a long time and gave rise to a variety of conjectures. It has been determined only within the last few years. as we shall see farther on. The relation of the human parasites of this genus to mosquitoes has been established for several species, although there seems to be some confusion from the difficulty of always identifying with certainty the larval filariæ. The species concerned are: *Filaria bancrofti, F. perstans, F. demarquayi* and *F. philippinensis.* With other species of *Filaria* investigations and experiments with mosquitoes have been entirely negative and these are supposed to have some other blood-sucking arthropod for an intermediate host. In addition to certain human filariæ the transmission by the mosquito has also been proved for *Filaria immitis* of the dog.

THE FILARIAL WORMS.

The adult filariæ are long, thread-like, transparent worms. The female is considerably larger than the male. In *Filaria bancrofti* the female measures from 85–90 mm. ($3\frac{3}{8}$–$4\frac{9}{16}$ inches) in length by 0.24–0.25 mm. in diameter; the male measures about 40 mm. ($1\frac{7}{8}$ in.) in length and 0.1 mm. in diameter.

The adults of *Filaria bancrofti,* as already stated, live in the lymphatics or in the connective tissues of different parts of the body of human beings; the two sexes are often side by side, or a number of individuals are associated, and they are capable of living there for a long time. When present in the lymphatic vessels they may produce serious pathologic conditions, caused, according to Manson, by obstructing at certain points the flow of the lymph. This accumulates and dilates the vessels and lymphatic spaces, and this mechanical distension is accompanied by an irritation of the vessels and of the surrounding connective tissue. It causes frequently very great swelling, and sometimes results in the extraordinary deformities of different parts of the body known as *elephantiasis arabum.* It seems, however, that these effects do not appear until long after the infection and it is well known that in elephantiasis the filariæ are no longer present. Dr. Lebredo particularly points out the abundance of the parasites in children and the large number of cases in which marked symptoms of the disease are absent.

The female *Filaria,* enclosed in the lymphatic vessels, is viviparous and gives birth to an immense number of microscopic embryos. These embryos are eel-shaped, enveloped in a loose sheath, and are very active. They spread in the lymph and then with it into the blood, and it is in the blood that they are commonly observed

PERIODICITY OF FILARIÆ.

The embryos of *Filaria bancrofti* are usually in abundance in the blood of the peripheral circulation only during the night, or during sleep; during the day, or when the patient is awake, they can not be found. There seems to be no good explanation of this periodicity, nor is it absolutely exact, but it appears to constitute a very curious adaptation of the parasite to the nocturnal habits of the mosquito which serves as an intermediary host.*

Manson discovered the periodicity of the embryos. He placed a patient whose blood contained filariæ in a room where mosquitoes were plentiful. After the patient had gone to bed a light was placed beside him, and the door left open for the mosquitoes to enter. Later, when many mosquitoes had entered, the light was put out and the door was closed. In the morning mosquitoes filled with blood were captured, and the blood in their stomachs was examined and found to contain more filariæ than an equal quantity of blood taken directly from the patient. Since then the periodicity of the filarial embryos in the peripheral circulation has been abundantly verified. In fact, as with one species of *Filaria* the embryos appear at night while with another they are only in evidence in the daytime and with still others there is no periodicity apparent, this phenomenon is largely relied upon for determination of the parasite. The periodicity is, to a certain degree at least, determined by the habits of the host. In the case of *Filaria bancrofti* the appearance of the embryos in the peripheral circulation seems to be determined by the decreased action of the heart during sleep, rather than by the time of day. Mackenzie succeeded in reversing the time of appearance of the filariæ by inducing his patients to sleep by day and keeping them active at night. Manson found that when a patient sleeps alternately, sometimes by night, sometimes by day, the periodicity of the filariæ disappears altogether.

In the case of *Filaria perstans* and *F. demarquayi* there is no marked periodicity, and the absence of periodicity is given as one of the characteristics of *F. philippinensis*. The African *Filaria diurna,* which is believed by Manson and others to be the embryo form of *Filaria loa,* is present in the peripheral circulation only in the daytime. Numerous experiments with mosquitoes of a great variety of species, to determine the transmitter of *Filaria diurna,* have all proved negative and, while a number of diurnal blood-sucking insects have been suspected, the actual transmitter remains unknown. Fülleborn and Rodenwaldt in their investigations with filariæ of dogs from Italy found that there were two forms (one of them probably *Filaria immitis*) one of which showed periodicity while the other did not.

EVOLUTION IN THE MOSQUITO.

Later Manson ascertained that when these embryos are taken into the stomach of the mosquito they cast their envelope, penetrate the wall of the stomach and thus enter the general body cavity. The embryos then make their way into the muscles of the thorax and lodge within the muscle bundles. They now loose their activity and shorten and thicken very appreciably. It is only after they have become fixed and immovable that they actually begin to grow. According to Looss and others, when the larval filariæ have reached a length of about 0.24 mm., and 0.03 mm. thickness, they begin to show signs of returning activity.

* Recently the question of the cause of the periodicity of the filarial embryos has been very ably discussed by Dr. Ernst Rodenwaldt, based on the investigations of Fülleborn and himself. The subject is a complex one and we recommend to those sufficiently interested the perusal of the original paper.

The movements, however, to the end of the ripening stage of the larva remain slow and very circumscribed. Generally the larvæ are found in extended position in the muscle fibers, these latter disintegrating into a fine granular substance which serves as nourishment for the larvæ. A variable proportion of the larvæ die during this stage.

When the larvæ have reached a certain size (given by various investigators as from 1.006 to 1.8 mm.) they leave the muscles and return to the general body-cavity. They now are very active and generally make their way to the anterior end of the mosquito, penetrating from the thorax into the head and from thence into the labium. Occasionally filariæ go astray and get into the abdomen; they have also been found in the hollows within the legs and palpi.

Lebredo gives the following synopsis of the filarial development within the mosquito:

"1. The insect sucks the blood of a patient infected with filaria.

"2. The embryo loses its sheath in the stomach of the mosquito, ecdysis.

"3. Migration from the stomach to the thorax. This migration always takes place through the gastric wall, since both orifices of the gastric dilatation are completely closed when the stomach is full. The embryo leaves its sheath in the gastric contents or caught in the wall of the stomach, where it is left at the moment of exit.

"4. The embryo rests in the thorax, and goes through the following transformations:

"(*a*) Narrowing and invagination of the tail.

"(*b*) Invagination continues and the embryo grows shorter and wider.

"(*c*) Widening and shortening continue, and the invaginated portion forms a hyaline appendix.

"(*d*) Period of growth and formation of the three lobes."

Then follows the escape of the fully developed larvæ into the general body-cavity. This is the period of its greatest activity which generally results in its gaining the interior of the labium. Then the larva awaits the next step in its evolution, the transfer to its vertebrate host.

It has been frequently observed that the proportion of embryo filariæ contained in the blood within the mosquito's stomach is much greater than in the same quantity taken directly from the circulation. Various explanations have been offered, but Fülleborn has shown that this difference is only an apparent one, being due to the dehydration of the blood within the mosquito's stomach. At the same time this thickening of the blood makes it viscid and this serves, as it were, to hold the sheath when the embryo moults, as it does at this time.

The time necessary for the development of the larval filaria to its final active condition is variable. Manson first gave a period of seven days but no such rapid development has been observed by others and he himself admits that there may have been an error in his observation. James, in India, states the period to be from 12–14 days; Bancroft, in Australia, never saw them before the 16th or 17th day, and the period was extended to 35 days in cold weather. The governing factor is evidently the temperature. Looss found that in the Egyptian winter some of the larvæ were not fully developed until the 41st day after the infection of the mosquito. Lebredo made extensive experiments with filaria and mosquitoes in Havana. He found that from August through October the filarial larvæ developed in 15 days; from December to January from 19 to 23 days were necessary. These differences were found to co-ordinate very well with the temperatures shown by meteorological records. Fülleborn, in Germany, found that the filariæ failed to develop within the mosquito at ordinary room temperature; but he obtained satisfactory results by keeping the mosquitoes in an artificially heated room.

Filaria immitis of the dog differs somewhat from *Filaria bancrofti* in its mode of evolution in the mosquito for it undergoes development within the Malpighian tubes instead of in the thoracic muscles. The larvæ, when fully developed, pierce the closed distal ends of the Malpighian tubes and in this way get into the general body-cavity and from there into the head and finally the interior of the labium. The development of *Filaria immitis* requires about ten days; Grassi and Noè, and also Fülleborn, found that after that period the larvæ had reached the labium.

MODE OF TRANSMISSION TO THE VERTEBRATE HOST.

Manson followed the evolution of the larval filariæ within the mosquito only to development within the thoracic muscles. Upon these observations he based a theory to the effect that the mosquitoes falling into the water disintegrated rapidly after death and liberated the parasites, and that the water containing them, when drunk by human beings, carried the parasites once more into the human body. Manson was undoubtedly influenced in the formulation of this theory by the, at that time, general belief that the female mosquito was very short-lived and died immediately or soon after disposing of her eggs. Later Bancroft, finding that the female mosquito remained alive a long time, felt that the filaria must have other means of reaching its ultimate host and the necessity for some other explanation. He suggested two ways in which he thought man might become infected. One of these was by accidentally swallowing the infected mosquito; the other that while the mosquito is biting, the filaria, under some stimulus, re-entering the digestive tract when the mosquito bit, made its way along the proboscis, finally penetrating the human tissues.

Studies published in 1900, by Low, by James, and by Grassi and Noè, arrived very near the truth. In fact these latter authors succeeded in producing, as they believed, in the case of *Filaria immitis* of the dog, an infection by means of the bites of filaria-bearing mosquitoes. They further produced convincing evidence that the filariæ left the mosquito when it sucked blood, and thus they were the first to demonstrate the direct transfer of filariæ by mosquitoes. No experiments with *Filaria bancrofti* and man had ever been attempted on account of the serious consequences of filarial infection.

The discovery by the above-mentioned investigators, at nearly the same time, that the larval filariæ, upon leaving the thoracic muscles of the mosquito, for the greater part made their way to the proboscis, and there remained, head foremost, for an indefinite period, pointed to direct transfer by the mosquito's bite.

Low, whose paper was published first, stated that the filariæ reached the human host "not along the salivary duct as is the case with the malarial parasite, for this channel is manifestly too minute to accommodate a body relatively so gigantic as the filaria; not along the œsophagus or pharynx, as Bancroft suggested; but by making an independent passage through the base of the labium, and pushing forwards along the proboscis between labium and hypopharynx amongst the stylets." Low was correct in his statement that the filariæ do not leave the mosquito by the salivary ducts or œsophagus but he was mistaken, as we shall see, in the manner of their escape. The error was due to faulty interpretation, as his own illustrations, from his microscopic preparations, show.

James, a little later in the same year, as the result of experiments in India with filaria-bearing mosquitoes, announced that he had found the ripe larvæ inhabiting the labium. Throughout his paper he employs the term "labrum" instead of labium, but reference to his figures shows that this is a lapsus and that he had found the true condition. In consequence he accepted the doctrine of the transmission of filariæ direct by the mosquito, which he had up to then opposed. He procured further evidence by observing the behavior of filariæ, taken from the mosquito, when placed in water and in blood. He found that those larvæ which had been placed in water soon became slower in their movements, and, after two and a half hours were dead. Those placed in blood retained their activity undiminished for a long time and lived fully seven hours.

In papers published still later in the same year Grassi and Noè verified that the ripe filarial larvæ inhabit the interior of the labium and there wait until the mosquito bites to migrate to their ultimate host. They supposed that when the labium was doubled upon itself in the act of biting a tension of this organ was produced which caused it to rupture along the dorsal groove and liberate the filariæ. They believed that they had detected a labium thus ruptured among their preparations.

Finally, in 1901, the true method of escape of the filariæ from the labium was indicated by Annett, Dutton and Elliott, although they were unable to demonstrate it. These authors studied carefully the mouth-parts of the mosquito and found that dorsally at the tip of the labium and connecting the labellæ there is a delicate membrane and that this is the weakest point in the labium. They showed that the filariæ most probably made their exit at this point, not only because it is the weakest, but also because the path of the filariæ lay in this direction and they were often found in the anterior portion of the labium. The membrane in question has been termed, in honor of one of these investigators "Dutton's membrane."

That this last explanation is the correct one was not demonstrated until 1905, when Dr. Mario G. Lebredo, of Havana, published the results of his investigations. Lebredo was not only able to show that the filarial larvæ escape by piercing the delicate membrane at the tip of the labium, but also that this does not happen when the mosquito sucks water, sweets or vegetable juices—a suggestion which had been previously made but generally rejected.

Lebredo shows by his experiments that it is the heat from the body of the prospective host that stimulates the filariæ to leave the proboscis of the mosquito.

"A mosquito is selected in which the filariæ have reached their final stage of development, and are lodged in the labium. It is best to select an insect 28 to 30 days, or more, after infection. After removal of the wings and legs the insect is placed alive upon a slide and irrigated with a very weak salt solution. No cover-glass is employed. Under the microscope it is possible to see, through the transparent walls of the labium, the actively moving worms within that structure.

"If no pressure is used, these movements may be watched for hours without observing the escape of a single worm.

"Usually all the setæ are enclosed within the labium, thus preventing a clear view of the movements of the filaria. In order to obviate this difficulty I press very lightly with the side of a needle upon the base of the proboscis, and then with the point of a needle inserted between the setæ and the labium, I pry them further apart. The filariæ can now be distinctly seen actively moving and agitating the two tracheal tubes. The worms occupy usually the proximal third of the labium; sometimes they extend further out.

"The slide is now placed near the flame of a Bunsen burner. This must be done very carefully in order to avoid fatal over-heating to the insect and the parasite. Watching the preparation, an unusual activity in the movements of the filariæ is now to be seen, and the cephalic end particularly becomes agitated as if seeking a point of exit. This cannot be found laterally because of the chitinous covering, and the filaria advances toward the anterior extremity of the labium. If the liquid is allowed to cool, the movements become slower and even cease altogether. Upon warming carefully again, and adding more tepid fluid, the movements are revived until the worms reach the point of the labium. If now the application of heat is stopped, we find that the worms appear to feel around with their cephalic extremity, but fail to break out.

"I am sure that there is no natural orifice at the terminal end of the labium, because if there were, the filaria, having reached this point, would find no obstacle to its exit. And, furthermore, a careful study of the extremity fails to discover any orifice.

* * * * * * * *

"If the heat is kept up carefully and steadily we can see the embryo seeking the point, making pressure there, and finally perforating the cuticle at a certain point.

"This perforation is made quite suddenly, for we see the cephalic end jump out, as it were; the rest of the worm following slowly by serpentine movements. As soon as it reaches the fluid the serpentine movements continue, but the worm ceases to be able to advance. This remarkable difference in the results obtained by the movement indicates that the soft tissues at this stage are the natural element of the worm, and that it is prepared to move on into the human tissues directly from the mosquito. In water, on the other hand, the filaria not only cannot live, but cannot even move from place to place.

"In their exit the worms follow the regular order in which they occur in the labium and head. We have seen two worms making their exit at the same time.

"Occasionally, after two embryos have been started out, it has been necessary to warm the liquid again in order to bring other worms down from the head to the labium. Of course, after the first embryo has broken out, the others find their way out with greater readiness."

Finally, the last step in the process of filarial infection remained obscure until 1908, when it was made known by Fülleborn. This is the mode of entry of the worms into the body of the vertebrate host. It was supposed that the filariæ gained access to the body directly through the wound inflicted by the mosquito and while it is engaged in sucking. This Fülleborn disproved, both by careful direct observation and by long series of preparations of skin with the parasites in the act of penetrating.

"According to the suppositions of most authors the place at which the filariæ enter the skin is through the channel made by the puncture of the mosquito. At this point the entrance of the filariæ can not well take place during the process of sucking, for between and besides the piercing setæ the filariæ can not penetrate because the stylets form a compact bundle which tightly plugs the channel of the puncture. It is possible that they sometimes choose this prepared passage after the mosquito has taken flight, for during the act of sucking, which only lasts a very short time, it appears that, as a rule, they do not enter the skin at all; in my experiments I only found them in the skin when there had been an interval, not too short, between the act of sucking and the cutting away of the skin (involving the killing of the filariæ). But that the filariæ certainly do not need the perforation made by the mosquito to get into the depths of the skin is apparent from the fact that I also found them in the skin when no mosquito puncture had taken place and they were simply placed upon the skin of the experimental animals; they evidently behave similarly to the *Ankylostoma* larvæ, a supposition which Eysell has also expressed."

MOSQUITOES THAT TRANSMIT FILARIASIS.

The full development of the filarial larvæ, and consequently their transmission, can only take place with certain species of mosquitoes. In others the embryos are either digested or eliminated through the digestive tract, or they undergo a partial metamorphosis and then die.

In the case of *Filaria bancrofti* a number of species of mosquitoes are effective hosts, but in an unequal degree. The most important transmitter of this parasite is evidently *Culex quinquefasciatus,* the common house-mosquito of the tropics. This is the species which has been used by Bancroft in Australia under the name *Culex ciliaris,* by Manson in China and by Low in Santa Lucia under the name *Culex fatigans,* and by Lebredo at Havana as *Culex pipiens.* There is every reason for believing that these observers all had this same mosquito, which is so widely distributed and abundant throughout the tropical and subtropical regions. James, in India, found *Anopheles rossii,* and a second undetermined species of the same genus, to be efficient hosts; the same was found to be true with *Anopheles costalis* by Annett, Dutton and Elliott in West Africa. For Italy and Spain *Anopheles maculipennis, A. bifurcatus, A. pseudopictus* and *Culex penicillaris* are reported as transmitters. The identification of this last mosquito seems open to doubt. Other species of mosquitoes in which *Filaria* has been found to develop are *Anopheles annulipes, A. albimanus, A. minutus, A. nigerrimus, Aëdes calopus, Mansonioides uniformis* and *Mansonia pseudotitillans* (*?=titillans*). James, in his experiments, found that *Filaria bancrofti* developed partially in *Culex microannulatus* and *Aëdes scutellaris.*

Ashburn and Craig have followed the development of *Filaria philippinensis* in *Culex quinquefasciatus* but got only negative results with *Aëdes calopus.* There appears to be some doubt that this *Filaria* is a valid species but Looss considers it distinct.

Fülleborn, in his experiments in Germany, used *Anopheles maculipennis* and *Aëdes calopus.* He found that *Filaria bancrofti, F. perstans* and *F. demarquayi* underwent partial development in the *Anopheles* and then perished. One *Aëdes calopus* showed a developmental stage of *Filaria demarquayi* in the thoracic muscles. With *Filaria immitis* of the dog Fülleborn found that *Anopheles maculipennis* became practically always infected. *Aëdes calopus* became infected in the proportion of one to five. Nevertheless he found this latter species the more satisfactory for experimentation because, in the high temperature necessary for the development of the filariæ, the *Anopheles* suffered great mortality.

SUGGESTED RELATIONS OF MOSQUITOES WITH OTHER DISEASES.

While it seems reasonable to suppose that mosquitoes, together with other biting insects, may be responsible for the transfer of certain diseases which do not necessarily require a secondary host for complete development, such relation has never heen proved. They have been accused or suspected of being important agents in the transfer of leprosy, in the carriage of bubonic plague, of tropical ulcer and other skin diseases, of Malta fever, of the horse sickness of South Africa, and of other maladies, even of cancer. Some of these diseases have never been satisfactorily investigated. With others it has been shown that they are transmitted in other ways. Thus bubonic plague is now well known to be transmitted by the bite of certain fleas and Malta fever is acquired through the consumption of the milk of goats affected with this disease.

EFFECT OF MOSQUITO BITES.

The bite of nearly all mosquitoes causes some irritation but this varies in degree with different species and with the individual bitten. It is by no means always the largest mosquito which inflicts the most painful bite. Very serious results have been attributed to mosquito bites. However, beyond a doubt, when serious results follow these are due, not to the bite itself, but to the scratching indulged in by the victim. In such cases it is the infection from the finger nails which causes the trouble and this may indeed be serious. In sensitive persons the inclination to scratch is well-nigh irresistible; it will, however, be found that if one exercises self-control in this respect the effect of even the severest bite will pass very quickly.

Réaumur thought that a poisonous fluid was secreted by the mosquito and that its purpose was to cause the blood to flow more readily when it bites. Later observers either accepted this statement or denied the existence of such fluid, stating that the swelling following the bite was caused by the irritation of the puncture without the aid of a poison. Dimmock (1881) convinced himself that a poisonous saliva was introduced. He noticed that if the mosquito punctures the skin without entering a blood vessel, although it may insert its proboscis for nearly its full length, no poisonous effect is produced upon the skin, but when the proboscis strikes blood and the insect draws it, the subsequent swelling and poisonous effects are obvious. He argued that these effects indicate a constant outpouring of some sort of poisonous fluid during the blood-sucking process.

Miall (1895) maintains that it can not positively be said whether poison is injected into the wound or not. His statement is, "No poison gland has hitherto been demonstrated, and there is some reason to believe that the irritation of the wound is slight in cold weather and only becomes intense during great summer heat." But in our chapter on the anatomy of mosquitoes we have shown that Maclosky has demonstrated a differentiation in the salivary glands, one of each set being modified to secrete the poison. Fritz Schaudinn is inclined to believe that the mosquito bite is poisonous not because of any poisonous secretion of the salivary glands, but because of toxins produced by plant parasites in its œsophageal diverticula.

The purpose of the mosquito poison has been the subject of some conjecture. The old Réaumur hypothesis, that it causes the blood to become more liquid and more readily sucked up by the mosquito, has had its adherents. Osten Sacken and Miall, however, believe that it is probable that the piercing mouth-parts of the mosquito were originally acquired for the purpose of sucking the juices of plants, and Maclosky advances the idea that the chief food of mosquitoes is not animal blood but the proteids of plants, and that probably the poison injected may prevent the coagulation of proteids and so promote the process of suction.

Prof. John B. Smith was inclined to believe in the Réaumur hypothesis, that the poison prevents the clotting of the blood in the stomach of the mosquito. He says:

"A mosquito bites, primarily to obtain food; there is neither malice nor venom in the intent, whatever there may be in the act. Theoretically there would seem to be no reason why there should be any pain from the introduction of the minute lancets of the insects, and the small amount of blood-letting is usually a benefit rather than otherwise. Unfortunately, however, in its normal condition the human blood is too much inclined to clot to be taken unchanged into the mosquito stomach; hence, when the insect bites, a minute droplet of poison is introduced, whose function it is to thin out the fluid and make it more suitable for mosquito digestion. It is this poison that sets up the inflammation and produces the irritation or swelling. If we make a puncture wound with a fine needle, a small droplet of blood will exude which will almost at once harden into a clot, and if we attempt a little later to break that clot, we will find it tough and hard to disintegrate. If we allow a mosquito to bite until it is fully gorged and then smash it, we find that the blood from the gorged abdomen is much more fluid and spreads out thin. If we further allow it to dry, there will be no clot; but a thin spread of material which is brittle and breaks readily into fragments.

"The pain is caused entirely by the action of the poison in breaking up the blood, and as the first act of a biting mosquito is to introduce this poison into the wound, the pain and inflammation will be the same, whether the insect gets its meal or not. In fact, it has been said that if a mosquito be allowed to suck its fill and then fly, the bite will not itch, and there is just a basis of justification for this. The poison introduced will act upon just so much blood, and if that be absorbed with the poison by the insect, little or nothing will be left in the wound. If, however, the mosquito be killed as soon as the poison is introduced, the latter will have to be absorbed by the human system and the disintegrated blood mass with it. This is the basis of fact behind the popular belief that a bite does not hurt if you allow a mosquito to complete its meal and withdraw the lancets naturally."

The popular belief referred to by Smith in this last sentence seems to have a basis of exact observation, and such an observation was originally made by Humboldt in the early part of the last century. Humboldt states that when one lets a mosquito suck its fill there is no swelling and no pain. He often tried the experiment on himself, in the valley of the Rio de la Magdalena, on the advice of the natives. He wondered whether the insect only injects the poison at the moment when it is frightened away, or whether it sucks back the poison when it is allowed to suck as much as it will. He inclined to the latter opinion, for when he allowed *Culex cyanopterus* * to peaceably bite the back of his hand, he noticed that the pain, which was very strong in the beginning, diminished as the insect continued to pump up the blood and that it ceased absolutely at the moment when the sucking was finished. One of the writers is inclined to believe from his own experience that when a mosquito is allowed to drink her fill there is less irritation than when she is frightened away by an ill-advised slap.

RELATIVE SUSCEPTIBILITY.

The amount of irritation caused by the poison of mosquitoes varies greatly with different individuals. This was already pointed out by Humboldt and other early writers. Some people suffer severely from their bites, while others are not at all affected. This is a matter of common observation. We have already shown in quoting from Réaumur severe instances of the irritation caused by the bites of many of these insects, which caused the limbs to swell until amputation was seriously considered. Réaumur also brings out the point of relative susceptibility. He found that not only are peasants with sun-burned and work-hardened skin bitten as often as ladies with delicate skin, but he states that he has observed that among ladies with whom he happened to be in the country, some were attacked while others with equally fine skin were not attacked. Arguing then that certain skins are distasteful to mosquitoes he considered that there must be some means of rendering all skins distasteful. He advocates experimenting with different liquids for this purpose and especially decoctions of such plants as the mosquitoes seem to avoid, as he had noticed them to leave some plants immediately after alighting on them. Smith's observations on this point are interesting:

"Susceptibility to mosquito poisoning varies enormously. Some persons do not even notice mosquitoes biting under ordinary conditions, though they may be honestly unaware of their exemption. I remember enjoying a drive with a man

* Probably the species described by Humboldt as *Culex cyanopennis* (Voyage aux Rég. equinoct. v. 2, p. 340 (1819)): we have not been able to identify it.

who told me of his sufferings from mosquito bites while a specimen was deliberately filling itself from his lower lip, not in the least disturbed by the talk. Mr. Brehme does not notice marsh mosquito attacks at all; but he bolts green-bead flies. Mr. Brakeley captures *perturbans* by looking at his ankles occasionally and bottling any specimens he may see there. It is only when he sees them that he knows they are present and yet *perturbans* is a hard biter!

"On the other hand, I have met many persons to whom even a single bite was a torture and who were in positive agony during a stay along shore. In such persons puffy swellings appear and cover an area an inch or more in diameter from a single bite. When bites are at all numerous the suffering is intense and the appearance pitiable. Between these extremes all intergrades are found; but I have never found a man yet, who, in a mosquito region, had not at times been driven out by mosquitoes.

"Personally the insects bother me, but the pain is usually temporary and, if I refrain from scratching, a matter of a few minutes only. And this brings up the matter of species; for a man may be exempt as against one species and not another. Boatmen and others along shore, who never know whether mosquitoes are present in their own territory, suffer severely and swear loudly when they get within range of the inland mosquitoes; and the contrary is equally true.

"Nowadays I scarcely mind *sollicitans* at all, and *cantator* does not worry me much. *C. pipiens* is more troublesome and its bites sometimes cause distinct swellings; but I can sleep through any attack save that of *Anopheles*. This has a different song and a different manner of attack, and somehow I do not feel at ease near it. I will awaken at any time to a specimen buzzing about, where I would not mind any species of *Culex*. These are, of course, personal characteristics, and may not apply to any other individual. The case is cited merely to show that there is a difference between the virus of the species and between the susceptibility of individuals.

"There is also a difference in the manner of attack. Some species hover about for a long time, selecting a place to puncture; others dart in at once, giving scarcely any notice of their arrival; some fly at the least disturbance, while others can scarcely be driven off when once they have tasted blood. . . ."

There can be little doubt that people become inoculated against this poison. Persons living in mosquito-ridden localities as a rule suffer less than those who come there from more favored regions, and it seems likely that after a severe case of mosquito poisoning the inoculating effect may last for a long time. An instance of this was sent us in 1900 by the late lamented Edward Everett Hale, who wrote:

"I think I am an instance of inoculation by mosquitoes' virus. More than fifty years ago I went into the Maine woods, going to Katahdin. The first afternoon we were out hardly an hour, but at night, when we went into camp, I counted sixty well defined mosquito bites on my right hand alone. Now from that time to this I have hardly been troubled by mosquitoes. I dislike their song at night, and if I saw one on my hand I should kill it, but after the moment of the sting I never remember that I have been bitten."

ECONOMIC LOSS FROM MOSQUITOES.

LOSS FROM MALARIA.

The senior author, in a publication of the U. S. Department of Agriculture entitled "Economic loss to the people of the United States through insects that carry disease," has discussed the effect of malaria as follows:

"The west coast of Africa, portions of India, and many other tropical regions have always, at least down to the present period, been practically uninhabitable by civilized man, owing to the presence of pernicious malaria. The industrial and agricultural development of Italy has been hindered to an incalculable degree by the prevalence of malaria in the southern half of the Italian peninsula, as well as in the valley of the Po and elsewhere. The introduction and spread of malaria in Greece is stated by Ronald Ross, and with strong reasons, to have been largely responsible for the progressive physical degeneration of one of the strongest races of the earth.

"In the United States, malaria, if not endemic, was early introduced. The probabilities are that it was endemic, and it is supposed that the cause of the failure of the early colonies in Virginia was due to this disease. It is certain that malaria retarded in a marked degree the advance of civilization over the North American continent, and particularly was this the case in the march of the pioneers throughout the Middle West and throughout the Gulf States west to the Mississippi and beyond. In many large regions once malarious the disease has lessened greatly in frequency and virulence owing to the reclamation of swamp areas and the lessening of the number of the possible breeding places of the malarial mosquitoes, but the disease is still enormously prevalent, particularly so in the southern United States. There are many communities and many regions in the North where malaria is unknown, but in many of these localities and throughout many of these regions Anopheles mosquitoes breed, and the absence of malaria means simply that malarial patients have not entered these regions at the proper time of the year to produce a spread of the malady. It has happened again and again that in communities where malaria was previously unknown it has suddenly made its appearance and spread in a startling manner. These cases are to be explained, as happened in Brookline, Mass., by the introduction of Italian laborers, some of whom were malarious, to work upon the reservoir; or, as happened at a fashionable summer resort near New York City, by the appearance of a coachman who had had malaria elsewhere and had relapsed at this place. In such ways, with a rapidly increasing population, malaria is still spreading in this country.

"To attempt an estimate of the economic loss from the prevalence of malaria in the United States is to attempt a most difficult task. Prof. Irving Fisher, in one of his papers before the recent International Tuberculosis Congress, declared that tuberculosis costs the people of the United States more than a billion dollars each year. In this estimate Professor Fisher considered the death rate for consumption, the loss of the earning capacity of the patients, the period of invalidism, and the amount of money expended in the care of the sick, together with other factors. In making these estimates he had a much more definite basis than can be gained for malaria. The death rate from malaria (as malaria) is comparatively small and is apparently decreasing. Exact figures for the whole country are not available. From a table comprising 22 cities it appears that two-thirds of the deaths from malaria in the United States occur in the South—one-third only in the North. The death rate from malaria by States is available only for the following registration States: California, Colorado, Connecticut, District of Columbia, Indiana, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, South Dakota, and Vermont, all of which are Northern States. For these States the census reports from 1900 to 1907, inclusive, give the following death rates:

DEATHS DUE TO MALARIA IN THE REGISTRATION STATES.
1900-1907.

Year.	Number of deaths from malaria per 100,000 population.	Total deaths from malaria.	Year.	Number of deaths from malaria per 100,000 population.	Total deaths from malaria.
1900	7.9	2434	1904	4.2	1391
1901	6.3	1791	1905	3.9	1321
1902	5.4	1738	1906	3.5	1415
1903	4.3	1410	1907	2.8	1166

"Estimating, from the preceding table, the average annual death rate due to malaria, at 4.8 per 100,000 population, and considering that the registration area includes only 16 of the Northern States (assuming fairly, however, that the death rate in the other Northern States is the same), it seems reasonably safe to conclude that the death rate from malaria for the whole United States must surely amount to 15 per 100,000. It is probably greater than this, since the statistics from the South are city statistics, and malaria is really a country disease. Thus it is undoubtedly safe to assume that the death rate for the whole population of the United States is in the neighborhood of 15 per 100,000. This would give an annual death rate from malaria of nearly 12,000 and a total number of deaths for the 8-year period 1900–1907 of approximately 96,000.

"But with malaria perhaps as with no other disease does the death rate fail to indicate the real loss from the economic point of view. A man may suffer from malaria throughout the greater part of his life, and his productive capacity may be reduced from 50 to 75 per cent, and yet ultimately he may die from some entirely different immediate cause. In fact, the predisposition to death from other causes brought about by malaria is so marked that if, in the collection of vital statistics, it were possible to ascribe the real influence upon mortality that malaria possesses, this disease would have a very high rank in mortality tables. Writing of tropical countries, Sir Patrick Manson declares that malaria causes more deaths, and more predisposition to death by inducing cachectic states predisposing to other affections, than all the other parasites affecting mankind together. Moreover, it has been shown that the average life of the worker in malarious places is shorter and the infant mortality higher than in healthy places.

"But, aside from this vitally important aspect of the subject, the effect of malaria in lessening or destroying the productive capacity of the individual is obviously of the utmost importance, and upon the population of a malarious region is enormous, even under modern conditions and in the United States. It has been suggested that the depopulation of the once thickly settled Roman Campagna was due to the sudden introduction of malaria by the mercenaries of Scylla and Marius. Celli, in 1900, states that owing to malaria about 5,000,000 acres of land in Italy remain—not uncultivated, but certainly very imperfectly cultivated. Then also, in further example, in quite recent years malaria entered and devastated the islands of Mauritius and Réunion, practically destroying for a time the productiveness of these rich colonies of Great Britain and France.

"Creighton, in his article on malaria in the Encyclopædia Britannica, states that this disease 'has been estimated to produce one-half of the entire mortality of the human race; and inasmuch as it is the most frequent cause of sickness and death in those parts of the globe that are most densely populated, the estimate may be taken as at least rhetorically correct.'

"Is it possible to make any close estimate of the ratio between the number of deaths from malaria and the number of cases of the same malady? No perfectly sound basis for such an estimate is apparent. In the English translation of Celli's work on 'Malaria According to the New Researches,' published in London in 1900, it is stated that the mortality from malaria in Italy from 1887 to 1898 varied from 21,033 in the first-named year to 11,378 in the last-named year, and the mean mortality for the period is assumed to be about 15,000. In 1896 a count of the patients in the hospitals in Rome was made, and the mortality rate of 7.75 per thousand of the actual patients was established. Calculating then on this basis, and at this rate, the number of cases per year for Italy was placed at about 2,000,000. According to this estimate, and with the average mortality for the United States of 12,000 as above indicated, the approximate number of cases for the United States would be about 1,550,000. It seems obvious, however, that Celli, in using the basis of hospital patients only, must have underestimated the number of cases for the Kingdom, since of the people in the country suffering from malaria the proportion entering the hospital must be relatively small. Therefore the death rate from malaria of malarial patients in the hospital must be greater than the death rate from malaria of the people who suffer from this disease in the whole country. In fact, so great must this discrepancy necessarily be that it would not seem at all unlikely to the writer if the number of persons suffering from malaria in Italy were in reality nearer 3,000,000 than 2,000,000.

"The same argument will hold for the United States, and more especially so since as a rule malaria in this country is of a lighter type than in Italy; in fact an estimate of 3,000,000 cases of malaria in the United States annually is probably by no means too high. It will not be an exaggeration to estimate that one-fourth of the productive capacity of an individual suffering with an average case of malaria is lost. Accepting this as a basis, and including the loss through death, the cost of medicines, the losses to enterprises in malarious regions through the difficulty of securing competent labor, and other factors, it is safe to place the annual loss to the United States from malarial disease under present conditions at not less than one hundred millions of dollars. Celli has shown that in Italy the great railway industries, for example, feel the effect of malaria greatly. According to accurate calculations one company alone, for 1400 kilometers of railway and for 6416 workmen in malarious zones, spends on account of malaria 1,050,000 francs a year. The same writer states that the army in Italy from 1877 to 1897 had more than 300,000 cases of malaria.

"The loss to this country in the way of retardation of the development of certain regions, owing to the presence of malaria, is extremely great. Certain territory containing most fertile soil and capable of the highest agricultural productiveness is practically abandoned. With the introduction of proper drainage measures and antimosquito work of other character, millions of acres of untold capacity could be released from the scourge at a comparatively slight expenditure. These regions in the absence of malaria would have added millions upon millions to the wealth of the country. Drainage measures are now being initiated by the United States. Parties of engineers are being sent by the

It means a listless activity in the world's work that counts mightily against the wealth-producing power of the people. Finally it means from two to five million or more days of sickness with all its attendant distress, pain of body, and mental depression to some unfortunate individuals of those five States.'

"Referring to the Delta region in Mississippi, which lies along the Mississippi River in the western part of the State of Mississippi, extending from the mouth of the Yazoo River north nearly to the Tennessee line, Herrick says that it is the second best farming land in the world, having only one rival, and that is the valley of the Nile.

"'Still,' says Herrick, 'this land to-day, or at least much of it, can be bought at ten to twenty dollars an acre. Thousands of acres in this region are still covered with the primeval forest, and the bears and deer still roaming there offer splendid opportunities for the chase, as evidenced by the late visit of our Chief Executive to those regions for the purpose of hunting. Why is not this land thickly settled? And why is it not worth from two to five hundred dollars an acre? If it produces from one to two or more bales of cotton to an acre, and it does, it ought to be worth the above named figures. A bale of cotton to the acre can be produced for thirteen dollars, leaving a net profit of twenty to forty dollars for each bale, or forty to eighty or more dollars for each acre of land cultivated. Moreover, this land has been doing that for years, and will do it for years to come, without the addition of one dollar's worth of fertilizer. Land that will produce a net profit of forty to eighty dollars an acre is a splendid investment at one, two, or even three hundred dollars an acre. Yet this land does not sell in the market for anything like so much, because the demand is not sufficient, *for white people positively object to living in the Delta on account of malarial* chills and fevers. A man said to me not long ago that he would go to the Delta that day if he were sure that his own life and the lives of the members of his family would not be shortened thereby. There are thousands exactly like him, and the only reason that these thousands do not go there to buy lands and make homes is on account of chills and fevers. But there is a time coming, and that not far distant, when malaria in the Delta will not menace the would-be inhabitants. When that time comes it will be the richest and most populous region in the United States.'"

At the beginning of this chapter are mentioned the ravages of the disease in India and Africa. The situation in these countries is well summed up by Prof. A. E. Shipley in a paper on malaria,* from which we quote:

"It has been said that one-half the mortality of the human race is due to malaria. This may very well be an exaggeration, but there can be little doubt that, of all the ills that flesh is heir to, malaria is the most deadly, and exercises the most profound influence on the distribution and activities of man. It will be seen later that the disease is most rife where the densest populations are found, and the mortality of such closely crowded area as India gives some idea of the enormous loss of life and the widespread suffering caused by this disease. In 1892, out of a total population in India of 217,255,655, the deaths from all causes reached the figure of 6,980,785. Of these, 4,921,583 were ascribed to 'fever.' All these fevers were not, of course, malarial, but comparison with other statistics leads to the belief that a high percentage of them was caused by malaria. Major Ross states that in 1897 over 5,000,000 deaths in the same country were recorded as due to 'fever,' and that out of a total strength of 178,197 men in the British army in India, 75,821 were treated in the hospitals for malaria. Fifty years ago the loss from malaria amongst the European popu-

* Pearls & Parasites, by Arthur E. Shipley, London, 1908. (The chapter on malaria covers

were 192 deaths at Pensacola; in 1887, 62 deaths in the Southern States; in 1893, 52 deaths; in 1897, 484; in 1898, 2456 cases with 117 deaths; in 1903, 139 deaths were recorded, mostly at Laredo, Tex., and in 1905 there was a serious outbreak at New Orleans and in neighboring towns, including one locality in Mississippi, in which 911 deaths were recorded for the whole country.

"The actual loss of life from yellow fever during all these years, when compared with the loss from other diseases, has been comparatively slight, but the death rate is perhaps the most insignificant feature of the devastation which yellow fever epidemics have produced, and the disease itself has been but a small part of the affliction which it has brought to the Southern States. The disease once discovered in epidemic form, the whole country has become alarmed; commerce in the affected region has come virtually to a standstill; cities have been practically deserted; people have died from exposure in camping out in the highlands; rigid quarantines have been established; innocent persons have been shot while trying to pass these quarantine lines; all industry for the time has ceased. The commerce of the South during the epidemic of 1878, for example, fell off 90 per cent, and the hardships of the population can not be estimated in monetary terms. With such industrial and commercial conditions existing from Texas to South Carolina, many industries at the North have suffered, and, in fact, the effect of a yellow fever summer in the South has been felt not only all over the United States, but in many other portions of the world.

"All these conditions, as bad as they have been, do not sum up the total loss to the national prosperity during past years. Cities like Galveston, New Orleans, Mobile, Memphis, Jacksonville, and Charleston, subject to occasional epidemics, as they have been in the past, have not prospered as they should have done. Their progress has been greatly impeded by this one cause, and thus the industrial development of the entire South has been greatly retarded."

ENDEMIC DISEASES AS AFFECTING THE PROGRESS OF NATIONS.*

"In referring to the spread of malaria in Greece, the relation of this disease to the rise and fall of national power has been touched upon in an earlier paragraph. The subject is one of the widest importance and deserves a more extended consideration.

"The following paragraphs are quoted from Ronald Ross's address on Malaria in Greece, delivered before the Oxford Medical Society, November 29, 1906:

"'Now, what must be the effect of this ubiquitous and everlasting incubus of disease on the people of modern Greece? Remember that the malady is essentially one of the infancy among the native population. Infecting the child one or two years after birth, it persecutes him until puberty with a long succession of febrile attacks, accompanied by much splenomegaly and anæmia. Imagine the effect it would produce upon our own children here in Britain. It is true that our children suffer from many complaints—scarlatina, measles, whooping cough—but these are of brief duration and transient. But now add to these, in imagination, a malady which lasts for years, and may sometimes attack every child in a village. What would be the effect upon our population—especially our rural population—upon their numbers and upon the health and vigour of the survivors? It must be enormous in Greece. People often seem to think that such a plague strengthens a race by killing off the weaker individuals; but this view rests upon the unproven assumption that it is really the weaker children which can not survive. On the contrary, experience seems to show that

* Quoted from Howard, L. O., Economic loss to the people of the United States through insects that carry disease. U. S. Dept. Agr. Bur. Ent. Bull. 78, pp. 36-38, 1909.

it is the stronger blood which suffers most—the fair, northern blood which nature attempts constantly to pour into the southern lands. If this be true, the effect of malaria will be constantly to resist the invigorating influx which nature has provided: and there are many facts in the history of India, Italy, and Africa, which could be brought forward in support of this hypothesis.

"'We now come face to face with that profoundly interesting subject, the political, economical, and historical significance of this great disease. We know that malaria must have existed in Greece ever since the time of Hippocrates, about 400 B. C. What effect has it had on the life of the country? In prehistoric times Greece was certainly peopled by successive waves of Aryan invaders from the north—probably a fair-haired people—who made it what it became, who conquered Persia and Egypt, and who created the sciences, arts, and philosophies which we are only developing further to-day. That race reached its climax of development at the time of Pericles. Those great and beautiful valleys were thickly peopled by a civilization which in some ways has not been excelled. Everywhere there were cities, temples, oracles, arts, philosophies, and a population vigorous and well trained in arms. Lake Kopais, now almost deserted, was surrounded by towns whose massive works remain to this day. Suddenly, however, a blight fell over all. Was it due to internecine conflict or to foreign conquest? Scarcely; for history shows that war burns and ravages, but does not annihilate. Thebes was thrice destroyed, but thrice rebuilt. Or was it due to some cause, entering furtively and gradually sapping away the energies of the race by attacking the rural population, by slaying the new-born infant, by seizing the rising generation, and especially by killing out the fair-haired descendant of the original settlers, leaving behind chiefly the more immunised and darker children of their captives, won by the sword from Asia and Africa? . . .

"'I can not imagine Lake Kopais, in its present highly malarious condition, to have been thickly peopled by a vigorous race; nor, on looking at these wonderful figured tombstones at Athens, can I imagine that the healthy and powerful people represented upon them could have ever passed through the anæmic and splenomegalous infancy (to coin a word) caused by widespread malaria. Well, I venture only to suggest the hypothesis, and must leave it to scholars for confirmation or rejection. Of one thing I am confident, that causes such as malaria, dysentery, and intestinal entoza must have modified history to a much greater extent than we conceive. Our historians and economists do not seem even to have considered the matter. It is true that they speak of epidemic diseases, but the endemic diseases are really those of the greatest importance. . . .

"'The whole life of Greece must suffer from this weight, which crushes its rural energies. Where the children suffer so much, how can the country create that fresh blood which keeps a nation young? But for a hamlet here and there, those famous valleys are deserted. I saw from a spur of Helikon the sun setting upon Parnassus, Apollo sinking, as he was wont to do, towards his own fane at Delphi, and pouring a flood of light over the great Kopaik Plain. But it seemed that he was the only inhabitant of it. There was nothing there. 'Who,' said a rich Greek to me, 'would think of going to live in such a place as that?' I doubt much whether it is the Turk who has done all this. I think it is very largely the malaria.

"In considering carefully this suggestive argument of Major Ross does it not appear to indicate the tremendous influence that the prevalence of endemic disease must exert upon the progress of modern nations, and does it not bring the thought that those nations that are most advanced in sanitary science and preventive medicine will, other things being equal, assume the lead in the world's work? Who can estimate the influence of the sanitary laws of the

Hebrew scriptures upon the extraordinary persistence of that race through centuries of European oppression—centuries full of plague years and of terrible mortality from preventable disease? And what more striking example can be advanced of the effect of an enlightened and scientifically careful attention to the most recent advances of preventive medicine upon the progress of nations than the mortality statistics of the Japanese armies in the recent Russo-Japanese war as compared with the corresponding statistics for the British army during the Boer war immediately preceding, or for the American Army during the Spanish war at a somewhat earlier date?

"The consideration of these elements of national progress has been neglected by historians, but they are nevertheless of deep-reaching importance and must attract immediate attention in this age of advanced civilization. The world has entered the historical age when national greatness and national decay will be based on physical rather than moral conditions, and it is vitally incumbent upon nations to use every possible effort and every possible means to check physical deterioration."

LOSSES FROM MOSQUITOES ASIDE FROM THE CARRYING OF DISEASE.

Entirely aside from the loss occasioned by mosquitoes as carriers of specific diseases, their abundance brings about a great monetary loss in other ways.

REDUCED VALUE OF REAL ESTATE.

Possibly the greatest of these losses is in the reduced value of real estate in mosquito-infested regions since these insects render absolutely uninhabitable large areas of land otherwise available for suburban houses, for summer resorts, for manufacturing purposes, and for agriculture. The money loss becomes most apparent in the vicinity of large centers of population. The mosquito-breeding areas in the vicinity of New York City, for example, have prevented the growth of paying industries of various kinds, and have hindered the proper development of large tracts to an amount which it is difficult to estimate in dollars and cents and which is almost inconceivable. The same may be said for other large cities near the sea-coast, and even of those inland in low-lying regions.

The development of the whole State of New Jersey has been held back by the mosquito plague. This point has been insisted upon by Dr. John B. Smith, in his excellent article entitled: "The general economic importance of mosquitoes," in the Popular Science Monthly for April, 1907, and he has put it so strongly, and he is so familiar with the New Jersey conditions, that we quote from his article as follows:

"There is no exaggeration in the statement that the elimination of the mosquito would add ten millions to the taxable value of real estate in two years. [In the vicinity of New York City?] Let me illustrate: New York City is a highly desirable place of residence in winter; but less so in summer, and there are thousands of residents of New York City who are well able to afford a summer home within an hour or two from town, and who are quite willing to pay for it. New Jersey has many places ideal in situation and accessibility, and one such place developed rapidly to a certain point and there it stood, halted by the mosquitoes that bred in the surrounding marsh lands. Country club, golf, tennis and other attractions ceased to attract when attention was necessarily focused on the biting or singing pests that intruded everywhere, and the tendency was to sell out. But the owners were not ready to quit without a fight, and an improvement society was formed which consulted with my office and followed my advice. In one year the bulk of the breeding area was drained, mosquitoes have since been absent almost entirely; one gentleman, not a large owner, either, told me his property had increased $50,000 in value, and new settlers began to come in. This year one of the worst breeding areas of the olden day was used as a camping ground and 100 new residences are planned for next year.

"New Jersey has miles of sea coast that is unequalled for summer resorts. All but a few points are practically abandoned as uninhabitable. Barnegat Bay and its surroundings constitute a fisherman's paradise, and again and again settlements have started, done well for a season and have been abandoned. Those who came one year never came again, and many who came for a month stayed only a day.

"The only thing that prevents a continuous line of summer resorts along the entire shore line is the mosquito pest, and were that removed there would be a scramble to get land.

"We may take the result on Staten Island as an example. This Island, now a part of Greater New York, is geographically a portion of New Jersey, separated from the mainland by a narrow stream or 'kill,' on both sides of which salt marsh flats extend for a mile or more to the highland. The southern and eastern shore is a continuation of the New Jersey coast line from the mouth of the Raritan River, and like it has a number of indentations more or less bordered by salt marsh areas. On all these marshes mosquitoes bred in uncounted millions and spread throughout the island. Result: several square miles of most desirable territory for suburban residences entirely unsettled. There are two shore resorts, South Beach and Midland Beach, feeble imitations of Coney Island in some directions, but more desirable in others, that just maintained themselves despite their attractions. During the day conditions were tolerable along shore, but as soon as the sun was low in the horizon trouble began, and as it became dusk the fight began, and pleasure seekers sought shelter behind screens or started for home.

"This past summer, under the supervision of Dr. A. H. Doty, state quarantine officer, the salt marshes have been drained in the manner advocated by me, and the beginning was made on the eastern and southern shores, where Midland and South Beach are situated. I need hardly say that very few believed in good results, and scepticism was general even in circles where we might have expected material support. But we got the needed money, secured a contractor within our estimate, and the eastern and southern shore work was done before the breeding season set in.

"Result: there have been very few mosquitoes of any kind, and practically no marsh mosquitoes along this shore during the entire season. Visitors stayed longer and came more frequently to both beaches, which enjoyed a season of unparalleled prosperity, taxing the full capacity of the transportation companies. As the season advanced, the drainage work extended farther and farther away from the populated sections, permanent residents began to notice that nobody was putting in screens, and that screened porches were never used. On the golf links games could be carried on while the light lasted, and outdoor dinners and suppers became the rule at the Country Club. When it was fully realized that there was practically no mosquito pest, and the improvement in the character of the drained territory was obvious, there was a change in public sentiment. Plans were made for extending the attractions at the beaches, and many thousands will be put into new amusement enterprises during the present winter. Land values stiffened and very little was offered for sale.

"Two industrial enterprises decided to locate on the marsh area on the west of the island, and these are expected to employ, respectively, 4000 and 6000 men, most of whom will undoubtedly settle near-by. These enterprises will result in actually reclaiming a large section of the marsh, which is something that mosquito drainage does not and was not intended to accomplish."

A much earlier case of a similar nature to those described by Doctor Smith has been elsewhere mentioned by one of us. Not far from a large town on the north shore of Long Island Sound, prior to 1900, there was a stretch of land lying in such a way that it afforded a large number of excellent cottage and villa sites. But mosquitoes were so numerous there that even domestic animals could not be kept in a healthy condition and, as a resident of a nearby village expressed it, "the sole population consisted of a few smoke-dried fishermen and their dogs." In this locality, by the enterprising work of one man, a company was formed, the land was bought, the mosquito breeding-places were practically abolished, summer residences were built, and the company realized many thousands of dollars in the course of two years.

LOSS TO AGRICULTURE.

Agricultural regions have suffered from this cause. In portions of the Northwestern States it has been necessary to cover the work-horses in the fields with sheets during the day. In the Gulf region of Texas at times the market value of live stock is greatly reduced by the abundance of these insects. In portions of southern New Jersey there are lands eminently adapted to the dairying industry, and the markets of New York, Philadelphia and the large New Jersey cities are at hand. In these localities herds of cattle have been repeatedly established, but the attacks by swarms of mosquitoes have reduced the yield of milk to such an extent as to make the animals unprofitable, and dairying has been abandoned for less remunerative occupations.

The conditions of the thoroughbred race horses at the great racing center, Sheepshead Bay, Long Island, was so impaired by the attacks of mosquitoes as to induce those interested to spend many thousands of dollars, a few years ago, in an effort to abate the pest.

Smith, by way of example, calls attention to the indirect damage to the cranberry crop through mosquitoes. It seems that in New Jersey, about the time when cranberries ripen, the country may become covered with swarms of mosquitoes from the salt marshes, and under such conditions it is impossible to get pickers for the crop. He says that gangs of Italians have been brought down from Philadelphia, and have begun to work in good spirit, but that by noon of the same day they have been so badly bitten that they have had to give up the work and return to the city. Such conditions do not occur every year, nor do they last through the season, but they are of sufficiently frequent occurrence as to make cranberry culture most uncertain since the farmer hesitates to start the crop when he may be compelled to see the berries rot on the ground because he can not get laborers who can stand the plague of the mosquitoes.

COST OF SCREENING.

In the economic loss caused by mosquitoes there should be included the outlay for protective measures. All over the United States, for these insects, and for the house fly as well, it has become necessary to screen habitations. The cost of screening houses alone must surely exceed ten millions of dollars per annum, especially if we add the expense of screening rain-water tanks in the Southern cities.

THE VALUE OF RECLAIMED LANDS.*

"The general value of lands reclaimed from swamps is obvious. Practically all of Holland has been reclaimed from the sea. Large areas of the most valuable farming land in the world have been reclaimed from nonproductive swamps. To the nonproductiveness of swamp land must be added the great danger that exists in its continuance through the invariable presence of disease-bearing mosquitoes. The drainage of swamps not only destroys unlimited breeding places of mosquitoes, but vastly increases the value of the land for farming purposes and for other utilitarian uses. Either reason amply pays for the operation. The late Prof. N. S. Shaler, in his report to the North Shore Improvement Association, showed that fields gained by marsh drainage possess the greatest fertility and their endurance to cropping without manuring exceeds that of any other agricultural land except possibly arid regions which are irrigated. The range of crops is great and includes all ordinary farm and garden crops except in some places Indian corn. Reclaimed swamp lands are especially adapted for truck farming, because it is easy to maintain the level of under-ground water where the roots of the plants can reach it. Professor Shaler shows that the larger part of the best irrigable land in Holland, and much of that in Belgium, northern Germany and eastern England has been gained from what was originally tidal fields. He estimates not less than 10,000 square miles in those countries to have been redeemed in this way.

"The only large example of diked and improved marshes in the northeastern United States is at Green Harbor, Mass., where 1,200 acres have been won to tillage, about one-half being used for hay fields and the other for different crops. The result obtained in the farming of this land is excellent. Asparagus has produced large crops continuously for more than twenty years without the use of any fertilizer.

"Prof. Milton Whitney, Chief of the Bureau of Soils, of the United States Department of Agriculture, some years ago drew up the following statement at the request of the writer, concerning the value of reclaimed swamp land:

"'Swamp lands, by virtue of their position, become the repository of highly fertile material washed from the uplands by the rains. As a general rule, the immediate surface of any soil is the most fertile portion of that soil, resulting from the fact that this surface material is in physical condition, and most exposed to the action of the weather, the sun, rains, and air. This surface is the first portion removed during rains, and is the portion carried down into the swamps and deposited. When erosion goes on at such a rapid rate that both the surface and the underlying raw soil are washed away, the resulting bottom land deposit is frequently sterile. Witness the mud flats and swamps along the Sacramento River, in California, which have been covered with mud from the hydraulic mines of the Sierra Nevadas. Here large areas have been ruined by the mud, and will not become fertile until the weather has acted upon the material long enough to make the soil an acceptable medium for plant growth.

* Quoted from Howard, L. O., Preventive and remedial work against mosquitoes. U. S. Dept. Agr., Bur. Ent., Bull. 88, pp. 53-62, 1910.

Fortunately, most of our lowlands and swamps receive only the more gentle washing or the most fertile materials from the uplands.

"'Swamp lands contain an unusual amount of organic matter, and for that reason are easy to maintain in proper tilth, light to work, and warm. From their low position, water is generally abundant, or easy to obtain for irrigation by pumping or diversion from nearby streams.

"'Swamp lands and tide marshes are considered the most valuable of lands in the world's older countries. Their inherent fertility is recognized, and the ease with which they are cultivated and irrigated is greatly appreciated. In England for two hundred years the tide lands have been under reclamation, and to-day over 1,000,000 acres are in a 'matchless state of fertility.'

"'In Holland extensive areas have been reclaimed from the sea. The greater part of the country lies at or below the level of the sea, and is reclaimed from a jungle of swamps and savannas. Holland to-day represents one of the most successful attempts at swamp reclamation. Lakes have been drained by diking and pumping, and plans are now on foot to drain the Zuyder Zee, an arm of the ocean.

"'In our own country, swamp reclamation has been carried out on a large scale in the Middle Western States. Ohio, Indiana, Illinois, Michigan, and Wisconsin have great areas of productive land once swamp but now the most fertile and reliable land in those States. The tide marshes around Puget Sound, in Washington, have been lying untouched until within the last few years, but the recent great influx of Scandinavians has resulted in a movement toward the reclamation of these lands, and excellent farms are being established.

"'In California one of the greatest areas of swamp peat land in the world lies in the Sacramento-San Joaquin Delta. Over 1,500,000 areas of peat from 6 to 40 feet thick are ready for reduction in productive capacity, and to-day large areas are being reclaimed. Yields of 500 bushels of potatoes, 6000 pounds of asparagus, 60 bushels of barley and oats have been common, and with proper farming such yields should continue to be common.

"'Wherever properly reclaimed swamp lands are found their fertility is recognized; almost without exception they are more fertile than surrounding uplands. They are frequently used in special crop production, such as in growing celery, asparagus, cranberries, or onions, but in dairying or general farming they are unexcelled as permanent pasture or hay land. The consensus of opinion in districts where swamps have been reclaimed and farmed for many years is that there is no more valuable portion of the farm than the swamp, properly reclaimed.'

"There is much swamp land in the United States within easy reach of the best markets. New Orleans is surrounded by swamps, but here the problem of reclamation is rendered exceedingly difficult owing to the vast area involved and the periodic invasion by the Mississippi River in front, and Lakes Borgne and Pontchartrain in the rear. The city of New York is in the immediate neighborhood of vast areas of swamps and marshes, and even the partial drainage of this land is being productive of admirable results. The great value of stable land in the vicinity of New York for manufacturing purposes is uncontested, and even the partial drainage of the breeding places of salt-marsh mosquitoes in portions of New Jersey adjacent to New York has resulted, aside from limiting the mosquito supply, in the increase in value of the lands to the owners. After the first ditching the crop of salt hay nearly doubles. The operations carried on conjointly between the city of Brooklyn and the town of Sheepshead Bay, a few years ago, is indicative of the remunerative results to be obtained by simple and beneficial operations. The contents of the ash barrels of the city of Brooklyn were conveyed out into the salt marshes upon specially constructed trolley tracks and in large metal tanks. The tanks were so made that upon reaching the terminus they were taken up by machinery, carried out by an overhead trolley line, and by machinery dumped at a given spot. In this way some hundreds of acres of salt marsh were covered with a 12-foot layer of the contents of the ash barrels of Brooklyn. The layer was packed down by water and contained so much organic matter that almost immediately grass and sun flowers began to grow. At the end of the second year enough soil had formed so that Italians had begun to plant cabbages and other vegetables.

"The Government is taking up the subject of reclamation of swamp lands through its Reclamation Service, and extensive surveys are being made by the United States Geological Survey. Under the United States Department of Agriculture appropriations have been made for some years to enable the Secretary of Agriculture to investigate and report upon the drainage of swamps and other wet lands and to prepare plans for the removal of surplus waters by drainage.

"A number of interesting and important publications have already been issued by the United States Department of Agriculture, two of which are of general interest, namely, Circular No. 74, Office of Experiment Stations, Excavating Machinery Used for Digging Ditches and Building Levees, by J. O. Wright (pp. 40, figs. 16); and Circular No. 76, Office of Experiment Stations, The Swamp and Overflowed Lands of the United States, by J. O. Wright (pp. 23, pl. 1). The first of these publications described the use and construction of different classes of dredges, including dipper, clam-shell, rotary, roller, scraper, elevator, and hydraulic dredges, and drag boats; first cost and cost of operation of dredges; machines for building levees; machine for tile ditching. The second gives an estimate of the area of swamp lands in the different States, its ownership, present value, cost of reclamation, and probable value when reclaimed, and discusses the state laws relating to drainage. It is shown in the latter circular that there are in the United States 119,972 square miles of swamp lands, an area which, collected together, would be as large as England, Ireland, Scotland and Wales together, or larger than the six New England States, New York and the northern half of New Jersey. It would make a strip 133 miles wide reaching from New York to Chicago. Not all of this swamp land, however, is suited for agriculture, but from the data collected by the Office of Experiment Stations of the United States Department of Agriculture, it seems certain that in the eastern portion of the United States there are 77,000,000 acres that can be reclaimed and made fit for cultivation by the building of simple engineering structures. It is a noticeable and significant fact that 95 per cent of this entire area is held in private ownership. The following paragraphs taken from this Circular No. 76 express the desirability of such drainage from the monetary point of view in very forcible terms:

"'There is no question as to the fertility of swamp or overflowed land, and when it is protected by embankments to keep out the overflow and is relieved of the excess of water by proper drainage its productiveness is unexcelled. In nearly every one of the States large areas of similar lands have been reclaimed by draining and embanking and have proven to be the most productive farm lands in the districts in which they are located. Illinois, Indiana, Iowa, and southern Louisiana have taken the lead in work of this kind, and in no other part of the country do we find more profitable or higher-priced farms than in those States. Along the Atlantic coast sufficient work has been done to indicate that the vast extent of salt marsh reaching from Maine to Florida can by proper methods be won to agriculture, and when reclaimed the soils are especially adapted to market gardening.

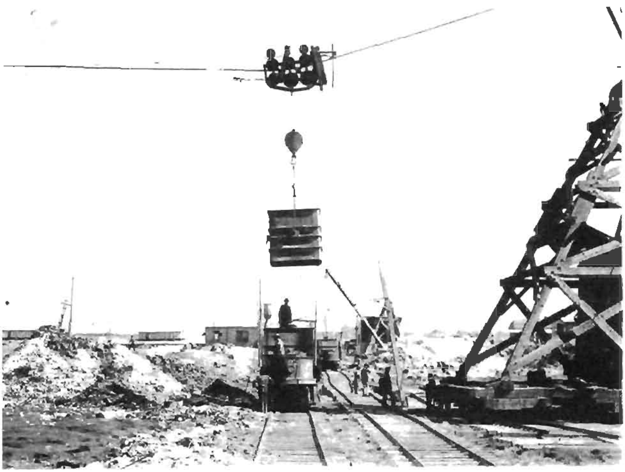
"'To ascertain why these lands have been allowed to remain so long in their present state we must look to some cause other than their lack of fertility, as this has been fully established by chemical analyses of the soil and by hundreds of productive farms that have been made from such lands.

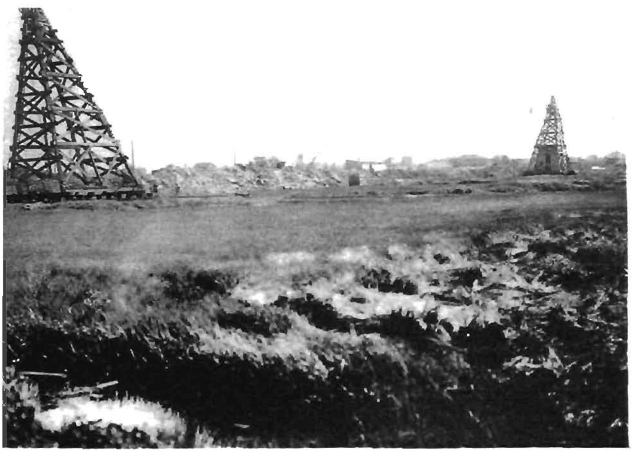
"'In the early settlement of our country the farms were located on what were considered the most desirable tracts, determined by accessibility, natural water supply, and the fertility of the soil. As civilization extended westward the home seeker selected the rolling prairie that needed little or no drainage, so that the swamps and overflowed lands were passed by, and only recently has au imperative demand arisen for their reclamation. The desirable farming land is practically all occupied or held for speculation, and to meet the needs of our steadily increasing population it is necessary for this swamp land to be drained and put to proper use. Its nearness to market and its great fertility make it very desirable for small farms.

"'Can these lands be drained, what will it cost, and how can the work best be done are questions of vital interest to the American people. After considering what has been done to reclaim the marshes of Holland, two-fifths of which lie below the level of the sea, and the difficulties that have been overcome in draining the fens of England, it would be a reflection on the skill and intelligence of the American engineer to proclaim the drainage of our swamp lands impossible. On the contrary, the engineering problems are simple, as most of these lands are several feet above sea level and have natural creeks or bayous that need only to be improved by straightening, widening, and deepening to afford outlets for complete drainage. In case of some of the river bottoms and the salt marsh along the coast it is necessary to build levees to prevent overflow and to construct internal systems of drainage with sluice gates or pumps to discharge the water from within, and by the use of modern machinery this work is neither difficult nor expensive. Levees can be built and ditches excavated with suitable dredges at a cost ranging from 7 to 16 cents per cubic yard. Large works in swamps where the land is overflowed are readily and cheaply constructed in this manner.

"'As to the cost of draining these lands, and whether or not it will pay, we have but to refer to the numerous works of this kind that have been completed. In those States where large areas of swamp land have been thoroughly drained by open ditches and tile drains the cost ranges from $6 to $20 per acre, while in places where tile drainage was not required the average cost has not exceeded $4 per acre. Judging from the prices which prevail in a large number of these districts where work of this kind is being carried on, it is safe to estimate that the 77,000,000 acres of swamp can be thoroughly drained and made fit for cultivation at an average cost of $15 per acre. The market value of these lands in their present shape ranges from $2 to $20 per acre, depending upon the location and prospect of immediate drainage, with an average of probably $8 per acre. Similar lands in different sections of the country that have been drained sell readily at $60 to $100 per acre at the completion of the work, and in many instances, when situated near large cities, they have sold as high as $400 per acre. To determine whether or not it will pay to drain these lands we have but to consider the following figures:

Cash value of 77,000,000 acres after thorough drainage at $60 per acre		$4,620,000,000
Present value of this land at $8 per acre	$616,000,000	
Cost of drainage at $15 per acre	1,155,000,000	
Value of land and cost of draining		1,771,000,000
Net increase in value		$2,849,000,000





Operations of filling in salt marshes, Sheepshead Bay, Long Island, with the

"'These figures, though large, are not fanciful, but are based on results obtained in actual practice in different sections of the country where work of this kind has been done. An extended investigation shows that in every case where a complete system of drainage has been planned and carried out the land has increased in value many fold. In some instances, however, much time and money have been wasted because the work was undertaken without any well-defined plan or it was not sufficient to afford adequate and complete drainage.

"'The reclamation of swamp and overflowed lands is no longer an experiment; it has become a highly profitable business when based on correct principles. The methods of drainage practiced in different parts of this country and in some of the foreign countries are being carefully considered, and many experiments are being made to determine the best and most economical methods of draining land, and the information thus collected is being classified and the results compared and general rules deduced, which, if followed, will in all cases bring highly beneficial results. The comparative cost of the different methods of doing the work and the most satisfactory way of providing funds are also being duly considered.

"'Were this 77,000,000 acres of swamp and overflowed land drained and made healthful and fit for agriculture and divided into farms of 40 acres each, it would provide homes for 1,925,000 families. Swamp lands, when drained, are extremely fertile, requiring but little commercial fertilizer, and yield abundant crops. They are adapted to a wide range of products and in most instances are convenient to good markets. While an income of $15 to $20 per acre in the grain-producing States of the Middle West is considered profitable, much of the swamp land in the East and South would, if cultivated in cabbage, onions, celery, tomatoes, and other vegetables, yield a net income of more than $100 per acre.

"'In addition to the immediate benefits that accrue from the increased productiveness of these lands, a greater and more lasting benefit would follow their reclamation. The taxable value of the Commonwealth would be permanently increased, and healthfulness of the community would be improved, mosquitoes and malaria would be banished, and the construction of good roads made possible. Factories, churches, and schools would open up, and instead of active young farmers from the Mississippi Valley emigrating to Canada to seek cheap lands they could find better homes within our own borders.

"'Holland, two-fifths of which lies below the level of the sea, has been reclaimed by diking and draining, and now supports a population of 450 per square mile. Her soil is no better than the marshes of this country, and her climate not so good as that of the Southern States, yet we have within our border an undeveloped empire ten times her area.

"'There is no good reason why this condition should longer continue, and it is to be hoped that the American people will soon take steps to abate this nuisance and make these lands contribute to the support and upbuilding of the nation.'

"In an important article by Mr. H. C. Weeks, in the Scientific American Supplement for January 5, 1901, on the subject of drainage work, the following interesting statements are made:

"'Cases exist, however, of persons being unwilling to be convinced, and continuing their opposition even after a successful reclamation, as are seen in the official records of Massachusetts, while examinations by the State have shown a great improvement in the sanitary and agricultural conditions. In the instance of Green Harbor, in that State, it is shown that the death rate of the reclaimed districts averages lower than the general death rate of the State, that there is a steady increase in summer visitors, and that many houses are being built. The testimony of persons of wide knowledge and ample experience in the science and art of agriculture is adduced, showing the good results in that field, and yet it fails to silence opposers. Besides mentioning the remarkably heavy crops of hay, much preferred by his horses to the best from the uplands, also the excellent crops of strawberries and vegetables raised in these lands, one such qualified observer gives his experience as to asparagus in such convincing words that they are quoted in full: 'While visiting the Marshfield Meadows on April 19, 1897, I found asparagus already up, very nearly high enough to cut. I was surprised at this, for my own asparagus had just appeared above the surface of the ground, although growing on land so warm that I am usually first to ship native asparagus to Boston market. I was also surprised at the size of the stalks, they being much larger than the first set of stalks that appear on my land. When I consider the fact that the land on which this asparagus was growing has produced large crops every year for twenty years without fertilizers of any kind, and still produces better crops than my land, which has had $600 worth of fertilizers to the acre applied to it during the last twenty years, it convinces me that this land, for garden purposes, surpasses any which I have ever examined. . . .

"'We realize, in a measure, the great value of the material which nature has for ages been storing up for man's future use, if he be wise enough to avail himself of it.'

"The drainage work done by other countries has given many practical examples of beneficial results from the mosquito standpoint, and from other points of view as well. The details have very recently become available, through the kindness of the United States consul at Milan, Italy, of very extensive drainage operations carried on near Milan, which involved the reclamation of nearly 80,000 acres of land. These details may be found in the Scientific American Supplement No. 1637, May 18, 1907, pages 26233 to 26235. The work cost $3,200,000, and the annual cost of operation is estimated at $16,000. The beneficial results are summarized as follows:

"'1. In both Mantua and Reggio this tract, comprising 77,867 acres, cultivable only for a sparse crop of poor hay and, on account of the vapors arising from its stagnant swamps, dangerous for pasturage during practically all the year, has been made cultivable, in one year, for wheat, grapes, fruits, and hay, and rendered good for cutting into farms on which people can erect homes in safety.

"'2. The market values, not only on the 78,000-acre tract but on all contiguous territory, even to the outer bounds of the affected provinces, have leaped to figures equal to two or three times those prevailing before the opening of the Bonifica, i. e., from $120 to $250 or $300 per acre.

"'3. Farm labor, which formerly expressly avoided these provinces, and made difficult the harvesting of the extensive crops, has been attracted there by the changed conditions; while on account of the demand created by the active development of the drained tract, wages have not been knocked down by the plentitude of supply.

"'4. Live-stock maladies are under better control.

"'5. The public health has been afforded a sure and scientific protection.'

"*SALT MARSH LANDS IN NEW JERSEY.*

"So much work has already been done in New Jersey that, as repeatedly pointed out in this work, the value of the operations already carried on in that State is very great, if only as an indication of what can be and should be done elsewhere. The whole question of the New Jersey salt marsh and its improvement has been considered by Dr. John B. Smith in Bulletin No. 207 of the New Jersey Agricultural Experiment Station. In this work he gives a consideration of the location of the salt-marsh area, the kinds of salt marsh, the vegetation on

the marshes, the present value of the marshes, their actual value, effect of drainage on crops, the needs of salt grass and black grass, and a general consideration as to how the marshes may be reclaimed and who is to pay the expense.

"It appears that the present value of the marshes is very small. As a matter of fact, they are either not taxed at all or at such a low rate as to add little to the income of the taxing body. Some of the owners have never paid any taxes, and in some of the townships there is no record of ownerships in the assessor's hands and therefore no notices can be served. It is pointed out, as an evidence of the recognized worthlessness of such land, that none who work on them consider in the least the results of interference with natural drainage; railroads build embankments across them, and pay no attention to the water courses except large creeks. The result is that the marsh often becomes water-logged, and a good salt-hay meadow is turned into a quagmire, and not even the owner protests. Railroads cut sods from the meadows without inquiry as to the ownership of the land, and holes of all sizes are scattered over the meadow, most of them unconnected with tide water, leaving stagnant pools in which mosquitoes breed.

"He points out that all salt marsh, of what he names the third type, which is that area above mean high tide and more or less completely covered with vegetation, may be made to produce an income of from $10 to $40 per acre annually, and that there are many hundreds of acres that do produce such incomes.

"In considering the effect of drainage upon crops he gives a number of interesting instances, three of which are quoted:

"'The Newark meadow has an area of about 3500 acres, and hay has been cut on parts of it for many years. Before the 90's it was generally cut by men who wished to use it as food for stock or as bedding, and some ditches were cut by those who noticed that well-drained land produced much better crops than such as were either too dry or water-logged. After the 90's a number of banana houses opened in Newark and created a demand for salt hay to use in layering the ripening fruit. This demand led to the cutting of more territory around the edges of the marsh, and $5 a ton was paid for the crop. With the introduction and increase of the glass industry the demand for hay, to be used as packing, increased steadily, and yet greater areas were cut; and in order to get at these areas the cutting was done in the winter, after the meadow was frozen solid, for at no other time could the product be carted off. And this was the condition of affairs in 1904, when the mosquito drainage was done by the city, but under the supervision of the writer. It might be said here that this drainage work was not looked upon with any favor by owners and haymakers, the latter especially protesting vigorously. One man threatened to smash the ditching machine, and yet another promised to shoot the first man that set a spade into his property. The work went on, nevertheless, and altogether nearly 400,000 feet of ditches went into this 3500 acres.

"'The results are as follows: On the Hamburg section, where in 1903, on an area nearly one mile square, about 100 tons of hay were taken off during the winter, 250 tons were carted off in 1904, only one year later. The meadow has hardened up right along, and in 1907 nearly the entire area was cut by machine, and a crop of 800 tons, valued at $7.50 per ton, is harvested. Yet a worse place was the area, about one by three-fourths of a mile, known as the Ebeling tract, little more than a sunken meadow before 1904, from which no more than 30 tons of usable grass were obtained. After the ditching the meadow began to rise and improve, and at present writing is at least seven inches above its 1903 level, and correspondingly improved in texture. The crop has increased from 30 tons to 600 tons, not quite so good as the other, but worth an average of $7 per ton. Other areas which had theretofore produced nothing are now being cut.

The total cut in 1903 was between 1000 and 1200 tons; the 1907 crop will come close to 3000. And that is not the limit of productiveness.

"' Forty years ago the Elizabeth marshes, containing about 2200 acres, were quite generally cut over and good crops of hay were obtained. There was considerable ditching done, but it was not kept up, and as the marsh was crossed and cut up by the railroads without regard to the drainage system, matters became gradually worse; the meadow rotted, the black and salt grass was replaced by sedges and other useless stuff, and less and less was cut each year until, for a decade past, little or nothing has been cut from the area west of the Central Railroad. Where as much as 5000 tons had once been harvested, less than a thousand tons were harvested in 1903. In 1906 ditches were cut in the southeastern section of the meadow in the course of the mosquito work, and an area on which hip boots were needed in that year can now be safely traveled dry shod. Where we found sedge and useless grasses over two-thirds of the area in 1905, on that same proportion we now have good salt and black grass. In another year, if the ditches are not interfered with, the sedge will be practically out. The balance of the area was ditched early in 1907, all the work being completed early in July. Shallow depressions that have been water covered and mosquito breeders for twenty years are now dry and covered with the salt-marsh flea-bane. The grass which was ten to twelve inches high last year is now twenty to twenty-eight inches high and much more dense. For the first time in nearly twenty years hay is being again cut in areas west of the railroad and in the area between Great Island, Elizabethport and the Central Railroad.

"' In draining the Shrewsbury River marshes in 1904, the same sort of opposition from hay producers was encountered that we met on the Newark marshes, and it was objected that the ditches cut up the land and made work harder. Nevertheless, the work was done and the result is a crop just double—mostly from longer, thicker grass. Before 1904, two tons per acre was considered a good crop; now, good and bad together, it averages four tons, and local conditions furnish a market that pays $10 per ton.'

" In his annual report for the year 1908, Doctor Smith states that his investigations showed that a very small part of the salt-marsh area produces as great a crop as it should, and that what is produced does not bring as good a price as it should. The market for salt hay is slight, due in part to the character of the crop and partly to the uses to which it is put. Since the crop is not certain it can not be relied upon, and the price varies with the size of the harvest. Salt hay is used largely for packing, and the amount demanded depends upon business conditions. In 1907 there was a very large crop of hay, but there was a business depression at the same time which brought about so low a price as to scarcely repay harvesting. He shows that salt hay is altogether too valuable to be used for packing material alone, and that if an annual crop could be expected it could be used to supplement upland hay in feeding horses and cattle. The drainage work done by Doctor Smith under the state mosquito law will put the meadows into such shape that the amount of hay produced will be increased without increase of cost except in harvesting, and will enable the production of dependable crops. He states that on July 21, 1908, he had the opportunity of seeing, at Stratford, Conn., an area of about 1500 acres of salt marsh, drained and partly diked and reclaimed. The largest part of the acreage was devoted to raising salt hay of the best quality, for which good prices were received. On the diked marsh 100 acres had been kept free from salt water since 1904. On this territory strawberries, asparagus, onions, and celery were being raised, and, while the asparagus was not of the best quality and the strawberry plants were in no way unusual, the onions and celery were of the best—in fact the celery was so good that most of the market gardeners in that vicinity preferred to get their supplies from this source.

"Doctor Smith points out that there are many hundreds of acres along the shores of Barnegat Bay, and especially along its upper portion, where a very small amount of diking will serve to keep out salt water and fit the land for certain truck crops. He also shows that along a large portion of the Barnegat Bay line cranberry plants grow annually to the very edge of the salt-marsh line, but that these could not be improved because there was no way out across the marsh for surface water. With the ditching going on, this land will become available in large part at least and will allow the owners to derive a revenue from land which is at present practically nonproductive. Of course taxes will then be raised and the income of the townships in which this land lies will be increased."

INFLUENCE OF WIND ON THE DISPERSAL OF MOSQUITOES.

The majority of mosquitoes do not appear to fly very far. Those of the genus *Anopheles* are seldom found more than a half mile from their breeding-places. The evidence as to mosquitoes being carried by winds is unsatisfactory and more or less conflicting; this is doubtless due partly to the fact that species of different habits are involved and partly to the unscientific character of the observations. It must also be remembered that the records are sure to be shaped in accordance with the preconceived ideas of the observer. The common house mosquitoes are seldom found far away from their breeding-places. The salt-marsh mosquitoes, however, migrate, possibly sometimes aided by the wind, but, as recent evidence shows, more probably flying into the wind. The more careful observations on mosquito behavior show that for the most part mosquitoes will not fly when there is a strong breeze. Possibly the only exceptions are the mosquitoes of the northern prairies, where the low night temperatures oblige them to be active during the day in spite of the constant high wind. Full accounts of two remarkable mosquito migrations, observed by the Hon. J. D. Mitchell, of Victoria, Texas, are given on pages 22 to 24 of "Mosquitoes" (Howard). These are of sufficient interest to quote in full:

"I have witnessed, in my life, two migrations of mosquitoes, that will always be fresh and vivid in my memory.

"Where the Colorado River empties into Matagorda Bay, a marsh is formed over the lowlands, by a raft in the river; this marsh contains about eighteen square miles, and is a magnificent breeding-place for mosquitoes.

"I used to ranch it on the peninsula-like body of land, formed by Carancahua Bay on the east, Matagorda Bay on the south, Keller's Bay and Creek on the west, and the Calhoun County north line on the north (refer to coast maps of Texas). The distance between my ranch property and the marsh above described is, by bay route, about forty miles; the way the crow flies, about thirty-five miles. My ranch was situated on Carancahua Bay, near the north end of land.

"The first migration occurred in October, 1879. There had been an overflow from the upper country, which filled the aforesaid marsh, but the balance of that section was very dry and needing rain, and there were no mosquitoes. A fairly strong easterly wind had been blowing for three days; on the evening of the third day the mosquitoes arrived, flying high, about fifty feet, and looking like a cloud or mist over Carancahua Bay. At the ranch they set everything on fire that had blood in it, and all work was suspended by unanimous consent. Cattle and horses rounded-up milled continuously; all work stock was turned loose as quick as possible and they went to the round-ups at full speed, and little or nothing was done for nearly five days; by this time the main body had passed, though plenty remained to make everything uncomfortable for about two weeks. This migration was from east to west and the line was about three miles wide—above and below this there were no mosquitoes.

"Migration No. 2 occurred in October, 1886. They came from the same marsh before described—this migration confined itself to the Matagorda Bay shore line, reaching inland about half a mile; there were as many mosquitoes in this limit as there were in the three miles of migration No. 1. They clouded the sky, bent down the grass with their weight, and made all driftwood and ground the same color. All stock left the shore and went north outside of the line of marsh. The wind was light and from the south, and did not affect the mosquitoes in their flight, which was westward; the main flight was low, ten or twelve feet high and always in the same direction. With three other men I rode into the swarm to a large pile of drift and trash and set it on fire, and stood in the smoke for some time watching them. They passed sometime during the third day, leaving very few stragglers behind. By inquiry, I traced both of these swarms from the marsh before described to fifteen or twenty miles west of my ranch, a total distance, air line, of fifty or sixty miles.

"No. 1 crossed Trupalacios Bay, where it was five miles wide, and Carancahua Bay, where it was one mile wide. No. 2 holding to the shore line, crossed Trupalacios Bay, three miles, Carancahua Bay, at Pass, 300 yards, Keller's Bay, at Pass, half mile, Cox's Bay, one and a half miles, and Port Lavaca Bay, four miles."

When Dr. John B. Smith began his work in New Jersey nothing exact was known of the breeding habits of the salt-marsh mosquitoes, or of their powers of migration. The fact of their ability to migrate was denied by nearly all entomologists. Doctor Smith's early work resulted in the determination of the life-history of *Aëdes sollicitans*, and his later work, that in 1903–4, resulted in a complete demonstration of the migratory habits of *A. sollicitans*, *A. cantator* and *A. tæniorhynchus*. He was led to investigate the matter carefully on account of the fact that anti-mosquito operations carried on in certain New Jersey towns, on the theory that the entire mosquito supply was bred locally, were unsuccessful; furthermore, the salt-marsh mosquitoes were found far inland and in numbers too large to have been carried by trains; and lastly, experiments indicated that they would not breed in fresh water. The controlling argument was the presence in overwhelming numbers of adult salt-marsh mosquitoes where no trace of their larvæ could be found. Doctor Smith had previously watched *sollicitans* carefully on many occasions and had found that it flies quite readily against even a brisk wind, and makes good progress. He placed himself several times in an alley in the direct line of the wind and watched the mosquitoes come sailing against it without apparent effort. He had driven, as have many of us, over infested roads at quite a rapid pace, and had found that the mosquitoes hovering over the horse and about the carriage had no difficulty in keeping up. He had been in a steam launch which was followed by a mosquito swarm for more than five miles, across an open stretch of water.

In order to understand the sudden appearance of great numbers of mosquitoes on the salt marshes and their subsequent migration a knowledge of the breeding habits of these mosquitoes is essentiai. These are discussed in another part of this work (p. 146).

Dr. Smith's method of investigating the migrations of the salt-marsh mosquitoes was to station observers on the marshes before the larvæ matured. Careful search was made for several miles back in order to prove that none of these mosquitoes were there. Then the appearance of the first brood of adults on the salt marshes was noted early in the season. They were watched for a day or two slowly advancing until they reached the first ridge of mountains. A second brood, maturing during the last days of June, 1903, was watched in the same way, and the early days of July brought inland the greatest swarm of mosquitoes he had even seen. They reached New Brunswick July 2d and included the three species above mentioned. One of Dr. Smith's assistants, Mr. Viereck, was, at the same time, observing at Cape May, and watched the peninsula filling with *sollicitans* bred at the shore. Away from the shore he could not find the larvæ, while the adults swarmed. He noted that after continuous south wind the marshes became practically free from mosquitoes, whereas a few days later blood-filled specimens with developing or developed ovaries returned to the marshes from the upland. This, he thought, was a return migration for oviposition, all the specimens being worn. Dr. Smith now has no hesitation in stating that these salt-marsh species may migrate inland for 40 miles.

Flights to sea are apparently not infrequent, although they have been but seldom recorded. According to Dr. Smith salt-marsh mosquitoes are not uncommon 5 miles out, and have been reported 15 miles out.

Dr. H. R. Carter, discussing this subject in 1904, thinks that salt-marsh mosquitoes are "quite frequently carried considerably over a mile by light, steady breezes, long continued." He records the occurrence of a great swarm of salt-marsh mosquitoes in the Gulf of Mexico, many miles from land, as follows: "The writer has personal knowledge of the flights of myriads of mosquitos (Culex solicitans as he remembers) which were carried by wind fifteen or eighteen miles from the Louisiana marshes across Chandeleur Sound to vessels in the sound and to Chandeleur Island. In both cases the wind had blown moderately and steadily for two or three days from the marshes."

Dr. Alfred G. Mayer, the Director of the Marine Laboratory of the Carnegie Institution at Tortugas, Florida, found that the Tortugas Islands are occasionally invaded by swarms of migratory mosquitoes. He investigated the conditions on the seven islands carefully in 1908 with reference to possible breeding-places of mosquitoes and he describes these as follows:

"The seven Islands of the Dry Tortugas, Florida, are composed exclusively of wave-worn and wind-blown fragments of shells and other calcareous remnants of marine animals and plants which once lived in the water surrounding the keys. These particles form a loose, coarse, soil which does not permit the growth of mangroves, and which is so porous that no puddles or standing pools of water are to be seen even immediately after the most copious tropical rains. There are no enclosed lagoons or areas of relatively stagnant salt-water as in many other keys of the Florida-Bahama region, and all parts of the Islands are dry and elevated from 3 to 9 feet above sea-level. The islands are covered with bay cedar bushes, cactus, and coarse grasses, and it is certain that there are no natural breeding places for mosquitoes within the group.

"On Garden Key *Stegomyia* [*Aëdes calopus*] breeds within the numerous cisterns of Fort Jefferson. No mosqnito larvæ have ever been seen during ten years of observation in the cisterns of the light-house on Loggerhead Key; this being doubtless due to the purity of the water which is collected upon slate roofs and runs at once into the concrete cisterns.

"The iron cisterns of the Carnegie Institution Laboratory, also on Loggerhead Key, are covered with kerosene oil, and no mosquitoes breed within them. All tin cans and garbage on Loggerhead Key are towed daily out to sea and cast over-board.

"I mention these details merely to show that mosquitoes can breed only on Garden Key, Tortugas, the other Islands of the group affording no suitable places for this purpose."

Dr. Mayer informs us that no mosquitoes other than *Aëdes calopus* breed upon the Tortugas and that the nearest breeding-grounds for other species are upon the Marquesas Keys which are the lands nearest to the Tortugas group, and lie 40 nautical miles to the eastward of Loggerhead Key. The Marquesas are low-lying mud flats covered by a dense growth of mangrove bushes and Dr. Mayer states that myriads of mosquitoes breed there during the summer season. "On damp, but rainless days, when the sky is over-cast, and the wind blows from Marquesas toward the Tortugas, mosquitoes in considerable numbers suddenly appear upon Loggerhead Key. They also drift upon the Tortugas during damp moonlight nights, but it is remarkable that when the wind shifts and blows from some direction other than that from the Marquesas the mosquitoes disappear from Tortugas in a few hours." At our request, Dr. Mayer has secured a specimen of one of these mosquitoes which he secured in 1910. It proved to be *Aëdes niger*, the Antillean form of *Aëdes tæniorhynchus* which extends over to Florida. The last-named species is the one for which the migratory habit is best established. Dr. Mayer even thought that mosquitoes occasionally crossed from Cuba, a distance of 90 miles, but such a distance is considerably in excess of anything observed by others. It must be considered that Dr. Mayer's statements, as well as those of others, are based upon the assumption that the mosquitoes are carried by the wind or fly with it. This is by no means demonstrated.

Other observers have found that these mosquitoes fly against the wind. One of us (Knab) has observed that in Saskatchewan the most abundant mosquito of that region (*Aëdes spenceri*) flies against a strong wind. Mr. A. H. Jennings has informed us that in his investigations in Panama he found that *Anopheles* invariably flew against the wind. With reference to Prof. Mayer's belief that mosquitoes fly from Cuba to the Tortugas, a distance of 90 miles, we could only accept this in the presence of convincing proof. Investigations will have to be carried on much more thoroughly before any conclusion can be reached regarding the origin of the mosquitoes found in the Dry Tortugas.

In August, 1909, many newspapers contained accounts of the appearance of a swarm of mosquitoes in the Gulf of Mexico, sixty miles from the nearest land, and on August 24 a sheet of marine data from the U. S. Hydrographic Office was received at the Bureau of Entomology, filled out by Captain Young of the steamship "Concho," Key West to Galveston, as follows: "Civil data Aug. 6, '09; Ship's time 10 a. m.; Latitude 28.40; Longitude (Greenwich) 92.30; Cloud of mosquitoes large, lazy and hungry. Wind N. E. Moderate at the time. The above mosquitoes were about 60 miles from the nearest land. I never before experienced mosquitoes over 5 miles from land, and only a few times even at that distance." No specimens of the mosquitoes were received, but in view of Mr. Mitchell's observations quoted above, there seems no reason to doubt the explicit record of Captain Young to the Hydrographic Office of the United States government.

Grubbs, in a paper previously quoted, in the course of his investigations of vessels as carriers of mosquitoes, at the Gulf Quarantine Station, concludes from evidence submitted that in seven cases of sailing vessels in the Gulf of Mexico mosquitoes came aboard; in two instances two miles from shore, in one instance ten miles from shore, in three instances fifteen miles, and in one instance twenty miles. Among these mosquitoes there were no malarial or yellow fever forms, all belonging to species of *Aëdes*.

The following paragraphs are taken from a letter received in 1903 from Surgeon A. C. H. Russell, United States Navy, of the U. S. F. S. "Newark," written at Port of Spain, Trinidad. These paragraphs contain an important contribution to the subject under discussion:

"At Montevideo, Uruguay, while the 'Newark' and the 'Detroit' were at anchor more than two miles from the shore, mosquitoes in considerable numbers were frequently blown on board by the land breeze. I send you a specimen of these mosquitoes, which I caught in my cabin last June. The land breeze which brought them off was moderate in force. [The species proved to be ***Anopheles annulipalpis*** Arrib.]

"At Ilha Grande, Brazil, mosquitoes were blown or flew on board the ships at anchor more than a mile from shore. . . .

"While the 'Detroit' was at target practice in June, 1903, off the English Banks, River Plate, nine miles from Flores Island and fourteen or fifteen miles from the mainland of Uruguay, a moderate breeze blew mosquitoes on board in swarms during several days and nights. The insects were most numerous at night. The opposite shore of the river was from sixty to a hundred miles away. These mosquitoes were small, delicate and black colored. Unfortunately no specimen of them was caught and preserved.

"Lieutenant Commander J. H. Hetherington, U. S. N., states that, while he was attached to the U. S. Coast and Geodetic Steamer 'Gedney' in the spring of 1884, the ship went out one morning early to take soundings on a shoal to the eastward and southward of Galveston, Texas. Just after anchoring at the shoal about 9 o'clock a. m., a heavy squall of rain passed over the ship from the westward. After it had rained hard for a few minutes the weather became clear and warm. As soon as the rain ceased, it was seen that the ship was infested with a dense swarm of large, black or dark looking mosquitoes that were unusually voracious and immediately attacked every one. In a few hours they had entirely disappeared. The ship was at that time about 27 miles from land.

"The mosquitoes ordinarily noticed on board ship in Galveston Harbor were of a light brown color, and smaller than those which came with the squall above mentioned.

"Manson states in his work on tropical diseases that ships anchored a mile *from shore are safe from infection by mosquitoes.* The experience of our ships at Montevideo and at Ilha Grande shows that this distance does not afford such protection and that the crew of a ship in any port, of the harbor of Rio for example, is liable to be infested by mosquitoes."

Of course Manson meant infested by *Anopheles* or other disease-bearing mosquitoes. Surgeon Russell found *Anopheles* only in one case; and its presence on board ship about two miles from shore can not be accepted as proof that the mosquito had flown this distance.

It is evident from the foregoing that the mosquitoes concerned in migrations, in the strict sense of that term, are the coast species of *Aëdes*. In the regions we have under consideration in this work the species concerned are *Aëdes tæniorhynchus, A. niger, A. sollicitans* and, along the northern portion of the Atlantic coast, *Aëdes cantator*. It appears from the observations of H. J. Quayle that on the California coast *Aëdes quaylei* and *Aëdes squamiger* behave in a similar manner.

Only the females are concerned in these migrations and there is little reason to doubt that their object is to obtain food. It is probable that those females which obtain blood and survive accidents return to the salt marshes to deposit their eggs. It is doubtful, however, that in these migrations the wind is a necessary factor or even that, in most cases, it has an important influence. In other words we must consider those cases in which large swarms of mosquitoes are said to have been carried a considerable distance by the wind as problematical.

The following observations, in so far as they relate to one of the so-called house mosquitoes, which have entirely different habits from those already considered, are of some interest. We quote directly from "Mosquitoes in Hawaii" by D. L. Van Dine:

"The writer has not observed evidences of migration among the species of mosquitoes occurring in these Islands. Invariably the source of mosquitoes infesting any district has been found to be nearby natural and artificial collections of water, usually artificial collections in the immediate vicinity. Mr. [H. W.] Henshaw, in speaking of invasions of mosquitoes, says in a letter to the writer:

"So far as my own observations extend such accidental invasions of mosquitoes are rare in these Islands, the insects here as a rule being extremely local. Nevertheless that such accidental dispersal of the pests in the Islands does actually occur is proved by an instance in point which came under my personal observation in June, 1899, at Pahala, Kau (Island of Hawaii). Mr. C. M. Walton, the then manager of the plantation, informed me that prior to the visitation of the pests about to be described, mosquitoes were practically unknown about the village; if found at all it was in such small numbers as to cause no annoyance, and mosquito-nets were unknown.

"In the spring of 1899 there was an unusual quantity of waste water from the mill and this ran down to the flats about a mile below and there formed a series of small ponds aggregating a considerable expanse of shallow water. Not long after the formation of the ponds swarms of mosquitoes made their appearance about the mill and in all the dwellings, evidently brought there by the strong trade winds which blew directly from the ponds. At the time of my visit the mosquitoes (*Culex pipiens* *) put in an appearance about dusk and soon rendered life a burden and sleep impossible except under nets which every householder had been compelled to provide for every bed.

* The mosquito under consideration is *Culex quinquefasciatus*, Say.

"A few days later I visited the Kapapala Ranch, distant from Pahala about four miles in an air line and about five miles from the ponds in question and there found a similar state of affairs. Mr. Julian Monserratt, manager of the ranch, told me that the invasion occurred at the same time as at Pahala prior to which no mosquitoes had been seen at or near the ranch headquarters where, indeed, there was no possible breeding place for them.

"Unquestionably the clouds of mosquitoes originated in the same ponds below Pahala and were carried by the trade winds not only to Kapapala but for miles over the surrounding country in the direct track of the breezes. At Pahala, at least, the colonization has proved to be permanent as here, as elsewhere on cane plantations where water flumes are in use, leaky flumes form small pools at many points along their track which make ideal breeding places for mosquitoes. . . .

"Mr. Henshaw has since informed the writer that the ponds mentioned are quite exposed and unsheltered by vegetation, and agrees with the writer that had the ponds been surrounded by trees or had vegetation intervened to which the insects could have clung for shelter, the distribution would not, probably, have been so widespread."

It is doubtful that the trade wind played the rôle in the dispersal of these mosquitoes attributed to it by Mr. Henshaw. It should be noted that *Culex quinquefasciatus* is nocturnal and it is well known that the trade wind dies down at night. The mosquito's greatest activity therefore occurs at the time when the air is calmest. It does not follow from Mr. Henshaw's account that he actually saw the mosquitoes being carried by the wind; he found the mosquitoes and concluded that the wind had brought them. This last criticism will also apply to a very large part of the previously quoted observations.

CARRIAGE OF MOSQUITOES BY SHIPS, RAILROADS, AND OTHER CONVEYANCES.

Just as is the case with many insects now cosmopolitan and which have been taken from their original home to other parts of the world through the operations of commerce, mosquitoes are carried not only from one part of a given country to another in carriages, in railroad trains and on river boats, but they have been, and are yet, to a more limited extent perhaps, carried from one country to another by ocean vessels. It seems reasonably well established that Hawaii had no aboriginal mosquito fauna and that the mosquitoes found there were brought over in sailing vessels many years ago; these could only have maintained themselves during a long voyage by breeding in the water supply of those vessels. In this way it is a practical certainty that the yellow fever outbreak in Philadelphia in 1793, and the other less grave epidemics in northern cities preceding and following that notable occurrence, were brought about by the arrival in these ports, at the proper season of the year, of sailing vessels from the West Indies carrying *Aëdes calopus*. Perhaps these mosquitoes were already infected, or breeding in the water supply of the vessels, biting yellow-fever patients on board at the proper period, and afterward healthy individuals, would perpetuate the disease. Such a vessel tying up to a wharf might emit many infected mosquitoes which, biting persons on land, and subsequently breeding in numbers in water barrels or other accumulations of fresh water on or near the wharves, would start an epidemic which would progress gradually inland from the water front, as was the case in Philadelphia and in other places. The same method of travel accounts also for the European outbreaks. The shortening of sea voyages by the introduction of steam has, in a way, increased the possibility of mosquito carriage from one place to another; but, in another way, it has lessened this possibility, since the water supplies of ships are of late years, as a rule, so kept that mosquitoes can not breed in them.

The natural geographical distribution of the yellow-fever mosquito, now well known to coincide with the tropical and subtropical life zones, does not limit its possibilities in this direction. As is shown in the section on the geographic distribution in the United States the yellow-fever mosquito is often found in midsummer or late summer breeding north of its permanent range, only to die out there with the winter. This can be only when it is carried north by artificial conveyances during the summer, flying out and breeding for a generation or so where proper breeding-places are at hand. Thus, in August, 1904, it was found to be breeding on the grounds of the Exposition at St. Louis. The yellow-fever mosquito is particularly adapted to such carriage. In the late summer of 1908 one was found in Washington, D. C., in all probability brought up from the South on a through train over one of the southern railroads.

One of the writers (Howard) has often gone to bed in a sleeping car at New Orleans and suffered all night from mosquitoes which were carried along with the train. Mr. J. O. Martin, an entomologist and good observer, in September, 1901, coming to Washington on the train from New Orleans, noticed that at nightfall the train stopped in a swamp just outside of New Orleans, and mosquitoes came in through the open windows in very large numbers. Mr. Martin, knowing what had been written about the carriage of mosquitoes by railroad trains, noticed carefully the rest of the journey and states that a considerable proportion of the mosquitoes which entered the train just outside of New Orleans were still in the train on its arrival in Washington.

A number of instances have been published where mosquitoes were introduced into new localities by the rearrangement of trains and the putting on of night trains on railroads where there had previously been no night service. Some of these are mentioned in "Mosquitoes" (Howard). One of these instances relates to the introduction of mosquitoes into the City of Mexico. Since its publication the writers have been informed by Prof. A. L. Herrera, of the City of Mexico, that the statement that mosquitoes were first brought to the City of Mexico from Vera Cruz on the completion of the railroad from the gulf to the city, is incorrect, but that they first made their appearance in the City of Mexico in 1885, on the completion of the Mexican National Railroad, having been brought down from the valley of the Rio Grande at Neuvo Laredo. Prof. Herrera further stated that during the summer time almost every train from the north brings many mosquitoes down to the City of Mexico. These escape from the cars, take advantage of the abundant breeding-places and soon multiply excessively. This statement was made in 1902. Since that date the admirable sanitary work in the City of Mexico, under the direction of Dr. Liceaga, has greatly reduced the mosquito breeding-places of that city.

In regard to steamships the same general facts hold. Mr. Busck has found the yellow-fever mosquito on a steamer a day out from Jamaica, and he also found it on board a Ward Line steamer in New York harbor.

An excellent and suggestive paper on "Fruit Vessels, Mosquitoes and Yellow Fever," was read before the Louisiana State Medical Society at New Orleans, April 28, 1903, by Dr. Edmond Souchon, then president of the Louisiana State Board of Health, and afterwards printed in the Journal of the American Medical Association for June 13, 1903. Careful collections were made of the mosquitoes arriving at New Orleans on board fruit vessels from Central American ports, and these mosquitoes were determined in Washington at the Bureau of Entomology. This paper, while indicating a great improvement over old conditions, still, at the same time, showed how in previous years yellow fever had been brought to New Orleans.

The habit of *Aëdes calopus* of seeking dark and protected places for hiding is well known to everyone who has observed it. It will crawl into pockets, under coat lapels, and under turned-up trouser-ends, or it will hide in the folds of garments hung in closets or upon the walls of a bedroom. Having these habits, it is extremely liable, as Finlay already pointed out in 1881, to be transported from one place to another in trunks. Garments folded in New Orleans and packed loosely into a trunk may give out *calopus* hundreds of miles away.

The gradual spread of the yellow-fever mosquito from lower altitudes to higher ones in Mexico has been pointed out in the general consideration of the habits of this insect, but it should be here stated that while this species breeds naturally throughout the moist tropical regions near the Gulf of Mexico and near the Pacific, its carriage to higher altitudes on the railroads running up from Tampico and Vera Cruz is an almost daily occurrence. Through this constant carriage on railway trains the species has become established at higher altitudes where the conditions are suitable. Thus, at Córdoba it established itself at first in the immediate vicinity of the railway station and gradually spread upward from this center year after year until now it may be found breeding in the center of the town, at a considerable distance from the station. The same thing occurred still higher, at Orizaba (4200 feet). It has established itself at Carasal on the Inter-Oceanic Railway. It also occurs at points on the railway from Tampico to Monterey (1600 feet) and it has been found in the summer time at Saltillo—much higher than Monterey. It is doubtful whether, had the railroads not been constructed, the yellow-fever mosquito would have ever become established at many of these elevated inland localities.

Mr. C. P. Lounsbury, government entomologist of the Cape of Good Hope, is authority for the statement that the railroads in Cape Colony have been responsible for taking mosquitoes to many inland towns which before the introduction of train service were quite free from this pest.

Skuse, writing of *Culex quinquefasciatus*, considers that it was introduced into Australia from Europe by sailing vessels and says: "As the railway lines extend so this mosquito reaches portions of the country often hitherto exempt from it, and it has been, and is being, communicated to other places along the coasts by water traffic" (Proc. Linn. Soc. N. S. W., ser. 2, vol. 3, 1889, p. 1718).

Not only by sailing vessels, steamships, and railroad trains are mosquitoes carried without flying. Grassi has stated that he counted 200 specimens of *Anopheles* on the inside of a stage coach during a drive lasting two hours through the plains of Capaccio, and the same observer also, by the way, has recorded the capture of *Anopheles* in a railway carriage traveling from Florence to Berlin. Mr. J. K. Thibault, Jr., of Scott, Arkansas, in a letter to the senior author, states that in his region mosquitoes are constantly being transported over the country by buggies, covered wagons, and even, in the case of *Aëdes cyanescens*, on the backs of horses. He has known *Anopheles quadrimaculatus* and *Culex abominator* to be quite frequently carried forty miles in a day, and as they will not leave a vehicle while it is in motion, it will be seen that they may travel even greater distances. One of the writers has never suffered more severely from the attacks of mosquitoes than in a night drive in Louisiana in the autumn of 1907. The stage in which he was driving for a number of miles in company with Mr. W. D. Hunter, of the Bureau of Entomology, seemed filled with most vicious mosquitoes which made no attempt to leave the vehicle, but remained in it from the banks of the Mississippi River to the point of destination.

Goeldi, in his " Os mosquitos no Pará," expresses the belief that the steamers on the river Amazon are responsible for a wholesale carriage of the yellow-fever mosquito and for its general introduction into all of the small towns far up the river; he attributes to this source the introduction of yellow fever at Yquitos, Peru, which is practically the head of navigation.

Balfour, at Khartoum, found that the steamers plying on the Nile were all badly infested with mosquitoes, both *Aëdes calopus* and *Culex quinquefasciatus* breeding on them in abundance. Not only were these mosquitoes a source of great annoyance to everyone on board, but by these steamers the towns along the route were constantly restocked with mosquitoes.

" For a long time it was difficult to control the breeding places on the steamers, but in the autumn of 1904 the Director of Steamers and Boats issued more stringent regulations to engineers and native reises, and the result was soon apparent. Steamer after steamer arrived free from mosquito larvæ, Khartoum North became a more comfortable place of habitation, and the wells in the river zone of Khartoum were less frequently re-infected."

The section of the Report of Working Party No. 1, Yellow Fever Institute, Public Health and Marine-Hospital Service, which relates to the transportation of mosquitoes by ships is of much interest, since it gives the result of actual ship examinations at Vera Cruz and indicates how the insects are carried. It is quoted in full:

" This subject was not studied in detail on account of lack of facilities, but sufficient information was gathered to make it worth mentioning. The only time we found mosquitoes actually breeding on board a vessel was in the instance of the American schooner *John H. Crandon*. This schooner had arrived from Mobile, Ala., with a cargo of lumber twenty days previous to our examination. Water and provisions had been taken on at Mobile. The examination was made on account of a case of yellow fever occurring among the crew. The wooden tanks were examined and found to contain larvæ of *Stegomyia* by thousands. The iron water tanks were examined, but owing to their depth and small openings none were found. Iron water tanks, as a rule, are more securely covered and are given more attention than the wooden containers. The two or three barrels, placed in front of the galley and forecastle, are more frequently infested and in every instance perference was given them in the examination. The box of the carpenter's grindstone offers another favorite place for the breeding of this insect. An examination of the cabins was made to determine the presence or absence of adult insects. In the room from which the man with yellow fever was taken, the insects were found in abundance, both normal and blood fed, resting in the shady corners on dark objects hanging around the room. Considerable effort is necessary to detect mosquitoes when they are few in number; each cabin should be gone over systematically, passing the hands in the corners and gently shaking the hanging articles until every object above the floor has been gently disturbed. The forecastle and galley of this schooner, immediately behind the breeding barrels, harbored the insect in abundance.

"The steamship *William Cliff* is of interest in connection with the transference of mosquitoes by vessels as well as furnishing data relative to the period of incubation and spread of malaria among a crew where all outside influences were removed.

"This vessel sailed from Liverpool, England, on May 29, 1902, with the following itinerary:

Arrived.	Port.	Sailed.
June 11	St. Thomas	June 12
June 15	Colon	June 16
June 19	Kingston	June 20
June 25	Tampico	June 26
June 27	Vera Cruz	July 1

"Until arrived in Tampico no sickness had occurred on board; while leaving that port one man was taken sick with a vague chill, and illy defined pains. Two days later, June 28, four of the crew were taken sick with pronounced chills, pains in the head, extremities, and back, and high fever. The following day, June 29, four more including the captain, were taken sick in like manner; on June 30, two more were taken sick.

"On June 29, the blood of two of the cases was examined for the plasmodium malaria with negative results. Their absence was accounted for by the large doses of quinine administered prior to the examination. On July 1, two new cases were examined; in one the tertian parasite was obtained, the other was negative.

"The disease clinically was of the tertian type, about half-intermittent, the balance remittant. All, with one exception, responded readily to quinine. The exception resisted the quinine for three days. An examination of the ship was made to determine the genera and species of mosquitoes on board. Of these there were three genera and four species in abundance, as follows:

"*Anopheles argyrotarsis, Culex fatigans, Culex tæniorhynchus, Janthinosoma Lutzii.*

"All the varieties mentioned were found in the forecastle and after wheel-house, the crew's quarters being aft instead of forward. The cabins failed to show the presence of mosquitoes on the examination of June 30, nor were any noted previous to that time.

"*Anopheles argyrotarsis* were present in Vera Cruz, though in very small numbers; so scarce, that up to that time only one specimen had been taken. This mosquito is also native to Tampico and Colon. According to the history of the crew, which on snch subjects is very unreliable, they stated that while at Tampico they had not been molested by mosquitoes, while at Colon all hands suffered severely from bites. The character of the fever is extremely suggestive of a Colon infection, the tertian type being comparatively rare, both in Tampico and Vera Cruz. Another point that makes Colon infection seem positive is the period of incubation that invariably takes place after primary malarial infection. This period has been variously stated to be from one day to several weeks. Our own observations (Parker—report to Surgeon-General, October, 1901) on this point are limited to a single observation that included three crews, one of a steamship and two of schooners at Jacksonville, Fla., during the fall of 1901. In this instance the three vessels arrived at Jacksonville from northern ports at about the same time, and lay at a badly infected part of the town. Cases of malaria appeared simultaneously on all three boats fourteen days after arrival.

"Dr. D. D. le Favre (Roussky Vratch, October 19, 1902), in an experiment on himself, showed that the actual period of incubation of malaria in one instance was twelve days.

"Those long periods of incubation in the malignant tertian and quotidian undoubtedly account for many infections that have been classed as being yellow fever.

"It is a well-known fact, which one of us (Parker) has experienced, that steamers lying in Habana Harbor become badly infested with mosquitoes, which insects remain on board the steamship during the voyage to Progreso and thence to Vera Cruz, appearing at night in the cabins in considerable numbers.

"It will be seen, then, that there is considerable evidence to support the assertion that these insects are constantly being transferred from one locality to another through the medium of ocean commerce. In this distribution the iron ship, on account of its concealed water tanks, acts in the nature of a mechanical host, while wooden vessels, on account of the loosely covered deck containers, not only act as a mechanical host, but under favorable conditions, as in calm or gentle weather, or lying at anchor, furnish the proper medium for the propagation especially of domestic species.

"Passed Assistant Surgeon Grubbs, U. S. Public Health and Marine-Hospital Service, has collected data at the Gulf Quarantine Station relative to the transference of mosquitoes by vessels. In a total of 82 vessels inspected to determine the presence of these insects, he found *Stegomyia fasciata* in the adult stage on three wooden vessels, all from Vera Cruz. One of the vessels was the *John H. Crandon* mentioned above."

Surgeon Grubbs's paper above referred to (Bulletin No. 11, Yellow Fever Institute) is interesting as giving the results of an effort to get exact information on this point. It is quoted as follows:

"At the present time, when evidence is pointing with more and more clearness to the mosquito as the sole means of transmitting yellow fever, nothing is of greater interest to the quarantine officer than to decide to what extent and under what circumstances these infecting insects may be carried by vessels.

"This subject may be approached in three different ways: First, by observations on the length of time after leaving infected ports vessels may develop yellow fever; second, by experiments with mosquitoes under artificial conditions made to simulate as much as possible those of nature; and third, by actual observation of vessels arriving from ports at the time infected or where the presence of the *Stegomyia fasciata* render them liable to infection.

"While it will require data obtained by all these means and extending over a long period to arrive at any conclusions sufficiently accurate to allow them to influence quarantine procedure, still I believe the last method of observation cited will throw more light on the subject than the first two.

"It is for this reason that every vessel arriving at Gulf Quarantine Station from Stegomyia-infected ports has, since the 1st of July last, been carefully examined to ascertain if mosquitoes were present on board, and, if present, their variety, where and when they came aboard, and under what conditions.

"Gulf Quarantine Station is an especially good point for these observations, from the fact that it is 10 miles from the mainland, and because vessels bound here do not pass near land, and so but rarely take on mosquitoes en route, and even these, as will be seen, are always the marsh-bred varieties of *Culex*. Besides, the examination of at least a thousand mosquitoes on Ship Island has convinced me that there are no *Stegomyia* here.

"Each vessel inspected was carefully searched, the inspector being armed with a cyanide killing bottle, and in addition the captain was asked the following questions:

"1. Were there any mosquitoes on board on your outward voyage, consisting of ——— days?

"2. If so, did they come aboard before departure from home port or at sea, and under what circumstances?

"3. Were there any mosquitoes on board at your destination or on homeward voyage?

"4. If in port—
(a) How far were you from shore?
(b) Prevailing wind and weather?

"5. If on homeward voyage (consisting of ——— days) —
(a) Were they from port?
(b) Did they come aboard at sea, on what day, and how far were you from land?
(c) Were there wigglers in any of your tanks at any time?

"During the five months from June 1 to November 1 observations were made on 82 vessels, all arriving from ports where the *Stegomyia* is believed to exist in quantities. Of these 78 were sailing vessels and 4 were steamers.

"Of these 82 vessels, 65 claimed to have had no mosquitoes aboard at any time during the voyage or at port of departure, and their absence having been confirmed by search, we can dismiss them from consideration and pass to the remaining 17.

"Five of these had mosquitoes on board at their ports of departure, 2 being rid of them as soon as they were well at sea, while 3 others carried them two days and were then no more troubled, except one schooner on which they reappeared in quantities five days before she reached port, when she was 20 miles from shore.

"Nine sailing vessels, having no mosquitoes on board before sailing, had them appear at sea, in one case from the water casks in which the captain found larvæ. But in the other cases they doubtless came from land which was at the time distant—20 miles in one case, 15 miles in three cases, 10 miles in one case, and 2 miles in the last two instances. In all these vessels the mosquitoes found on board on arrival at this station were the common varieties of *Culex*, there being no *Anopheles* or *Stegomyia* among them.

"*Stegomyia fasciata* were found on board and were identified in the remaining three cases, as follows:

"The schooner *Susie B. Dantzler* arrived from Vera Cruz, Mexico, on July 16, 1902, after a voyage of fifteen days. The captain stated that mosquitoes came aboard in large quantities at Vera Cruz, although he lay a half mile from shore and there were variable winds with squalls and rain all the time. The number of the insects decreased on the voyage but were always in evidence, and we caught four or five of them here. No larvæ were found in any of the tanks, and as the captain had repeatedly examined them without result in his efforts to be rid of the mosquitoes, I believe the insects found on board here came all the way from Vera Cruz.

"The schooner *Eleanor* arrived from Vera Cruz on July 17, 1902, thirteen days out. She had no mosquitoes on board before reaching Vera Cruz, but there quantities came on board. Her moorings were half a mile from shore and the winds were variable. The captain stated that he could not get rid of the insects after sailing, although the number decreased very much and there were no larvæ in any of the tanks. At the time of her inspection here we caught and identified a number of *Stegomyia*.

"The brigantine *John H. Crandon* arrived at the station July 27, 1902, twenty-two days from Vera Cruz, where she had one case of yellow fever on board. At that port she lay a half mile from the sea wall, three-eights of a mile from an infected prison, and within 200 yards of an infected vessel. *Stegomyia fasciata* were found on board by Acting Assistant Surgeon Hodgson before she sailed, as well as larvæ in the tanks. All during the trip there were mosquitoes in abundance, and a veritable plague of *Stegomyia* was found on board on her arrival here. There was a constant buzz in the forecastle, and anyone entering was sure to be attacked by several mosquitoes. Specimens were caught in almost every protected part of the vessel, and all were found to be *Stegomyia fasciata*. The captain had emptied several water barrels because he found they were breeding mosquitoes, but the water remaining had no live larvæ, although many old moults were seen. As breeding was surely going on in the tanks during a part of the voyage at least, it would be impossible to say how long any particular mosquito had been aboard or if any of them had been brought here from the infected port.

"*Summary*.—The above facts may be summed up as follows:

Vessels having no mosquitoes on board at any time............	65
Vessels having mosquitoes on board in port of departure......	5
Vessels on which mosquitoes (*Culex*) appeared en route.......	9
Vessels arriving with *Stegomyia fasciata* on board............	3

"Three and a half per cent, then, of all vessels brought *Stegomyia* on a voyage averaging seventeen days.

"*Conclusions*.—From but one season's observations at a single quarantine station we can not assume to draw any hard and fast conclusions regarding the probability of *Stegomyia*, infected or not, being carried by vessels. Nevertheless, I think we may conclude, first, that mosquitoes can come aboard vessels under favorable conditions when the vessel is not over 15 miles from shore; second, that *Stegomyia* can be carried from Mexican or West Indian ports to those of our Gulf States; third, that they can board a vessel lying at anchor a half mile or less from shore, being conveyed by the open lighters used or flying aboard, and finally, that a vessel moored a short distance from land may become infected with yellow fever, our old beliefs to the contrary notwithstanding."

MOSQUITOES IN THE COURTS OF LAW.

So far as known to the writers, it has only been since the disease-bearing function of mosquitoes has become rather generally accepted that these insects have appeared in courts of law. Three rather interesting cases are mentioned below, without any definite statements as to dates and other very exact details, for the purpose of calling attention to an interesting phase of practical entomology.

About 1900, in a southern town, there was a great deal of malaria and especially among the operatives of certain large cotton mills, the motive power of which was supplied by two large dams. The proprietors of the dams deemed it possible that the trouble was caused by the pollution of the dam water by the sewage of a State institution nearby, and complained to the health officer. It seemed that the health officer was the attending physician at the State institution, and, resenting the implication concerning the sewage of the institution and being familiar with the fact that mosquitoes carried malaria, he claimed that the trouble was due to the breeding of *Anopheles* mosquitoes in the mill dams or in the back waters caused by the dams. He therefore secured an order from the State Board of Health, demanding the abolition of the dams in the interest of health. This order was resisted by the proprietors of the mills and the case was brought before the courts. The proprietors speedily informed themselves on the subject of the etiology of malaria, reading all the latest publications on the subject. They then cleaned up the margins of the dam, presented a copy of a recently published book on mosquitoes to each of twelve physicians of the town, and offered a reward of $50 each for every *Anopheles* larva that could be found in the dams. The physicians all made search and no larvæ were found. Whereupon, each physician was summoned as an expert witness in the trial. In the meantime an expert entomologist was engaged to come to the town to examine the conditions at the dams and to find the breeding-places of *Anopheles* in the surrounding country. This expert found no *Anopheles* in the dams, but he found the mosquitoes breeding practically everywhere throughout the community, with the exception of the dams. He found unused springs, chance pools and puddles swarming with *Anopheles* larvæ. He often found them (since it was at wet season) breeding in water standing in the furrows in the corn fields, the soil being a strong clay.

At the first trial, expert testimony was brought forward to the effect that the mosquitoes probably bred in the marshes at some distance back of the dams, and that these marshes could not be drained so long as the dams remained. The case was adjourned and before the time of the next court the proprietors of the dams had bought certain portions of this back land and had successfully drained it, showing that the existence of the marshes was not necessarily due to the existence of the dams. Ultimately, the case was *nolle prosequi*, and the dams remain today.

Another interesting case occurred in a town near Boston. A member of the Board of Health, greatly interested in the subject of malaria and malaria mosquitoes, found *Anopheles* breeding extensively in certain stone quarries, particularly in the abandoned portions of the quarries which had been worked. The proprietors of the quarries were sued, with the idea of forcing them to fill up the abandoned portions of the quarries, and the case came to trial in Boston before a referee. Expert testimony was heard and the judge finally announced, before hearing all of the testimony which was prepared, that he had no doubt from what he had already heard that the quarries were breeding malaria mosquitoes and that their existence constituted a menace to the health of the people living nearby; but, that he would not decide in favor of the prosecution for the reason that such a decision would constitute a dangerous precedent, and that it would render all owners of excavations or mill dams or similar necessities to industry liable to prosecution on what might be in some cases grounds that would be trivial compared with the magnitude of the interests involved.

The third case occurred about 1903, in Texas. The plaintiff alleged that the defendant, a certain railway, had constructed a large water tank or pool near his premises, that the water in the tank became stagnant (caused by decaying vegetation, etc.), producing poisonous vapors, gases, and disease-bearing germs, which, escaping from said pool, reached and permeated the premises of the plaintiff, causing foul odors and sickness. The evidence showed that since the construction of the pool, mosquitoes were more numerous in plaintiff's home than before. The railway surgeon testified that malaria was caused solely by mosquitoes, and that large bodies of water, such as the defendant's pool, would not produce as many mosquitoes as smaller and shallower bodies of water, and, therefore, that the malaria of which the plaintiff complained was probably derived from other sources than the railway water tank. Thus, the mosquito aspect was only the collateral issue in the case, introduced curiously enough by the defendant and not by the plaintiff. The trial was by jury and a verdict was rendered for the plaintiff, largely owing to the submittal to the jury by the judge of the issue of malarial poison caused by noxious and poisonous vapors.

PROTECTIVE AND REMEDIAL WORK AGAINST MOSQUITOES.

For many centuries humanity has endured the annoyance of mosquitoes without making an intelligent effort to prevent the annoyance, except for smudges, preparations applied to the skin, and removal from localities of abundance. And it is only within comparatively recent years that wide-spread community work against mosquitoes has been undertaken, this having resulted almost directly from the discoveries concerning the carriage of disease by these insects.

As obvious a procedure as it might seem to be, the abolition of mosquito breeding-places is a comparatively new idea. The treatment of breeding-places with oil to destroy the larval forms is, however, by no means recent. As early as 1812, the writer of a work published in London entitled "Omniana or Horae Otiosiores" suggested that by pouring oil upon water the number of mosquitoes may be diminished. It is stated that in the middle of the 19th century kerosene was used in France in this way, while in the French quarter in New Orleans oil was placed in water tanks before the Civil War, the idea having possibly come from France to New Orleans or vice versa.

Another early recommendation of the use of oil was given by an anonymous writer in the Magazin Pittoresque, vol. 15, pp. 178–182 (1846) in an article on the "Mosquito and Its Metamorphoses." The phraseology translated into English is as follows: "When one has recognized that the ponds or ditches existing close to houses are swarming with the larvæ of mosquitoes, one can immediately destroy this dangerous race by spreading on the surface a little oil, which extends in a very thin film and prevents the little insects from coming up to breathe. This proceeding is especially easy to put into practice upon the irrigating tanks in gardens, since it is in such places that the greatest number of mosquitoes develop."

Again, quite recently, Mr. John P. Fort, of Athens, Georgia, has written to one of us (Howard) that about the year 1854 his father, Dr. Thomlinson Fort, was physician to the penitentiary at Milledgeville, Ga., a place of about two thousand people; this had become infested with mosquitoes so as to cause much complaint. Dr. Fort had the matter investigated, and it was found that the mosquitoes originated in the tan-vats of a tan-yard in the penitentiary, and in a large cistern attached to the livery stable in the city. He ordered oil to be put upon the water in the tan-vats, and the mosquitoes were destroyed.

In 1892, some exact experimentation was undertaken by Howard, in Green County, New York, which indicated the amount of kerosene necessary for a given water surface, and the duration of efficiency. These experiments also showed that adult mosquitoes are captured by the kerosene film; that is to say, adult females alighting on the surface of the water for the purpose of depositing eggs, or for drinking, are destroyed by the kerosene before the eggs are laid. The account of these experiments, published in "Insect Life," vol. 5, No. 1, pp. 12–14 (September, 1892), attracted much attention among persons interested and received extended newspaper notices. From this it resulted that practical work on a larger or smaller scale was carried on with success, by H. E. Weed, at the Mississippi Agricultural College; by Dr. John B. Smith, on Long Island; by Prof. V. L. Kellogg on the campus of the Stanford University of California; by Rev. John D. Long, at Oak Island Beach, Long Island Sound; Mr. W. R. Hopson, near Stratford, Conn.; Mr. R. M. Reese, in Baltimore; Mr. W. C. Kerr, on Staten Island; M. J. Wightman, at an Atlantic coast resort, and by Dr. St. George Gray, in the British West Indies. The publication of the extensive mosquito article in the bulletin on house-hold insects (No. 4, n. s., Division of Entomology, U. S. Department of Agriculture, 1896) by Howard and Marlatt, intensified this interest, and was productive of other successful work.

With the discovery of the disease-bearing relation of mosquitoes, first with malaria and next the yellow fever, public interest in their destruction became intensified, and large-scale remedy work was done at many points. Bulletin No. 25, n. s., Division of Entomology, U. S. Department of Agriculture (1900), by Howard, devoted considerable space to the subject of remedies, and indicated in the main those remedies which are of use today and are to be recommended upon a sound basis of practical experimentation. It is probably unfortunate that the writer of this bulletin laid so much stress upon the use of petroleum as to obscure in a way the much more vital measures of thorough drainage and the complete abolition of breeding-places; but the idea that was prominent in his mind at the time the bulletin was written was "Let us stop mosquito breeding at once in an economical way, and then let us take our time in more expensive, more elaborate, and more radical measures." The same criticism can be made and the same partial, though by no means satisfactory, explanation urged in the case of Howard's book "Mosquitoes," published in the spring of 1901; but both bulletin and book served a good purpose, and together undoubtedly helped to start, to a great measure, the anti-mosquito work which has since been carried on in the United States.

Practically beginning with 1901, there has been a rather rapid increase in anti-mosquito work by individuals and communities, but this work has not progressed with anything like the rapidity demanded by the distressing conditions of many localities and in fact of great areas. Yet, it is probably accurate to state that more intelligent work of this kind has been done in the United States than in any other country. This is probably due to the greater prevalence of mosquitoes in the United States than in any other highly civilized country, but the well-known practical character of the American people is also an element.

During the summer of 1900, Mr. W. J. Matheson carried on some admirable anti-mosquito work at his large place at Lloyd's Neck, Long Island. This work was most thoroughly done and was most successful, no mosquitoes breeding in localities where they had previously swarmed to such an extent as to render them almost uninhabitable. In the autumn of 1900, there was a migration of salt-marsh mosquitoes to Lloyd's Neck from salt marshes bordering on Center Island. Mr. Matheson induced the practical owners of Center Island to take up extensive work during the summer of 1901, and this work was carried through in a very perfect manner by Mr. H. C. Weeks, engineer in charge, and was described in the "Century Magazine" for July, 1902. In the summer of 1901 was also begun by far the largest piece of work as yet undertaken. It originated on the northern shore of Long Island in the regions between Hempstead Harbor and Cold Spring Harbor, and was carried on under the auspicies of the North Shore Improvement Association, a group of wealthy and prominent residents of this part of the Island. The work during the summer of 1901 included an almost microscopic survey of the region and the preparation of a map showing the breeding-places of the several kinds of mosquitoes. It included also the preparation of reports by entomological experts, a report by Professor Shaler, of Harvard University, on marsh areas and related subjects; an account of the work done on Center Island during 1901; and engineering reports, including recommendations for treatment, by Mr. H. C. Weeks. A volume was published in the spring of 1902 entitled "Reports on Mosquitoes, with Map" (New York, Press of Styles and Cash), which will form a very sound basis for thorough ocean-shore community work for some time to come. Following the survey of the work by the North Shore Improvement Association, in 1901, there were carried on by private individuals and by the Association, in 1902, certain remedial and preventive operations. One of the most interesting of this series was performed on the estate of Mr. W. D. Guthrie. By means of a dyke and a sluice gate a large marsh area was drained out, and the breeding of the salt-marsh mosquitoes was stopped. A stretch of 75 acres of land was reclaimed, the soil was disintegrated and properly treated, with the result that cabbages, turnips, and celery were grown at the close of the summer of 1902.

The year of 1902 was also marked by the first effort to secure anti-mosquito legislation from one of the United States. The State Entomologist of New Jersey, Doctor John B. Smith, backed by an intelligent public sentiment, tried to secure the passage of a bill by the State Legislature during the winter of 1901–2, appropriating ten thousand dollars for the purpose of investigating

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1. School children finding mosquito breeding-places, Worcester, Mass.
2. Mosquito class-work, Worcester, Mass.

the possibilities of the wholesale destruction of the salt-marsh mosquito and other kinds of mosquitoes. The bill passed one branch of the Legislature, but failed in the other branch. The Governor of the State, however, was able in other ways to provide Doctor Smith with a limited sum to carry on researches. In this work he discovered a number of most interesting and vitally important facts concerning breeding habits of the salt-marsh mosquitoes, indicating that the breeding-places of this species are more or less circumscribed, and that the matter of control is by no means as expensive as would appear at first sight, and it was these discoveries that eventually led to the passage of the law which will be mentioned later.

Admirable community work was taken up during 1901–2 by other New Jersey towns, notably South Orange, Elizabeth, Montclair, Monmouth Beach, and Summit. Independent work was begun in greater New York, under Doctor Lederle, and mapping mosquito breeding-places within city limits was begun. Independently, the health officers of Brooklyn, Jamaica, and Bronx Borough began efficient work, while the summer resorts of Arverne and Woodmere reduced the mosquito supply by intelligent operations. At Willets Point intelligent and efficient work was carried out on a small scale. In Massachusetts interesting and important work was done at Brookline and at Worcester. In Brookline, the Board of Health first considered the work in August, 1901, and in September all the breeding-places of the malaria mosquito and of the other mosquitoes were treated. In 1902, all pools, ponds, ditches, and other breeding-places, including catch-basins, were located on the town map. The approximate areas were determined and the number of catch-basins ascertained. Breeding-places of *Culex* and *Anopheles,* respectively, were determined, and also the places where both kinds were breeding—this being done in order to ascertain the proper intervals for treatment; that is, whether every two weeks or every three weeks. Public dumps and other places where accidental receptacles of water might be found were also located on the maps. Light fuel oil was used on all breeding-places. The public dumps proved to be very important in the work, since many accidental receptacles, like bottles, cans, wooden and tin boxes, and the like, were found to contain larvæ. Where these were breakable, they were simply broken; when not, they were carried and dumped into pools to assist in filling these.

This Brookline work was so thorough that the community was greatly relieved from the mosquito pest, although in the autumn some low meadows near the town, where drainage work had been postponed, were found to be breeding mosquitoes in great numbers.

At Worcester, the work was of the most interesting kind. Dr. William McKibben and Dr. C. F. Hodge started the crusade. Breeding-places were mapped and photographed and public lectures were given. The school children of the several grades were interested and were organized into searching parties. Many breeding-places were filled up and others were treated with kerosene. A strong point was made in Worcester, by those engaged in the crusade, of the prevalence of malaria in many places in the city. The relation between the mosquito breeding-places and the houses where there were malaria patients was effectively pointed out, a map was prepared showing the exact distribution of malaria in the city, and photographs were made showing the character of the breeding-places of the malaria mosquito. It is probable that these Worcester efforts to interest the school children were the first made in this direction, although the idea was carried out to a much greater extent later in San Antonio, Texas, under Doctor Lankford, as will be pointed out on subsequent pages. Other work, during the summer, was carried on at Pine Orchard and Ansonia, Connecticut; at Old Orchard Beach, in Maine; and on the campus of the Michigan Agricultural College, in Michigan. Strong efforts were made during the summer to start work at Baltimore, but for a time the City Council refused to make appropriations. At Atlanta, Ga., the Sanitary Department used a large amount of kerosene in the stagnant pools and swampy places around the city, and warned the citizens to watch their rain barrels and keep their gutters open. A great many pools of water were drained, and in the negro quarters of the city the sanitary inspectors were constantly on the lookout for standing water in buckets and other chance receptacles. The matter was taken up with the County Commissioners and the area of preventive measures was extended toward the close of the season. In Savannah some work was done and the number of mosquitoes reduced very considerably. Oil was used diligently by the sewer-cleaning forces and was placed in the catch-basins. So great was the relief that many people in Savannah for the first time used no mosquito-bars. At Talladega, Alabama, under the direction of Doctor B. B. Simms, anti-mosquito work was commenced early in the season and was carried out systematically and thoroughly. No place that could possibly prove a breeding-place was overlooked. The application of kerosene was repeated several times during the year. St. Louis took up the work early in July, and the Municipal Assembly made an appropriation for supplies. The Health Department, however, was hampered for lack of men and little work was done.

Such were the early steps in the mosquito crusade in this country. Many other communities have taken up the work since 1902. Some, through inefficient work, have allowed their efforts to lapse, and have become more or less indifferent. Others have gone ahead and have spent considerable sums of money in their mosquito fight.

In the early days of mosquito warfare there was great indifference combined with incredulity as to the danger from mosquitoes, even among the medical profession, and particularly in the South. This indifference and incredulity, however, have now, for the most part, passed away. Boards of health very generally appreciate the desirability of anti-mosquito work, and as rapidly as town councils can be induced to appropriate the necessary funds, the work is going ahead.

Excellent anti-mosquito work, backed by rather modest funds, has been carried on during the past few years in Honolulu, under the direction of the then Entomologist of the Hawaiian Agricultural Experiment Station, Doctor D. L. Van Dine. In Porto Rico some work is being done, as well as in the Philippines, under the United States government. In Cuba and in Panama the work has been of a standard character, and the operations at these points will be more fully mentioned in subsequent paragraphs.

In other parts of the world many striking examples of value of anti-mosquito work have been shown comparatively recently, and several of these will be detailed later.

In the pages that follow the aim has been to give a full consideration to the subject of remedies and preventives, discussing not only those which have been found to be of the greatest value, but also others of lesser or even no value, since an expression of opinion concerning all may well be considered desirable. A large part of the following information has been published by the senior author under the title "Preventive and Remedial Work Against Mosquitoes" as Bull. 88, U. S. Dept. Agr., Bur. Ent., 1910. For a condensed summary of the best remedies the reader is referred to Farmers' Bulletin 444 of the U. S. Department of Agriculture, which may be had for the asking.

PROTECTION FROM BITES.

SCREENS AND CANOPIES.

Such obvious measures as the screening of houses, the use of netting for beds and the wearing of veils and gloves after nightfall in badly infested regions, need no consideration in detail. But even in such an apparently simple matter as house screening certain points must be taken into consideration. It may be incidentally stated that with proper treatment of breeding-places screening is unnecessary. The expense to which the people of the United States go for screens against mosquitoes and flies is enormous, and has been estimated at $10,000,000 annually.

In screening a house, as Doctor John B. Smith has pointed out in his Bulletin No. 216 of the New Jersey Agricultural Experiment Station, the attempts frequently fall far short of protection:

"Adjustable, folding, or sliding screens are never tight, and when the insects really want to get indoors they work their way patiently between the two parts of the screen or between its frames and the window. But even a well-fitted screen either sets tightly into the frame or, running like a sash, may offer leaks when a window is only partly opened. . . . There is abundant opportunity for the insect to get in between the net and lower cross bar; in fact, there is no real protection at all. Where the netting is fixed to the outside of its frame, so that there is no space between it and the lower part of the sash, the insects nevertheless find their way in between the window sashes. . . . It has been already said that the mosquitoes will, in certain seasons, attempt to make their way through the screens, and they have less trouble with wire netting than with any other because the meshes are even in size and the strands smooth. Some of the fabrics used for nettings, especially of the cheaper grades, have the threads so fuzzy that it is simply impossible for the mosqnitoes to make their way through, and they rarely even try it except where there is a tear, or where the threads have been spread apart leaving an unusually large opening. Where an onslaught is made on wire netting it can be checked by painting lightly with kerosene or oil of citronella. I have tried both and found them successful."

In addition to these mechanical difficulties it often happens that the cellar and attic windows of houses are not screened. This is a great mistake, since mosquitoes will enter these windows and pass the winter in both cellars and attics. They also descend unused chimneys, so that fire-places require screening.

With regard to bed canopies there is reason for the greatest care. There should be ample material to admit of a perfect folding of the canopy under the mattress, and the greatest care should be taken to keep the fabric well mended. It often happens in mosquito regions that little care is taken of the bed nettings in the poorer hotels, and it is necessary for perfect protection that a traveler in the Southern States should carry with him a pocket housewife and should carefully examine his bed netting every night, prepared to mend all tears and expanded meshes.

Veils and nettings for camping in the tropics are absolute necessaries. Light frames are made to fit helmet-like over the head and are covered with mosquito netting. Similar frames readily folded into a compact form are made to form a bed covering at night, and every camping outfit for work in tropical or malarial regions should possess such framework and plenty of mosquito netting as an essential part of the outfit.

An illustrated advertisement in Ross's "Mosquito Brigades" shows a folding hood mosquito net especially for the use of travelers when taking rest. This is 6½ feet long, 4 feet wide, and 2 feet high. It is a frame arrangement which can be opened by the traveler so as to envelop himself when he is lying down. The frame is easily carried in the hand, being only 40 inches long by 4 inches in diameter when folded. There is also given an illustration of a small, compact mosquito house for use by travelers while writing, reading, or taking their meals. It is large enough to contain two persons seated, and is constructed with a frame which is earily portable. The frames are manufactured by White & Wright, surgical instrument makers, 93 Renshaw Street, Liverpool. No doubt other apparatus of the same kind is manufactured and to be purchased at large outfitting establishments, such as the Army and Navy Stores in London.

Some attention has been paid to the subject of the size of the mesh of screens with especial reference to the yellow-fever mosquito. Working Party No. 2 of the Public Health and Marine-Hospital Service, at Vera Cruz, conducted a few experiments to determine the question of the size of the mesh. Their experiments were conducted by placing screens with a varying number of meshes to the inch over breeding-jars and putting bananas, syrup and other food on the other side so as to tempt the hungry mosquitoes to pass through. The fruit and other food was placed in a jar which was inverted over the mosquito breeding-jar, and a piece of gauze or netting was inserted between the two jars so that the mosquitoes would have to pass through the meshes in order to appear in the upper jar. As a result it was found that both males and females passed through a netting containing sixteen strands or fifteen meshes to the inch, but could not pass twenty strands or nineteen meshes to the inch. It therefore became evident to these observers that the large-meshed mosquito bars ordinarily used in Vera Cruz would not offer proper protection and that window screening must also be of a finer mesh than is sometimes employed.

Goeldi refers to this screen question, both in regard to the yellow-fever mosquito and to the common rainwater-barrel mosquito, in connection with some very interesting observations about the range of variation in the size of the individuals of the same species, a fact which is frequently noticed with other insects but to which special attention has not been called elsewhere with mosquitoes.

"Frequently I have observed, both in *Stegomyia fasciata* and in *Culex fatigans,* alongside of individuals of normal stature, individuals very much smaller —veritable dwarfs. This observation may be made on specimens captured in freedom as well as on those in captivity, in this last case the phenomenon repeating itself rather frequently. There are sometimes born individuals, both males and females, so small that they easily pass through the mesh of wire gauze much closer than the mesh of 'Grassi's gauze' which today is produced on a large scale in Italy with a view to the prophylaxis against *Anopheles* and malaria (Grassi, himself, recommends a gauze that shall not have less than nine meshes in 1½ centimeters of distance, which corresponds to little linear squares 1.7 mm. to the side). The government of the State of Pará imported from Italy, for my experiments, a gauze under this name which had but six threads to 1½ centimeters of linear extension, corresponding to squares of 2½ mm. along one side. I refer particularly to this last brand, which I consider sufficient as a rule, for application to hospitals, to impede the invasion of mosquitoes from outside, but which I found, nevertheless, insufficient for the walls of my cages destined for experiments on mosquitoes like *Stegomyia fasciata* and *Culex fatigans* in captivity.

"In general, the phenomena of *macrosomia* and *microsomia* in plants and animals are related directly with greater or less abundant nutrition, and I do not believe that the quoted dwarf race of *Stegomyia* and *Culex* is to be explained in any other way than by a sparse alimentation and a delayed development in the larval stage. On this point I have at hand experiments in proof: Larvæ bred in clear water—that is to say, relatively poor in assimilable substances—gave me imagos of small stature. Furthermore, it is yet to be shown that I am deceived in my opinion that the frequency of dwarf individuals captured in freedom is not notably greater at certain periods, assuming almost the character of a rule. Thus this year, in the last weeks of October and in November, before we entered fully upon the rainy season, I got the impression that the females of dwarf dimensions were particularly numerous. I doubt that this is the work of a mere accident: it is very possible that the frequency of dwarf individuals, normally possible during the whole year, may be periodic and represent a case, somewhat diminished, of what is called in entomology 'dimorphism of seasons.' Theoretically there can be no serious obstacle in accepting the argument that in the height of the dry season, with the growing lack of water, the conditions of life for the larvæ become more difficult, thus favoring the generation of mosquitoes below the normal dimensions. Impoverished water and reduced food may really, as we have seen above, oblige the larva to take two or three times the period normally necessary for its development and to acquire the necessary growth for its metamorphosis. I have the feeling that hibernation, in the sense in which this word is accepted in zoologic literature, may well for the tropical and equatorial Culicidæ find its expression in two ways: (1) Delayed development of the larvæ; (2) Dwarfed stature of the imagos."

***Note by Translator.*—Doctor Goeldi enters into a long explanation as to hibernation, evidently for the benefit of equatorial readers who might accuse him of the malnse of technical terms. He refers to the phenomenon of "seasonal lethargy" and endeavors to trace a connection between the circumstances favoring the development of the perfect insects in parallelism with the "periodicity of yellow fever." His final paragraph is as follows:**

"It would be a mistake to believe that these dwarf individuals of *Stegomyia* are less aggressive and sanguinary than those of normal stature. They behave in a precisely similar manner; their bites are not less painful, as I have had frequent occasion to prove."

A study of the question of mosquito bars or canopies, both for indoors and out-of-doors, has been made by Dr. F. Arnold, the District Medical Officer of Health, Northern Transvaal, and he has published an interesting article on the subject in The Transvaal Agricultural Journal for October, 1907, pages 13–15. He illustrates the mesh of different nettings purchased in Pretoria, labeling a netting with a mesh 1 mm. in width as good, one of 2 mm. as doubtful, and one of 3 mm. as bad. These nettings were tested by stretching them over the mouths of three large pill-boxes, and in each pill-box was put a known number of live, uninjured mosquitoes. The boxes were placed on a chair alongside his bed, where they remained all night, with the idea that by placing the mosquitoes near a sleeper they would be anxious to get at him, and the natural conditions existing in a bedroom would be imitated; that is, there would be a mosquito and a sleeper separated by a net. The conclusions coincided with those above indicated. Doctor Arnold continues his directions in the following words:

"In this country the bell-shaped bedroom mosquito net is almost always used; box-shaped nets are rarely seen. In Eastern countries the box-shaped net is generally used fixed on to a large four-posted bed; such an arrangement has the great advantage that the net can be drawn tight and there is within it so large a space for the sleeper that his limbs, if uncovered, are not likely to come in contact with the net.

"Frequently the bell net has too small a ring at the top and the netting is not sewn on to the calico which closes the ring, but is gathered-up above it by a running thread; such an arrangement causes folds to be formed in the net above the ring and through the grooves of these folds mosquitoes enter freely. Again, the net is often allowed to hang loose on the bed or it is drawn over the whole bedstead on to the ground. When hanging loose it affords very little protection, for it will, during the night, certainly come in contact with the face, arms, etc., which will be bitten through the net. If placed right over the bedstead then its lower margin must be heavily-weighted with a long and continuous sand bag, and every care must be taken to drive away mosquitoes which may be sleeping on the dark under side of the mattress; in out-lying districts white ants would, in one night, make short work of net and sand bag if lying on a mud floor. How, then, should a net be made and arranged?

"Proceed as follows: Obtain a ring of wood or iron, in diameter two and a half to three feet; close it with a piece of stout calico; on this calico, around the circumference of the ring, sew the mosquito net very carefully, using netting of the mesh shown as No. 1. Suspend the net to the ceiling in the usual way. Next arrange the bedding as is done on board ship; that is to say, take the upper sheet, blanket and counterpane and fold the margins inwards at the sides and at the foot; all the bedding which will cover the sleeper will then lie on the top of the under sheet. Now tuck the mosquito net under the mattress all round, drawing it tight. On going to bed draw out the net at one side, creep in under it, and carefully tuck it back under the mattress. The sleeper is now in a cage; it does not matter how much he kicks about the net will remain true, and, provided that a fair-sized bed is used, there is not much risk of an unclothed part of the body touching the net. For use on the veld many kinds of stretchers, etc., have been devised. The writer has used a folding stretcher which carries four thin upright rods. Through eyes in the upper ends of these rods runs a cord, and over the whole structure is placed a box-shaped net. The net sold with the stretcher has its lower margin weighted; it is intended that this lower margin should lie on the ground. But this is a theoretical arrangement. First, one rarely gets a flat piece of ground free of grass and stones whereon to place the stretcher; secondly, a sudden gust of wind causes the hanging net to 'ride-up' on the feet of the stretcher; and, lastly, a stone or grass lifts up the lower margin of the net.

"The net, etc., should be arranged as follows:—Take a large, long blanket, 7 ft. x 5 ft., fold it lengthways, and lay it on the stretcher to serve as a mattress. Arrange the blankets which will cover you just as the top-bedding is arranged for an in-door bed. Tuck in the net carefully all round under the blanket-mattress, taking especial care to cross the folds of the net round the upright rods. Crawl in under the net and close it in the usual way. The stretcher used by the writer, when opened for use, measures six and a half by two and a half feet, and stands fifteen inches above the ground. The whole outfit (stretcher, rods and net) weighs 26 lbs. and can be packed into a canvas sack measuring three feet by thirteen inches."

The Medical Department, of the U. S. Army, is now advising the Quartermaster-General's Department that, in the belief of the experts of the Office of the Surgeon-General, screens with 16 meshes to the inch will exclude the yellow-fever mosquito and the malarial mosquitoes. Col. J. R. Kean has given us this information, and states that this opinion is based upon some very careful experiments made by Doctor Juan Guiteras in 1908. Colonel Kean writes further that Dr. Charles F. Craig, of the Medical Corps, U. S. Army, reports that a 16-mesh to the inch gauze was always successful in excluding *Anopheles* mosquitoes in the Philippines, and he was stationed at Camp Stotsenburg where these mosquitoes were exceedingly abundant. Since it is known that certain of the anopheline mosquitoes of the Philippines are smaller than species found in the United States, the Surgeon-General of the Army has directed that the Board for the study of Tropical Diseases investigate the question further. Doctor Guiteras's report to Colonel Kean has been sent to us, and we print it as follows:

"The bronzed wire gauze of 16 threads to the inch that was sent to me by you for trial as to its efficiency in barring the passage of stegomyia mosquitoes, has been subjected to a series of experiments in our laboratory at Las Animas Hospital.

"I should state that we had heretofore acted under the impression that an 18 wire mesh was required; that we had never employed in this hospital any but the 18 wire mesh, and that this opinion was in part based on experiments that had been made by Dr. Rosenau of the Public Health and Marine-Hospital Service. I do not think, however, that Dr. Rosenau gave his experiments as conclusive.

"The following equipment was used for our experiments:

"A large cage or wooden frame, closed in with wire gauze made of 18 threads to the inch. The cage had a double door, and measured 2.10 meters long by 1.50 meters wide, and 1.93 meters high.

"An ordinary wooden tub measuring 0.40 meters in diameter, and covered with bronzed wire gauze of 16 threads to the inch.

"A small cage measuring 0.54 meters by 0.26 meters by 0.34 meters, consisting of a frame covered with wire gauze of 18 threads to the inch. This long cage was divided across by a double partition consisting of 2 pieces of 16 mesh gauze separated by a space 2 centimeters wide. Each compartment was provided with an opening for the hand.

"The experiments were made exclusively with the stegomyia mosquito. They were commenced on the 1st of June of this year.

"On the 1st of June, 100 stegomyias, male and female, were let loose in the large cage where they found dry food (sugar), but no water. In the cage was placed the tub, three-quarters filled with rain water, and closed with 16 mesh gauze. After six days all the mosquitoes in the cage had perished, evidently for want of water. No mosquitoes had passed the 16 mesh gauze. No eggs were found in the water, and no larvæ developed there.

"On July 4th, 200 stegomyia mosquitoes, male and female, were let loose in the same cage. On the 9th there were only two insects left alive. On the 10th these two were dead. No mosquitoes, eggs or larvæ were found within the tub or in the water. This experiment was, in every respect, a repetition of the first.

"In the small cage the experiment was four times tried of placing three unfecundated females on one side, and three males on the other. Both groups were provided with food and water, and the females were occasionally allowed to bite. These females had been obtained from pupæ that had been kept isolated, each one in separate bottles, so that all possible contact with the male could be excluded. The double partition in the cage prevented the possibility of contact through the partition. The males and females never passed through the partition and the females were not fecundated.

"The experiment was also repeatedly tried of keeping males and females together on one side of the partition, and food and water on the other side. Banana, sugar, molasses were tried separately. At times also the hand was kept in the empty compartment for periods of from 30 to 40 minutes. If no water was allowed on the side occupied by the mosquitoes they promptly died. Otherwise they endured long, but were never able to pass across, nor could we ever see any evidences that they made any attempt to push themselves across.

"Another series of experiments were made by darkening one side of the cage with a dark cloth. The mosquitoes were placed sometimes on the dark side, and sometimes on the uncovered or light side. These insects were allowed food and water during the experiment. They never passed through the partition.

"It is my opinion that we may conclude from these experiments that the *stegomyia calopus* can not pass through the wire gauze sent for trial. The gauze is a 16 wire mesh; that is, it presents 16 wires or threads to the linear inch."

Dr. Samuel T. Darling, Chief of Laboratory of the Board of Health, Department of Sanitation, Isthmian Canal Commission, in a paper entitled "Studies in Relation to Malaria," Washington, Government Printing Office, 1910, gives the results of certain observations upon the size of mesh of wire screen. He finds that at the Isthmus a 16-mesh screening answers the purpose against malarial mosquitoes, but that against the yellow-fever mosquito, while practically safe, it is not absolutely so. Out of several hundred mosquitoes, 8 species were able to make their escape through a 16-mesh screen, as follows:

	Number of specimens escaped.
"*Stegomyia calopus:*	
Males	10
Females	6
Culex cubensis, male	1
Culex rejector, male	1
Culex extricator, female	1
Aedes angustivittatus, female	1
Uranotænia lowii, female	1"

SCREENING BREEDING-PLACES.

What we have said in regard to the size of mesh to be used in window screens and canopies applies equally well to screens over possible breeding-places to prevent the breeding of mosquitoes or the issuing of mosquitoes which have bred therein. In cities like those in the Gulf States, where the rain-water supply is conserved in large tanks, screening is necessary and is now enforced, Galveston and New Orleans perhaps being the first to make this an important health measure. But rain-water barrels everywhere must also be screened in the same way, except where fish are used to kill the early stages of mosquitoes. In out-of-the-way places, however, where it is difficult to get good screens or where the expense of screening is seriously to be considered, a cheap cover may be made for well-mouths or water barrels, such as described by Dutton in his Report of the Malaria Expedition to the Gambia and which he states was devised by Doctor Forde.

"This cover consists of a large iron hoop obtained from discarded barrels, to which is fastened all round a piece of stout calico or sacking free from holes, in such a manner that a good deal of sag is left in the material. After water is obtained from the well the hoop is thrown over the mouth, and the calico catching on the rim of the well completely closes the entrance and is kept taut by the weight of the iron hoop. This cover is so simple, and, however carelessly applied, must so effectually close the entrance of the tub against mosquitoes, that I think it is well worthy of extensive use in the town. Dr. Forde has lately informed me that these covers are now being made in Bathurst, and are sold to the natives for the sum of four pence."

PROTECTIVE LIQUIDS.

A number of different substances have been in use to rub upon the skin or to put near the bed as a protection from mosquitoes. Spirits of camphor rubbed upon the face and hands, or a few drops on the pillow at night will keep away mosquitoes for a time, and this is also a well-known property of oil of pennyroyal. The use of oil of peppermint, lemon juice and vinegar have all been recommended for use as protectors against mosquitoes, while oil of tar has also been used in bad mosquito localities. A mixture recommended by Mr. E. H. Gane, of New York, is:

Castor oil	1 oz.
Alcohol	1 oz.
Oil of lavender	1 oz.

The oil of citronella has come into very general use in the United States in the past few years. The odor is objectionable to some people but not to many and it is efficacious in keeping away mosquitoes for several hours. A mixture recommended by Mr. C. A. Nash, of New York, composed of

1 oz. oil of citronella
1 oz. spirits of camphor
½ oz. oil of cedar

has been the most efficacious mixture tried by the writer. Ordinarily a few drops on a bath towel hung over the head of the bed will keep *Culex pipiens* away for a whole night. Where mosquitoes are very persistent, however, a few drops rubbed on the face and hands will suffice. This mixture in the experience of the writer has been efficacious against all mosquitoes except *Aëdes calopus,* the yellow-fever mosquito. This mosquito begins to trouble the sleeper at day-break and by that time the efficacy of the mixture has largely passed, and one is apt to be in his soundest sleep. If, however, one could arrange to be awakened just before day-break and apply the mixture, returning for the last nap, it is probable that it would be efficacious.

Fishermen and hunters in the north woods will find that a good mixture against mosquitoes and black flies can be made as follows:

Take 2½ lbs. of mutton tallow and strain it.

While still hot add: ½ lb. black tar (Canadian tar).

Stir thoroughly and pour into the receptacle in which it is to be contained. When nearly cool stir in 3 oz. of oil of citronella and 1½ oz. of pennyroyal.

Oscar Samostz, of Austin, Tex., recommends the following formula:

1 oz. oil citronella.
4 oz. liquid vaseline.

Apply freely to exposed parts.

Mr. B. A. Reynolds, of the Bureau of Entomology, has used successfully in New Orleans 20 minims of oil of citronella to the ounce of vaseline or lanoline, preference being given to the latter.

Doctor Durham, of the English Yellow Fever Commission to Pará, Brazil, told the writer that he and the late Doctor Myers found that a 5 per cent solution of sulphate of potash prevented mosquitoes from biting, and that they were obliged to use this mixture while at work in their laboratory in Brazil to prevent themselves from being badly bitten.

An anonymous correspondent of "American Medicine," who signs himself F. A. H., says:

"I would advise the use of the oil of cassia, for the odor is not offensive to human beings and it is an irritant poison to all kinds of insects. Besides, its power remains for a long time after it has dried."

Pure kerosene has been used for this same purpose. An excellent example of its practical use came to the writer in a letter from Dr. W. H. Dade, an Army Surgeon, writing from the Philippine Islands under date of November 15, 1901:

He stated that during November, 1900, while traveling up the Cagayan River on the steamer *Raleigh,* they were bothered greatly by mosquitoes, both during the day and night, *Culex* and *Anopheles* both being present and breeding in fire buckets along the sides of the vessel. The buckets were teeming with larvæ. They did not seem to have thought of putting kerosene in the buckets in order to stop the breeding, but at the suggestion of Doctor Dade a rag was saturated with kerosene, the face, hands and feet were smeared with it and the rag was put where it could be conveniently reached. When aroused from sleep by mosquitoes another application was made. "Those who had not used these means before seemed perfectly surprised at the splendid immunity gained. The odor and the greasy feeling imparted were the only drawbacks to its use."

Doctor Dade continued to experiment with this remedy after his return from an unsuccessful attempt to capture General Aguinaldo, and found that the addition of one part oil of bergamot to sixteen of kerosene imparted an odor scarcely objectionable, and at the same time added sufficient body to the kerosene to prevent evaporation in less than six to eight hours. After that, when the soldiers had to leave the post, and after it became impracticable to carry cans with them in the field for a long or protracted march, this mixture was used with the result that the list of malarial patients was noticeably shortened. The oil of bergamot was hard to obtain and is too expensive to be used wholesale, but the soldiers rarely objected to the odor of kerosene and the bergamot was not continued.

In moist tropical regions where one perspires profusely, the oily mixtures on the skin considered under this heading are transient in their effects. Under these circumstances they should be applied rather liberally to the clothing, particularly about the neck and wrists.

SMUDGES AND FUMIGANTS.

Hunters and campers have been in the habit of using almost anything that will make a dense smoke as a smudge to drive away mosquitoes. In Bermuda, fresh cascarilla bark is burned for this purpose, and elsewhere other green bark and vegetation. For household use, however, a number of different substances have been tried.

PYRETHRUM OR CHRYSANTHEMUM.

For many years finely ground powders known as pyrethrum powder, chrysanthemum powder, Persian insect powder, or Dalmatian insect powder, have been used to kill insects. They became famous for their insecticidal effects long before their composition was known. Their use seems to have originated in Asiatic countries beyond the Caucasus Mountains. The powder was sold at high price by the inhabitants and was brought by merchants to Russia and western European countries. The nature of the powder was kept a secret until the beginning of the last century, when an Armenian merchant, Mr. Jumtikoff, learned that the powder was obtained from the dried flowerheads of certain species of composite plants of the genus *Chrysanthemum* (*Pyrethrum*) growing abundantly in the region now known as Transcaucasia. The son of Mr. Jumtikoff began to manufacture the article on a large scale in 1828, and since then the pyrethrum industry has steadily grown and now the export in dried flowerheads from that part of the country is very important.

The species grown commercially in the Transcaucasian region is *Chrysanthemum roseum*. The species grown in Dalmatia is *C. cinerariæfolium*, and the crop in Dalmatia, Montenegro and Herzegovina is now the principal source of the powder in commerce. Thirty years ago it was considered the most valuable export of Dalmatia. The best powders are made from the dried flowerheads of these plants. The essential principle resides in the oleoresins, which are fugitive, so that the strength of the powders disappears with age or exposure. Powders imported from Europe are not so strong as powders made in this country from imported dried flowerheads brought over in bulk. For this reason it was, many years ago, deemed very desirable to establish a pyrethrum-growing industry in the United States, and in 1881 the United States Entomological Commission imported and distributed the seeds of the two species above mentioned to a number of correspondents in different parts of the country. The total success was inconsiderable. Further experiments another year met with comparative failure. About this time more extensive plantations were made in California and an insect powder was made by the Buhach Producing and Manufacturing Company, of Stockton, California, which, being American grown and freshly ground, came into use, and is still being produced and sold under the proprietary name of "buhach," the word being supposedly derived from a Slavonic word "buha," meaning flea. An article by the late D. W. Coquillett on the production and manufacture of this powder will be found in Bulletin No. 12, Division of Entomology, United States Department of Agriculture, 1886, pp. 7 to 16.

Formerly most of the insect powders sold in the shops in this country had pyrethrum powder as a basis. It is now difficult to get a pure and thoroughly efficient powder. There is often adulteration. Frequently the powder made from the dried flowerheads is adulterated with powder made from the stems, or with other adulterants. Under the U. S. Insecticide Act of 1910 it is now required that the manufacturers of insect powders indicate on the label the composition of the powder, unless made of the flowerheads of the following three species: 1. *Chrysanthemum* (*Pyrethrum*) *cinerariæfolium* (Trev.) Bocc.; 2. *C.* (*P.*) *roseum* Web. & Mohr.; 3. *Chrysanthemum marshallii* Aschers (synonym: *Pyrethrum carneum* M. B.).

Pyrethrum powders are usually used dry and are puffed or blown into crevices frequented by insects, or puffed or blown into the air of a room in which there are mosquitoes or flies. The burning of the powder in a room at night is a common practice. The powder is heaped up in a little pyramid which is lighted at the top and burns slowly, giving off a dense and pungent smoke with an odor very much like that of the Chinese punk used to light firecrackers. Often the powder is moistened and moulded roughly into small cones, and after drying it burns readily and perhaps with less waste than does the dry powder. Of late years in mosquito countries a number of mosquito pastilles have been sold, and many of these are moulded from powders that contain more or less pyrethrum. The efficacy of the burning pyrethrum in a close room is almost perfect. It will not actually kill all the mosquitoes, but will stupefy them and cause them to fall to the floor where they may be swept up and burned. With the windows open, however, and constant currents of fresh air blowing through the room, this fumigation is not especially effective, and it is necessary for protection to sit in the cloud of smoke.

The pungent odor of burning pyrethrum is not disagreeable to most people, but to some it is disagreeable, and with certain susceptible individuals it produces headache. It is apparently possible, however, to volatilize the oil without producing the actual smoke. Mr. H. W. Henshaw informs us that a few years ago a man in Hawaii patented an appliance for producing this volatilization which is all that can be wished for. The powder is placed on a brass or other metal screen above the chimney of a kerosene lamp, the idea being to dissipate the vapor of the volatile oil. According to Mr. Henshaw the effect of this method is most remarkable. "Besides being very economical in powder there is only a very slight odor perceptible and that is not at all unpleasant. The effect on the mosquitoes is immediate and all that can be wished for. They simply clear out." Another method of burning the powder that has often been employed by the writer consists in puffing it from an insufflator into a burning gas jet. This is a simple method where gas is used for illuminating purposes and produces a vapor that suffocates all mosquitoes and other insects that may be in the room.

While pyrethrum has been mainly used as a means of clearing living-rooms of mosquitoes, and has ordinarily been burned in the rooms while they were occupied, it has also come into use in the extensive fumigation of houses in cases of epidemics of yellow fever, in the effort to rid houses of mosquitoes and to destroy all mosquitoes hibernating in cellars, attics, or disused rooms of residences, as well as similarly hibernating mosquitoes in barns and outhouses. While reasonably effective for such purposes it does not seem to be as effective as some of the other substances to be mentioned later and at the same time it is more expensive.

As to the quantity to be used, the regulations of the Board of Health of New Orleans, adopted May 25, 1903, specify the burning of 4 ounces of pyrethrum powder to 1000 cu. ft. of space, but the President of the Board, Dr. Edmond Souchon, a little less than a year later wrote to the U. S. Marine-Hospital Service that this quantity was found insufficient for thorough work, and that 1 pound of the powder to every 1000 cubic feet of space is necessary. As a matter of fact, however, the New Orleans Board of Health abandoned pyrethrum about that time on account of the fact that the fumes do not kill mosquitoes but simply stupefy them, so that they have to be brushed up and burned. Not willing to run the slightest chance of having mosquitoes survive by escaping destruction after being stupefied, the Board decided to use sulphur fumes in preference.

Nevertheless, on account of the fact that the fumes are not noxious to human beings, there still remains a decided use for pyrethrum in everyday work in mosquito-inhabited regions.

MIMMS CULICIDE OR CAMPHOR-PHENOL.

During a yellow fever outbreak in New Orleans, in the summer of 1905, a Mr. Mimms, a chemist of New Orleans, invented a mosquito fumigant which was experimented with rather extensively and found to give good results. It was made of equal parts by weight of carbolic acid crystals and gum camphor. The acid crystals were melted over a gentle heat and poured slowly over the gum, resulting in the absorption of the camphor and a final clear, somewhat volatile, liquid with rather an agreeable odor. This liquid is permanent and may be kept for some time in tight jars. In fumigation work 3 oz. of this mixture is volatilized over a lamp of some kind for every 1000 cubic feet of space. A special apparatus for the purpose has been perfected by Doctor H. A. Veazie, of New Orleans, but a simple apparatus may be made from a section of a stovepipe, cut so as to have 3 legs and outlets for draft, an alcohol lamp placed beneath and a flat-bottomed basin on top. The substance is inflammable but the vapor is not explosive. The vapor is not dangerous to human life except when very dense, but it produces a headache if too freely breathed. One of the writers (Howard), in New Orleans on the 8th of November of the epidemic year (1905), in company with Doctor J. H. White, in charge of the Public Health and Marine-Hospital Service operations in the city during the epidemic, Doctor Rupert A. Blue, Doctor Richardson, Doctor H. A. Veazie, and several other assistant surgeons in the service, took part in the fumigation of a room containing about 1200 feet of space. A number of specimens of *Culex quinquefasciatus* were flying about the room. There were 2 boxes, each about 1 foot long with gauze sides, containing ½ dozen or more live mosquitoes each; there was a large tube, 2 inches in diameter, and possibly 1½ feet in length, the mouth of which was covered with mosquito bar and which lay on its side on the mantle piece and contained several live mosquitoes. About 6 ounces of the mixture were volatilized and the room was kept closed, without any effort to artificially stop cracks, for exactly one hour. Upon re-entering and airing the room, all mosquitoes were found to be dead and a cockroach was also found dead on the floor, having come up from between the cracks. The vapor is lighter than air, and the mosquitoes in the room, previously unnoticed, soon after fumigation sought the lower air strata of the room, gradually descending towards the floor and towards the windows which were on one side of the room only. Sheets of manila paper had been spread before each window and on these sheets, at the end of the hour, were found dead all the mosquitoes to be found in the room.

An account of experiments with this mixture, containing details of apparatus, etc., by Past Assistant Surgeon Berry, of the U. S. Public Health and Marine-Hospital Service, is published in the Public Health Reports for February 2, 1906, vol. 21, No. 5, pp. 83 to 89. The conclusions reached by Doctor Berry are as follows:

"1. Culicide in the proportion of 4 ounces per 1000 cubic feet used for 2 hours with apparatus similar to that used by us kills *Culex pungens, Stegomyia,* and *Anopheles maculipennis* and temporarily stuns the house fly.

"2. In the proportion of 3 ounces to 1000 cubic feet it does not always kill the *Anopheles maculipennis.*

"3. Culicide takes fire spontaneously if heated sufficiently. It is therefore necessary to keep the liquid at a certain distance from the flame; it is also better to have more than one basin in a large space, and about 8 ounces is the maximum quantity to use in one pan. All large cracks must be pasted up—the doors and windows if loose fitting. Gummed paper spread under a window left light would be of great benefit. (I concur with Passed Assistant Surgeon Goldberger as to the closing up of large cracks, but more for preventing weakening of the strength of the gas in the room by diffusion than from any belief that insects might escape from the room.)

"4. In the minds of intelligent operators, and used according to the methods employed by us, it ranks next to sulphur as an insecticide in practical fumigation.

"5. Culicide vaporizes and later cools, condensing on exposed surfaces again as it cools. Whether in this way it injures articles of gilt and the like was not investigated. In practical work the only articles removed from rooms were food stuffs and animal pets and no complaint of injury was received. It gradually evaporates, leaving a persistent, though not disagreeable, odor.

"As to the cost with the present high prices of the ingredients of Culicide, the cost of fumigating a room with 4 ounces to 1000 cubic feet is 16 cents per 1000 cubic feet, as compared with sulphur of 7 cents, and pyrethrum of 50 cents, using 2 pounds of each of the latter per 1000 cubic feet. The estimate does not take into consideration the alcohol used to evaporate the Culicide, but this is not much more, if any, than that used to ignite pyrethrum or sulphur pots. A further saving in favor of Culicide is that the apparatus can be easily carried in the hands from place to place. Had sulphur been used in the instances cited a wagon would have been necessary to transport the materials, which were, in the case of Culicide, conveyed in street cars. The gang would have had to be larger to move the many articles from a house necessary to be removed in sulphur fumigation, to say nothing of the larger amount of pasting to be done. Likewise at the end of the fumigation the time required to remove apparatus from the room is much less. For this and other reasons, if the cost of the labor is counted, I do not believe Culicide is much more expensive than sulphur, and if the cost of the articles damaged by sulphur is considered, the difference would be in favor of Culicide."

This compound is known also by the name of camphor-phenol. Under this name it has been experimented with by Passed Assistant Surgeon Francis. His results, derived from a long series of tests with large numbers of mosquitoes, indicate that it is unsatisfactory as a culicide. These were published in Public Health Reports, vol. 22, no. 13, pages 346 to 348 (March 29, 1907). It was found that the fumes penetrated very poorly and that large amounts of the compound were necessary to obtain results. Evaporated in amounts of from 4 to 10 ounces per 1000 cubic feet of space it proved inefficient. When 8 ounces to 1000 cubic feet of space were evaporated it softened the varnish on furniture, so that articles placed upon it adhered and were ruined. Furthermore the substance is rather expensive to be used in large enough quantities to be effective.

PYROFUME.

Dr. J. H. McCormack, of Mobile, Alabama, has discovered that Pyrofume, derived by a fractional distillation from pine wood, as a by-product in the manufacture of turpentine, is a valuable and good fumigant for mosquitoes. It is a clear liquid of a straw color, has a pungent taste, and the odor of pine woods. It is said to be harmless to mucous membranes, skin, fabrics, colors, polished metal and painted wood work. A report of the experiments with this substance by Passed Assistant Surgeon Francis, of the U. S. Public Health and Marine-Hospital Service, is published in Public Health Reports, June 29, 1906, vol. xxi, No. 26, pp. 711, 712. A summary of Dr. Francis's experimental work follows:

"1. As compared with sulphur, pyrofume stands on an equal footing in price.

"2. Whereas the Federal regulations require two hours exposure to sulphur, pyrofume is efficient against mosquitoes in one hour.

"3. While sulphur is injurious to metals, fabrics, paint, and colors, pyrofume leaves them unchanged.

"4. Pyrofume is suitable for fumigating the engine rooms and cabins of ships, and for cars and fine residences.

"5. In amounts necessary to kill mosquitoes it does not injure bananas.

"6. A person can walk about in a room full of fumes and can sleep without discomfort in a room two hours after fumigation.

"7. It requires only five minutes to fumigate a large room of 5000 cubic feet.

"8. The fumes are generated outside the room and conducted into it."

The conclusions were favorable, but the substance has not been taken up in the practical work of the Public Health Service on account of the fact that special contrivances necessary for the best application of the substance have not yet been perfected.

SULPHUR DIOXIDE.

The damage done by sulphur dioxide to household goods is the principal objection to its use as a fumigant, but in the case of yellow-fever epidemics, where absolutely thorough fumigation is necessary, it is the most reliable of all substances to use. It was used practically exclusively in the anti-mosquito work during the yellow-fever outbreak of 1905 in the city of New Orleans. Houses suspected of containing yellow-fever infection were fumigated in the most thorough way. Every effort was made to close all crevices in the rooms fumigated. Heavy paper was pasted over all apertures, including cracks. This gas is obtained by burning flours of sulphur or lump sulphur in a small pot, fire being started with alcohol. It should be used on a bright day and pots and polished metal and delicate things should be removed. It has been found that two pounds of sulphur for each 1000 cubic feet of space will be perfectly efficient against mosquitoes and other insects. Sulphur candles may be used where available. For an excellent account of certain careful experimentation with sulphur, see an article by Passed Assistant Surgeon Francis, of the U. S. Public Health and Marine-Hospital Service, published in Public Health Reports, March 29, 1907, vol. xxii, No. 13, pp. 346 to 348.

Writing of sulphur, Giles objects to pure sulphur fumigation on account of the difficulty of burning it, and suggests a mixture of one part of nitre and charcoal to eight of sulphur, the mixture being made up in pastilles weighing four ounces each by means of a little gum water, dried in the sun. In India he burned one of these pastilles for every thousand feet of space and found that the effect was admirable, and that even in thatched buildings hardly a mosquito escaped. After fumigating, the floor of a bathroom in which hardly any mosquitoes could be found was covered with dead mosquitoes, which indicates not only the efficacy of the fumigant, but also the effectual ways in which the Indian mosquitoes hide. He suggests that the fumigating should be done towards the end of the hibernating season, and during the heat of the day, when practically all of the mosquitoes are under shelter. He urges the adoption of this method of fumigation in all government barracks, showing that each pastille costs no more than one Lee-Medford cartridge, and that the annual bill for invaliding men who have been educated to use the latter is so heavy that it would be well to adopt any measure likely to diminish it.

In the course of the admirable work carried on in recent years in Rio de Janeiro, and which has achieved such brilliant results, it has been found that sulphur has given the best results in the disinfection of houses. Cruz has given the following account of the method employed:

"The house to be disinfected was completely closed. Every opening or orifice where gas might escape was sealed with gummed paper. The furniture, too, after being thoroughly cleansed, is tightly closed. Metallic or gilded objects are protected with a covering of vaseline. After the roof is covered over with canvas the garrets are opened for the free access of sulphur gas. The canvas is fastened to the walls with laths. Then sulphur is burned in the proportion of 10 to 20 grams per cubic meter, being deposited in several receptacles distributed about the house and kept clear of the floor. Each receptacle should not contain more than 1 kilogram (2.2 pounds) in order to insure complete combustion. In the vacant spaces under the roof the burning sulphur should be placed in receptacles set into others containing water, to avoid danger of fire. After all the receptacles are placed the workmen close up the only exit left open and keep the house thus sealed for not less than 2 hours. The heated air and that displaced by the sulphur gas escapes through the crevices of the roof, but the mosquitoes are kept in by the canvas covering."

In the admirable fight against the yellow-fever mosquito in New Orleans in the summer of 1905, the following directions for fumigating with sulphur dioxide were given out by the health authorities:

"Remove all ornaments of metal, such as brass, copper, silver and gilt from the room that is to be fumigated. All objects of a metallic nature, which can not be removed, can be protected by covering the objects tightly with paper, or with a thin coating of vaseline applied with a brush.

"Remove from the room to be fumigated all fabric material after thoroughly shaking. Open all drawers and doors of furniture and closets.

"The room should be closed and made as tight as possible by stopping all openings in chimney, floor, walls, keyholes and cracks near windows and doors.

"Crevices can be closed by pasting strips of paper (old newspapers) over them with a paste made of flour.

"The sulphur should be placed in an iron pot, flat skillet preferred, and this placed on bricks in a tub or other convenient water receptacle with about an inch of water in the bottom. This is a precaution which must be taken to guard against accidents, as the sulphur is liable to boil over and set fire to the house.

"The sulphur is readily ignited by sprinkling alcohol over it and lighting it.

"The apartment should be kept closed for two hours, and then opened up and well ventilated.

"*Note.*—To find the cubic contents of the room, multiply the length of the room by the width, and this total by the height, and to find the amount of sulphur necessary to fumigate the room divide the cubic contents by 500, and the result will be the amount of sulphur required in pounds.

"Take, for example, a room 15 feet long, 10 feet wide and 10 feet high, we would multiply 15 x 10 x 10, equals 1500 cubic feet. Divide this by 500 and you will have the amount of sulphur required, viz.: 3 pounds."

After a rigid series of experimental tests, Rosenau, of the U. S. Public Health and Marine-Hospital Service, concludes that sulphur dioxide is unexcelled as an insecticide. He shows that very dilute atmospheres of the gas will quickly kill mosquitoes, and that it is quite as efficacious when dry as when moist. He shows that it has surprising power of penetrating through clothing and fabrics, and that it will kill mosquitoes even when hidden under four layers of toweling *in one hour's time and with very dilute proportions. He states that although* this substance has long been disparaged as a disinfectant because it fails to kill spores, it must now be considered as holding the first rank in disinfection against yellow fever, malaria, filariasis, and other insect-borne diseases.

MERCURIC CHLORIDE.

In the Public Health Reports, volume 24, No. 50, December 10, 1909, pp. 1859–1861, Surgeon G. M. Guiteras, U. S. Public Health and Marine-Hospital Service, has recounted a series of experiments with this substance, the use of which was first suggested to him by G. F. Matzke, steward on the American steamer "Beecham," who told Doctor Guiteras that he had used it in the cabin of his vessel with success. Doctor Guiteras carried out a series of five experiments in a room 12 feet high by 15 feet by 13¼ feet, having a capacity of 2385 cubic feet, sublimating the mercuric chloride in a porcelain evaporating dish over an alcohol lamp. Mosquitoes in cages approximately containing a cubic foot of space, covered with wire gauze, were exposed at varying elevations in the room, and from 30 to 60 grams of mercuric chloride were sublimated at exposures varying from two to three hours, at temperatures of from 77 to 88 degrees. Mosquitoes in the upper part of the room were invariably killed, while some of those very near the floor escaped, most of the latter however being killed, and the remainder never recovering perfectly, except in one experiment where the temperature was only 77° F. Twenty-five grams of mercuric chloride were found to be sufficient for 1000 cubic feet of space. He showed that about 20 minutes are consumed in sublimating 60 grams of the chloride; that brass work is not tarnished, and that nickel-plated work and instruments are not tarnished when wiped off immediately after fumigation. He further showed that painted surfaces are unaffected unless the chloride is sublimated close to them and they are not immediately wiped off. Moreover it does not affect colored silk, cotton or woolen goods. The poisonous qualities of the substance, in Guiteras's opinion, do not constitute a real danger. When the room was opened after the experiments, he found it filled with a thick mist, but the room was entered without any especial precaution and the windows were opened. In a few minutes the vapor was carried away, leaving a slight deposit on the surfaces within the room. This was allowed to remain for two or three days, and the room was used in the meantime without any bad results. The deposit, however, should have been removed with a damp cloth, and with this ordinary care, the experimenter believes, there will be no danger in the use of the substance.

The advantages he considers to be, the facility of obtaining mercuric chloride, the small quantity necessary, and the simplicity of its use; a good alcohol lamp and a porcelain evaporating dish constitute all the machinery necessary, and its use is certainly much more convenient than sulphur where the operators have to carry about heavy iron pots and barrels of sulphur. As to expense, he shows that at one dollar per pound the 25 grams used per one thousand feet cost somewhat less than half a cent, whereas two pounds of sulphur per one thousand cubic feet would cost six cents. Moreover, it is pointed out that in practical work on a large scale the expense and trouble of hauling the disinfecting equipment from one place to another would be greatly diminished. He concludes that while mercuric chloride can not altogether take the place of sulphur, it has a hitherto unrecognized effect, especially with reference to flies and mosquitoes.

OTHER FUMIGANTS.

In the early anti-mosquito work in European cities different substances were experimented with. Fermi and Lumbao, in their outlined experiments, recommend chlorine gas. These writers advise that 4 or 5 spoonfuls of chloride of lime be placed in a dinner plate and that from 5 to 10 cubic centimeters of crude sulphuric acid be poured upon it. This liberates the chlorine gas which kills the mosquitoes. The same writers claim that the vapors of chloral act rapidly, killing mosquitoes in a few seconds. Celli and Casagrandi in their early experiments in Italy recommended a substance called larycith III, which is probably a misprint for larvicide. This is dinitrocresol, a yellow aniline color, which kills adult mosquitoes when burned in small quantities. Formaldehyde gas was recommended in 1890, but has been found to have almost no insecticidal value.

Doctor John B. Smith found that the powdered stramonium or jimson weed (*Datura stramonium*) can be burned to advantage in houses. He recommends 8 ounces to fumigate 1000 cubic feet of space. He states that it should be made up by the druggist with nitre or saltpetre, 1 part to 3 parts of *Datura,* so as to burn more freely. He states that the fumes are not poisonous to human beings, are not injurious to fabrics or to metals, and can be used with entire safety. He suggests that it be burned in a tin pan or on a shovel. (See Bulletin 216, New Jersey Agricultural Experiment Station, page 12.)

A long list of fumigants is given by Celli in his work entitled "Malaria according to the new researches," and this list has received a critical review which carries at the same time the results of certain experimental work by Arthur J. Kendall, in Bulletin No. 1 of the Laboratory of the Board of Health, Isthmian Canal Commission, Panama, 1906. Bulletin No. 2 of the same service (1906) contains an account of experiments in practical culicidal fumigation, also by Doctor Kendall.

The burning of dried orange peel has been recommended as a deterrent against mosquitoes, but there seem to be no records of conclusive experiments, although we have been assured of its efficacy by a Japanese physician visiting the United States.

In the course of his experiments with different disinfectants against mosquitoes, Rosenau, of the Public Health and Marine-Hospital Service, in Bulletin No. 6, of the Hygienic Laboratory (September, 1901), did his principal work with the formaldehyde and sulphur dioxide. We have mentioned his conclusions with regard to the latter substance in a previous paragraph. Formaldehyde gas, on account of its germicidal use, was early suggested against mosquitoes when their importance in the rôle of carriers of disease was ascertained, so that exact experimentation was necessary. Rosenau's results were as follows:

"Formaldehyd gas is a feeble insecticide. Mosquitoes may live in a very weak atmosphere of the gas overnight. It will kill them, however, if it is brought in direct contact in the strength and time prescribed for bacterial disinfection. For this purpose any of the accepted methods for evolving the gas is applicable, but the methods which liberate a large volume in a short time are more certain than the slower ones.

"Direct contact between the insects and the gas is much more difficult to obtain in ordinary room disinfection against mosquitoes than against germs, because the sense of self-protection helps the former to escape from the effects of the irritating gas. They hide in the folds of towels, bedding, clothing, hangings, fabrics, and out-of-the-way places where the formaldehyd gas does not penetrate in sufficient strength to kill them. The gas is polymerized and deposited as paraform in the meshes of fabrics, which prevents its penetration, and large quantities are lost by being absorbed by the organic matter of fabrics, especially woolens. In our tests, whenever the insects were given favorable hiding places, such as in crumpled paper or in toweling, they quickly took advantage of the best place for themselves and thus escaped destruction.

"There is a striking analogy between the strength of the gas and the time of exposure necessary to penetrate the fabrics in order to kill mosquitoes, and the strength and time necessary to penetrate in order to kill the spores of bacteria.

"Mosquitoes have a lively instinct in finding cracks or chinks where fresh air may be entering the room, or where the gas is so diluted that they escape destruction. They are able to escape through incredibly small openings. Some of the smaller varieties, such as the *stegomyia fasciata* can get through a wire screen having 12 meshes to the inch. Therefore, formaldehyd gas can not be trusted to kill all the mosquitoes in a room which can not be tightly sealed.

"It is concluded, that to succeed in killing all the mosquitoes in a closed space with formaldehyd gas, the following definite requirements are essential: A very large volume of the gas must be liberated quickly, so that it may diffuse to all portions of the space in sufficient concentration. The room must have all the cracks and chinks where the insects may breathe the fresh air carefully sealed by pasting strips of paper over them. The room must not contain heavy folds of drapery, clothing, bedding, or fabrics in heaps, or so disposed that the insects may hide away from the full effects of the gas."

REMEDIES FOR MOSQUITO BITES.

It must have been the experience of most people that ordinarily little swelling and irritation results from the puncture of a mosquito where there has been no scratching or rubbing of the part. But individuals vary greatly in this respect and it is undoubtedly true that not only do different species of mosquitoes vary in their effect but that different individuals of the same species may also vary. The application of household ammonia has been found by many to give relief and alcohol is also said to stop the irritation. Dr. E. O. Peck, of Morristown, N. J., finds glycerine a sovereign remedy. Touch the bite with glycerine and in a few minutes the pain is gone. Dr. Charles A. Nash, of New York City, marks the punctures with a lump of indigo and states that this instantly stops the irritation, no matter whether the application is made immediately or after the lapse of a day or so. The most satisfactory remedy known to the writer from his own personal experience has been moist soap. Wet the end of a piece of ordinary toilet soap and rub it gently on the puncture and speedily the irritation will pass away. Mr. Charles Stevenson, of Montreal, writing to the Canadian Entomologist in September, 1901, stated that he had found naphthalene mothballs to afford immediate relief from the bites of dangerous diptera including mosquitoes and that a friend of his had used it successfully on flea bites. He advises rubbing the mothball on the affected part for a few minutes. Naphthalene is also recommended by Prof. Boges, Director of the National Board of Health at Buenos Ayres.

Iodine is frequently recommended for this purpose, and a note in a recent number of the Journal of Tropical Medicine and Hygiene recommends a modification in the shape of 30 to 40 grains of iodine to the ounce of saponated petroleum, stating: " A few drops rubbed in a mosquito bite or wasp sting allay the pain instantaneously."

Rev. R. W. Anderson, rector of St. Thomas and St. Denis, wrote us from Wando, South Carolina, some years ago, that he has often found that by holding his hand to a hot lamp chimney the irritation of mosquito punctures would be instantly relieved.

APPARATUS FOR CATCHING ADULT MOSQUITOES.

In a paper entitled " A Preliminary Account of the Biting Flies of India " (Bulletin No. 7, Agricultural Research Institute, Pusa, India), Mr. H. Maxwell-Lefroy, Imperial Entomologist, describes on pages 12 to 15 an apparatus which he used to catch mosquitoes in his bungalow. In the U. S. Daily Consular Trade Reports, Department of Commerce and Labor, Bureau of Manufactures, March 3, 1909, page 10, Consul General William H. Michael, of Calcutta, mentions this apparatus, stating it to be an invention by Mr. Lefroy. In his account, however, Mr. Lefroy does not claim it as an invention of his own.

He used a wooden box, lined with dark geen baize and having a hinged door; the trap was 12 inches long, 12 inches broad and 9 inches deep; a small hole, covered by a revolving piece of wood or metal was prepared in the top of the box, and tin was placed on the floor inside. Owing to the habit of mosquitoes to seek a cool, shady place in which to rest, such as a dark corner of the room, or bookshelf, or something of the sort, they will enter this trap, which is put in the part of the room most frequented by mosquitoes; all other dark places being rendered uninhabitable, so far as possible. Mr. Lefroy writes: " My room being open to the verandah, hordes of mosquitoes come in, and as the room is lined with bookshelves there are many desirable sleeping places. The trap stands in a shady corner, and a large number of mosquitoes enter it when they come home in the morning; the rest are usually driven out of the bookshelves either with a duster or a little tobacco smoke. Finding this desirable sleeping place untouched they go in; the door is then slammed and fastened. At the top of the box is a small hole with a movable plate to close it; through this a teaspoonful or less of benzene is introduced and the plate put back. After a little time all the mosquitoes are dead. The box is taken to the verandah and opened there till the fumes of benzene escape."

In this way Mr. Lefroy caught 2336 mosquitoes in thirty-one days, a daily average of 83.75; daily average of females 22.68. At the same time 23 of the biting sand flies of the genus *Ceratopogon* were caught. He further states that whereas the inmates were before disturbed with mosquitoes and sand flies, which especially attacked the baby, the pest practically entirely ceased. All of the mosquitoes were not exterminated, but so large a portion were destroyed that the inmates of the house suffered no more. Mr. Lefroy goes on to say: "I am not prepared to recommend this as a universal remedy. It must be sensibly used; a small amount of personal effort in teaching a servant is necessary at first. But where mosquitoes are a plague, especially to little children, the housekeeper's thirst for the blood of the mosquito may rise to so great a pitch that she will welcome this device and take a delight (as we do) in counting the corpses daily."

The idea of Mr. Maxwell-Lefroy's apparatus was probably first announced by Nuttall and Shipley (Journal of Hygiene, January, 1902, vol. 2, p. 73) in the following words:

"We are moreover inclined to believe that suitably constructed coloured boxes or colour-traps might be of practical utility in and about houses infested with mosquitoes. By periodically closing the boxes and sweeping out the contained insects into a receptacle, or, possibly by rendering the interior of the boxes sticky, a considerable number of mosquitoes might be destroyed."

This idea was gained by Nuttall and Shipley in the course of their experiments with boxes of different colors to ascertain the color most attractive to *Anopheles* mosquitoes.

G. Blin (Bull. Soc. de Pathol. Exotiqne, vol. 1, pp. 100–103, 1908) records certain experiments made in Dahomey, in 1905, with trap-holes (*trous-pièges*). His procedure consisted in digging in the ground, near houses infested by mosquitoes, oblique holes where the mosquitoes would come to seek darkness and protection from the heat. Then, during the day the mosquitoes were destroyed with a little improvised kerosene-torch, such as a wisp of straw or a stick soaked in kerosene.

Doctor Külz (Archiv für Schiffs- und Tropen-hygiene, 1909, v. 13, p. 645) states that these experiments of Blin were the first trap-box or trap-hole experiments, evidently overlooking the earlier work of Nuttall and Shipley.

An interesting home-made apparatus in common use in many parts of the United States is very convenient and effective. It consists of a tin cup, or of a can cover, nailed to the end of a long stick in such a way that a spoonful or so of kerosene can be placed in the cup which may then, by means of the stick, be pressed up to the ceiling so as to enclose one mosquito after another. When pressed up in this way the captured mosquito will attempt to fly and be caught in the kerosene. By this method perhaps the majority of the mosquitoes in a given bedroom, certainly all those resting on the ceiling, can be caught before one goes to bed.

What seems an excellent idea, and which can be put in practice under certain conditions, in the way of catching adult mosquitoes, was described in the Montclair (N. J.) Herald of July 29, 1910, in which it is stated that Mr. John T. Lyman, of 183 Cooper Avenue, Upper Montclair, has a small vacuum carpet cleaner which is run by the electric current obtained by removing an electric light bulb and connecting the motor of the cleaner to the socket. Just before retiring, it is said, Mr. Lyman runs the cleaner over the walls of the sleeping room, not allowing it to touch the walls, but keeping it at a distance of several inches; the result is that every mosquito, fly or other insect resting upon the walls is sucked into the dust bag at the lower end of the machine. This work, it is said, is accomplished in two minutes to each room, and Mr. Lyman and his family retire to rest undisturbed.

A similar apparatus was used in the spring of 1910 by Dr. E. F. Phillips, of the Bureau of Entomology, against the house fly. He found that by using a nozzle with a fairly wide opening, such as is used in cleaning carpets, the flies were sucked in quickly and almost always before they could make an effort to escape. Doctor Phillips states that when the flies get into the dust-bag there is no chance for escape as they are covered with dust and soon die.

DESTRUCTION OF LARVÆ.

In considering the destruction of larvæ we will first take up those measures which involve the use of what have come during recent years to be termed "larvicides." The dictionary definition of the word insecticide is "One who or that which kills insects, as insect powder"; therefore, a definition of larvicide would be one who or that which kills larvæ. But in mosquito work it has come to be applied to those substances which are applied to bodies of water in which mosquito larvæ are living, and which results in their destruction in one way or another. These substances, for the most part, are either poisons or more frequently oils which, forming a surface film, destroy the larvæ when they come to the surface to breathe. Ronald Ross long ago pointed out the great desideratum in this direction in the following words: "I have long wished to find an ideal poison for mosquito larvæ. It should be some solid substance or powder which is cheap, which dissolves very slowly, and which, when in weak solution, destroys larvæ without being capable of injuring higher animals. What a boon it would be if we could keep the surface of a whole pond free from larvæ simply by scattering a cheap powder over it, once in six months or so. It is very possible that such a substance exists, but unfortunately we have not yet discovered it." (Mosquito Brigades, London, 1902, pp. 33 to 34.)

A great many experiments have been tried with poisonous substances in the search for the desideratum described by Dr. Ross, but although it is now seven years since he wrote this paragraph we still have not discovered it. As early as 1899 Celli and Casagrandi published an account of an elaborate series of laboratory experiments on the destruction of mosquitoes by various chemicals in a paper entitled "La Distruzione delle Zanzare," published in the Annali d'Igiene Sperimentale. These experiments resulted in little practical good, and one of the best of the larvicides, namely, the petroleum products, was discredited by the authors in question.

PERMANGANATE OF POTASH.

In the last few years many substances have been experimented with, both in the United States and in other parts of the world, and there has been from time to time a newspaper notice, or a series of newspaper notices, of some new substance which careful experimentation has shown to be of little or no service. In this way the use of permanganate of potash received much advertising in 1900, but, as one of the writers has elsewhere pointed out, as a result of careful experimentation it was found that small amounts of the chemical have no effect whatever upon mosquito larvæ. They were, however, killed by using amounts so large that, instead of using a handful to a 10-acre swamp, as had been stated in the newspapers, at least a wagon load would have to be used to accomplish any result. Moreover, after the use of this large amount and after the larvæ were killed, the same water 24 hours later sustained freshly hatched mosquito larvæ perfectly, so that even were a person to go to the prohibitive expense of killing mosquito larvæ in the swamp with permanganate of potash, the same task would have to be done over again a few days later.

SULPHATE OF COPPER.

In 1904 a publication by the Bureau of Plant Industry of the U. S. Department of Agriculture, on the use of sulphate of copper against algæ and other microscopic plant life, put certain newspaper men on the wrong track and a number of articles were published making the erroneous statement that the Department of Agriculture recommended sulphate of copper as a perfect remedy against mosquito larvæ. So widely was this alleged discovery heralded that careful experiments were at once made by the Bureau of Entomology, by Doctor Smith, of New Jersey, by Doctor Britton, of Connecticut, and by other entomologists, with the result that the substance was found to be of very slight value as a larvicide, and of really no practical value whatever.

CERTAIN PROPRIETARY COMPOUNDS.

Several proprietary mixtures or mosquito compounds have been prepared and placed on sale for the purpose of destroying mosquito larvæ. A number of these have been brought or sent to one of the writers for experimentation but, considering the cost, none of them has been of as great practical value as petroleum. In his report on the mosquitoes occurring in the State of New Jersey, 1904, Doctor John B. Smith describes a number of experiments with substances of this kind, notably with certain soluble carbolic acid and cresol preparations, with chloro-naphthaleum, and with phinotas oil, and in his report for 1907 he gives the results of certain experiments with a substance known as "killarvæ." It is not necessary, however, to consider any of these substances in this connection except to state that phinotas oil has met with considerable use, since it forms a milky compound with water which settles through a pool and destroys not only mosquito larvæ, but all other animal life in the water. It is used in cesspools and receptacles of that kind, and it has found wide application in the anti-mosquito work on the Isthmus of Panama.

CACTUS PASTE.

We have already spoken of the use of certain substances for forming so dense a covering over the surface of the water as to exclude mosquito larvæ from access to air, thus bringing about their destruction. A method of bringing about this result is described by Consul Wm. H. Bishop, of Palermo, Sicily, in the Monthly Consular and Trade Reports, No. 331, April, 1908, in which he quotes from an account of the experiments made by the Chief of the Sanitary Service at Gaboon, French Africa, with cactus as a substitute for petroleum in the extermination of mosquitoes in warm climates. Beyond this account by Mr. Bishop, we have no further information of this remedy:

"The thick, pulpy leaves of the cactus, cut up in pieces, are thrown into water and macerated until a sticky paste is formed. This paste is spread upon the surface of stagnant water, and forms an isolating layer which prevents the larvæ of the mosquitoes from coming to the top to breathe and destroys them through asphyxiation. It is true that petroleum can do the same service, but in warm climates petroleum evaporates too quickly and is thus of little avail. The mucilaginous cactus paste, on the contrary, can hold its place indefinitely, lasting weeks, months, or even an entire year; and the period of the development of the larvæ being but about a fortnight, it has the most thorough effect."

PETROLEUM.

This substance has been more extensively used in the United States than elsewhere and it is better understood in this country. In choosing the grade of the oil, two factors are to be considered. First, it should spread rapidly; second, it should not evaporate too rapidly. The heavier grades of oil will not spread readily over the surface of the water, but will cling together in spots and the coating will be unduly thick. The rapidity of spread of film is also important. Ronald Ross, in his "Mosquito Brigades," pp. 34 to 35, makes the following statement:

"Mr. Hankins of Agra informs me that the addition of Amyl alcohol greatly expedites the formation of the film; and it is very necessary to obtain a film which makes its way between the stalks and leaves of water weeds."

Early in the course of anti-mosquito work in the United States careful experiments were made by Mr. W. C. Kerr, in the work of the Richmond County Club, on Staten Island. He tried several grades of oil and found a low grade of oil known as "fuel oil" to be best adapted to the work. Of the oils which he tried, some contained too much residuum of a thick nature, which appeared as a precipitate and could scarcely be pumped, some were too thick in July weather and could not be pumped at all, while others were limpid, easily handled, made a good uniform coating on the ponds, and were very effective. So long as oil flows readily and is cheap enough the end is gained, provided it is not too light and does not evaporate too rapidly. The grade known as light fuel oil was recommended by one of the writers to the U. S. Army workers in Cuba, at the close of the Spanish War, and was found to be effective. The price of oil of this kind has varied from $2.25 per barrel to $3.00 per barrel, f. o. b., Philadelphia.

In his early Catskill Mountain experiments one of the writers ascertained that about an ounce of kerosene to 15 square feet of surface space is about the right proportion, and that such a film would remain persistent for 10 days, or slightly longer. He noticed further that even after the iridescent scum had apparently disappeared there was still an odor of kerosene about the water and that adult mosquitoes avoided it.

In the work done by Mr. H. J. Quayle, near San Francisco, oiling was done upon ponds that could not be drained, upon standing pools remaining in creekbeds during the summer, and some was also done on marsh lands. The oil used was a combination of heavy oil of 18-degrees gravity and light oil of 34-degrees gravity, in the proportion of 4 to 1. This mixture made an oil that was just thin enough to spray well from an ordinary spray nozzle, and yet was thick enough to withstand very rapid evaporation. It was applied by means of a barrel pump where this could be used, but in the creeks and other situations, which could not be reached by horse and wagon, the ordinary knapsack pump was used. The price of the heavy oil at Burlingame, California, was 2 cents a gallon, and of the lighter oil 2½ cents a gallon. Mr. Quayle found that the duration of efficiency depended somewhat on the nature of the pool and its exposure to winds, but in no case could it be counted upon as thoroughly effective after a period of four weeks.

This period of four weeks brings up the question as to the frequency of applications of kerosene. The persistence of the oil will undoubtedly vary with the temperature and with the character of the pool—whether exposed to the direct rays of the sun, shaded by trees, or exposed to the wind. Three weeks will probably be the maximum period of efficacy with light fuel oil. The army in Cuba renewed the oil every two weeks.

The application of kerosene to the surface of the water can be made in several different ways. If the oil is thin it may be simply poured upon the surface and will spread itself. The spraying method, either with the barrel pump, by knapsack pump, or bucket pumps must be used for the heavier oils and where there is much aquatic vegetation. One of the writers watched the oiling of ponds with a spraying pump in a New Jersey town several years ago. The water treated was all in small woodland ponds, and there was necessarily a great waste of kerosene. The spray was diffused and became scattered over the vegetation on the borders of the pond, a large share of it being wasted in this way, while the shore vegetation was killed. On small ponds the oil can be sprinkled to advantage out of an ordinary watering pot with a rose nozzle or, for that matter, pouring it out of a dipper or cup will be satisfactory. In larger ponds pumps with a straight discharge nozzle may be used. A straight stream will sink and then rise and spread until the whole surface of the pond is covered without waste. The English workers in Africa advise mopping the petroleum upon the surface of the water by means of cloths tied to the end of a long stick and saturated with kerosene. The use of such a mop may be desirable, even where a straight discharge pump *has been used, in order to commingle detached surface sheets of oil.* In some of his early work on Staten Island, Dr. Doty, the Health Officer of New York, used a pump with a submerged discharge, throwing the oil out at the bottom of a pool and allowing it to rise to the surface. It seems that the idea was to destroy the insects feeding at the bottom more quickly, but as most mosquito larvæ rise to the top to breathe, there is practically nothing to be gained by such a method.

The use of larvicides in tropical regions introduces certain new features which complicate the problem of mosquito destruction to a certain extent. Colonel Gorgas, and his corps of workers at Panama, have been using petroleum very extensively, just as they did at Havana. They find, however, that at Panama the rapid growth of vegetation prevents the oil from spreading uniformly and that it can not make a thin uniform film over the surface of water in which vegetation grows. They find also that algæ on the surface of the waters form with the oil a dark scum, which collects at the bottom of shallow pools. This scum later breaks up and floats about on the surface, rendering succeeding oilings less efficacious, and necessitating the use of larger quantities of oil. They also find that where vegetable debris collects in a large body of water it will be blown about as a mass, its location changing with the wind. Mosquito larvæ also hide in this vegetation, which protects them from fish. The wind blows the oil to one side of the surface and, of course, where the film is not perfect the larvæ find free places to breathe. It evaporates very rapidly in the tropics. During the rainy season it is washed away very rapidly before it destroys all of the larvæ. The bulk of the oil and the cost of transportation in rough territory for work on a large scale are disadvantages. In such work they found that they must constantly occupy themselves in removing vegetation before oil is applied, in order to avoid using excessive amounts of oil. They found that new growths of algæ developed very rapidly after the oil had united with the previous crop and sunk to the bottom.

CORN OIL.

Some effort has been made to find if there are any other oils that may be used to better advantage than petroleum. A suggestion was once made by Mr. W. J. Matheson that corn oil might be used. This is a substance which is made rather extensively in certain parts of the country and which, considering the enormous crops of corn grown in western States, which in fact are so great that sometimes in years of overproduction corn is burned as fuel, might reasonably be supposed to be a cheap oil. This, however, is not the case and its price is prohibitive as compared with ordinary grades of kerosene. Experiments undertaken in 1900 indicated that corn oil does not spread readily. It gathers together in large patches on the surface of the water, and mosquito larvæ rising to the surface and finding themselves under a patch of oil will simply wriggle violently until they find the spaces between the patches where they can breathe comfortably and live. In this experiment the object was not only to secure a cheap and efficient oil, but to secure a persistent oil which will not evaporate, and which will remain for at least several weeks over the surface of the water. Its non-spreading qualities, however, as well as its price, removes it from practical consideration.

PHINOTAS OIL.

In the Panama work, as previously stated, phinotas oil is used, and has been found to have the following advantages over crude oil: It acts as a poison and kills the larvæ very rapidly. It brings the larvæ out of their hiding-places at once, and is useful as an aid in the detection of the presence of mosquito larvæ. It is found also that in continuous heavy rains the larvæ are killed by the phinotas oil before the rain dilutes the treated water to any great extent. They find, however, that phinotas oil has certain disadvantages: It kills fish in a solution of 1 to 5000, and it loses its efficiency very soon after application, so that eggs may be laid upon the treated water and the larvæ develop. Colonel Gorgas points out that there is considerable variation in the quality of this preparation, as shipped to the Isthmus. Some will kill larvæ quickly in a solution of 1 to 3000 parts of water, while other lots require for the same results 1 part to 1000.

THE IDEAL LARVICIDE.

Colonel Gorgas has published the following list of desiderata for the perfect larvicide for use in the tropics, agreeing with the opinion expressed by Ronald Ross when he returned from his first visit to Africa, that nothing as yet known is perfectly satisfactory:

" (a) Low ultimate cost.

" (b) Ability to affect and kill mosquito larvæ promptly, the more rapidly the better. It must be effective in moving water as well as in still water.

" (c) Ability to form a solution with water and to thoroughly diffuse and mix with all the water of a small pond if applied only to one part thereof. Also the substance must not lose it larvacidal properties for a week or more after its application. The longer it will retain its larvacidal properties, after it has been placed in the body of water, the more valuable it will be.

"(d) Ability to diffuse in water and through all parts of a body of water such as in a pond containing grass, water lilies, other aquatic vegetation, and vegetable débris.

" (e) Ability to kill green algæ promptly.

" (f) A concentrated larvacide is necessary so that one part of it to five thousand or more parts of water will promptly kill mosquito larvæ and pupæ.

" (g) Non-poisonous to human life or animals when taken in a strength of 1 to 1000 and accidentally used as drinking water.

" (h) That it have the property of discoloring the water to which it is applied, or of giving off sufficient odor to induce persons not to use water containing it in solution for drinking purposes.

" (i) That the odor, if present, be not so obnoxious as to make its presence in water in ponds or streams near habitations undesirable.

" (j) That it shall have a safe flash test and be nonexplosive.

" (k) That it shall be sufficiently stable so that it may be kept 'standardized.' "

LARVICIDE OF THE ISTHMIAN CANAL COMMISSION.

In his " Studies in Relation to Malaria," Dr. Samuel T. Darling, of the Isthmian Canal Commission, gives the following account of experiments with larvicides:

"A number of experiments were carried out for the purpose of obtaining a cheap and efficient preparation for destroying mosquito larvæ. Crude petroleum oil was frequently too viscid to have a spreading power of the highest efficiency. When mixed with crude carbolic acid, however, its spreading powers were increased. From laboratory tests it was determined that crude petroleum for surface use on pools should not be heavier than —° Baumé (American standard).

"Much of the crude carbolic acid supplied had been found upon analyses to *consist chiefly of inert neutral oils with a small proportion, 5 to 10* per cent, of tar acids, and, as this crude acid was used extensively as a disinfectant, experiments were conducted for the purpose of utilizing, if possible, this crude carbolic acid as a disinfectant and larvacide. It was found that crude carbolic acid, having a specific gravity not greater than 0.96 or 0.97, and containing about 20 per cent of phenols or tar acids, when made into a soap, with common resin and an alkali, yielded a product which was an ideal larvacide, having excellent diffusing and toxic powers, and at the same time was a very efficient germacide. It diffused perfectly with water, forming a milky emulsion very destructive to mosquito larvæ, and having a germicidal value of, or greater than, that of pure carbolic acid of a Rideal-Walker coefficient of 1 to 2. In this way a very valuable larvacide and disinfectant, miscible with water, was produced from a very inferior insoluhle disinfectant.

"The larvacidal powers, when tried with *Culex* and *Anopheles* larvæ, varied slightly with the quality of the crude carbolic acid, but an average result is as follows:

"Dilution 1 to 1000:	*Culex* larvæ dead in five minutes
	Anopheles larvæ, half grown, dead in five minutes.
	Anopheles larvæ, full grown, dead in ten minutes.
"Dilution 1 to 5000:	*Anopheles* larvæ, half and full grown, dead in five minutes.
	Culex larvæ, half grown, dead in three minutes.
"Dilution 1 to 10,000:	*Culex* larvæ, half grown, dead in sixty-four minutes.
	Anopheles larvæ, young, dead in fifty-two minutes.
	Anopheles larvæ, full grown, dead in one hundred and thirty-five minutes.
"Dilution 1 to 15,000:	Small *Culex* larvæ, dead in thirty-two minutes.
	Anopheles larvæ, full grown, dead in one hundred and twenty-three minutes.

"Anopheline larvæ seem to be slightly more resistant than *Culex* larvæ, and all pupæ are more resistant to the effects of the larvacide than larvæ are."

As the result of the experimental work with larvicides Colonel Gorgas and his assistants have constructed a larvicide plant at Ancon, and in the monthly report of the Department of Sanitation of the Isthmian Canal Commission for August, 1909, it is stated that 14,600 gallons of larvicide were made at a cost of $0.1416 per gallon. The method of preparing this larvicide is quoted from this report:

"The method of making same is as follows: 150 gallons of carbolic acid is heated in a tank to a temperature of 212° F.; then 150 pounds of powdered or finely broken resin is poured in. The mixture is kept at a temperature of 212° F., 30 pounds of caustic soda is then added and solution kept at 212° F. until a perfectly dark emulsion, without sediment, is obtained. The mixture is thoroughly stirred from the time the resin is used until the end.

"The resultant emulsion makes a very good disinfectant or larvacide. In fact 1 part of it to 10,000 parts of water will kill anopheles larvæ in less than half an hour, and 1 part to 5000 parts of water will kill anopheles larvæ in from five to ten minutes, or less. This property of killing larvæ rapidly is of great importance in the Tropics, where continuous rainy periods make crude oil or kerosene much less valuable as a larvacide than it is in northern latitudes having less rainfall. Also the larvacide acts as an algecide, and thus destroys the food and the hiding places of anopheles larvæ. As it takes up very little room, compared with the area it can be spread over, the cost of distribution will be much less than that of crude oil or kerosene—considering the large territory which the antimalarial work covers, this item alone is of great financial advantage to the department.

"Tests have recently been made to determine approximately how much of the new larvacide will be needed per month (rainy season) for each district.

"Although this larvacide will be used to a large extent, yet we shall continue to use crude oil for streams having a fair velocity, as such application gives excellent results and is as economical as larvacide would be, as the oil is spread in a very fine film automatically. In order to make the crude oil drip with continuous regularity, a piece of metal similar to that part of a flat-wick lamp which holds the flat wick is fastened to the oil container. It is made somewhat larger than the wick, so that the wick fits it loosely when saturated with the grade of fuel oil we use. This metal wick chamber is fitted to the oil container about 3 inches from its base. The space below the wick chamber is filled with a solution of caustic soda or of larvacide. As the oil is attracted along the wick by capillary attraction, it comes into contact with the larvacide or caustic soda and is 'cut,' rendered thinner. This method of procedure prevents the wick from being clogged by the thick fuel oil and enables the wick to drip the oil desired."

In the September, 1909, report, it is stated that the new larvicide was giving very satisfactory results and would undoubtedly reduce the cost of anti-malarial work, besides being more effective than crude oil in many places. It also has some value as a destroyer of vegetation, thus making conditions less favorable to mosquito breeding. In the October report satisfaction with its use is again expressed, and it is stated that the fact that it kills the grass at the edges of the ditches will be of importance in reducing the cost of anti-malarial work.

Mr. August Busck, of the Bureau of Entomology, U. S. Department of Agriculture, has recently had an opportunity to witness the effectiveness of this preparation and has furnished us the following account of its effects and manner of application:

"Friday I had a very excellent opportunity to observe the application and result in the field, in one of the outlying districts, near Rio Grande on the Isthmian Canal Zone. Here was about a mile and a half of a small slow-running stream, passing through a scattered native village and through thick brush, which for some reason had been overlooked or neglected. This was literally swarming with *Anopheles* larvæ and pupæ everywhere along the grassy edges and in the small pools caused by the native washerwomen, or by pigs, poultry and horses. It was about as nasty a place as I have seen, producing thousands of adults every day.

"The local sanitary inspector, Mr. Trask—one of the most efficient—kindly postponed action until I had been over the ground thoroughly, and then started a man with a knapsack-pump, another with larvicide supply for the pump and a foreman to oversee the job, from the head spring down along the stream; they walked right along and sprayed with a 1 to 6 solution as they went, covering the course in less than an hour. Within two minutes after the application on any part of the stream *all* mosquito larvæ there were dead.

"I remained several hours afterwards, so as to be able to work alone, dipped and looked carefully on knees and hands all along that stream, but *not one* live larva was found, where hundreds could be taken in a single dip before.

"A few hours after the application the water course was again quite clear and could be used for drinking and washing as before.

"The vegetation did not appear to have suffered in any way, though that might take longer to show. Most of the other water insects were dead, but a considerable number of water beetles, Hemiptera and dragon-fly larvæ withstood the treatment, and I have no doubt but that the percentage of the larvicide solution can be so regulated that it would kill all the mosquitoes and not the tougher predaceous insects.

"There were no fish in the stream, so I can not say, from personal observation, how it would affect them, but Mr. Trask says they can endure considerable of the larvicide without dying."

DESTRUCTION OF LARVÆ BY SENSITIZATION TO LIGHT.

Dr. Gunni Busck, of Copenhagen, has recently carried out novel experiments in mosquito destruction:

"I have this fall tried to solve the question of killing mosquito larvæ by an entirely different method, on the supposition that it might be possible, through solutions of suitable coloring matter (Erytrosin, Rose Bengal, etc.), to sensitize mosquito larvæ so that they would be killed by the sunlight or mere daylight, to which they are directly exposed under natural conditions, when they assume their normal position for respiration at the surface of the water.

"It was shown by my experiments that it really is possible to thus sensitize mosquito larvæ and that they die in thin solutions of the above mentioned colors, if they are exposed to light, even if only diffused daylight, while they remain alive, pupate and develop to adults in these same solutions, if they are kept in darkness.

"It was however necessary to use more concentrated solutions of the colors than I had anticipated, and as these colors moreover are rather expensive, the method can at present in no wise compete with the oil methods. The experiments will be continued and their scope widened this coming season."

POISONOUS PLANTS.

Decoctions and emulsions of an African leguminous plant, *Derris uliginosa,* have been recommended for larvicidal use, and experiments conducted by Balfour at the Wellcome Research Laboratories at Khartoum show that it has considerable potency. It also kills fish, different species of *Derris* being well known for this quality, so that even in regions where these plants are native they have only a limited use as insecticides.

Recently Daniels (Tropical Medicine and Hygiene, Part 1, 1909, pp. 77–78, 120) has advocated the use of the "tuba root," also belonging to the genus *Derris,* which is used in the East Indies to poison fish, to destroy mosquito larvæ. The commonly employed species is *Derris elliptica.* Other plants are employed in other parts of the world to stupefy fish and some of these might prove to be effective against mosquito larvæ. Daniels says of *Derris:*

"The roots are crushed and thrown into the water, and the milky fluid from the fresh roots, even in minute quantities, and much diluted, will destroy the larvæ, and for small collections of fluid, cesspits, etc., is highly effective, and though killing off most forms of animal life does not render the water as putrid or offensive as the use of oils. When fish are present these would be destroyed, and therefore this method is not advisable in larger collections of water."

SALT.

During the 1905 outbreak of yellow fever in New Orleans an attempt was made to destroy mosquito larvæ in the open gutters of the city by the use of common salt. Dr. H. A. Veazie wrote us that the results were good where the work was properly done. Shortly after operations were begun there was a flight into the city of *Aëdes sollicitans* from the salt marshes northeast of New Orleans. Indignant citizens ascertaining from experts the name and habits of the species jumped to the conclusion that salting the ditches had brought about suitable breeding conditions for *sollicitans* and that the invasion of the city by that species was a direct result of the work of the sanitary officials.

ABOLITION OF BREEDING-PLACES OF HOUSEHOLD MOSQUITOES.

In considering this question, just as in considering so many questions relating to mosquitoes, a complication arises from the diversity of facts concerning the life-histories of the different species of mosquitoes, facts discovered, for the most part, within the past ten years. At the time of the publication of Bulletin 25, New Series, Division of Entomology, U. S. Department of Agriculture, in 1900, the habits of but a very few species of mosquitoes were known and the generalizations drawn from the knowledge of these few species were altogether too broad and must now be greatly modified. The breeding-places of different species are quite peculiar. Those of the commonest household mosquitoes, namely *Culex pipiens* in the North and *Culex quinquefasciatus* and *Aëdes calopus* in the South, correspond best with the generalizations formerly made, breeding as they do in every receptacle of water about residences, and the abolition of all such accumulations of water means their destruction. Where the rain-water barrel or the rain-water tank are necessary they should be screened. In New Orleans and other southern cities the boards of health are now enforcing the screening of these receptacles. The screening should be done with extreme care, a fine mesh screen being used and the fitting made very perfect.

About a given house the waste places in the immediate vicinity should be carefully searched for tin cans, bottles, wooden or tin boxes in which water can accumulate, and all such receptacles should be destroyed or carted away. The roof-gutters of the building should be carefully examined, to make sure that they are not clogged so as to allow water to accumulate. The chicken-pans in the poultry yard, the water troughs for domestic animals, the water-cup of the grindstone, are all places in which mosquitoes will breed, and in them water should not be allowed to stand for any length of time. In the South the water accumulating under water tanks should be treated or drained away. The urns in the cemeteries at New Orleans have been found to breed mosquitoes abundantly. The holy-water fonts in Catholic churches, especially in the South, have commonly been found to breed mosquitoes; in some places sponges have been substituted for standing water, and other churches have adopted a closed font, which allows the holy water to issue through a small spigot. In still other churches salt has been put in the water to prevent the breeding of mosquitoes.

Even in the house mosquitoes breed in many places where they may be overlooked. Where the water in flower vases is not frequently changed mosquitoes will breed. They will breed in water pitchers in unused guest rooms. They will breed in the tanks in water closets when these are not frequently in use. They will breed in pipes and under stationary washstands where these are not frequently in use, and they will issue from the sewer traps in back yards of city houses during dry spells in the summer time, when sewers have not recently been flushed by heavy rains. In warehouses and on docks they breed abundantly in the fire buckets and water barrels.

In country houses in the South, where ants are troublesome and where it is the custom to insulate the legs of the tables with small cups of water, mosquitoes will breed in these cups unless a small quantity of kerosene is poured in. Where broken bottles are placed upon the stone wall to form a cheval-de-frise, water accumulates in the bottle fragments after rains and mosquitoes will breed there. Old disused wells in gardens are frequent sources of mosquito supply even where apparently carefully covered, and here the nuisance is easily abated by the occasional application of kerosene. The same thing may be said of cesspools. Cesspools are frequently covered with stone and cement, but the slightest break in the cement will allow the entrance of these insects. Breeding often goes on in cesspools without the cause of the abundance of mosquitoes in the neighborhood being suspected. One of the writers remembers, for example, on one occasion walking through a New Jersey garden and noticing a covered cesspool with a slight crack in the cement. He remarked upon the danger to the proprietor of the estate, who replied that mosquitoes could not possibly gain entrance to the water. Later in the evening, about dusk, the same spot was passed again and a cloud of mosquitoes was seen issuing from the crack so abundantly that at a little distance it seemed like a stream of smoke. A little kerosene put a stop to further breeding.

Fountains and ornamental ponds are frequent breeding-places, and here the introduction of fish, as indicated in another place, is usually all-sufficient. It frequently happens, however, that the grass is allowed to grow down into the edges of ornamental ponds and mosquito larvæ find refuge among the vegetation and so escape the fish. Broad-leaved water plants are also often grown in such ponds, and where these broad leaves lie flat upon the surface of the water, as they frequently do, one portion of a given leaf may be submerged so that mosquito larvæ may breed freely in the water over the submerged portion of the leaf, protected from fish by the leaf itself. It is necessary, therefore, to keep the edges of such ornamental ponds free from vegetation and to choose aquatic plants which will not afford mosquito larvæ protection. In many small country towns, even where there is a water supply, tanks are to be found under the roofs, to supply bathrooms. Such tanks should be screened, since mosquitoes gain entrance to the tankroom, either through dormer windows or by flying up through the house from below. About a large old house there are so many of these chance breeding-places that only the most careful search will find them all. Frequent change of water, or the use of kerosene, will render them all harmless.

PREVENTION OF SEWER BREEDING.

In community work in cities all of the points mentioned must be borne in mind, and in the portions of the community where the residences are for the most part detached villas, in the absence of swampy surroundings, the householders are in the main responsible for the presence of mosquitoes. There are, however, breeding places for which the town may be said to be responsible, and these entirely aside from public fountains, reservoirs or marshes. It seems unlikely that in any general sewerage system mosquitoes breed in the sewers proper. That they do breed in the catch basins is well known. The purpose of the catch-basin is to catch and retain, by sedimentation, sand and refuse which would otherwise enter the sewer and obstruct it. It is intended to be water-tight and to hold a considerable body of water which stands in it up to the level of

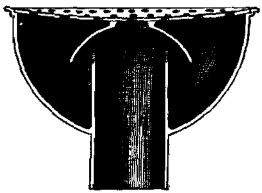

FIG. 6.—*Type of catch basin in common use in back yards of Washington houses in which water stands permanently.*

the outlet pipe. Such catch basins are very commonly used in back yards and at the crossings of streets. The water is replaced only by rain or when street or yard surfaces are washed. In dry seasons the period of stagnation may last several weeks, certainly long enough for mosquito breeding. As a matter of fact, mosquitoes in midsummer do breed in such basin-traps or catch-basins. In the work against mosquitoes in Brookline, Mass., in 1901 and 1902, previously referred to, *Culex pipiens* was found breeding abundantly in catch-basins, and more than 1000 such basins were regularly treated with petroleum. It is a matter of common observation in the city of Washington that during the usually dry months of July, August and September, mosquitoes are very numerous throughout the city, in quarters where there are no possible breeding-places other than these catch basins, and more particularly the large catch basins of the sewer outlets at the street corners.

The suggestion has been made that in cities it may, under certain circumstances, be possible for mosquitoes to breed in water accumulating in the underground troughs of electric railways, but so far as known to the writers no exact affirmative observations have been made. That there is abundant opportunity for water to accumulate in these troughs and that it does so accumulate there can be no doubt.

Referring again to the breeding of mosquitoes in catch-basins or sewer-traps, it was shown as early as 1900 by Mr. T. Pergande, of the Bureau of Entomology, that the common rainwater-barrel mosquito breeds in small sewer-traps in the rear of houses in southeast Washington. He determined this point by putting a gauze screen over the sewer-trap in his own yard and finding adult mosquitoes under the screen, morning after morning. Of late years, in practically all the city of Washington, and in fact, notably in the northwest section, where is to be found the better class of residences, and where the general conditions are such as to preclude the possibility of the breeding of mosquitoes in other places, sewer-trap bred mosquitoes are very annoying, especially during the dry spells in July, August and September. At one time the city catch-basins, located at the corners of the streets, were flushed at least once in ten days, under the orders of an efficient official in charge of sewers for the District of Columbia. This procedure, if fully carried out, would prevent the breeding of mosquitoes in these basins. The private catch basins, usually situated near the kitchen door, are not under city control and are so constructed as to hold water indefinitely and to permit the breeding of a lesser number of mosquitoes during a protracted dry spell. It is easy to avoid this breeding by putting a small cupful of kerosene into the sewer trap at intervals of from ten days to two weeks. But the difficulty arises that during the months in question, in the northwest quarter of the city, many houses are closed for the summer, and the treatment of the catch-basins on the premises of temporary absentees can only be accomplished by someone in authority, as a sanitary inspector, for example. Malarial mosquitoes occasionally breed in these catch basins, as one of us (Dyar) found two larvæ of *Anopheles* in a small catch basin in the yard of his premises during August, 1912. They were easily removed by flushing the drain.

REMOVAL OF BROMELIACEOUS PLANTS.

Sir Rubert Boyce, in his "Mosquito or Man?," calls especial attention to the wild pines or Bromeliaceæ as breeding places of mosquitoes in the American tropics, and to the extraordinary numbers in which these epiphytes occur in certain localities. He states that one Saman tree, which was cleaned up for the purpose of destroying mosquito breeding-places, yielded 26 cart-loads of these epiphytes whose total weight was 3.62 tons. He shows that each plant may hold from ten to twenty ounces of water and that the total volume of water represented by these parasites of a single tree was probably equivalent to a good-sized pond.

DRAINAGE MEASURES AGAINST NON-DOMESTIC SPECIES.

The drainage of swamp areas for agricultural or other industrial reasons needs no argument nor treatment here. The value of reclaimed swamp land for various purposes is treated somewhat in extenso in an earlier section, "Value of Reclaimed Lands." The drainage of swamp areas primarily in order to improve sanitary conditions and to reduce the annoying scourge of mosquitoes, which in itself frequently prevents the proper development of neighboring regions, is in operation and needs no argument. Drainage on a small scale for the purpose of doing away with mosquitoes has been practiced for a long time. In "Mosquitoes," p. 198, Howard shows how, by an expenditure of $40 for drainage, in the summer of 1900, in a Maryland village, malaria was practically abolished, although the previous summer there had been one or more cases in every family in the district.

One of the editors of the *Scientific American*, Mr. Beech, has given a good illustration of the good effect of drainage work prior to the general interest in mosquito destruction, which is quoted (loc. cit., pp. 208–209) as follows:

"In the town of Stratford, Conn., where I have resided for the past forty-five years, we have been greatly plagued by swarms of mosquitoes, so great, in fact, that the 'Stratford mosquito' became a well-known characteristic of Stratford. We have in the southern part of our town, bordering on the sound, several acres of marsh-land or meadow, which would become periodically overflowed with water in the summer and a tremendous breeding-ground for mosquitoes, and this plague to the town continued until about 1890–91, when a party from Bridgeport, Conn., purchased a large section of the meadows and began to protect them by a dike, both on the north and south ends, which shut out the water. In addition to this, numerous drain ditches were made which helped to carry the water away. The result of this work made the land perfectly dry and spongy, so that after a rain no pools collected on the surface of the meadow and the creation of the mosquitoes was prevented. The transformation was so remarkable that people outside the town would hardly believe that it had been effected, and a year or two later the town voted a special appropriation of $2000 to the party who undertook to build the dike and render the meadows mosquito-proof. It had also the effect of placing on the market a large tract of land elevated from the sound, for residences, and as many as twenty-five summer residences have been built upon this land bordering on the sound, and the number is increasing each year. They are free from mosquitoes, so that the operation shows the economy and the benefit that will result by using some means for eliminating the mosquito-breeding pools."

A great deal of valuable drainage work has been done in the past few years in salt-marshes of the North Atlantic coast, and there is one instance of this on the Pacific coast. All had the direct idea of doing away with the salt-marsh mosquitoes, which have unusual powers of flight and are able to proceed inland for many miles, thus annoying the inhabitants of a large extent of country. One of the first operations of this kind was conducted by the wealthy owners of Center Island off the north coast of Long Island, in Long Island Sound. This work led to the somewhat extensive work under the organization known as the North Shore Improvement Association, referred to elsewhere, and which included simple operations over a considerable distance along the north shore of Long Island. These operations took place in 1902–1903. Later, some excellent work was done at Lawrence, Long Island, and the following account, taken from the "Report of the [New York] State Entomologist," Dr. E. P. Felt, for 1905, gives an excellent idea of methods and results:

"A most striking illustration of this work is that given by Lawrence, L. I., which has amply demonstrated the feasibility of controlling the salt marsh mosquitos by relatively simple and comparatively inexpensive ditching operations. The annual expense is only about $1000 and the total expenditure on these operations during the past four years does not exceed $10,000, in spite of the fact that the village is situated upon a narrow neck of land with the extensive salt marsh areas of Jamaica bay to the north and west and large marshes south and east, all producing in former days millions of mosquitoes which invaded the village in swarms with every favorable breeze. Some of these marshes extend almost to the center of the village, which is so completely surrounded that a journey of 2½ miles in almost any direction will bring one to a salt marsh. More unfavorable conditions for mosquito control could hardly be found, and before this work was attempted mosquitos swarmed in the village in May and remained in numbers most of the season. The second year swarms did not invade this territory till June, and last year it was the first of July before they appeared. Our investigations at the end of last July showed that there were practically no mosquitos in the center of the village. It was our privilege to sit on a piazza one evening when conditions were most favorable for mosquito activity. Though it was cloudy with only a little breeze and rather warm, not one appeared. Previous to this antimosquito work it was said that one could not sit on this piazza without being covered by netting, and the owner even went to the trouble of making a framework to hold netting suspended over individual chairs, so that his family and guests could sit in comfort.

"This very desirable result has been brought about by a drainage system so planned that the entire length of all ditches will be flushed by every tide. The general practice is to run these ditches within about 200 feet of firm ground and sometimes closer, making them 18 to 24 inches in width, from 2 to 3 feet deep, with main ditches here and there to tidal channels. A few headland ditches are run into the more dangerous swampy areas in baylike extensions of the marsh. Such ditches require no surveying and cost only 1½ cents a running foot. A little experience enables one to lay them out properly and the tides make the determining of levels extremely easy. It was very interesting to compare the conditions between ditched areas and undrained marshes. The former were so free from mosquitos that one could tramp upon them with practical immunity from bites, though occasionally a few mosquitos were seen on one's person. No larvæ were found and in fact there were very few places where breeding was possible. Undrained marshes presented a very different condition. Mosquitos swarming in adjacent woodlands made driving very uncomfortable, and when on the marshes one was attended by considerable swarms of vicious biters, even in midday. Here and there breeding pools were literally black with young wrigglers. This contrast between drained and undrained areas would doubtless have been much greater were it not for the fact that our inspection was made during such a dry time that even undrained marshes presented comparatively few favorable breeding places.

"Experience at Lawrence has shown that deep ditches with perpendicular sides are far more permanent than shallow ones with sloping sides. The attempt to slope the bottom of the ditch so that all the water will drain out invariably results in depressions which may become dangerous breeding places and the drainage value of the ditch itself is much lessened. Sloping sides afford opportunity for the growth of grass and sedges with the result that the ditch soon becomes choked with vegetation. The deep perpendicular ditches described above remain entirely free from vegetable growth, and with a little care in removing sods and drifting matter will last for years. Some dug four years ago were in perfect condition last July, though the grass growing along the sides overhung and almost hid the ditch from view in places. An area of 25 feet on each side is easily drained by such a ditch. The village now has 40 miles of marsh drains which require more or less attention from three men during most of the open season. They keep the ditches clear, supplementing their work by judicious oiling here and there wherever mosquito larvæ are abundant and then have considerable time available for perfecting the system and ditching more distant marshes. Experience showed that a considerable number of salt marsh mosquitos bred on that portion of Jamaica bay northwest of the village were brought in by southwest followed by northeast winds. This led to the extension of ditching operations some 2 miles beyond the village limits. The work in the immediate vicinity of Lawrence was done partly at public expense assisted by contributions from owners benefited, though it was impossible to secure the co-operation of persons owning the distant marshes, which latter were drained entirely at village expense. The existence of such breeding areas is an imposition upon adjacent communities and it is only a question of time before public opinion will demand a law either compelling owners to abate such nuisances or else provide for their suppression at public expense. The money invested by Lawrence in this work, a total of less than $10,000, has amply justified itself in vastly improved conditions. The village and its vicinity have been entirely freed from breeding places, though occasionally it is subject to late summer invasions by hordes of mosquitos when favorable winds bring them from undrained marshes. Even this will be obviated when the value of the work becomes more generally appreciated and then the cost of the operations will be amply returned in increased land values, to say nothing of the satisfaction accruing from the absence of these dangerous and annoying pests."

On the north shore of Long Island, in Connecticut, and especially in the vicinity of New Haven, certain simple ditching operations have been carried on which have resulted, at a comparative small expense, in a very considerable reduction of the mosquito supply.

In California, in connection with work carried on by the California State Agricultural Experiment Station, in 1905, some excellent work was done under the auspices of the Burlingame Improvement Club, in San Francisco, under the direction of H. J. Quayle, of the Experiment Station. The territory involved is included in the upper portion of the San Francisco peninsula, extending from south San Francisco on the north to San Mateo on the south, a distance of about 10 miles. The salt-marsh area included consisted of a narrow strip along the San Francisco Bay shore, varying from ½ to 2 miles in width, and 10 miles long. No part of the area was continually covered with water, and it is all above the lowest high tide. The higher tides, however, particularly those accompanying full moon, almost completely submerge the area and result in the development of large broods of salt-marsh mosquitoes. The operations are described as follows:

"The actual work of control was commenced February 27th, when a gang of men was started to work at ditching on the salt marsh. This work was started near the Blackhawk dairy, where the marshes begin north of Burlingame, it being the intention to work northward toward San Bruno, and make the work permanent as far as we would be able to go in a single season. However, the work went rapidly and the troublesome areas north of Millbrae were not so numerous as was figured, and consequently practically the whole area was covered during the past season.

"The ditching in the Blackhawk area consisted in connecting the pools and areas of standing water with the tidal creeks in order that they might drain more rapidly and before a brood of mosquitoes would have time to develop. The largest of these ditches were 12 inches wide and about 15 inches deep, and these served as main channels into which smaller laterals were cut. These laterals, and, indeed, the greater part of all of the ditches, were but one spade wide, and one or two spades deep, according to the depth of the pool to be drained. Only where the pools were very large and a great quantity of water to run off in a short time was it necessary to make larger ditches. By ' a spade ' here is meant the common California spade, which is about 6 inches wide and 10 inches high. The Eastern drain spade has not yet found its way to California; undoubtedly it would be preferable for the deeper ditches in this kind of work. In addition to the well-defined pools there was a considerable area in the Blackhawk region which was covered with but a few inches of water for a considerable time after each high tide, and before the rains ceased in the spring water stood over this area almost continuously. Such areas had to be treated by making a number of parallel ditches from 50 to 75 feet apart, in order to permit of sufficiently rapid drainage. Rather extensive ditching was done here to make the area safe while the rains were still continuing, while later in the season, when the rains ceased, it would have been safe with much less ditching. Small pools that were far from tidal creeks were made safe by filling in rather than draining. The size of the pool, and the length of ditch necessary to drain, will determine which of the methods is to be followed. In this way the marsh area was gone over, doing away with all the places where larvæ were found or were likely to be found, for a distance of about a mile along the bay northward, where the diked area was met with.

" This part of the marsh presented a more difficult problem. The dike, having been neglected for ten or twelve years, was in poor condition, and there were several breaks in the upper end near Millbrae. The gates were not in working order, and their floors were too high to drain the area enclosed.

" The breaks in the dike at the upper end permitted the water to back up at the opposite side, and this, together with the fresh water from the hills, kept the water level, at almost high tide, over a large part of the area. To make matters worse, the dike, just after it was built, was in effective operation just long enough to thoroughly dry the ground and cause it to crack. These cracks, which are 4 or 5 inches wide and 2 or 3 feet deep, still exist, forming a complete network over most of the area. Mosquitoes were found breeding in this area, and it was next to impossible to get over the ground, even with waders. A considerable part of the area was submerged to the depth of a foot or more, thus concealing from view the cracks and tidal creeks, which one was likely to fall into at any step, and which made any attempt at rapid progress somewhat discouraging.

" It was at once evident, under these conditions, that if the area was to be controlled, the dike must be either cut through in a number of places in order to allow a freer circulation of water, or the breaks must be repaired and the gates put in operation, and the water kept out. The latter scheme was the one followed, because it would be possible to make the area thoroughly dry, and thus the results would be more certain. In attempting to operate the gates we were made to appreciate the effect of a ten or twelve years' coating of rust on the large screws by which the gates were manipulated. After the gates were put in operation the breaks in the dike were repaired and the weak places strengthened. The largest break repaired was immediately joining the upper gate. This was 30 feet wide, and by the action of the water had worn down so that at high tide there was a depth of 10 feet of water. A double wall of sheet piling about 6 feet apart was sunk here and the space between filled in with earth. The other breaks were repaired by sinking a single wall of sheet piling in the center and filling in on both sides with dirt.

"After these repairs were completed the gates were operated, opened at low tide and closed at high tide, for a week, but at the end of this time there was still much water in the area, because the gate floors were not low enough to lower the water level sufficiently. This made it necessary to lower the gate floors and add an extension to the gates to reach the lower level. This being done the gates were again operated for several days, but it was found that, due to seepage of water through the dike in many places, hand operating would have to be kept up almost indefinitely. It was, therefore, necessary to replace these old-style gates, operated by hand, by automatic ones, and these were, consequently, put in at both the upper and lower gates, and the floors lowered 32 and 20 inches respectively. These gates were made to swing on an axle at the top, the lower end being free and easily moved by the pressure of the water, so that at low tide it was opened by the pressure of water on the inside, and closed as the water from the high tide rose on the outside.

"This tidal creek which served as an outlet for the lower gate had become filled in to a depth of 2 or 3 feet during the period the gate was closed, and this was cleaned out for 300 or 400 yards toward the bay in order to drain out the area inclosed by the dike.

"With this work done upon the dike the area inclosed by it was treated in much the same way as that outside, except that the network of cracks, already mentioned, had to be filled in in many places, and several of the tidal creeks deepened. The reward for all this work came later in the season when the area was changed from a veritable breeding ground to the safest portion of the marsh. Indeed, this area was the key to the situation, and the excessive abundance of mosquitoes in this particular territory was without doubt due to this extensive breeding ground.

"It is appropriate to mention here the connection of this work with the reclamation of marsh lands. This tract of 500 or 600 acres, which had been useful only for duck-hunting, is now thoroughly dry and could be put to agricultural uses at very little additional expense. Such work has already been extensively taken up on the marshes below San Mateo, and it has been found that a good crop of grain can be raised on such land in the second year of its cultivation. It is safe to predict that all the marsh land involved in the present campaign will be under cultivation before many years, and because of its proximity to the metropolis of the coast should he very valuable.

"Besides the marshes already mentioned, permanent control work was done on the marsh about Millbrae and northward to San Bruno, and also some drainage work at Coyote Point, opposite San Mateo. The work at these places was much the same as that already described, and further details are unnecessary.

"In addition to this permanent work there was some oiling done on the marsh where the ditching and filling work were not rapid enough to keep ahead of a developing brood. The total amount of oil applied, however, did not exceed 400 gallons, and most of this was applied to the large tidal creeks in the reclaimed land opposite San Mateo. The remainder was applied to pools where wrigglers appeared after a high tide, and, the brood being checked, we had until the next high tide in which to make the pools permanently safe."

During 1908, 200 acres of salt-meadow land on the shore of Little Neck Bay, between Bay City and Douglaston, Long Island, were drained by simple ditching measures. This work was done at the instigation of the Bay Side Park Association and the Douglaston Civic Association, both associations forming a joint committee to promote the extermination of mosquitoes. They went to the

Board of Health of Flushing and enlisted its aid under a new law which permits the Board of Health to enforce the drainage of mosquito breeding-places. The Board of Health issued its orders to the owners of the meadow lands, commanding them to drain their properties within ten days. The movement was most successful, and by October 24, 1908, 75 miles of ditches had been dug on the Flushing meadows, and the work was still going on.

The most extensive work of this character has been undertaken by the State of New Jersey. One of the writers (Howard), in an address on "The Recent Progress and Present Conditions of Economic Entomology," delivered before the Seventh International Zoological Congress, Boston, August, 1907, made the following statement:

"But the work done by Smith, in New Jersey, and that which he has under way in his large-scale campaign against the mosquitoes of that State are of such a unique character that they force special mention. The mosquito destruction measures carried on by English workers, and especially by those connected with the Liverpool School of Tropical Medicine, in different parts of the tropics controlled by England, has been large-scale work of great value. That done by the army of occupation in Cuba was of enormous value, so far as the city of Havana was concerned, and an assistant just returned from the Isthmian canal zone assures me that it is possible to sit now out-of-doors of an evening upon an unprotected veranda anywhere in the zone without being annoyed by mosquitoes, and without danger of contracting malaria or yellow fever.

"These are all great pieces of work, but when we consider the condition that exists in the State of New Jersey, and the indefatigable and successful work of Smith in the handling of the most difficult problem of the species that breed in the salt marshes, and of his persistent and finally successful efforts to induce the state legislature of that wealthy but extremely economical State to appropriate a large sum of money to relieve New Jersey from its characteristically traditional pest—we must hold up our hands in admiration."

Chapter 134, of the Laws of 1906 for New Jersey, which went into effect on November 1, 1906, and the passage of which was largely due to the efforts of Doctor Smith, is here quoted:

"AN ACT to provide for locating and abolishing mosquito-breeding salt-marsh areas within the State, for assistance in dealing with certain inland breeding places, and appropriating money to carry its provisions into effect.

"BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey:*

"1. It shall be the duty of the director of the State Experiment Station, by himself or through an executive officer to be appointed by him to carry out the provisions of this act, to survey or cause to be surveyed all the salt-marsh areas within the State, in such order as he may deem desirable, and to such extent as he may deem necessary, and he shall prepare or cause to be prepared a map of each section as surveyed, and shall indicate thereon all the mosquito-breeding places found on every such area, together with a memorandum of the method to be adopted in dealing with such mosquito-breeding places, and the probable cost of abolishing the same.

"2. It shall be the further duty of said director, in the manner above described, to survey, at the request of the board of health of any city, town, township, borough or village within the State, to such extent as may be necessary, any fresh-water swamp or other territory suspected of breeding malarial or other mosquitoes, within the jurisdiction of such board, and he shall prepare a map of such suspected area, locating upon it such mosquito-breeding places as may be discovered, and shall report upon the same as hereinafter provided in section eight of this act. Requests as hereinbefore provided for in this section may be made by any board of health within the State, upon its own motion, and must be made upon the petition, in writing, of ten or more freeholders residing within the jurisdiction of any such board.

"3. Whenever, in the course of a survey made as prescribed in section one of this act, it is found that within the limits of any city, town, borough or village there exist points or places where salt-marsh mosquitoes breed, it shall be the duty of the director aforesaid, through his executive officer, to notify, in writing, by personal service upon some officer, or member thereof, the board of health within whose jurisdiction such breeding points or places occur, of the extent and location of such breeding places, and such notice shall be accompanied by a copy of the map prepared as prescribed in section one, and of the memorandum stating the character of the work to be done and its probable cost, also therein provided for. It shall thereupon become the duty of the said board, within twenty days from the time at which notice is served as aforesaid, to investigate the ownership, so far as ascertainable, of the territory on which the breeding places occur, and to notify the owner or owners of such lands, if they can be found or ascertained, in such manner as other notices of such boards are served, of the facts set out in the communication from the director, and of the further fact that, under chapter sixty-eight of the laws of one thousand eight hundred and eighty-seven, as amended in chapter one hundred and nineteen of the laws of one thousand nine hundred and four, any water in which mosquito larvæ breed is a nuisance and subject to abatement as such. Said notice shall further contain an order that the nuisance, consisting of mosquito-breeding pools, be abated within a period to be stated, and which shall not be more than sixty days from the date of said notice, failing which the board would proceed to abate, in accordance with the act and its amendments above cited.

"4. In case any owner of salt-marsh lands on which mosquito-breeding places occur and upon whom notice has been served as above set out, fails or neglects to comply with the order of the board within the time limited therein, it shall be the duty of said board to proceed to abate under the powers given in sections thirteen and fourteen of the act and its amendments cited in the preceding section, or, in case this is deemed inexpedient, it shall certify to the common council or other governing body of the city, town, township, borough or village the facts that such an order has been made and that it has not been complied with, and it shall request such council or other governing body to provide the money necessary to enable the board to abate such nuisance in the manner provided by law. It shall thereupon become the duty of such governing body to act upon such certificate at its next meeting and to consider the appropriation of the money necessary to abate the nuisance so certified. If it be decided that the municipality has no money available for such purpose, such decision shall be transmitted to the board of health making the certificate, which said board shall thereupon communicate such decision forthwith to the director of the Agricultural Experiment Station or his executive officer.

"5. If, in the judgment of the director aforesaid, public interests will be served thereby, he may set aside out of the moneys appropriated by this act such an amount as may be necessary to abate the nuisance found existing and to abolish the mosquito-breeding places found in the municipality which has declared itself without funds available as prescribed in the preceding section. Notice that such an amount has been set aside as above described shall be given to the board of health within whose jurisdiction such mosquito-breeding places are situated, and said board shall thereupon appoint some person designated by said director or his executive officer a special inspector of said board for the sole purpose of acting in its behalf in abating the nuisance found to be existing, and all acts and work done to abate such nuisances and to abolish such breeding places shall be done in the name of and on behalf of such board of health.

"6. If in the proceeding taken under section four of this act the common council or other governing body of any municipality appropriate to the extent of fifty per centum or more of the money required to abate the nuisance and to abolish the mosquito-breeding places within its jurisdiction it shall become the duty of said director of the Agricultural Experiment Station to set aside out of the moneys herein appropriated such sum as may be necessary to complete the work, and in all cases preference shall be given, in the assignment of moneys herein appropriated, to those municipalities that contribute to the work and in order of the percentage which they contribute; those contributing the highest percentage to be in all cases preferred in order.

"7. In all cases where a municipality contributes fifty per centum or mor of the estimated cost of abolishing the breeding places for salt-marsh mosquitoes within its jurisdiction, the work may be done by the municipality as other work is done under its direction, and the amount set aside as provided in section si may be paid to the treasurer or other disbursing officer of such municipality fo use in completing the work; but no payment shall be made to such treasurer o other disbursing officer until the amount appropriated by the municipality ha been actually expended, nor until a certificate has been filed by the director o his executive officer stating that the work already done is satisfactory and sufficient to obtain the desired result, and that the arrangements made for its completion are proper and can be carried out for the sum awarded.

"8. In all investigations made under section two of this act the report to b made to the board of health requesting the survey shall state what mosquitoe were found in the territory complained of, whether they are local breeders o migrants from other points, and, in the case of migrants, their probable source whether the territory in question is dangerous or a nuisance because of mosquit breeding, the character of the work necessary to abate such nuisance and abolis the breeding places, and the probable cost of the work. Said board of healt must then proceed to abolish the breeding places found under the general power of such boards, but if it shall appear that the necessary cost of the work sha equal or exceed the value of the land without increasing its taxable value, suc board may apply to the director aforesaid, who may, if he deems the matter o sufficient public interest, contribute to the cost of the necessary work, provide that not more than fifty per centum of the amount shall be contributed in an case, and no more than five hundred dollars in any one municipality.

"9. All moneys contributed or set aside out of the amount appropriated i this act by the director of the Agricultural Experiment Station in accordanc with its provisions shall be paid out by the Comptroller of the State upon th certificate of said director that all the conditions and requirements of this ac have been complied with, and in the case provided for in section five payment shall be made to the contractor upon a statement by the person in charge of th work, as therein prescribed, attested by said director, showing the amount du and that the work has been completed in accordance with the specifications of hi contract.

"10. For the purpose of carrying into effect the provisions of this act, th said director of the State Agricultural Experiment Station shall have power t expend such amount of money, annually, as may be appropriated by the Legis lature; *provided*, that the aggregate sum appropriated for the purposes of thi act shall not exceed three hundred and fifty thousand dollars. The Comptroller of the State shall draw his warrant in payment of all bills approved by the director of the State Experiment Station, and the Treasurer of the State shall pay all warrants so drawn to the extent of the amount appropriated by the Legislature.

"11. This act shall take effect November first, one thousand nine hundred and six.

"Approved April 20, 1906."

This law was drafted only after the most careful observations by Doctor Smith and his assistants, and after they had made themselves perfectly familiar with the conditions existing in the salt-marsh area in New Jersey and with the exact life-histories of the different species of mosquitoes involved, and also after preliminary drainage work had been undertaken and carried to successful conclusion over part of the area without the assistance of State funds.

Doctor Smith had found that three species, of approximately similar habits, develop in the salt marshes of New Jersey and migrate inland for long distances—up to 40 miles in some instances—thus making local work on the part of inland communities by no means perfectly efficient. Citizens' organizations had, for example, done excellent work in the way of destroying household and other fresh-water breeding mosquitoes, in South Orange, Summit, and other inland towns; but occasional inland migrations of swarms of salt-water species necessitated the retention of house screens and discouraged the community workers. The salt-marsh species, studied by Doctor Smith, are *Aëdes cantator, A. sollicitans,* and *A. tæniorhynchus.* The former is the more northern and earliest, forming the bulk of the specimens on the marshes north of the Raritan River. South of that point *cantator* makes an early brood only and *sollicitans* is the abundant species during the rest of the season until late fall when *cantator* sometimes reappears. He found that *tæniorhynchus* is never so common as the others and is a midsummer species. All of these species lay their eggs in the marsh mud, and Doctor Smith found that these eggs may retain their vitality for three years, even if repeatedly covered with water. He found that every time a marsh becomes water-covered some eggs hatch, and if the water remains long enough the larvæ reach maturity.

To prevent these mosquitoes breeding in the marshes, a system has been developed by which the force working under the State Entomologist makes deep narrow ditches in the salt marshes by means of special machinery. These ditches are 10 inches wide and generally 30 inches deep, the sides being perpendicular. The upper twelve or eighteen inches of the ordinary salt marsh is peat or turf, and the water drains readily from it. Below this peat is sand, mud or clay; and at 30 inches a depth has been reached which is below high-water mark and below the point at which vegetation is likely to start. The ditches are placed from 50 to 200 feet apart, depending upon the character of the marsh, but more often 200 feet apart than less.

Anticipating the ultimate passage of a State bill, work of this character was begun on the Shrewsbury River in 1902, and at the present time the marshes on both shores are drained in their full length. In 1903–4, the marsh areas belonging to the cities of Elizabeth and Newark were drained at the expense of the cities, and, in 1906, systematic drainage work was begun on the Hackensack marshes and continued along the shores of Middlesex and Monmouth counties. along both shores of the Raritan River, and along the numerous small rivers and creeks running into the Newark and Raritan bays and into the Arthur Kill.

During the year 1906, and in the preceding experimental work 4900 acres of marsh land were drained and 710,000 feet of ditches were put in. During the season of 1907, 10,951 acres of territory were cleaned up and 1,505,524 feet of ditching was put in. During the season of 1908, 6669 acres of marsh land were dealt with, and 888,650 feet of ditching was made. Out of the 1909 appropriation 2672 acres of marsh were drained with 329,800 feet of ditching. This gives a grand total of 25,192 acres of marsh land, and 3,633,974 feet of ditches. The drained area extends from the Hackensack at Secaucus to the mouth of Toms River on Barnegat Bay, a distance of nearly 70 miles of shore line.

In addition there are about 10 miles on Long Beach in which experimental work was done among the sand hills, in the pockets where the marsh mosquitoes bred whenever there was a storm or a storm tide to fill them. Here no ditches could be made because the layer of turf was very thin and below it was sand. Nor could outlets be obtained to tide water without the expenditure of disproportionately large sums. The smaller depressions were filled with brush held in place by a layer of sand, and this served to gather and hold the blowing sand in high winds, causing a complete filling after a year or two. Ditches were dug and the larger depressions were drained to a center, where a pond varying from 6 to 15 feet square was dug three or four feet deep and a large barrel sunk into the center. This brought the level below that of the bay and kept water permanently present: in fact there was an appreciable rise and fall of water with the tides and the water drained naturally to these low points. The ponds were then stocked with killies (*Fundulus* sp.). Some of these pools are now three years old and the fish have multiplied. Altogether this plan has worked well and required little looking after.

As to the amount expended up to the end of 1910, that under the State appropriations totaled $58,500. About $10,000 has been spent in addition by various municipalities and probably $75,000 would cover what has been spent in the entire marsh-mosquito work in New Jersey. This includes also the cost of administration since 1905.

The estimated cost for the total salt-marsh work in the State was $350,000 and up to date the proportionate cost of the work actually done is within the amount estimated for the whole.

The work has been largely original in its character, from the beginning of the observations upon the habits of the insects, through the development of special machinery and the ascertaining of the important fact that this simple and very rapid and economic form of drainage meets the requirement by stopping the breeding of these annoying insects. One of the writers (Dr. Howard) has visited the marshes, has seen the excellent results of the work accomplished, and has watched the operation of digging the ditches.

A bit of work, excellent in its results and very economical in its cost, in the way of the drainage of an upland marsh, is described by Doctor Smith in his report for 1908. A new normal school was about to be constructed on Montclair Heights, and there were swampy areas nearby which a committee of the State Board of Education considered to be dangerous as mosquito breeding-places. Doctor Smith caused an inspection to be made early in April, and found that there was a danger point in which not only the ordinary pool mosquitoes but malarial mosquitoes could develop. At a cost of $250, three thousand feet of ditching was placed or improved and all the surface water was drained to a culvert through a railroad embankment. The heavy rains of May gave excellent opportunity for testing the effectiveness of the work and no mosquito breeding was found there throughout the season.

THE PRACTICAL USE OF NATURAL ENEMIES OF MOSQUITOES.

Almost no practical use has been made artificially of the natural enemies of mosquitoes except with fish. It is true that about 1898 Mr. Albert Koebele imported into Hawaii from California a large number of western salamanders (*Diemyctylus tortosus* Esch.), which were liberated in the upper part of the Makiki stream in the hope of reducing the large number of mosquitoes breeding in small pools and in the taro fields. He kept two of these salamanders for several weeks in an open tank and they devoured all mosquito larvæ that occurred there; and while hundreds of the newly hatched mosquito larvæ could always be observed, none of them ever reached full growth. Whether these salamanders have increased in Hawaii and at present form an element in mosquito control is not recorded.

It has been suggested to breed mosquitoes of the genera *Psorophora* and *Megarhinus*, the larvæ of which are extremely voracious and feed upon the larvæ of other mosquitoes; but *Psorophora* itself in the adult condition is an aggressive biter, so that to breed it for predaceous purposes is hardly to be considered; in other words, the remedy might prove worse than the disease. However, Dr. Oswaldo Gonçalves Cruz, Director-General of the Board of Health in Rio de Janeiro, told one of the writers in November, 1907, while on a visit to Washington, that *Lutzia bigotii* is used in Rio to destroy the larvæ of the yellow-fever mosquito. The *Lutzia* larvæ are exclusively predaceous, and this species is introduced in regions where the yellow-fever mosquito abounds, and its larvæ destroy the other larvæ.

For a long time fish have been used practically on a small scale. For example:

"It was stated a number of years ago in *Insect Life* that mosquitoes were at one time very abundant on the Riviera in South Europe, and that one of the English residents found that they bred abundantly in water tanks, and introduced carp into the tanks for the purpose of destroying the larvæ. It is said that this was done with success, but the well-known food-habits of the carp seem to indicate that there is something wrong with the story." (Mosquitoes, p. 161.)

In the southern United States for many years intelligent persons here and there have introduced fish into water tanks for this purpose. Mr. E. A. Schwarz found in 1895 that at Beeville, Texas, a little fish was used for this purpose. The fish was called a perch, but its exact specific character is not known. Prior to 1900, Mr. F. W. Urich, of Trinidad, wrote the Bureau of Entomology that there is a little cyprinoid, common in that Island, which answers admirably for the purpose. In a letter to the Bureau of Entomology Mr. J. B. Fort, of Athens, Georgia, writes that about 1854 his father, Dr. Tomlinson Fort, living at Milledgeville, Georgia, found that mosquitoes were breeding extensively in a cistern owned by certain livery-stable keepers. They refused to use oil upon their cistern, and Mr. Fort was instructed by his father to catch some small fish from a creek nearby and place them in the cistern. About a dozen or more small fish were so placed and in a day or so all of the larvæ were destroyed. This instance is mentioned as indicating the early use of fish on a small scale in cisterns.

In "Mosquitoes" (1901), Howard recommended the practical use of sticklebacks, top minnows (*Gambusia affinis* and *Fundulus notatus*) and the common sunfish or pumpkinseed, and these fish, especially the top minnows and the sunfish, were used with success in a number of instances in small ponds. An instance has been described in a letter to the Bureau of Entomology by C. T. Anderson, of Anderson, Washington County, Florida, who wrote that he had a spring on his place that swarmed with mosquito larvæ in the summer time. He got about a dozen top minnows and put them into the spring without telling the rest of tbe family. In a day or two a member of the family remarked that there were no wrigglers in the water. Mr. Anderson verified the observation, and after many months was able to state that no mosquito larvæ had been seen since.

The common goldfish proves to be an excellent mosquito feeder and during the summer of 1901 Mr. J. Kotinsky, of the Bureau of Entomology, conducted a series of laboratory experiments with goldfish in an aquarium. He found they were voracious feeders on mosquito eggs, preferring them to larvæ. He further noticed that the fish, after taking several larvæ into the mouth, would eject some of them. Further, he found that in a large jar containing four goldfish and many hundreds of mosquito larvæ, a few of the larvæ succeeded in transforming and emerging as adult mosquitoes. The food supply was evidently in excess of the capacity of the fish.

At an earlier date than this Mr. H. W. Henshaw, of the Biological Survey of the United States Department of Agriculture, was staying at Fruitville, near Oakland, California. The house was badly infested with mosquitoes. He found the source of supply to be a lily pond about 7 x 12 feet in size and fully 3 feet deep, which was fairly swarming with larvæ. He got a half dozen goldfish from San Francisco and put them in the pond. The following day they were so badly bloated they could hardly swim, and in a few days there was not a single larva left. The fish bred in the pond and from the time of their introduction there was a very marked decrease in the number of mosquitoes in that locality.

Mr. Wm. Lyman Underwood, of the Massachusetts Institute of Technology, in "Science" for December 27, 1901, describes an interesting experience with goldfish:

"About six years ago at my home in Belmont, near Boston, Massachusetts, I constructed a small artificial pond in which to grow water-lilies and other aquatic plants, and also to breed, if possible, some varieties of goldfish—though the latter object was a secondary consideration. The advisability of making this pond had been somewhat questioned on account of its close proximity to my house and the fact that such ponds are likely to become excellent places for the propagation of mosquitoes. Nevertheless, the plan was carried out and the pond was stocked with goldfish taken from natural ponds in the vicinity where they had been living and breeding, to my personal knowledge, for a number of years.

"The aquatic garden has proved a success and the goldfish have meantime thriven and multiplied. Moreover, no mosquitoes attributable to the pond have appeared and I have been unable to find any larvæ in it, although I have searched repeatedly and diligently for them. I have always believed that the absence of mosquito larvæ from this pond was due to the presence of the goldfish, and I have so stated in a paper 'On the Drainage, Reclamation and Sanitary Improvement of Certain Marsh Lands in the Vicinity of Boston' in the *Technology Quarterly*, XIV, 69 (March, 1901), as follows: 'In the water [of this pond] are hundreds of goldfish that feed upon the larvæ of mosquitoes and serve to keep this insect pest in check.' . . . I took from the pond a small goldfish about three inches long and placed it in an aquarium where it could, if it would, feed upon mosquito larvæ and still be under careful observation. The result was as I had anticipated. On the first day, owing perhaps to the change of environment, and to being rather easily disturbed in its new quarters, this goldfish ate eleven larvæ only, in three hours; but the next day twenty were devoured in one hour; and as the fish became more at home the 'wigglers' disappeared in short order whenever they were dropped into the water. On one occasion twenty were eaten in one minute, and forty-eight within five minutes. This experiment was frequently repeated, and to see if this partiality for insect food was a characteristic of those goldfish only which were indigenous to this locality, I experimented with some said to have been reared in carp-ponds near Baltimore, Maryland. The result was the same, though the appetite for mosquitoes was even more marked with the Baltimore fish than with the others. This was probably due to the fact that they had been in an aquarium for a long time before I secured them, and had been deprived of this natural food. I also tried the experiment of feeding commercially prepared 'goldfish food' and mosquito larvæ at the same time, and found that in such a case the goldfish invariably preferred the larvæ.

"It is not as generally realized as it should be that goldfish will thrive in our natural northern waters. In my experience they can easily be bred in any sheltered pond where the water is warm and not fed by too many cold springs, and for many years they have been breeding naturally in many small ponds in the vicinity of Cambridge, Massachusetts.

"When it is once understood that these fish are useful as well as ornamental and comparatively hardy, it is to be hoped that they will be introduced into many small bodies of water where mosquitoes are likely to breed, and thus be employed as a remedy for mosquitoes sometimes preferable to kerosene."

The year 1908 in the Island of Cyprus proved to be the most malarious year since 1885. Careful examination of conditions was made by Dr. George A. Williamson, whose report will be found in the Journal of Tropical Medicine and

Hygiene, September 15, 1909, pages 271–272. A careful search was made in the marshes to the north and south of Larnaca, but no breeding-places of *Anopheles* mosquitoes were found, and subsequent search showed that the malarial mosquitoes were breeding in the tanks and wells of private houses. Here kerosene could not be used, and the use of goldfish was advised. Wherever the advice was followed, the results were perfect. One well described by Williamson was about twenty feet deep and had a wide mouth. This well contained *Anopheles* larvæ in enormous numbers, and of five persons living within its immediate neighborhood four became infected with malaria. This well, not being in use, was filled in, but a large tank which was near it was stocked with goldfish and all *Anopheles* larvæ were destroyed by them.

Sir Rubert Boyce, in his recently published volume "Mosquito or Man?" (London, John Murray, 1909), calls attention to the fact that in Barbados, where it is a very common practice amongst the natives to keep one or two small goldfish in the drinking-water barrel, the native residents, in reply to the question as to why the fish were put in the barrels, stated that they had been taught to do so by their parents or grandparents for the reason that if a maliciously inclined neighbor should poison the water the goldfish would die, turn up and float on the surface, thus indicating that the water was dangerous.

An excellent discussion of the relative value of the different small fish of the Atlantic coast-region for practical use against mosquito larvæ has been published by Mr. William P. Seal, a naturalist of many years experience in handling fishes, and the following paragraphs, taken from this article, may be considered as authoritative. (See Scientific American Supplement, May 30, 1908, vol. 65, no. 1692, pp. 351–352.)

"As a destroyer of *Anopheles* the writer has for several years advocated the use of *Gambusia affinis*, a small viviparous species of fish to be found on the South Atlantic coast from Delaware to Florida. A still smaller species of another genus, *Heterandria formosa*, is generally to be found with *Gambusia* and is of the same general character. The females are about one inch long, and the males three-quarters of an inch. Both of these species are known as topminnows, from their habit of being constantly at the surface, and feeding there. The conformation of mouth, the lower jaw projecting, is evidence of their top-feeding habits. Both of these species are to be found in great numbers in the South in the shallow margins of lakes, ponds, and streams in the tidewater regions wherever there is marginal grass or aquatic and semi-aquatic vegetation. They are also to be found in shallow ditches and surface drains where the water is not foul, even where it is but the fraction of an inch deep. In fact, if any fishes will find their way to the remotest possible breeding places of the mosquito, it will be these. And they are the only ones, so far as the writer's observation goes, that can be considered useful as destroyers of *Anopheles* larvæ.

"*Gambusia* is found in the Ohio Valley as far north as southern Illinois, where the winter climate must be at least as severe as that of the coast of New York and New Jersey.

"Dr. Hugh M. Smith, Deputy U. S. Fish Commissioner, informed the writer that he had examined the stomachs of several hundreds of *Gambusia* in the Chesapeake Bay and Albemarle Sound waters, and had found the contents to be principally mosquito larvæ. . . .

"While, as has been stated, all fishes have some measure of usefulness, if only in the way of deterrent effect, there are only a few species likely to be found in waters in which mosquitoes breed. The most important of these are the gold fish (introduced), several species of *Fundulus* (the killifishes), and allied genera, three or four species of sunfish, and the roach or shiner and perhaps one or two other small cyprinoids. In addition there are a few sluggish and solitary species like the mud-minnow (*Umbra*) and the pirate perch (*Aphredoderus*). The sticklebacks have been mentioned in this connection, but the Atlantic Coast species, and probably the entire family, are undoubtedly useless for the purpose, being bottom feeders, living in the shallow tide pools and gutters, hidden among plants, or under logs and sticks at the bottom, where they find an abundance of other food.

"In the salt marshes there are myriads of killifishes running in and out and over them with each tide, while countless numbers of other and smaller genera, such as *Cyprinodon* and *Lucania* remain here at all stages of the tide. So numerous and active are all of these, that there is no possibility of the development of a mosquito where they have access.

"Of the killifishes two species, *Heteroditus* and *Diaphanous*, ascend to the furthest reaches of tide flow, but it is a question as to whether they would prove desirable for the purpose of stocking land-locked waters, since they are a good deal like the English sparrow, aggressive toward the more peaceable and desirable kinds. Even *Cyprinodon*, which would at first thought be a valuable small species in this respect, is viciously aggressive toward goldfish and no doubt all other cyprinoids. It is so characteristic of all the cyprinodonts, that they can only be kept by themselves in aquaria. They are the wolves or jackals of the smaller species.

"The writer has come to the conclusion, after many experiments in both tanks and ponds, that a combination of the goldfish, roach, and top-minnow would probably prove to be more generally effective in preventing mosquito breeding than any other. The goldfish is somewhat lethargic in habit, and is also omnivorous, but there is no doubt that it will devour any mosquito larvæ that may come in its way, or that may attract its attention. The one great objection is that they grow too large, and the larger will eat the smaller of them. That is one of the drawbacks to goldfish breeding. There is no danger of over-population, but there is of the reverse. Whether or not it is the same with the roach, they are never excessively numerous, although no doubt the most abundant and most widely distributed of the Cyprinidæ. They are largely the prey of predaceous fishes, and never approach to the numbers of the killifishes. But at all events they are not lethargic like the goldfish, being on the contrary one of the most active of the family, and equally at home in flowing or stagnant water. The roach is always in motion, back and forth, and around and about, on a never-ending patrol.

"The top-minnows would supply the deficiences of the other two species, and in combination they should very thoroughly populate any waters not already stocked with predaceous kinds, and exercise an effective control. One of the great difficulties in the case is that there are dozens of kinds of insect larvæ besides those of the mosquito, and other forms of life as well, which are natural and possibly preferred food of the fishes, thus requiring an enormous population to devour them all.

"The larvæ of gnats, midges, ephemera, and other flies and insects which breed in the water, as well as the many small crustceans, afford a menu of delicacies that would stagger a gourmand. The above combination of mosquito destroyers might be supplemented by two small species of sunfish, *Enneacanthus obesus* and *E. gloriosus*, which live among plants and would be a check on larvæ other than the mosquito. The black-banded sunfish, ***Mesogonistius chætodon***, would also be desirable for this purpose, if they were not so difficult to obtain in large numbers. One or both species of ***Enneacanthus*** can be found wherever there are aquatic plants. The above-mentioned five species in combination seem to be the most suitable for pond protection of all those which are known to thrive in still water, and which in any degree possess the desired qualities. As has been stated, the killifishes would probably be found to be undesirable. In their natural habitat, the tidal streams and great expanses of small marsh, their efficiency is unquestioned.

"There are many places at the seashore where there are swales or hollows filled with grasses and bushes, which in periods of rainfall become breeding places for the mosquito, especially of *Anopheles*. If these places are stocked with fish, the result is that when they dry up the fish perish, and the operation must be repeated after each filling.

"The writer has suggested digging holes about four feet square down through the turf into the sand stratum in the deepest part. Two feet is usually sufficient to secure a constant water supply where the fish can exist until the hollow is again rain-filled. *Cyprinodon* and *Lucania* would be desirable for such places, and they are to be found everywhere in the ditches and tide pools on the flats.

"To add variety to the treatment of the subject, it might not be amiss to suggest that there is a fish, *Anablops*, inhabiting the fresh waters of South America, which seems to be specially adapted to this purpose. To quote: 'These small fishes swim at the surface of the water, feeding on insects, the eye being divided by a horizontal partition into a lower portion for water use, and a portion for seeing in the air.'"

Acting largely upon Mr. Seal's advice, Doctor John B. Smith, the State Entomologist of New Jersey, with Mr. Seal's help, in November, 1905, brought *Gambusia affinis* and *Heterandria formosa* from North Carolina into New Jersey, which were distributed as follows: 8000 in spring and natural drainage rivulets flowing into the ice pond at Westville, N. J., 600 in a landlocked pond near Delanco, 600 in a mill pond between Merchantville and Evesboro, 600 in landlocked waters near Delair, and 400 in ponds of the Aquarium Supply Co., at Delair. In Doctor Smith's report for the year 1906, it was stated that the experiment was in large part a failure. Whether it was due to the destruction of the introduced fish by black bass, pike, yellow perch and sunfish, or whether because of other enemies, or because of their dislike to their changed conditions they found their way during the spring rains to rivulets flowing to the Delaware River, or whether they escaped in other ways, could not be told. In his report for 1907, however, Doctor Smith states that the *Gambusia* was found in large numbers in Teal's Branch of Pond Creek, a small tributary of Delaware Bay at Higbee's Beach, by Mr. Henry W. Fowler, of the Academy of Natural Sciences, Philadelphia, and Messrs. H. Walker Hand and O. H. Brown. These gentlemen found it also very abundant in New England Creek, another tributary of Delaware Bay just north. Doctor Smith states that Mr. Seal was inclined to claim that this finding was the result of his work in 1905, but that Mr. Fowler doubted this conclusion since the points where found were 90 miles distant from points of introduction.

Although the opinions of Mr. W. P. Seal, here quoted, are authoritative, it may not be out of place at this point to quote the interesting account by F. E.

Lutz and W. W. Chambers, of their observations made in the interests of the North Shore Improvement Association of Long Island, in 1902, published in November, 1902, by the Association:

"The value of fish in this work cannot be overestimated, although too much dependence is often put upon them. The fact that a pond is stocked is not conclusive evidence that it is free from larvæ. Often the owner points with pride to his fine large fish, when really they are so large as to be useless. Large fish remain in the deep water, rarely coming 'in shore' where the larvæ stay. Then, too, large fish are apt to go after larger morsels than mosquito larvæ. This was shown, for example, in one of our tests made at Cold Spring. We put three each of goldfish, silverfish, sunfish, and mud minnows in one of the fish hatchery tanks.

"Two days later one of the mudminnows had died and another disappeared. We then put a large number of larvæ into the tank, and after the lapse of an hour took out the fish, killed them, and examined the contents of their stomachs. The missing mudminnow was found in a large sunfish (4½ inches), but no larvæ were with it.

"Concerning the best kind of fish for our purpose we should recommend silverfish. Sticklebacks proved quite unsatisfactory for us. The ordinary 'mummie' or top minnow (*Fundulus*) of this vicinity will live in fresh water, but is the least valuable of the promising candidates.

"In a series of tests, under all sorts of conditions, if we give top minnows a value of one (1.0), the mudminnows (umbridæ) rank about 1.3, sunfish (2½ to 4 inches long) 1.4; while goldfish and silverfish (2 to 3 inches long) are tie at 1.5. This last is to be expected, as the goldfish are simply a highly-colored silverfish. However, silverfish have two advantages over goldfish. First, they only cost about one-fourth as much (a cent and a half apiece), and secondly, just as a cur is hardier than a high-bred dog, so silverfish are hardier than goldfish."

It should further be here stated that Britton has experimented with a yonng pike (*Lucius americanus*) less than an inch in length and has found it to eat *Anopheles* larvæ with avidity. (Rept. Conn. Exp. Sta., 1904, p. 308.)

For a discussion on the transfer of several species of mosquito-eating fish from salt water into fresh water see a note by Eugene Smith entitled "Fundulus and fresh water," Science, n. s., vol. 35, no. 891, Jan. 26, 1912, pp. 144–145. Previous discussion of water changes as affecting *Fundulus* by F. B. Sumner occurs in Science, vol. 34, no. 887, pp. 928–931.

FISH INTRODUCED INTO HAWAII.

In the early part of 1903, Mr. D. L. Van Dine, Entomologist of the Hawaii Agricultural Experiment Station of the U. S. Department of Agriculture, brought up the question of introducing top minnows into Hawaii, since his investigations of the mosquito problem in the Islands indicated that no effective natural enemies existed there. Dr. David Starr Jordan, to whom the problem was referred, informed Mr. Van Dine that while these fish had never been transported for such a great distance, they were extremely hardy, and that the experiment would be well worth while. The cost of the experiment, however, was prohibitive at the time, and it was not until 1904, when a Citizens' Mosquito Campaign Committee was organized in Honolulu, that the requisite funds were raised. Mr. Alvin Seale, an assistant of the U. S. Bureau of Fisheries, was chosen to do the work, and with an advance of $500 started in July, 1905, from Stanford University to the southern United States. He proceeded to Seabrook, near Galveston, Texas, where he found top minnows in large numbers. They were swarming in all the stagnant waters at sea level, as well as in various ditches, ponds, and standing pools. Mr. Seale found that mosquitoes were very plentiful about Seabrook, but after careful study he convinced himself that they did not breed at all extensively in the bodies of water containing the fish, but in temporary and artificial breeding-places such as isolated pools, tubs, and tin cans, not accessible to fish. Dr. Jordan had advised the collection of fish of the following genera: *Mollinesia, Adinia, Gambusia,* and *Fundulus,* all members of the family Pœciliidæ, the top minnows. Mr. Seale made careful examinations of the stomach contents of the minnows of the genera recommended by Dr. Jordan. These stomach contents were found to consist largely of larvæ of various insects including those of mosquitoes, of the egg masses of mosquitoes, of minute crustacea, and of some vegetation. The fish of the genus *Gambusia* were found to be the best insect feeders. Careful experiments were made, using 10-gallon milk cans, in order to determine the conditions under which the fish conld be successfully transported to Hawaii. These experiments included observations on temperature of the water and on changing the water, and it was ascertained that the best results could be obtained by transporting them in water of the normal temperature. The three most abundant species, *Gambusia affinis, Fundulus grandis* and *Mollinesia latipennis* were then collected and about 75 were placed in each can, a 20-gallon tank full of water being taken along as a supply reservoir. Mr. Seale left Seabrook on September 4, 1905. On the journey the fish were fed sparingly every morning at 8 o'clock on prepared fish food, finely ground liver or hard-boiled eggs. At half-past nine half of the water in each can was drawn off from the bottom, thus cleaning the cans by removing uneaten food and excrement. An equal amount of fresh water was added. At noon the cans were aërated by means of a large bicycle pump, a sponge being tied over the end of the hose to separate the air into fine currents. At four in the afternoon, two gallons of water were drawn off from the bottom and two gallons of fresh water put in, and the aëration was repeated just before bedtime. Careful tests of water at each place of changing were made by experimenting with two fish. At El Paso, Texas, there was so much alkali in the new water that the fish were killed; at Los Angeles and at San Francisco, the water was good. Twelve fish died between Galveston and San Francisco, and 15 between San Francisco and Honolulu. Honolulu was reached on September 15, 1905, with a loss of only 27 out of approximately 450 fish. On arrival the fish were placed in the four breeding-ponds prepared for them at Moanalua near Honolulu. The fish thrived in all of the ponds almost equally well. They were protected by screens from predatory fish and from being carried out to sea by freshets. In an official bulletin, issued July 25, 1907, Mr. Van Dine reported that the fish had multiplied rapidly and that from the few hundred introduced several hundred thousand had been bred and distributed. They had proved very effective destroyers of mosquito larvæ and also of mosquito egg-masses. Later advices show that the good work is continuing and that the experiment has been a great success.

FISHES IN THE WEST INDIES.

Girardinus pœciloides, a small top minnow, occurs very abundantly in Barbados, where it is known by the popular name "Millions." This fish is very small in size, the full-grown females measuring about 1½ inches in length, while the male is much smaller. The female is dull in color, without conspicuous markings, while the male is marked with irregular red splotches and has a circular dark spot on each side. The fish is a rapid breeder and thrives and multiplies in captivity, in water tanks, reservoirs and fountains, and garden tubs in which aquatic plants are kept. They are much used in this way, both in the towns and on the estates, to reduce the annoyance of mosquitoes. In 1905 this fish was introduced by the Imperial Department of Agriculture of the British West Indies from Barbados into St. Kitts, Nevis and Antigua. In 1906 it was introduced into Jamaica, and in 1908 into St. Vincent, St. Lucia and the city of Guayaquil in Eucador. An account of these introductions is given in a pamphlet entitled "Millions and Mosquitos," by H. A. Ballou, issued in 1908 by the Imperial Department of Agriculture of the West Indies (No. 55). In August, 1905, a number of fish were sent to Antigua in a kerosene tin. They arrived in good condition and were kept in a tank at the Botanic Station until they had sufficiently increased to be distributed. They were liberated in several ponds and streams and increased so rapidly that the Country Board of Health undertook the work of stocking all the ponds and streams of the Island. Three years after the first introduction all of the more or less permanent water of Antigua had been stocked, and Mr. Ballou states that many planters and others have commented on the evident abatement of the mosquito nuisance in many localities. At St. Kitts, the introduction was equally successful, but the local government did not take up the distribution of the fish as in Antigua. In Jamaica they were established with good results. Millions may be fed in captivity on mosquito eggs and larvæ, on raw beef or hard-boiled eggs, upon small insects of any kind, and even upon cornmeal. They are readily transported short distances in a kerosene tin, with no other preparation than a wire netting arranged near the top to prevent the fish from being thrown out if the water is splashed about.

The success of these West Indian experiments attracted the attention of the sanitary authorities at the Isthmus of Panama, and some "millions" were introduced into the Isthmus for the purpose of eating mosquito larvæ. Similar, and perhaps also the same species, already occurred on the Isthmus, but, nevertheless, the experiment was an interesting one. Under date of March 12, 1910, Colonel Gorgas, Chief Sanitary Officer, wrote one of us, as follows:

"Yours of March 1st is acknowledged. We brought over some of the minnows from the Barbados and have been breeding them here for the last year. We have also found some *Girardinus pœciloides* in the ponds and streams here that do very well as eaters of larvæ. I look with favor upon using these fish wherever we can. It saves considerable expense. When we get these fish in a suitable pond all we have to do is to keep the edges clean from grass and refuse so that the fish can get at them."

It does not appear that the "millions" have been tested on a large scale in the Canal Zone, and perhaps with the large scale topographic changes in progress there this is impossible. Recently J. A. M. Vipan has shown that no far-reaching results can be expected from the introduction of *Girardinus pœciloides* on the American mainland. Vipan states that the extraordinary abundance of these fish in the island of Barbados is due to the fact that no other fresh-water fish exist there to keep them in check. He points out that furthermore *Girardinus pœciloides* is already indigenous in some of the regions in which its introduction has been attempted and that other species of fish exist there which are equally efficient destroyers of mosquito larvæ. The reason why these fish do not multiply in the same degree as in the small islands of the Antilles is that they are preyed upon by other species of fish.

A BRAZILIAN FISH.

Excellent results are obtained in Rio de Janeiro, Brazil, by the use of a small fish known as the "barrigudo" (*Girardinus caudimaculatus*) which feed on the larvæ of mosquitoes most voraciously. In the great prophylactic work carried on in that city under the public health service, it is placed in tanks and other receptacles where it is impossible to use petroleum.

AN AFRICAN FISH.

Mr. J. Vosseler, in an article entitled "Fische als Moskito-Vertilger," published in "Der Pflanzer, Ratgeber für Tropische Landwirtschaft," for June 13, 1908, vol. 4, No. 8, pp. 118–127, gives an interesting account of some experiments with mosquito-feeding fishes in German East Africa. He brings out the point that on account of the great physical and chemical differences in the water inhabited by mosquito larvæ the selection of suitable species of fish is made difficult by several restrictions. He states that the shallow shores of rivers or large lakes can be excluded from consideration, since the young of most species of fish living there frequent the shores in shoals, and prey upon the various forms of animal life, mosquito larvæ included. Many water supplies, however, contain salt and other chemicals, and are polluted from various sources, even from the excrement of game coming to drink, while temporary collections, such as pools, puddles, irrigation ditches, contain turbulent muddy water. The level of the water in these different conditions is very variable, and the temperature of the water goes through great variations within a single day; often at the midday heat rising above the limit which most fishes can stand. A fish which would withstand all these conditions would be very exceptional. In considering the question of fish introduction, the capability of the species for acclimatization, its power of enduring long transportation, and its ability to multiply rapidly, even under adverse conditions, are of vital importance to success. In his travels through southern Oran (Algeria) in 1892, Mr. Vosseler *found a widely distributed species occurring* in thousands, *not only* in *the springs* of salt or magnesia water in the oases and in the irrigation ditches, but also in the highly polluted, badly smelling pools used to water camels, and in which 300 to 400 camels often waded in one day. He found the same species afterward in pure, fresh water, in hot springs, and in brackish water. He also found that it inhabits the subterraneous waters of the desert and is probably brought up by the boring of artesian wells. One of the officers of the garrison situated in the midst of a salt basin without outlet pointed out to Mr. Vosseler that this little fish eats mosquito larvæ, which explained the comparative absence of mosquitoes in that locality. Mr. Vosseler attempted the introduction of these fish into Germany and succeeded very well, in spite of inadequate preparation. They began to lay eggs within a week of their arrival and became accustomed to any animal food. They always prefer mosquito larvæ and small crustaceans. The fish in question is *Cyprinodon calaritanus*. The female is 8 cm. long and the male 5 cm. The eggs are attached singly to water plants or stones at the rate of one or two a day. Mr. Vosseler states that the excellent qualifications of the species are shared by other members of the same family, and in German East Africa at least two genera and five species are known to occur.

MR. THIBAULT'S OBSERVATIONS.

In considering the normal relation between mosquitoes and fish, Mr. James K. Thibault, Jr., Scott, Arkansas, in a recent communication presents his views and gives an interesting instance of mosquitoes breeding in the presence of fish, which he considers typical of conditions in some localities:

"Personally I do not think that mosquitoes *ever* breed in the presence of fish if the water is open, allowing the fish free access to the larvæ, yet it is a matter of common observation that under certain favorable circumstances some species do breed regularly in streams where fish are abundant. Yet even where conditions are favorable only a very few species seem to take advantage of it. So far as my own observations go the only mosquitoes that regularly do so in this locality are *Anopheles quadrimaculatus* and *Culex abominator*.

"Conditions are favorable where the surface of the water becomes carpeted with aquatic vegetation, which restrains the fish in their movements, yet allows ample room and protection for the larvæ of the above-named species. There is a certain deep, slowly running bayou here that is the main breeding place for *quadrimaculatus* and *abominator* at present while two years ago not a larva could be found there at all. The explanation is simple and may be given as a typical example of its kind. Two years ago launches passed through this bayou daily, and all logs and drift were removed as soon as found, so that the water had free passage and the pond weeds found no foothold, except very near the banks where they were completely destroyed by stock. After the launches stopped passing through this bayou, logs soon accumulated and the pond weeds immediately took possession, so that throughout the present season *quadrimaculatus* and *abominator* have bred continuously and abundantly in this bayou.

"It must be noted in passing that the larvæ, pupæ, and freshly emerged adults bred in such a location are invariably bright grassy green in color, which gives them additional advantage of the fishes. This is not the case with larvæ, etc., found in other places."

ALLEGED DETERRENT TREES AND PLANTS.

There are many statements scattered through the literature that there are certain trees and plants in the neighborhood of which mosquitoes are never found. Notable among these are the *Eucalyptus* trees and the castor bean plant. Of recent years there have been many newspaper notes about other plants, and in the Southern States the chinaberry tree is said to be repellant.

EUCALYPTUS.

The statement has often been made that the planting of *Eucalyptus* trees in malarial regions will drive away malaria. This idea had become rather firmly grounded before the discovery of the carriage of malaria by mosquitoes. It has been said, for example, that the planting of *Eucalyptus* trees in the Roman Campagna was followed by a noted improvement in the malarial conditions. *Eucalyptus* oil has been used to keep mosquitoes from biting. Mr. Alvah A. Eaton, of California, wrote to the Bureau of Entomology, Department of Agriculture, in 1893, that, in his opinion, where the blue gum grows no other remedy against mosquitoes need be sought for. He further stated that, no matter how plentiful mosquitoes may be, a few twigs or leaves laid on the pillow at night will secure immunity. Another correspondent of the Bureau, Mr. W. A. Sanders, wrote from California that he had planted *Eucalyptus* trees about his house 19 years previously and that they had reached a height of 140 feet. According to his statement an irrigating ditch ran through the grove, but there was never a single mosquito larva in the grove, although on both sides of the grove larvæ were plentiful. On the other hand, Dr. A. Dugés, of Guanajuato, Mexico, wrote the Chief of the Bureau on September 8, 1900:

> "I have received your very interesting study of the mosquitoes of the United States and thank you greatly for it. At the end of the book you speak of the utility of *Eucalyptus* for driving away insects. I have had some experience with these trees. *The fresh leaves placed upon the pillow will attract mosquitoes.* Thinking that the mosquitoes loved this plant I had placed the branches further away but without result. I have burned the leaves in my chamber, and the cursed beasts have resisted the smoke."

Eucalyptus trees of many species are now grown generally all through California, and the idea that they drive away mosquitoes must be abandoned. Mr. H. J. Quayle, in Bulletin 178 of the California Agricultural Experiment Station, states that in the Burlingame section, not far from San Francisco, all of the avenues are lined with *Eucalyptus* trees, and mosquitoes are most numerous where these trees are most abundant. In 1901 he captured a pint cup of mosquitoes immediately under *Eucalyptus* trees. Coyote Point is covered with *Eucalyptus* trees, yet the construction of a hotel on the point was abandoned on account of the abundance of mosquitoes.

Edmond and Etienne Sergent, in their anti-malarial work in Algeria, had occasion to study the question of *Eucalyptus*, and published their results, together with the results of their observations and experiments upon certain other plants supposed to be deterrent to mosquitoes, in the Comptes rendus des Séances de la Société de Biologie, November 14, 1903. With regard to *Eucalyptus* they show that the railway station of Ouled-Rahmoun, formerly greatly troubled by mosquitoes, was visited by them much less frequently after the cutting down of great *Eucalyptus* trees which surrounded it. The station of Ighzer-Amokran, which is isolated in the middle of a desert plain, is surrounded by a little grove of *Eucalyptus*. Before the windows and doors were screened the rooms were visited every evening by quantities of *Anopheles*. The traveling Kabyles who stopped at this station would never sleep at midday under the foliage of the *Eucalyptus*, for they said mosquitoes always came down on them. They went under the olives where they were never bitten.

RICINUS AND PAPAYA.

During the winter of 1901 a great deal was said in the newspapers about the planting of castor oil plant (*Ricinus communis*) to ward off mosquitoes. These notes were mainly based upon a consular report from Capt. E. H. Plumacher, U. S. Consul at Maracaibo, Venezuela. In this report Capt. Plumacher stated that his residence is surrounded by plantain and banana trees and that he was troubled in the past by a great number of mosquitoes which gathered in these trees. Following the example of old settlers, he planted castor seeds which grew up in profusion, with the result that no mosquitoes were to be found among the trees, although he kept the ground well irrigated. Capt. Plumacher came to Washington the following year and called on one of the writers April 18, 1901, bringing with him the seed of the particular variety of the castor oil plant with which he had noted the result above stated. The seeds were planted upon the U. S. Department of Agriculture grounds in Washington and observations indicated that mosquitoes were not at all deterred by the plants.

Some of the Venezuela seeds brought by Capt. Plumacher were sent to Mr. J. Turner Brakeley, of Hornerstown, New Jersey. He planted them in the early summer of 1901, and later in the summer observations were made with the result that mosquitoes were found both on these Venezuelan plants and on other castor oil plants. Mr. Brakeley wrote: " The castor oil plant is no good as a skeetonal protection in New Jersey. It may be a protection against the Venezuela mosquito, but it is no good where the blood pirates of New Jersey are concerned." In a report sent in from Progreso, Yucatan, September 17, 1903, U. S. Consul Thompson makes the following statement:

" The belief is current among the natives of Yucatan that a few castor oil plants growing in or near a dwelling will protect the inmates from mosquitoes and certain other noxious insects peculiar to Yucatan. This belief has been to a certain extent confirmed upon experiment by me personally. My dwelling at one time seemed to be peculiarly acceptable to mosquitoes. I planted a row of castor oil plants around the court yard and in a short time the mosquito was as rare as he was formerly a frequent visitor. My plants were destroyed by the cyclone and now the mosquitoes are as abundant as formerly."

Giles published a letter sent to the " Pioneer," an Indian journal, in 1901, in which the correspondent states that he had seen a recommendation of the castor oil plant as a deterrent for mosquitoes, and in consequence had six plants placed in pots in his room. The result was that the plants were thickly covered by the insects, which seemed "to be actually invigorated by the apparently stimulating effect of their new quarters."

The Sergents, in Algeria, experimented both with the castor oil plant (*Ricinus communis*) and with papaya or pawpaw (*Carica papaya*) on account of the reputation that these plants had as deterrents against mosquitoes. A pawpaw about 90 cm. high and in good condition was enclosed in a mosquito bar of tulle, oblong in form, with its axis directed perpendicularly to the window from which the light came. In the end of the bar nearest the window they suspended a raisin grape, as food for the mosquitoes, and a little vessel of water. Then at the opposite end of the bar they put in four females of *Anopheles maculipennis* and four females of *Culex pipiens*. They wished to see if the instinct which attracts the mosquitoes toward the light and towards an apparent way of escaping, and on the other hand the need of nourishment and water, would induce the mosquitoes to pass the middle portion of the bar which was entirely filled with large leaves of the pawpaw. At the end of four minutes one *Anopheles* and one *Culex* had passed from one end of the bar to the other; at the end of ten minutes another *Anopheles* and two *Culex* were seen to alight upon the pawpaw leaves and they remained there many hours. The mosquito bar was left in place for eight days. During this period the mosquitoes moved about freely and rested frequently upon the leaves and branches, sometimes for hours.

An experiment exactly similar was carried on at the same time with *Ricinus communis*, with the same results. When these experiments were concluded at the end of eight days one *Anopheles* and one *Culex* were found dead in the pawpaw mosquito bar, and in the *Ricinus* bar also one *Anopheles* and one *Culex*. But in similar cages in another room during the same time with *Carica* and *Ricinus* plants absent, six *Anopheles* out of twenty had died, and nine *Culex* out of twenty-eight. The authors concluded that pawpaw and castor oil plants are powerless against mosquitoes.

OCIMUM.

Another plant which is said to act as a deterrent is a lavender known as *Ocimum viride*, a perennial which grows from 3 to 6 feet in height and occurs from Senegambia southwards to Angola. Mr. A. E. Shipley in the *Tropical Agriculturist* of February 2, 1903, pp. 555-556, states that Major Burdon, resident of the Nupe Province, northern Nigeria, had given him the following account of the plant:

"A fragment of what turns out to be *Ocimum viride* was given me in August last at Lokoja, Northern Nigeria, by Capt. H. D. Larymore, C. M. G., R. A., Resident of the Kabba Province. Capt. Larymore's notice had been drawn to the plant by a native living in a low-lying part of the native town at Lokoja, who had told him that the natives suffered very little from the swarms of mosquitoes which existed in that part, as they protected themselves from them by the use of this plant.

"Capt. Larymore made inquiries and obtained a few specimens of the plant, which grows wild, though not very abundantly, in the neighbourhood of Lokoja. These specimens he planted in pots and boxes and kept in and about his house. The specimens I saw were about the size of a geranium.

"He informed me that the presence of one of these plants in a room undoubtedly drove the mosquitoes out, and that by placing three or four of the plants round his bed at night he was able to sleep unmolested without using a mosquito net. This is very strong testimony to the efficacy of the plant, for the house in which Capt. Larymore was living is, as I had cause to know well in former years, infested with mosquitoes."

Mr. Shipley further states that E. M. Holmes, in "Notes on the Medicinal Plants of Liberia," records that when chewed or rubbed the leaves of *O. viride* give off a strong odor of lemon thyme, and mentions that Dr. Roberts, of Liberia, entirely substituted the use of the plant for that of quinine in cases of fever of all kinds, giving it in the form of an infusion.

Mr. Shipley's article in the Tropical Agriculturist was reprinted in the British Medical Journal and was quoted in many other periodicals and in consequence many requests for seeds of *Ocimum viride* were received at the Royal Botanical Gardens at Kew from many parts of the world. About this time a report was received from Dr. W. T. Prout, at Freetown, Sierra Leone, and was published by Sir William Thistelton-Dyer in the *London Times* for July 27, 1903, and in *Nature*, July 30, 1903. Dr. Prout's report included an account of experiments made with the basil plant in relation to its supposed effect upon mosquitoes and he states that these appear "to dispose conclusively of the plants possessing any real protective value." He showed that growing plants have little or no effect in driving away mosquitoes, and are not to be relied upon as a substitute for the mosquito-net. He showed further that fresh basil leaves have no prejudicial effect upon mosquitoes when placed in close contact with them, and further that while the fumes of burnt basil leaves have a stupefying and eventually a destructive effect on mosquitoes it is necessary, in order to produce this effect, to bring about a saturation of the air which renders it impossible for individuals to remain in the room. He thinks that cones made of powdered basil would, when burned, have the effect of driving mosquitoes away, and that the plant to that extent might be found useful. Goeldi, in Brazil, has experimented with *Ocimum minimum* without the slightest beneficial result.

CHINABERRY TREES.

In spite of the statement that the chinaberry tree will protect against mosquitoes, observations have failed to show the truth of the statement, and in mosquito regions people are quite as liable to be bitten while sitting under a chinaberry tree as under any other tree. Nevertheless there is an observation upon record which makes further experiments desirable. In the Public Health Reports, volume xxi, No. 44, Nov. 1, 1901, Dr. G. M. Corput, Assistant Surgeon U. S. Marine Hospital Service, gave the results of experiments, conducted by tempting the mosquitoes to oviposit with cans of water hung in the branches of a variety of trees, to determine if any of them had a repellant effect. He found that in the can hung in the chinaberry bush there were no mosquito larvæ at any time, although larvæ were found in all of the other cans.

A number of other plants have been mentioned from time to time in the newspapers, some of them in a sensational manner. The New York papers, for example, in the summer of 1906, contained numerous notices of the so-called Phu-lo plant introduced from the Tonquin country in China by Baron de Taillac. This plant was said to be valuable as a fodder for cattle, and to drive away mosquitoes. An effort was made to determine the plant and Mr. W. E. Safford searched the literature of oriental economic botany without finding anything corresponding to it. He found that in the East Indies there is a *Verbascum* or mullein called Phul, the seeds of which are supposed to be narcotic, and the leaves used like those of tobacco. The leaves of this plant, although not good for general forage, are eaten by camels and goats. Assuming that this is the plant mentioned by the newspapers, there is nothing in the economic literature concerning its use as a mosquito deterrent.

PEAT.

An article in the London Times in 1908, written by an anonymous correspondent, refers to the absence of mosquitoes in swamps and marshes with peat. The writer says: "Given marshy lands and no peat, mosquitoes abound; given marshy land and peat, there are none." This article was answered by Mr. F. V. Theobald in *Nature,* October 15, 1908, pp. 607–608. Mr. Theobald showed that he had found *Anopheles nigripes* and *Anopheles bifurcatus* breeding in the water of peat cuttings in Wales and Somerset and on the far-famed Wicken Fen numbers of *Aëdes cantans*. He stated that mosquitoes are often very abundant in the fens, even where the peat is dug. Besides the species above mentioned he has found *Anopheles maculipennis* and *Culiseta annulata* in peaty water and near peat piles in northern Wales.

WATER PLANTS.

Ordinary pools of stagnant water are often the source of thousands of mosquitoes, the larvæ breeding with the greatest facility in such water. To some persons the presence of algæ and certain low forms of aquatic vegetation is evidence of the stagnation of the water, and an algal scum is frequently associated with the idea of mosquitoes in one's mind. But, it is perfectly plain that where the water covering of aquatic vegetation becomes extremely dense and complete mosquitoes can not breed, since there is no opportunity for the larvæ to come to the surface to breathe. It has often been a matter of surprise that mosquitoes are not more numerous in Holland, where the country is traversed by canals and dykes. Mosquitoes breed there, as elsewhere, in ponds and in chance receptacles of water, but it is said that no larvæ are present in the water of the canals. It is explained that this is so constantly agitated by the passage of boats and by the wind that mosquitoes can not breed there, and that in the smaller ditches and canals the surface of the water becomes so completely covered with a continuous layer of minute aquatic vegetation early in the summer that there is no opportunity for the extensive breeding of mosquitoes.

A short statement regarding the practical use of water plants occurs on pp. 1 and 2 of the 4th volume of Theobald's Monograph of the Culicidæ of the World. This statement may be quoted:

"Major Adie, I. M. S. ('Ind. Med. Gaz., xxxix,' June, No. 6, 1904), brings considerable evidence to bear on the benefit of *Lemna minor* as a means of keeping mosquitoes from laying their eggs on water. He shows that tanks covered with this green flat weed never contain larvæ of *Culicidæ*, whilst others at the same time of year are full of them.

"As a test he 'cleared certain areas near the banks of all *Lemna* and enclosed them with light floating structures, which were fixed enough to resist the winds—in fact made experimental pools. I was pleased,' he says, 'to find in due time plenty of *Anopheles* larvæ in these pools. This seemed to prove that *Lemna* acts as a mechanical obstruction to the process of egg-laying, and a very obvious method of prevention occurred to me. Why not deliberately promote the growth of *Lemna minor* in all unavoidable collections of water to prevent the propagation of mosquitoes?'

"This same green plant grows freely in England, and I have noticed a similar occurrence here. A pond close to my house was frequented by numbers of the larvæ of *Anopheles bifurcatus* and *A. maculipennis* every year. Two years ago its surface became smothered with *Lemna minor*, Linn., and *Lemna arrhiza*, Linn., no *Anopheline* larvæ could then be found. As this was the only breeding ground near, both species have practically died out.

"This small yet widely distributed genus of floating plants evidently has a very marked effect upon the frequence of *Culicid* larvæ in natural and artificial collections of water.

"The little *Lemna arrhiza*, or the Rootless Duckweed, occurs in Asia, Africa, South America and Europe, and apparently has the same effect as the larger *L. minor*."

An early suggestion as to the practical use of water plants occurs in Mr. William Beutenmüller's essay on the "Destruction of the Mosquito and House Fly," published in Dragon-Flies *vs.* Mosquitoes (The Lamborn Prize Essays, New York, 1890). Mr. Beutenmüller states that Mr. L. P. Gratacap, of the American Museum of Natural History, suggested the increase of fresh-water algæ as deterring the progress of mosquito larvæ in the water and as effecting their destruction before they can rise to the surface of the water to breathe. Mr. Beutenmüller, considering the suggestion important, stated that he believed "that the vast numbers of the fronds of Oscillatoria in the Central Park lakes [in New York City] have had a deterrent effect upon the propagation of mosquitoes in those localities. The requisition here is a largely disseminated mass of algæ, which, in such rod-like forms as Oscillatoria, will float through the water and by its intermixed and diffused stipes embarrass the development and movements of the mosquito larvæ." In fact, mosquito larvæ are frequently found in the presence of algæ and it is well known that *Anopheles* larvæ thrive where algæ are abundant. One of us (Knab) has found larvæ of *Culex tarsalis* abundant among a dense growth of algæ and larvæ of *Uranotænia* under the same circumstances.

The value of duckweeds was considered by Dr. H. P. Johnson in an appendix to Smith's New Jersey Report for 1902, and by virtue of the actual small-scale experiment tried, these observations are printed in full:

"While most forms of aquatic vegetation promote the breeding of mosquitoes, the *Lemnaceæ*, or duckweeds, are unfavorable, and in many waters almost or even wholly prevent it. These tiny plants consist merely of a floating frond, resembling a miniature lily pad. It is circular or more frequently lobated and three to six millimeters in diameter. From the under surface hang one or more roots, which never fasten in the soil, but derive their nourishment from the water. Its reproduction, mainly by division of the frond, is so rapid that in a short time (usually before July 1st) it completely mantles quiet waters, notably sheltered ponds and ditches, without perceptible flow. Its extraordinary abundance, often covering whole acres of shallow water, makes it an efficient protection from mosquito breeding. Wherever this plant forms a complete covering no larvæ have been found. Such places should never be treated with oil, for nature has provided a far more lasting and equally effective protection. It is probably impossible for a mosquito to lay her eggs on lemna-covered water. Even should larvæ wander in from adjacent waters, they would be unable to reach the surface for air, and would thus soon become asphyxiated. Larvæ of *Culex pungens*, injected by means of a pipette beneath the lemna in the jar . . . . died in less than an hour. Where the lemna mantle is not complete, but presents interspaces of open water, larvæ of both *Culex* and *Anopheles* will usually be found in small numbers only, for lemna waters are apt to harbor the various predaceous water bugs in great numbers."

To have any effect, the covering of *Lemna* must be complete and thick. The most abundant breeding-place of *Culex salinarius* known to us is a large marsh near Chesapeake Beach, Maryland, which was observed by one of us (Dyar) to be well covered with *Lemna* in June, but at the time no deterrent effect had been produced upon the breeding of the mosquitoes. *Culex abominator*, a locally abundant species in the lower Mississippi Valley, according to the observations of J. K. Thibault, Jr., and others, breeds by preference in permanent bodies of water thickly overgrown with duckweed. Recently it has been determined that this mosquito actually deposits its eggs upon the aquatic plants. *Anopheles* larvæ would obviously be much more easily deterred by *Lemna* than *Culex* larvæ, on account of their different habits of feeding. The *Lemna*, however, usually only acquires a luxuriant growth late in the summer, when the breeding of mosquitoes is largely over, and also it never occurs abundantly in temporary or semi-temporary pools which are the favorite breeding-places of most of our mosquitoes.

Recent observations by Charles A. Bentley, at Bombay, India, show that duckweeds may be successfully employed under certain conditions, at least in the tropics, but that their value has been very much overestimated. We quote his remarks:

"The presence of water-weed in a tank, well or cistern is often a source of danger, forming as it does an excellent shelter for mosquito larvæ. Some water plants, notably duck-weed or *Lemna* and *Azolla* have been suggested as being useful in preventing the breeding of mosquitoes. These suggestions do not appear to have been based upon careful observation and experiment. In my experience these plants are of little or no value in preventing the presence of mosquito larvæ. But there is a weed which I have met with in Bombay and elsewhere which under certain circumstances appears to be a useful preventive of mosquito larvæ. This plant is the rootless duck-weed or *Wolffia arhiza*. It takes the form of small bright green round grains without stem, roots or leaves. These grains float on the surface of the water just like a scum of bright green seeds. When it is growing in large amount so as to form a continuous layer on the top of the water no mosquito larvæ can live and pools and tanks covered in this way will be found quite free from larvæ. Anopheles larvæ placed in a bowl of water covered with a layer of *Wolffia arhiza* immediately assume an almost vertical position, hanging head downwards in a manner quite unnatural to them. After a short interval they sink to the bottom dead. The larger the larvæ the more quickly they die, as young larvæ can pass their tails between the plant grains and so get access to the air. Culex larvæ and Stegomyia larvæ are also destroyed, but the latter live for several hours in the weed-covered water. Where the continuity of the layer of *Wolffia arhiza* is broken by the presence of grass or reeds or large leaved weeds, mosquito larvæ are enabled to exist without difficulty, and it would appear therefore that before this plant could be used with success as a protection for tanks, the latter would have to be cleared of other growths. The round tank at the Mint which is usually covered with a good growth of *Wolffia arhiza* is free of mosquito larvæ, and so is the Nakhoda tank and several pools near Parel."

Recently the idea of cultivating such aquatic plants with practical ends in view in regard to anti-mosquito work has been taken up in German colonies in Africa. It is stated in the "Monthly Consular and Trade Reports," of the Bureau of Manufactures, U. S. Department of Commerce and Labor, for March, 1909, in a dispatch from Consul-General Richard Guenther, of Frankfort, that the director of fisheries at Biebrich, Dr. Bartmann, had found a duckweed-like plant of the genus *Azolla* to be especially well adapted to this use; and at the instance of Dr. Bartmann experiments were made at the malaria station at Wilhelmshaven. It was found that in a short time the growth of the plant covered the experimental waters with a layer of about 6 centimeters; this suffocated all the mosquito larvæ below and prevented the parent insects from depositing eggs in the water. Consul-General Guenther states that several years ago Director Bartmann communicated this method to the Mosquito-Destroying Commission at Eltville on the Rhine, which has used it repeatedly with good success.

One of the officials who took part in the question of mosquito extermination in the German African colonies was far from enthusiastic regarding the practical use of this plant, although it had been advertised on all sides in Europe and in this country. In his opinion, it may possibly be of some use in special places, but, so far as experiments have gone, it appears that the plants will not grow in dense or even moderate shade and therefore they are of no use in the tropical forests where there are large and small pools of water, the very places where it is most needed. Moreover, the *Azolla* plants do not stand any great cold nor do they stand short seasons, for which reasons their use is excluded from highland and northern regions. Further, they will not grow in brackish water and can not be utilized along sea-coasts, and, still further, in case of drouth they all perish and thus necessitate the restocking of pools and swamps that have been dry.

So positive were the statements published in the United States, as to the value of the *Azolla* plant to prevent mosquito-breeding, that one species was imported from Europe into the United States. Dr. John B. Smith, of New Jersey, investigated the plant in its natural habitat in Holland and also experimented with the introduced plants in New Jersey. His investigations, which need not be quoted here, demonstrated that for a number of reasons, which have been already indicated in the foregoing discussion, *Azolla* has no practical value.

ORGANIZATION FOR COMMUNITY WORK.

While in a large measure it is true that every individual householder practically breeds upon his own premises the majority of the mosquitoes that bother him, still in a closely built city those bred by one's neighbors must be taken into consideration. In isolated country houses the character of the region about must be considered by the individual who concerns himself with this work, so that here also some sort of an organization is desirable, and even frequently necessary, as in cases where swamp lands are to be drained or where occasional invasions of migratory species, such as *Aëdes sollicitans*, are to be feared. The control of all sources of mosquito supply in case of fresh water or brackish swamp land is usually too great a task for the individual, although on the large estates of great proprietors such work has been done at individual expense. In any sort of community, however, organization is desirable, not only to carry out the actual work but to produce and to emphasize a universal sentiment in favor of the mosquito crusade—a sentiment so strong and so general that every individual will cheerfully take part in the work. The pioneers in this country who, in 1901 and 1902, attempted to arouse such a public sentiment, had much difficulty in educating the people and in securing funds, but lately it has been an easier matter. Many communities, large and small, have taken up anti-mosquito measures, and such large cities as New York, Baltimore, New Orleans, Nashville, have given the question serious consideration in their city councils and in their boards of health, and have entered upon measures of greater or less efficacy. Many smaller towns have begun the crusade also, and those which have been especially active have been communities of summer resort. One of the early attempts was the formation of the North Shore Improvement Association of Long Island, which undertook a mosquito campaign involving over twenty-five square miles of territory along the north shore of Long Island, the territory including several villages and many country homes of wealthy people. Following the first year's work of this Association a national anti-mosquito society was formed to encourage just this kind of work, and this society has published instructions and pamphlets of information which are at the disposal of all communities desiring to enter upon the task of freeing themselves from mosquitoes.

Theoretically community work should be done under official auspices, and should be inaugurated by boards of health, but official action is slow, even in the United States where there is, as a rule, less red tape than in older countries. Moreover, official action in sanitary measures is often conservative as well as slow. As already pointed out, the health question is not the only one involved. Abundance of mosquitoes means enormous economic loss to a community, entirely aside from the important question of health, and individual property owners realize this more than do official bodies. It is only necessary to cite the increased value of real estate at summer resorts where the mosquito scourge has been wiped out, and the great value of reclaimed marsh land for manufacturing sites in the immediate vicinity of great cities, or for agricultural purposes at a greater distance from the great centers of population.

In community work, therefore, as well as in most other measures of reform, the organization of private citizens has usually been the initial step. Many communities have their own village or town improvement associations, and many cities have their citizens' associations constantly alert to discover needed reforms and improvements and to bring them emphatically to the notice of their elected representatives on the City Council and to the Mayor's appointees on the Board of Health. It is through the mosquito committees of such associations that very much of the work in this direction has been agitated and inaugurated, and doubtless this method will continue most effectively for some time to come.

The first step in undertaking such work is to interest several responsible persons whose names carry weight in the community, and then to raise a small fund, either by appropriations from funds at the disposal of the improvement society, or whatever it may be, or by private subscription. Then these persons, forming a committee, should issue a circular to every householder, signed by the whole committee, reciting very briefly the well-known facts concerning the breeding-places of mosquitoes and the measures which should at once be taken by householders. A good plan also would be to have a public lecture given by some expert, well illustrated, to which all householders should be invited. An excellent circular of the character just described was issued in the early summer of 1901 as follows:

The Village Improvement Society of South Orange.

South Orange, N. J.

The breeding place of the mosquitoes, that may infest your house, may be looked for within your own house or grounds, or in your immediate neighborhood.

The mosquito lays its eggs *only upon standing water* and passes the first ten days of its existence in the water.

Without standing water there can be no mosquitoes.

Dr. Howard says, "I feel sure that the cesspools in South Orange must be responsible for a great deal of your mosquito supply." Therefore:

Look to your cesspools,
cisterns,
watertanks,
and any barrels or other receptacles in which water may stand for a few days, either inside or outside the house.

It is suggested that you at once do away with every unnecessary water receptacle.

Put kerosene oil in your cesspools and on surface of necessary standing water, once in three weeks.

Oil placed on surface should not affect the taste of water drawn from beneath the surface, but when that is not considered advisable, water receptacles should be screened with a fine mesh screen.

The mosquito being not only a serious annoyance, but a constant menace to health, its extermination becomes a matter of public concern.

The cooperation of every household is requested.

Please report to............the location of any pools of stagnant water in your neighborhood.

After the issuing of the circular or the holding of the public lecture, or both, if the members of the committee are too busy, as they are likely to be, to engage to any extent in the actual superintending work, an intelligent superintendent must be chosen, who will familiarize himself with the biology of mosquitoes and especially with the character of mosquito breeding-places in general. He should at once be put to work upon a survey of the mosquito topography of the neighborhood. It will be well for him to make a map upon which every breeding-place, aside from the chance receptacles about houses, should be noted with the greatest accuracy and care. Every house having an uncovered water tank or having rain-water barrels should also be noted, and for each locality the most effective as well as the most economical remedy should he recorded. If these remedies demand any large-scale work estimates of the necessary expenditures should be indicated.

Such a careful report and map having been prepared and placed in the hands of the committee, the amount of funds necessary can readily be estimated, and the expenditure of such sums as it is found possible to raise can be considered and agreed upon. The work can then be easily carried on through the summer under the direction of this superintendent, and of course the amount of the expenditure and the number of employees will depend entirely upon the local mosquito-breeding possibilities.

Some small communities will find that a full understanding of the problem on the part of individual householders will bring about great relief as the result of individual work, and that the only organization necessary will be perhaps the signing of a pledge by individuals to take care of their own premises. In other communities the matter will be a little more serious, but there will be some where the employment of a single man for two or three days a week throughout the summer will result in freedom from mosquitoes. Again, however, in larger communities the enforcement of municipal regulations will be found to be necessary before a desirable result can be obtained, and where the village is built upon swampy land or is surrounded by swamps the expenditure of considerable sums of money will be found to be imperative.

In every community, however, there will pretty surely be ultra-conservative, recalcitrant and ignorant citizens—people who will not take the trouble to prevent the breeding of mosquitoes on their own premises—people in fact who will violently object to the entrance on their premises of an individual who will do the work for them. Such cases are not numerous, but they are always difficult to handle, and, in the absence of municipal action, moral suasion must be tried in the most ingenious ways which the committee can devise. Sir Ronald Ross, in his excellent work "Mosquito Brigades," in writing of such persons, puts it very happily in the following words:

"The qualities chiefly necessary [in a superintendent] are energy, persistence, and an entire indifference to public or private opinion. The need of the first two is obvious; that of the last requires some explanation. The self-appointed superintendent will be at once astonished, and perhaps alarmed, at finding that his philanthropic and wholly harmless efforts are met at the outset by a storm of letters to the local press, demonstrating the absurdity and even immorality of his intentions; proving that mosquitoes cannot be destroyed, that they spring from grass and trees; that they can be destroyed, but that it is wicked to make the attempt because they were created to punish man; that they do not carry malaria, because malaria is a gas which rushes out of holes in the ground, and rises as a blue mist over the country; that they do not carry yellow fever, which is due to the effect of the tropical sun on rotting vegetation; that they do carry malaria and yellow fever, but in such small quantities that they act beneficially as unpaid vaccinators of these diseases; and so on.* It is possible to ignore all such epistles, because, where they do not contradict each other, someone else is sure to contradict them; but an occasional letter in reply does good, and, to speak practically but rather cynically, serves to stimulate the necessary public interest in the work by keeping the letter-writers at such a pitch of exasperation that they give the campaign a constant stream of gratuitous advertisement in the newspapers. We are permitted to be cynical in a good cause.

"Fortunately, operations against mosquitoes can be conducted on a large scale without much reference to private opinions—fortunately, because the inertia of the masses regarding new pathological discoveries is so great that were we to depend upon converting them, nothing would be done for half a century. For some inscrutable reason, the man in the street, though he would scarcely think of contradicting a lawyer or an engineer on matters of law or engineering, finds himself quite equal to exposing the absurdities of the whole Medical Faculty on a medical matter.

"These operations require no sacrifices or co-operation on the part of the general public. Most householders are glad enough to have their mosquito larvæ destroyed, and their backyards cleaned up for nothing. The reader, therefore, if he sees fit to start the work we are considering, may quietly proceed in it undisturbed by criticism, and may calculate upon receiving not only as much public support as his work will require during its progress, but the thanks of his fellows at its termination. Indeed, the majority of the public will not be slow to recognise the value of his efforts, even if they do not understand the scientific reasons which have induced him to make them."

In community work, after making an effort to insure the absence of household breeding, the attention of the superintendent should be devoted to chance pools along the public roadway and to breeding-places in unused land. Drainage or filling in are the best measures to adopt. The superintendent will find it advisable to attempt first to extirpate those breeding-places from which the greatest numbers of mosquitoes are issuing. In this way, he will the sooner bring about an appreciable diminution of the number of the insects, and of course the sooner this diminution is noticed by the citizens the sooner will popular sentiment unanimously support the work. The less populous breeding-places may await treatment until a later date.

Large-scale operations requiring a considerable expenditure of money must be organized very perfectly as to detail. The first example of this large-scale work

* *Note.*—Dr. Ross states that he has "seen every one of these statements, and many others equally absurd, made at least half a dozen times in the British press."

done in the United States was carried on in the most intelligent way by the North Shore Improvement Association of Long Island, mentioned above. Here as an initial step work was done by the superintendent and engineer, Mr. H. C. Weeks, during the summer of 1901. Mr. Weeks completed the survey of the large territory and estimated the cost of all operations. Another survey was made by two biologists, Prof. C. B. Davenport and Mr. F. E. Lutz, of the Cold Spring Harbor Laboratory, then of the Brooklyn Institute of Arts and Sciences, and now of the Carnegie Institution. These gentlemen positively identified all breeding-places. Still another survey was made by the late Prof. N. S. Shaler, of Harvard University, who advised concerning the best methods of reclaiming the salt marshes included in the territory, where certain species of mosquitoes breed. Upon the basis of these surveys and reports the Association began in 1902 its active work of extermination.

The following is a summary, by Sir Ronald Ross, of the aims of anti-mosquito work, and it is so admirable that it is quoted in full:

"Summary of objects:—

"(1). We do not propose to exterminate mosquitoes in any entire continent. *We propose only to deal with them in the town in which we live, and in its suburbs.*

"(2). We do not propose to get rid of *every* mosquito even in this town. *We aim only at reducing the number of the insects as much as possible.*

"(3). We do not think it possible to drain or otherwise treat every breeding place in the town. *We aim at dealing with as many as possible.*

"(4). We cannot exclude mosquitoes which may just possibly be blown into the town from miles away. *We content ourselves with preventing the insects breeding in the town itself.*

"Summary of methods:—

"(1). We start work at once with whatever means we can scrape together.

"(2). We operate from a centre outwards.

"(3). We clear houses, backyards, and gardens of all rubbish; empty tubs and cisterns containing larvæ, or destroy the larvæ in them by means of oil.

"(4). We show people how to do these things for themselves, and how to protect tubs and cisterns by means of wire gauze.

"(5). When we have cleared as many houses as we determine to deal with, we clear them over again and again.

"(6). We fill up or drain away all the pools, ditches, old wells, and puddles we can—especially those which contain most larvæ.

"(7). Such pools as cannot be filled up or drained are deepened and cleared of weeds, if they contain larvæ.

"(8). Streams and water courses which possess larvæ are 'trained.'

"(9). Where we can do nothing else we destroy the larvæ periodically with oil, or by brushing them out with brooms, or by other means.

"(10). We endeavour to interest our neighbours in the work, and to educate the town into maintaining a special gang of men for the purpose of keeping the streets and gardens absolutely free of stagnant, mosquito-bearing water.

"Motto.—Our motto should be one which I think will shortly become the *first law* of tropical sanitation, namely—**No Stagnant Water.**"

After concluding an account of his own personal work at Lloyds Neck, Long Island, and of the work done by the North Shore Improvement Association, Mr.

W. J. Matheson, speaking before the First Anti-Mosquito Convention in New York, December 16, 1903, concluded that the work carried on had demonstrated that, with the exception of the salt-marsh mosquitoes, the mosquito nuisance can be controlled and abated in almost any locality where intelligent cooperation can be secured and a systematic inspection made of the premises for the purpose of destroying the breeding-places. Extermination, in his opinion, will exterminate just as far as the intelligent land owner is willing to carry it, but that it can not be done once and for all any more than weeding a garden or the cropping of a lawn can be done once and for all. He concludes his paper with the following words:

"So far as my experience goes, it has been demonstrated that mosquitoes can be as completely exterminated in any locality as dirt can be swept from a building, or as weeds from a walk, with the possible exception of the Culex Sollicitans, and with the exercise of no more intelligence and much less labor than is required in the performance of many domestic duties. My experience would lead me to conclude that if mosquitoes continue to exist in any locality, it is because the people are too indifferent to the annoyance to take the trouble to be rid of it."

THE IMPORTANCE OF INTERESTING CHILDREN.

Under the general head of "Remedies" we have mentioned the efforts made by Professor Hodge, in Worcester, Massachusetts, to interest the school children of the city in the search for mosquito breeding-places. This must have been in 1901–2. But, the most serious and productive effort seems to have been made at San Antonio, Texas, a year or so later, at the initiative of Dr. J. S. Lankford, of that city.

In November, 1903, there were a few cases of yellow fever in San Antonio which caused several deaths, and a consequent interruption of commerce that cost hundreds of thousands of dollars. In the effort to allay the panic, the existence of yellow fever was denied, not only by persons having business interests in the city, but by many medical men as well. Very many adults not only denied the existence of the fever in the city, but denied the relation between the mosquitoes and the fever. Perhaps the majority of the adults seemed too old to learn; and to the enlightened physicians it appeared impossible to begin education at the wrong end of life.

The Chairman of the Sanitary Committee of the School Board (Doctor Lankford) grasped the happy idea that if the children were properly educated, sanitary matters in the future would be much better attended to. He suggested to the Board that it would be valuable to educate all of the school children of the city in prophylaxis and make sanitarians out of them all. The School Board heartily approved of the proposition, and the campaign was at once begun to educate the children on the subject of insects as disease carriers. The best recent literature on the subject was procured and furnished to the teachers, and a circular letter was sent to them outlining a proposed course and offering a cash prize for the best model lesson on the subject. Teachers became deeply interested. A crude aquarium, with mosquito eggs and larvæ was kept in every school room, where the pupils could watch them develop; and large magnifying glasses were furnished in order that they might study to better advantage. The children were encouraged to make drawings on the blackboard of mosquitoes in all stages of development; lessons were given and compositions were written on the subject. Competitive examinations were held, and groups of boys and girls were sent out with the teachers on searching expeditions to find the breeding-places. Rivalry sprung up between the ten thousand public school children of the city in the matter of finding and reporting to the health office the greatest number of breeding-places found and breeding-places destroyed. Record was kept on the blackboards in the schools for information as to the progress of the competition, and great enthusiasm was stirred up. In addition to these measures, a course of stereopticon lectures was arranged, grouping the pupils in audiences of about one thousand, from the high school down, and, in Doctor Lankford's words,

"It was an inspiring sight to watch these audiences of a thousand children, thoughtful, still as death, and staring with wide-open eyes at the wonders revealed by a microscope. It seemed to me that in bringing this great question of preventive medicine before public school children we had hit upon a power for good that could scarcely be over estimated."

The result of this work, it is pleasing to say, was a decided diminution of mosquitoes in San Antonio. There was some opposition among the people, but on the whole the movement was very popular. One result of this work was that, while previously there had been from fifty to sixty deaths a year from malaria, this mortality was reduced seventy-five per cent the first year after this work was begun, and in the second year it was entirely eliminated from the mortality records of San Antonio.

In organizing community work against mosquitoes, the school children hereafter must be counted upon as a most important factor. Almost every child is a born naturalist, and interest in such things comes to them more readily than anything else outside of the necessities of life. They are quick witted, wonderfully quick sighted, and as finders-out of breeding-places they usually can not be approached except by adults of special training. One of the first steps that a community should take, is, therefore, to arouse the interest of the children in the public schools.

SOME RECENT WORK IN GERMANY.

The city of Leipzig quite recently has begun a crusade against malaria under the direction of the City Council. The following account of this work was sent in by U. S. Consul S. P. Warner, and is published in the "Monthly Consular and Trade Reports," for June, 1909:

"So many cases of malaria have recently occurred in those sections of Leipzig which are adjacent to any one of the four rivulets which flow through the city that the city council has decided to adopt stringent measures to exterminate the mosquitoes (*Anopheles*) that spread the disease.

"In order that the work of extermination may be thoroughly and systematically carried out the city council has notified all housekeepers in the infected sections of the city to carefully examine their houses or apartments for mosquitoes and to destroy any that may be found. Every household in the districts concerned has been furnished by the city council with a large circular, which, in addition to information as to the cause and spreading of malaria, contains advice as to the best means of destroying the malaria mosquitoes.

"Certain dates have been specified between which the houses are to be searched and the mosquitoes destroyed. At the expiration of the time specified inspectors appointed by the city council will visit each house and apartment and make careful examinations to see that the work of exterminating the mosquitoes has been properly carried out. Those who fail to comply with the regulations promptly and thoroughly will be subject to a fine of about $7.50."

WORK ALONG RIVER FRONTS.

Communities living along navigable rivers may have good anti-mosquito work hampered by the constant reintroduction of mosquitoes from boats landing at their river fronts. This point has been especially noted in the course of the excellent work done under the direction of Dr. Andrew Balfour at Khartoum on the Blue Nile. The following passage is taken from the First Report of the Wellcome Research Laboratories, pages 21–22:

"At an early period the steamers were found to be largely infected, especially with the larvæ of *Stegomyia fasciata*, and to a less extent by those of *Culex fatigans*. Anophelines, either as larvæ or imagines, have never been met with; but up-country, as will be noted later, the adults are frequently to be seen on board, and may remain as passengers for a considerable period. At first it was decided to use lime for the steamer bilges, but this was said, erroneously I believe, to act upon iron and to be unsuitable. Consequently crude petroleum was recommended, though not so good nor so easily applied. Along with this the periodical emptying of the bilge and fumigation with the sulphur squibs described by Colonel Giles were advised, the latter to get rid of the adult insects. Unfortunately in the case of the steamers familiarity had evidently bred contempt, for, at first, despite the co-operation of the Director of the Steamers and Boats Department, little energy was displayed by the engineers in charge, and the preventive measures were largely ignored, and in some instances even ridiculed. This was the more to be regretted as there is no doubt that mosquitoes can be banished from all the steamers if a little care and trouble were taken. Mr. Beadnell, of the Geological Survey, carried out these simple methods on the S. S. 'Nubia,' and practically cleared her of mosquitoes, so that for the first time he was able to sleep below in comfort. A great improvement also resulted in the case of the gunboat 'Zafir,' in which I went to Dueim and found to be simply swarming with adult Culices and their larvæ, while these measures absolutely prevented any mosquitoes breeding out on board the S. S. 'Amka' during a period of nearly two months, the greater part of which was passed in regions swarming with these winged pests. Latterly, I am glad to say, the engineers have been impressed with the necessity of doing all in their power to aid the brigade. This is the more necessary as it is easy for the steamers to infect the town and thus spoil much of the work done and render it futile."

EXAMPLES OF MOSQUITO CONTROL.

It is proposed in this section to describe briefly some of the most striking examples of successful warfare against mosquitoes that have been carried out since 1900 and bring them together into one consecutive account. Of many of them the details are not well known, on account of the inaccessibility of the documents of record.

WORK IN HAVANA DURING THE AMERICAN OCCUPATION, 1901-2.

One of the most striking examples of clean, efficient anti-mosquito work is that done by the American troops in Havana at the close of the Spanish War, under the direction of the Army Medical Corps, and under the especial direction of Col. W. C. Gorgas, U. S. A. In the statements which follow, Colonel Gorgas's published writings have been freely used.

Yellow fever had been endemic in Havana for more than 150 years, and Havana was the usual source of infection for the southern United States. By ordinary sanitary measures, improved drainage and similar means, the death rate of the city was reduced from 100 per thousand in 1898 to 22 per thousand in 1902. But these measures had no effect upon yellow fever, this disease increasing as the non-immune population increased, and in fact in 1900 there was a severe epidemic.

Aëdes calopus was proved to be the carrier of yellow fever early in 1901, and then anti-mosquito measures were immediately begun. Against adult mosquitoes no general measures were attempted, although screening and fumigation were carried out in quarters that were or had been occupied by yellow-fever patients. It was found that *calopus* bred principally in the rain-water collections in the city itself; that *Culex quinquefasciatus* bred everywhere, and that *Anopheles albimanus* bred principally in the suburbs in pools and puddles well protected by grass. Two mosquito brigades were started: one to take care of *calopus,* and the other of *Anopheles.*

The work of the so-called "stegomyia brigade" was confined to the built-up portions of the city. The city was divided into about thirty districts, and to each district an inspector and two laborers were assigned, each district containing about a thousand houses. The mayor of Havana issued an order requiring all collections of water to be so covered that mosquitoes could not have access, a fine being imposed in case the order was not obeyed. The water supply of Havana was very hard, and it was customary for every family to collect rain-water in barrels. As the majority of the people in the large tenement houses were poor, and as each family had a rain-barrel, the Health Department covered these barrels at public expense, leaving a small screen opening through which the water could enter and placing a spigot at the bottom through which it could be drawn. Every house in Havana, on the average, has a cesspool, the liquid contents generally seeping into the soil. The inspector on each visit had from four to six ounces of petroleum poured into the cesspool, and where this was not accessible it was poured into all closets connected with the cesspool. All receptacles containing fresh water that did not conform to the law were emptied, and, on a second offence, destroyed. If the owner was an old offender, he was prosecuted under the law and fined.

The result of this work of the so-called "stegomyia brigade" was that, while in January, 1901, there were 26,000 fresh-water receptacles containing mosquito larvæ, in January, 1902, there were less than 400 such receptacles containing larvæ; mosquitoes had rapidly decreased, and were entirely absent in many parts of the city. The result of this work, thoroughly done, was to wipe out yellow fever in Havana.

The "anopheles brigade" was organized for work along the small streams, irrigated gardens and similar places in the suburbs, and numbered from fifty to three hundred men. No extensive drainage, such as would require engineering skill, was attempted, and the natural streams and gutters were simply cleared of obstructions and grass, while superficial ditches were made through the irrigated meadows. Among the suburban truck gardens *Anopheles* bred everywhere in the little puddles of water, foot-prints of cattle and horses, and similar depressions in grassy ground. Little or no oil was used by the "anopheles brigade," since it was found in practice a simple matter to drain these places. At the end of the year it was very difficult to find water containing mosquito larvæ anywhere in the suburbs, and the effect upon the malarial statistics was striking. In 1900, the year before the beginning of the mosquito work, there were 325 deaths from malaria; in 1901, the first year of mosquito work, 151 deaths; in 1902, the second year of mosquito work, 77 deaths. Since 1902 there has been a gradual, though slower decrease, as follows: 1903, 51; 1904, 44; 1905, 32; 1906, 26; 1907, 23.

WORK AT THE ISTHMUS OF PANAMA.

The United States government has very properly used the services of Colonel Gorgas, who was in charge of the eminently successful work at Havana, by appointing him Chief Sanitary Officer of the Canal Zone during the digging of the Canal. In 1904 active work was begun, and Colonel Gorgas was fortunate in having the services of Mr. J. Le Prince, who has been chief of his mosquito brigades in Havana, and therefore was perfectly familiar with anti-mosquito methods. In Panama, as in Havana, the population had depended principally upon rain-water for domestic purposes, so that every house had cisterns, water-barrels and such receptacles for catching and storing rain-water. The cities of Colon and Panama were divided up into small districts with an inspector in charge of each district. This inspector was required to cover his territory at least twice a week and report upon each building with regard to the breeding-places of mosquitoes. All the cisterns, water-barrels and other water receptacles in Panama were covered, and in the water-barrels spigots were inserted so that the covers would not have to be taken off in drawing water. Upon first inspection, in March, four thousand breeding-places were reported in Panama alone. At the end of October less than four hundred receptacles containing larvæ were recorded; this gives one a fair idea of the reduction in the number of mosquitoes in the city. These operations were directed primarily against the yellow-fever mosquito, and involved the other species that inhabit rain-water barrels. Against the *Anopheles* in the suburbs the same kind of work was done which was done in Havana, with excellent results.

The same operations were carried on in the villages between Panama and Colon. There are some twenty of these villages of from five hundred to three thousand inhabitants each. The result of the whole work has been the elimination of yellow fever, and the very great reduction of malaria. The remarkable character of these results can only be judged accurately by comparative methods. It is well known that during the French occupation there was an enormous mortality among the European employees and that this was a vital factor in the failure of the work. Exact losses can not be estimated, since the work was done under seventeen different contractors. These contractors were charged one dollar a day for every sick man taken care of in the hospital of the Canal Company. Therefore it often happened that when a man became sick his employer discharged him to avoid the expense of hospital charges. There was no police patrol of the territory and many of these men died along the line. Colonel Gorgas has stated that the English consul who was at the Isthmus during the period of the French construction was inclined to think that more deaths of employees occurred outside of the hospital than in it. A great many were found to have died along the roadside while endeavoring to reach the city of Panama. The old superintendent of the French hospital stated that in one day three of the medical staff died from yellow fever, and in the same month nine of the medical staff. Thirty-six Catholic sisters were brought over as female nurses, and twenty-four died of yellow fever. On one vessel eighteen young French engineers came over, and in a month after their arrival all but one had died.

With the mosquito relation well understood, not a single case of yellow fever was contracted during the first two years under Doctor Gorgas, although there were constantly one or more yellow-fever cases in the hospital, and although the nurses and doctors were all non-immunes. The nurses never seemed to consider that they were running any risk in attending yellow-fever cases night and day in screened wards, and the wives and families of officers connected with the hospital lived about the grounds knowing that yellow fever was constantly being brought into the grounds and treated in nearby buildings. Americans, sick from any cause, had no fear of being treated in the bed immediately adjoining that of a yellow-fever patient. Colonel Gorgas and Doctor Carter lived in the old ward used by the French for their officers, and Colonel Gorgas thinks it safe to say that more men had died from yellow fever in that building than in any other building of the same capacity at present standing. He and Doctor Carter had their wives and children with them, which would formerly have been considered the height of recklessness, but they looked upon themselves, under the now recognized precautions, as safe almost as they would have been in Philadelphia.

The existence of endemic foci of yellow fever at points in constant communication with the Canal Zone, and the consequent danger of reintroduction of the disease, has made it necessary to maintain vigorous mosquito control. Aside from the comparatively simple control work against house-mosquitoes, a far more difficult and extensive campaign has been prosecuted against *Anopheles*. This has proved highly profitable through the resultant reduction in malaria and the consequent increased efficiency in the canal workers and saving of hospital expenses. The great difficulties imposed by the climate and topography of the region in this work against *Anopheles* were further increased by the operations in the construction of the canal which unavoidably created, at least temporarily, numerous breeding-places for mosquitoes.

No figures of actual cost of the anti-mosquito work either in Havana or in the Panama Canal Zone are accessible to us, but it is safe to say that it was not exorbitant and that it was not beyond the means of any well-to-do community in tropical regions.

WORK IN RIO DE JANEIRO.

One of the most difficult problems of its character was that of freeing Rio de Janeiro from its reputation as a great yellow-fever center. The difficulties were very great, and the amount of money required for efficient work was enormous. Rio de Janeiro has a population of more than 800,000 people; it extends over an area of 430 square miles; it is very irregular in its topography, varying in altitude from 1 to 460 meters above the sea level; it had at the time 82,396 houses, and, as in all great centers of population, the inhabitants of many of the houses, if not resisting the efforts of the sanitary authorities, surely did not facilitate them.

Work was begun in April, 1903, under the direction of the Public Health Service, but the organization effected was of a temporary character and needed the passage of new laws by Congress, which were enacted in January, 1904, and resulted in the reorganization of the hygienic service of Brazil. A service for the stamping out of yellow fever was created. One million six hundred and fifty thousand dollars was appropriated annually for this work. The service established included one medical inspector, ten sanitary inspectors (physicians), one administrator, one customs inspector, one accountant, seventy medical students, nine subchiefs, two hundred overseers, eighteen guards of the first class, eighteen guards of the second class, and one thousand workmen; and in addition to this personnel, the assistance of the Public Health Service corps of inspectors was called upon.

The city was divided into zones, according to the density of the population, and in these zones the work was divided into two sections: (1) Isolation and sanitation; (2) the policing of the infected districts. Under the first section, yellow-fever patients were removed to the pest house, residents were isolated, and houses were disinfected. The second, the sanitary police force, visited every building in the city, destroyed the early stages of mosquitoes, and abolished or screened standing water where possible. One force worked in buildings, and another in vacant lots, streams, marsh lands, etc. The following paragraphs relative to this work are quoted from an address made by Doctor Oswaldo Cruz before the Latin-American Medical and Sanitary Congress held in Rio de Janeiro, August 1 to 10, 1909.

"Yellow-fever cases were made known to the sanitary inspectors by the reports of medical assistants, of the head of the family in which a case occurred, or by any one to whom the facts of the case were known, in accordance with the requirements of the law. The sanitary service being advised, a competent group of inspectors and authorities were at once dispatched to the locality, having with them a physician. The latter ascertained if the case was one for isolation treatment (whether under or over four days after the onset of the disease), and if the case required isolation the same was carried out either in the dwelling house or in the hospital, hospital treatment being resorted to only when the dwelling was unsuited to isolation treatment or when the patient wished it. In such cases the patient was taken to hospital in a vehicle closed against the entrance of mosquitoes and the house was disinfected in accordance with the system below outlined. In the case of isolation in the home the physician chose a roomy quarter of the house with door opening into another secluded part of the house and with windows. If there were more than one door, the others were temporarily closed. The patient was kept under a netting enveloping the bed upon which he lay during the time permanent quarters were being arranged. The doors and windows of the room to be isolated and of the rest of the house as well were sealed to prevent the exit of mosquitoes existing there, the windows of the isolated room being fitted with wire screens in such a way as not to interfere with ventilation, all other openings to the outside or to other parts of the house being sealed with cloth or paper. The only door to be used in the use of the room must be specially fitted with a double door drum, provided with an arrangement which does not permit of both doors being opened at the same time. This apparatus prevents the entrance and exit of mosquitoes, and after the room is thus prepared the door and windows are closed and camomile is burned in the room 3 to 4 hours in the proportion of 10 grams per cubic meter of space. The room is then well ventilated and is ready to receive the patient. The rest of the house is well calked and isolated from the room in which the patient is placed and disinfected with sulphur gas, as below indicated. During this operation a sanitary inspector remains in the room with the patient and stops the entrance of any gas which may possibly find its way through some overlooked crevice. During the preparation for disinfection the sanitary authorities make a thorough inspection and destroy any mosquito larva they find, pick up or destroy any vessels lying about which might serve as a receptacle for mosquito-breeding water and close water boxes against the same danger. The patient remains in isolation for seven days, after which isolation may terminate, if the family so wishes. The infected district is then treated as above indicated; that is, by disinfection, sanitary policing, and medical supervision. Disinfection is carred on in two ways, one force working from the center toward the outer limits of the district and the other from the boundaries of the district inward. The area of infection being determined over as large an area as possible, these two sections separate, one of which begins immediately with the house in which the case of yellow fever occurred, the other beginning at those houses which might possibly have been infected at the greatest possible distance from the case in isolation. The purpose of such a system was to destroy all mosquitoes which might have carried infection within the district.

"While the disinfecting force is thus at work the police division, under the direction of a physician and of students who direct the different sections, operates throughout the infected district, making every effort to destroy all mosquito larvæ and to prevent the possible breeding of mosquitoes outside as well as inside the houses. Where larvæ are likely to exist in stagnant water or refuse of any sort, petroleum mixed with creoline, lysol, or similar products is thrown over the water or refuse in sufficient quantity to kill the larvæ instantly. Where it is impossible to use petroleum, as in the case of tanks and boxes for household use, a small fish, the 'barrigudo' or 'Girardinus caudimaculatus' is placed in large numbers in the water. This fish destroys the larvæ of mosquitoes most voraciously. Larvæ in the drains are destroyed by the use of Clayton gas, which is pumped into the sewer, which has been previously divided into compartments. Simultaneously with the disinfection the sanitary inspectors make daily inspection of the suspected district, examining every inhabitant supposed not to be immune, that is, children under 5 and all foreigners of less than 5 years' residence in Rio. These are subjected to the closest vigilance, being placed in isolation at the least tendency to rising temperature. Reports are made in writing, those to whom this duty falls being required to fill out daily a bulletin sent out by the medical inspector to the chief of each district. In this report must be given the record of any who work outside the district or who for any reason absent themselves therefrom, a record of their condition being also kept by the physician in the district in which they work or are temporarily resident. When any inhabitant absents himself from the district the record must show his address, where he will be subjected to vigilance on the part of the authorities there. If the person under vigilance evades the attention of the physician and withdraws without giving notice, the owner of the house in which he lived is fined, he himself is apprehended by the sanitary police, fined, and subjected to renewed vigilance.

"The vigilance in each district extends over a period of one month after the appearance of the last case. To give an idea of this service we will note the figures covering the prophylactic campaign in the infected district about the cotton factory, 'Fabrica das Chitas,' in 1906. The inspection was carried out by 18 doctors, who examined daily all suspected persons, in all, 7966 persons, of whom 2989 were not immune. Sixty cases were reported, of which only 19 proved to be yellow fever, and the district was declared entirely freed of infection after six months. With the combination of the three systems there is no doubt about cleaning up effectively any district in which yellow fever may appear. In normal conditions the police service is carried out with equal painstaking, especially in the districts where infection last appeared. When, after some time, there seems no longer to be danger of new infection, the inspectors allow water to stand in several marked spots most favorable to mosquito breeding. These pools are then carefully watched, and examined at frequent intervals. This is a sure way to indicate the presence of the mosquito and is a trap for those about to spawn. They are thus most easily destroyed. In many zones of the city these traps revealed the presence of no mosquitoes whatever."

The actual results which followed this admirable work are shown by a table indicating the death rate from yellow fever in Rio from 1872 to date, and which indicates that perfect success has been reached.

MORTALITY FROM YELLOW FEVER IN RIO DE JANEIRO FROM 1872 TO AUGUST, 1909.

Year	Deaths	Year	Deaths	Year	Deaths
1872	102	1885	445	1898	1078
1873	3659	1886	1449	1899	781
1874	829	1887	137	1900	344
1875	1292	1888	747	1901	2299
1876	3476	1889	2156	1902	984
1877	282	1890	719	1903	584
1878	1176	1891	4456	1904	48
1879	974	1892	4312	1905	289
1880	1625	1893	825	1906	42
1881	257	1894	4852	1907	39
1882	89	1895	818	1908	4
1883	1608	1896	2929	1909	0
1884	863	1897	159		

WORK IN VERA CRUZ AND MEXICO GENERALLY.

The President of the Superior Board of Health of the Republic of Mexico, Dr. Eduardo Liceaga, was one of the first to grasp the importance of the mosquito discoveries of the American Army Board, and one of the first to make an effort to turn them to account. As elsewhere, he met with conservatism and a certain amount of disbelief, but it was not long before he succeeded in establishing an anti-mosquito service for practically all of the towns in which yellow fever appeared to be endemic, and devoted especial attention to the larger sea-ports most frequently entered by foreign vessels. In 1893 the disease appeared in epidemic form in several cities of the Gulf States of Mexico and spread to some interior cities as well, such as San Luis Potosi and some in the State of Nuevo Leon. By the aid of strong executive orders on the part of President Diaz, the Superior Board of Health was able to take action in all of the States except one, and was able to arrest the epidemic. The plan of campaign was based upon the mosquito doctrine, and the measures involved the isolation of patients, the thorough disinfection of dwellings by sulphur dioxide, the drainage of swamps, covering of drinking-water reservoirs, and the use of petroleum.

In the course of this work and that which followed, taking Vera Cruz to be the oldest and most permanent focus of yellow fever in the Mexican Republic, and assuming that all the epidemics had found their origin in that place, the principal attention of the Superior Board of Health was devoted to that city. The town was divided into four districts, each of which was placed under the charge of an experienced physician, and each of these had first-class sanitary agents. Subordinate to these latter, second-class agents were appointed, and a certain number of laborers were added. As a result of this effective ogarnization, Carroll, writing his chapter on yellow fever for Osler's Modern Medicine at the close of 1906, was able to make the following statement: "In Mexico yellow fever has been eradicated from its endemic focus at Vera Cruz through the able efforts of Eduardo Liceaga, the President of the Superior Board of Health, whose complete grasp of the problem and whose enlightened and energetic action has added support to the mosquito doctrine, and would have controlled the disease absolutely if the same means of enforcement were available in Mexico as in Cuba in 1901."

The later developments of the work in the Mexican Republic under Doctor Liceaga's leadership have been remarkable. In the American Journal of Public Hygiene, new series, volume vi, No. 1 (February, 1910), is published Doctor Liceaga's "Annual Report on Yellow Fever in the Mexican Republic, from August 16, 1908, to date," a paper read before the American Public Health Association at Richmond, Va., October, 1909. The following paragraphs concluding this report will give an idea of the excellent results which have followed the work of the sanitary officials in Mexico:

"The campaign against Yellow Fever, which commenced in the Mexican Republic in the year 1903, has continued uninterrupted up to this date, without even suspending it during the Winter months as is done in other countries; that the war on the mosquitoes is so efficacious that there are none left in Veracruz, and consequently, there are no stegomyas, as demonstrated by the reports rendered by the physician of the Public Health and Marine Hospital Service of the United States, who is resident in that Port.

"The cases which have been observed in Merida and surrounding villages, arise from the existence in that city of over thirty thousand water tanks which could not be so easily and securely watched as those of Veracruz.

"In the entire section which was formerly devastated by Yellow Fever we continue to canalize the deposits of standing water and to fill up the hollows, as well as to spread oil on all those ponds which cannot be otherwise filled in or covered.

"We continue to fumigate the dwelling houses, workshops, schools, etc., in which we have encountered either cases of Yellow Fever or any suspected cases.

"We continue the surveillance over the passengers who travel by rail in any part of the region which formerly suffered from Yellow Fever, and this service is especially active along the line of the Tehuantepec Railroad.

"In the ports of Coatzacoalcos, on the Gulf Coast and Salina Cruz on the Pacific, it is nearly four years since a single case of Yellow Fever was observed."

WORK IN JAPAN.

Work in Japan, under Surgeon Major Tsuzuki, as early as 1901, confirmed experimentally the malarial relations of *Anopheles,* and later a large-scale experiment was carried on among the Japanese troops occupying Formosa, which, on account of its large scale, served to set at rest any doubts which had previously existed as to the value of mosquito protection. Portions of Formosa are malarious, and the following table indicates the conditions existing among the troops from 1897 to 1900, before there had been any control work in the modern sense:

	The number of patients	The number of deaths	Ratio of patients	Ratio of death
			Per cent	*Per cent*
1897	41,825	267	272.435	1.739
1898	34,752	270	249.394	1.938
1899	29,371	284	221.263	2.139
1900	30,224	272	222.414	2.002

From the 21st of September, 1901, to the 28th of February, 1902, work based on the mosquito theory was carried on by order of the Governor of Formosa, on the advice of Doctor Koike, Surgeon-General, as shown in following quotation. This account of the experiment is taken from an address by Dr. K. Tamura, Delegate from Japan to the Eleventh Annual Meeting of the Military Surgeons of the United States Army, June 7, 1902:

"Half the second company, first battalion of infantry at Kirun, Formosa, 115 in number, was employed from the day of their landing at Kirun, and we gave it the name of 'Protected troops.' This troop was thoroughly provided with means of protection from mosquito bites. They were confined in the casern from half an hour before sunset, to half an hour after sunrise, the casern having been specially made to prevent mosquitoes entering, and they wore gloves and coverings of the head, specially made for that purpose, when on service at night.

"The results of these new methods for the prevention of malaria were absolutely good. Another half of the second company (called by us comparison troop) and all the other companies of the battalion (called by us unprotected troop) had a great many malaria patients, but the protected troop had none.

"The table of the numbers of patients is as follows:

	Average number of men	Number of patients	Ratio of patients
			Per cent
Protected troop......	114.49	0	0
Comparison troop....	104.34	34	32.59
Unprotected troop....	646.36	285	44.09

"The experiment of Grassi in Italy shows that 5 cases of malaria were observed among 112 persons, and Celli observed 11 cases in 203 persons, but our case shows none in 114 persons.

"The news spread rapidly in the whole island and all the troops despatched there became very cautious regarding the bites of mosquitoes. This caution itself gave good results, and the number of patients and deaths decreased distinctly last year, compared with the preceding years.

	Number of patients	Number of deaths	Ratio of patients	Ratio of death
			Per cent	*Per cent*
From 1897 to 1900, average.	34,043	27,325	242.514	1.947
1901......................	22,438	14,500	173.211	1.149

"Now it is very clear that the prevention of Malaria is secured by guarding against mosquitoes, and we believe that Formosa will become a healthy island within a few years."

In the recent war between Russia and Japan, the Japanese gave the world an example of field sanitation hitherto unequaled in history, a vivid account of which will be found in an article "The Real Triumph of Japan," by Dr. Louis Livingston Seaman, formerly Surgeon-Major, U. S. Volunteers (New York, 1906), from which the following facts are drawn:

Longmore's tables, based on the records of the battles of the last 200 years, show that there has rarely been a conflict of any long duration in which there have not been four deaths from disease to one from bullets. In the Spanish-American War there were fourteen deaths from disease to one from battle. Japan in her war with China, in 1894, lost three from disease to one from bullets; but from February, 1904, to May, 1905, in her war with Russia four were lost in battle to one only from disease, the exact figures being 52,946 lost in battle and 11,992 lost from disease, and the significant fact must be added that of the total sick only 3.51 per cent were sick with infectious diseases. There were only 1257 cases of malaria in the whole army, six hundred thousand strong, in the eighteen months duration of the war. whereas in 1894, in the war with China, there had been 41,734 cases of malaria.

"At the outset of the campaign the purifying of cities occupied was begun and attention was paid to mosquito breeding-places. One of the orders issued was that the waste water of the barracks should be connected with the town gutters. Incidentally it may be noted that all articles sold publicly were required to be covered to protect them from flies. In the book of health instructions issued to soldiers occurred the paragraph, 'Malaria is spread by mosquitoes; therefore protect yourself from them as much as possible.' The soldiers had their camp kettles with them, they were furnished with water boilers, and all water had to be boiled before being drunk. They were furnished with mosquito bars, and every man was enveloped in a bar during the mosquito season.

"The occurrence of 1257 cases of malaria in an army six hundred thousand strong must be contrasted with a telegram sent from General Shafter at Santiago on August 8th during the Spanish-American War, which read 'At least seventy-five per cent of the command has been down with malarial fever from which they recover very slowly. . . .'"

It should be noted that Major Seaman was disappointed not to find mosquito nettings in the main hospital in Tokio and that he states that this hospital was inferior in this and certain other respects to the second and third reserve hospitals in Manila. He states that at some of the hospitals netting was added as the mosquito season approached, but it is only fair to infer that at this main hospital the Japanese surgeons knew what they were about and were certain that the absence of the mosquito bars involved no danger to the patients.

WORK IN ALGERIA.

In 1902 an anti-malarial campaign was begun in Algeria, under the auspices and at the expense of the Pasteur Institute of Paris. The work was begun in a small way, and the service was afterwards extended and supported by the Algerian government, and it is still being carried on. Drs. Edmond and Etienne Sergent were assigned to the work, and in 1903 published an account of the early demonstrations. The investigators propounded to themselves the following question: Is it possible, under the conditions existing in Algeria, to defend a group of Europeans from malaria? They decided to use no prophylactic measures whatever except the destruction of *Anopheles*. The management of the East Algerian Railroad placed at their disposal one of the stations of that line. This station, which was called Alma, was a hot-bed of malaria. Nine agents had been stationed there between the 1st of July, 1894, and the 1st of December, 1901. All of them were seriously ill with malaria, and the first eight left their positions on account of malarial fever by the advice of their physicians. The ninth was the man in charge at the time, who was very thoroughly infected. The families of these agents, concerning which there were no statistics, were all and always feverish, according to the best information. It seems that there did not exist a person who had ever lived in this station a single summer without contracting malaria. At the time when the work began, 26th of June, 1902, there were thirteen people living in the station; among them nine had been there a year or more and were malarious; four had arrived during the winter and had never had malaria. In the neighborhood of the station there were two families, one of Arabs and one of French. All members of these two families were malarious and refused to be protected, and therefore constituted a constant source of infection for the *Anopheles.* It was the same way with the travelers who came to the station to wait for trains leaving in the evening or at night. Most of them were Arabs coming from nearby places notoriously unhealthy. The conditions of the problem, then, were severe. It was necessary to protect from the bite of infected *Anopheles* four persons not previously exposed, and nine others already malarious, the latter from reinfection. The measures undertaken were to protect this group of people from adult *Anopheles* and to destroy the *Anopheles* larvæ. This was done in the usual way. The openings to the building, doors, windows and chimney, were screened. Breeding-places were searched for and all found were treated with kerosene. On leaving the station at night, veils and gloves were used, but in spite of this watchfulness it was not certain that all of the inmates invariably observed this precaution. The results were excellent. The numbers of the mosquitoes were greatly reduced by the work against the early stages; the building was almost entirely protected—so much so that but nine *Anopheles* succeeded in gaining entrance. At the end of the season not one of the four new people had shown the slightest symptom of malaria, a condition which it is safe to say had not occurred before in that locality, and the others, although having some fever, showed no indication of reinfection.

This was only an initial experiment, to prove what could be done, and the results were placed before the Governor-General of Algeria and the members of Congress as well as the departmental and communal authorities. The expenses incurred amounted to 304.80 francs. The governmental efforts since that time seem to have been very considerable. In 1904 malaria was pandemic in Algeria, but through increased knowledge and extended repressive measures, as the report for 1908 shows, the situation in that year was very much better than in 1904. The work included conducting demonstrations to instruct the people, in widening each year the territory covered, and in organizing anti-malarial campaigns in different localities by the physicians, engineers, etc., stationed in those localities. Propagandic work of all kinds is going on, including placards in the railway carriages and elsewhere, and teaching anti-malarial measures in all the schools. Later reports indicate an awakening of the country that can not fail to be productive of great good.

WORK IN ISMAILIA.

Another striking example of excellent work of this kind is found in the report, published in 1906, on the suppression of malaria in Ismailia, issued under the auspices of the Compagnie Universelle du Canal Maritime de Suez. Ismailia is now a town of 8000 inhabitants. It was founded by DeLesseps in April, 1862, on the borders of Lake Timsah, which the Suez Canal crosses at mid-distance between the Red Sea and the Mediterranean. Malarial fever made its appearance in very severe form in September, 1877, although the city had up to that time been very healthy, and increased, so that since 1886 almost all of the inhabitants have suffered from the fever. In 1901 an attempt to control the disease was made on the mosquito basis, and this attempt rapidly and completely succeeded, and all traces of malaria disappeared from the city after two years of work. The work was directed not only against *Anopheles* mosquitoes, but also against other culicids, and comprised, besides the usual measures, the drainage of a large swamp. The initial expense amounted to 50,000 francs, and the annual expenses since have amounted to about 18,300 francs.

The results may be summarized about as follows: Since the beginning of 1903 the ordinary mosquitoes have disappeared from Ismailia. Since the autumn of 1903 not a single larva of *Anopheles* has been found in the protected zone, which extends to the west for a distance of one thousand meters from the first houses in the Arabian quarter and to the east for a distance of 1800 meters from the first houses in the European quarter. After 1902 malarial fever began to decrease obviously, and since 1903 not a single new case of endemic malaria has been found in Ismailia.

WORK IN ITALY.

The senior author has prepared the following consideration of the anti-malarial work in Italy and this has for the large part appeared recently in the Atti della Società per gli Studi della Malaria, vol. 12, pp. 85-87, 1911:

"The marvelous work which has been done in the way of the reduction of malaria in the Italian peninsula, largely under the direction of prof. Angelo Celli, of the University of Rome, must meet the hearty admiration of the entire world. The reports which have been published and the articles which have been written about it, enthusiastic as most of them have been, still fail to produce upon the minds of the readers the effect that a study of the actual conditions on the spot brings about. We have introduced this information in this place for the reason that effective as this work has been it has not been directed against mosquitoes themselves, but has been carried on almost entirely by two other methods —mechanical protection and quininization. It was the good fortune of one of us (Howard) to visit the Campagna, near Rome, in the summer of 1902 when the work was practically in its infancy. The protection of the railroad stations and of the peasants' houses had begun, but the Campagna in those days was almost deserted, agriculture was at a standstill, the peasants emaciated, their skins the color of saffron, and the children from their emaciation and the characteristic protuberant abdomens were pitiable objects. The whole of Italy was practically malarious, and specially in its southern part and in the islands the mortality ran from 0.400 to 3.000. By the work that has been done, in the same regions the mortality now runs from 0.050 to 0.800. In North Italy, in Piedmont and Liguria, malaria is now practically non-existent, and the same may be said for the province of Marche. In the Campagna itself, the mortality runs from 0.010 to 0.050, or at least this was the condition in 1908, and affairs have improved since then. Again, it was Howard's good fortune to visit the Campagna with Celli in May, 1910. The metamorphosis in the intervening eight years was simply miraculous. The Campagna has become populous; new buildings are going up on every hand; the peasants are robust, well fed, and obviously healthy; the children are fat, rosy, and full of life; agriculture of the most intensive kind is going on everywhere; and capital has come down from North Italy and the price of land is rapidly increasing. Anopheles, however, is still breeding there, and can be seen in the irrigating and draining ditches. The whole country is reclaimed swamp, interspersed with small hills, with a tufa subsoil and volcanic rock beneath. Mechanical measures first undertaken to protect the buildings and huts with wire screens gradually reduced the percentage of infection with malaria from 65 per cent to 12 per cent. Beyond this point for a time it seemed impossible to reduce the disease, and then the quininization was begun.

"Government supplies of quinine were placed at points in the custom-houses where it could be readily had; poor people were given it for a time free; and it was made palatable for the children by giving pellets under proper dosage a heavy coating of chocolate, so that often babies cried for their medicine. Every possible means was used for advertising and for distributing. Conspicuous signs were posted along the roads and at the places of distribution. Small articles for sale in boxes contained the government directions concerning quinine, and even the covers of cheap cigarette packages were, and are, used for this purpose.

"In fact, a degree of ingenuity has been shown in this advertising which is worthy of the most ingenious Yankee advertising agent. The cigarette package cover bears the following statements (literally translated):

"'OFFICIAL QUININE

is a preventative and curative remedy of unquestionable efficacy against malarial fever.

"'OFFICIAL QUININE *is sold to the public* at very moderate prices by pharmacists, drug-stores, and by private agencies that are licensed.

"*It is sold at a special rate*

by the

'Maggazino di deposito' of Turin to charity organizations, to the city, to public and private persons who are obliged by law to furnish it gratuitously to the poor and laborers.

"'*Official quinine for gratuitous administration*

to the poor and laborers is prepared by the Central Military Pharmacy of Turin in tablets of 20 centigrams each, sugared in the form of candy.

"'*Official quinine for sale to the public*

is prepared by the Central Military Pharmacy of Turin in tablets of 20 centigrams each, enclosed in small tubes of 2 grams each.'

"It results from the universal use of quinine in the prescribed doses that the percentage of malaria has been reduced to less than 4 per cent, and this percentage is maintained, although the mechanical protective means have been practically abandoned. The straw huts are no longer screened, and of the houses only the upper-story bedrooms. Door-screens have been abandoned. The whole country is full of life and energy, and the richness of the soil is so great that in a comparatively few years the Campagna will be supporting an enormous population.

"Celli and his colleagues and supporters have the respect and affection of all the inhabitants of the Campagna, and the wonderful work which their eminent knowledge and great energy have accomplished is a model for other nations."

The Italian Society for the Study of Malaria, under whose auspices this magnificent work was done, was founded in July, 1898, by Angelo Celli, Giustino Fortunati, and Leopoldo Franchetti. In "Malaria, Internationales Archiv," for October, 1908, Professor Celli reviews the work of the Società per gli Studi della Malaria, and gives a summary of its results in these ten years which should be published here:

"1. Has confirmed and perfected the new mosquito-malarial theory of Ross;

"2. Has contributed new facts to the etiology, pathology, clinic, and therapy of the malarial infection;

"3. Has thoroughly studied the epidemiology of malaria according to the new theory, disclosing the agreements and lacunæ which have yet to be filled up;

"4. Has improved the prophylaxis of malaria and has introduced into practice the new mechanical prophylaxis based on the defense of the habitation and the person from the bites of mosquitoes. This being a relatively expensive prophylaxis, the Society has occupied itself with improving the antiplasmodic prophylaxis, making use largely of state quinine both for the most radical treatment possible and for the prophylaxis of malaria;

"5. Thence it has promoted and defended legislation in state quinine and in its gratuitous distribution to all the workers and to the poor living in malarial localities—a legislation which has been already adopted by other nations;

"6. In order to render possible this prophylaxis and to prolong the treatment as long as possible, it has had prepared the quinine in its most agreeable form—namely that of comfits and chocolates, the latter containing tannate of quinine, which has little taste and is better tolerated by children, and by those adults who cannot tolerate the ordinary quinine salts;

"7. With the propaganda of the facts and popular hygienic education, it has helped to organize the new national campaign against malaria;

"8. The results have been that since 1902, when the law on state quinine was promulgated, while the consumption of quinine has been yearly increasing, the mortality from malaria has, on the contrary, diminished almost three-fourths throughout Italy (from 16,000 to about 4000 deaths yearly); and in the Army, Custom-House offices and in some Communes, where the new laws have been better applied, the morbidity from malaria has greatly diminished;

"9. With the above-mentioned prophylaxis, eventually combined with the mechanical one, people can finally live and dwell in places which formerly they had to fly from, owing to the danger of malarial fevers; and consequently to-day one can better and more regularly carry out the hydraulic and agrarian sanitation.

"10. Our Society has endeavoured also to improve the execution of this, and of the relative laws, because by means of the agricultural and agrarian transformation of the land and colonization, rather than by the destruction of mosquitoes (a thing impossible to be done by us on a large scale), one can and must proceed to the definite liberation of the territory from malaria."

WORK IN OTHER PARTS OF THE WORLD.

Active and well-organized anti-malarial work is being carried on in many places in the tropics. An effort has been made to establish an anti-malarial league in Greece which has the support of wealthy people and of the nobility of several countries, but, aside from Italy, in practically none of the well-settled countries in temperate regions has any work of importance been done, even in regions whose development is distinctly held in check by this disease.

IN INDIA.

The government of India has never been able to carry out broad concerted measures, although most important investigations have been carried on in that country. It was decided to convene a conference to examine the whole question and to draw up a plan of campaign for the consideration of the general government and of the local governments. This conference assembled at Simla on October 11, 1909. In the resolution which brought about the call it is pointed out that the actual death-rate in India from malaria is five per thousand; that this represents about 1,130,000 deaths, and, as mortality in malarial fever is ordinarily low, a death-rate of even five per thousand indicates an amount of sickness, much of it preventable, which clearly calls for the best efforts that government can make to diminish it. An editorial in the Journal of Tropical Medicine and Hygiene for September 15, 1909, in speaking of this resolution and the proposed conference, anticipates that nothing will come out of the movement. It says, "To those, however, who have read many similar resolutions, and have, perhaps, acted on committees of the sort, the solemn rigmarole, with its characteristic touch on the 'prohibitive costs of attempts to extirpate the mosquito,' implies no more than an expedient to stave off the dreaded day when public opinion will force the Government of India to act instead of talk on this really and literally vital question."

The report of the conference as given in Nature, November 5, 1909, indicates that many important addresses were made, including one by Colonel Leslie, the Sanitary Commissioner of the government of India, and others by such well-known workers as Major James and Captain Christophers of the Indian Medical Service. Colonel Leslie advocated quinine prophylaxis. Major James introduced a discussion upon the distribution of malaria in India and advocated a general investigation in every province, similar to that which Captain Christophers made in the Punjab. Quite in the line of prophecies of the editorial in the Journal of Tropical Medicine and Hygiene, Major White, of the Indian Medical Service, stated that he considered the recommendations of past malaria conferences are costly, and almost prohibitively so if undertaken annually, and contended that more should be done with the propagation of fish which prey upon mosquito larvæ. At the termination of the conference various conclusions and recommendations were drawn up under the following main headings:

(1) Scientific investigation; (2) The agency by which investigation should be made; (3) Practical measures, including (a) extirpation of mosquitoes, (b) quinine treatment and prophylaxis, (c) education, and (d) finance.

THE UNITED STATES.

In the United States, it is sad to relate, almost nothing has been done in the way of an active campaign against malaria alone, even in restricted localities. It is true that extensive work has been done against mosquitoes, but in the most of these cases the incentive does not seem to have been to better the health of the people or to stamp out malaria. We have shown that in the New Jersey work the item of personal comfort is concerned and that of the enhanced value of real estate and the enhanced taxable value of land to the community, but the main fight there is conducted against mosquitoes that have no relation to disease. We have shown also that the fight against mosquitoes in the marsh lands back of Brooklyn was financed by a wealthy man whose immediate motive was to keep his race horses in better condition by preventing the annoyance of them by mosquitoes. In different communities there have been intelligent and up-to-date citizens who have made strong efforts to start anti-malarial campaigns, but they have not succeeded, through indifference on the part of city councils or other bodies controlling public funds. Many health officers themselves have seemed indifferent on this subject. In some localities citizens' associations, civic improvement societies and women's clubs have made efforts to improve the situation. Good work was done by such an organization in South Orange, New Jersey, and instances of this kind are scattered here and there at very long intervals over the country, but these efforts as a rule were spasmodic and only temporary in their effects.

One of the best pieces of work with a direct anti-malarial bearing that has been carried on in this country and that was begun at an early date was started on Staten Island under Doctor Doty, the health officer of the port of New York. The following account is largely taken word for word from a letter received from Doctor Doty, but it can not be directly quoted on account of occasional necessary alterations of the verbiage of a personal letter.

Staten Island, lying in New York harbor, had had a rather unenviable reputation on account of the great number of mosquitoes present and the continued presence of malaria. It was largely on account of the latter condition that Doctor Doty began his investigation in 1901. He soon found that there were two factors to deal with, namely the inland mosquitoes and the salt-marsh mosquitoes.

In the extermination of the inland mosquitoes, the section of Staten Island which was known to contain many cases of malaria both in the acute and chronic forms was selected for experimental work. This section consisted of a basin of lowland about a mile square containing about one hundred small dwelling houses some distance apart. Within its boundaries were a large number of stagnant pools varying in size from ten feet in diameter to an acre or more in area. A house-to-house visit showed that at least 20 per cent of the inhabitants of this district were suffering with some form of malaria, and in the immediate vicinity of every house were found typical breeding-places in the shape of old tinware, rain-water barrels, cisterns, cesspools and ground depressions, many of which contained larvæ. For the purpose of detecting the presence of adult *Anopheles*, glass tubes fitted with cotton plugs were distributed among the occupants of these houses with the request that the mosquitoes found in the house at night be captured and placed in the tubes. In the collections were found many *Anopheles*. These were particularly numerous in tubes coming from a small group of houses. In one of the latter was found a family consisting of five persons all of whom showed the acute or chronic form of malaria. Doctor Doty himself secured live mosquitoes from the interior of this house. On the first evening five were captured, and all but one were *Anopheles*. On the second evening twenty-two were collected, and of these more than one-half were *Anopheles*. In a house on the opposite corner was found a patient suffering from an acute attack of malaria.

In the beginning considerable difficulty was found in detecting the breeding-places of the *Anopheles*, but this became easier as the inspections became more thorough. For instance, in a group of two or three houses close together a number of *Anopheles* were captured, but their breeding-place could not be found for some time. Finally in the back yard of one of the houses, overgrown with weeds, was discovered a large metal receptacle with numerous *Anopheles* larvæ and with many adults in the immediate vicinity. This receptacle was almost entirely covered by underbrush. After this experience, the men employed learned to make the closest possible search.

The island was then divided into small districts which were visited by a mosquito corps consisting of five men, one of whom was a sanitary police officer connected with the New York City Department of Health. The equipment of the mosquito corps consisted of a large wagon provided with spades, rakes, hose, scythes and petroleum oil. A house to house inspection was made in each district. House owners or tenants were required to remove from about the premises all receptacles which might act as breeding-places, or to protect them. Rain-water barrels and cisterns were covered with wire netting, all roof gutters were repaired, and pools of water were covered with petroleum. In certain instances orders were sent to the owners of property containing depressions in the soil to fill these in or drain them. If these orders could not be enforced, the mosquito corps returned every ten days or two weeks and applied more petroleum. Copies of a circular of information were delivered so far as possible to each house on Staten Island by police officers, and this educational campaign brought about valuable cooperation on the part of the public.

In 1905 the details of this work were presented to the Department of Health of the city of New York, and the city government granted an appropriation for the drainage of the swamp land along the entire coast of the island. With the aid of this appropriation, ditching was carried on somewhat in the same manner in which it has been carried on in New Jersey. Down to the present time, between eight hundred and one thousand miles of ditches have been dug. The swarms of mosquitoes soon practically disappeared, window screens were discarded, and meals were served upon the verandas of the hotels.

With the malarial and other inland mosquitoes, the work was carried on in the manner above described, not only in the built-up portion of the island, but also in the open spaces between the small and scattered settlements. During the past two years cases of malaria on Staten Island are becoming very rare and for the past year Doctor Doty has been unable to secure any *Anopheles*, whereas in the beginning of the investigation they were found almost everywhere on the Island. The statistics of the Department of Health indicate the decrease of malaria from 1905 on. Prior to 1905 malaria was not regularly reported, but the number of cases was surely very much greater than that reported in that year. Since 1905, however, they are stated to have been as follows: 1905, 33 cases; 1906, 54 cases; 1907, 4 cases; 1908, 6 cases; 1909, 5 cases.

The work of exterminating malarial mosquitoes has been necessarily slow, as the area involved is considerable, the Island being about 16 miles long and four to six miles wide, with large areas between the various towns. The population probably is over eighty thousand inhabitants.

The expense of the operations down to 1910 was about $50,000; this of course includes the expense of the extensive drainage operations in the salt marshes. Doctor Doty, in addition to being the Health Officer of the port of New York, is a Commissioner of Health of New York City, and carried out this work in his capacity as a municipal officer and not as a State official.

There were some earlier and very much smaller pieces of work, which have previously been described by one of us.

Dr. W. N. Berkeley, in the *Medical Record* of January 26, 1901, gave an interesting account of a malarial outbreak in a small town near New York City during the summer of 1900. Around a large pond in the vicinity of the town four or five cases had developed in August. The first case was that of a coachman who had caught malaria elsewhere and had relapsed. From his quarters in a long row of stables on one side of the pond the infection had been passed along to other stablemen and servants on the same side, to the distance of a quarter of a mile from the original site; a quarter of a mile in another direction, across the pond, one other case appeared in a small child. Dr. Berkeley went to the town and discovered that *Anopheles quadrimaculatus* was fairly abundant in every bedroom of that area in which proper search was made. The breeding-places seemed to be segregated pools at the end of the pond (the pond itself contained fish) and post-holes and excavations. These last were numerous, as many buildings were going up. The following practical measures were adopted: (1) Extermination of all the *Anopheles* found in houses by a party of men sent out for the purpose, followed by a systematic introduction of screens in windows and doors; (2) filling in of the smaller breeding-places and the drainage of the pond; (3) the protection of every malarious patient by netting and otherwise from the bite of mosquitoes, so long as he had malarial parasites in his blood. The results were as prompt as they were gratifying. Not a single new case of malaria developed; *Anopheles* disappeared entirely from houses where it had been common, and *Culex* was greatly diminished in numbers.

It will thus appear that, considering the economic loss existing in the United States through malaria, nothing like the competent work has been done that should have been done within the territorial limits of the United States themselves. The United States government has done admirable work in Cuba, for another people, and it has done excellent work in the Isthmian Canal Zone, but in its own home territory it has done nothing. State governments have done almost nothing, if we except the drainage work done in New Jersey. Malaria campaigns have been local and on the whole very unsatisfactory.

The same comparative indifference holds in other countries, and often even where work is begun under good auspices and with excellent indications, it has failed of securing the best results. Major C. E. P. Fowler, R. A. M. C., in his report on malarial investigations in Mauritius, 1908, points out that on that Island the great fault has been in non-attention to small details, as for instance in dealing with neglected surface water such as is found in the small ditches along roadsides, in field drainage channels and in holes in the ground, and failure in keeping up the larger work already carried out. He states that no forethought seems ever to have been expended on keeping the work already carried through in proper working order. Where drains or ditches had been laid down only a few months previously he found them time after time choked with vegetation and forming excellent breeding-places for *Anopheles*. The same thing applied to rivers: the government had cleared them, but it seems to have been nobody's business to keep them clear. According to this report, there seems to be a general impression among all classes of people, not only in Mauritius, that to carry on anti-malarial work means the outlay of vast sums. People prefer to sit idle and complain that they have not the means to carry out the work. He shows that a few gangs of men can do a great deal in the way of ridding a district of breeding-grounds, and that their employment does not imply a heavy outlay.

It is true that even where work is not directed specifically against malaria, but against the mosquito nuisance, the breeding-places of *Anopheles* are for the most part disposed of, and they are prevented from breeding, together with the other species of mosquitoes, and for this reason a little space will be devoted to some of the productive efforts which have been made in the United States aside from those which have already been considered at some length.

In the early days of anti-mosquito work in this country, 1901 and 1902, the rather rare citizens who appreciated the situation and who did their best to stir up their communities to organized effort should be mentioned, as far as this has not been already done. Among them we have specifically in mind, Dr. Albert F. Woldert, of Philadelphia, and later of Texas; Dr. Henry Skinner, of Philadelphia; Dr. H. A. Veazie and Dr. H. G. Beyer, and a little later Dr. Quitman Kohnke, of New Orleans; Major Barton, of Winchester, Va.; Dr. W. S. Thayer, of Baltimore; Mr. Spencer Miller, of South Orange, N. J.; Dr. W. F. Robinson, of Elizabeth, N. J.; Dr. J. W. Dupree, of Baton Rouge. We have found it unnecessary to mention any entomologists in this list, and of course since those early days nearly every economic entomologist has become an apostle. After 1902 the ranks became greatly increased and at the present time conditions are being bettered, although still there is no large well-organized campaign directed solely against malaria.

An important step forward was taken in 1903 in the formation of the American Mosquito Extermination Society, in which W. J. Matheson, of New York, the president, and Henry Clay Weeks, also of New York, the secretary, were the leading movers. This Society, in which nearly all persons actively interested in the mosquito crusade became interested, was started for the purpose of educating the public, bringing about legislation, and of securing cooperation and interchange of ideas. It held its first anti-mosquito convention December 16, 1903, in New York City. The convention was called to order by Mr. Henry Clay Weeks, as acting chairman, who made some introductory remarks, after which officers were elected. The following papers were read:

"How a State Appropriation may be Spent," by John B. Smith.
"What a Rural Community can do," by Walter C. Kerr.
"The World-wide Crusade," by L. O. Howard.
"Does Extermination Exterminate Mosquitoes?" by W. J. Matheson.
"Remarks on Extermination Work at Morristown, New Jersey," by John Claflin.
"The Extermination and Exclusion of Mosquitoes from our Public Institutions," by P. H. Bailhache, Surgeon, U. S. Public Health and Marine-Hospital Service.
"Government Antimosquito Work," by Dr. J. C. Perry.
"The Sphere of Health Departments," by Dr. E. J. Lederle.
"The Exactness of Proofs of Transmission of Malaria by Mosquitoes," by Dr. W. N. Berkeley.
"The Long-Distance Theory," by Spencer Miller.
"The Value of Reclaimed Swamp Lands for Agricultural Uses," by Milton Whitney.
"Antimosquito Work in Havana," by Col. W. C. Gorgas, U. S. A.
"How the Law should Aid," by Paul D. Cravath.
"New York State's Part in Mosquito Extermination," by E. P. Felt.
"What the General Government should do," by F. C. Beech.
"Mosquito Engineering," by Henry Clay Weeks.
"The Work of the Department of Health, New York City," by Henry C. Weeks.

Following this meeting, a somewhat elaborate organization was perfected, including a general advisory board and an advisory board of entomologists. The proceedings of the convention were published in pamphlet form and were distributed free of charge. A mosquito brief was published as a folder giving mosquito information. In November, 1904, Bulletin No. 1, of the Society was published, which contained in condensed form an account of the work which had been done in the meantime. Bulletin No. 2 contained a report of the president and secretary to the Executive Council, published September 26, 1905, and in 1906 was also published a year-book for 1904–1905 which contained the proceedings of the second annual convention of the organization. These proceedings contained a number of valuable addresses, some of which may be mentioned:

"Diversities among New York Mosquitoes," by E. P. Felt.
"Mosquito Extermination in New Jersey," by John B. Smith.
"Extermination and Dissection of Mosquitoes," by M. J. Rosenau, of the U. S. Public Health and Marine-Hospital Service.

"Mosquito Extermination in New York City," by Thomas Darlington.
"The Mosquito Question," by Quitman Kohnke.
"The Relation of Mosquito Extermination to Engineering," by Cornelius C. Vermeule.

The society continued its work, and justified its organization. In 1907, however, it was deemed by the officers of the society that the objects of its existence could well be taken over by the National Drainage Association, which had been recently formed and which placed among its most prominent motives the idea of securing government action in reclaiming the marshes and swamps of the country. It was decided that the society should retire from its field of work and leave the same to the national government, to State, and other authorities, and to individuals.

In 1903–1904 work against mosquitoes was undertaken by the State Entomologist of Connecticut, Dr. W. E. Britton, who made careful mosquito surveys over the whole State and who published in his annual report for 1904 a careful and well-illustrated article devoted to showing how the mosquito nuisance can be abated. Since that time some active work has been taken up. In 1906 the Board of Health of Millburn township in New Jersey secured the services of Mr. Weeks, and published a pamphlet entitled "The Mosquito Nuisance in Millburn Township and How to Abate It."

At Worcester, Mass., an interesting crusade was begun early under the direction of Dr. William McKibben and Prof. C. F. Hodge. In Michigan work was carried on upon the campus of the Michigan Agricultural College. In Connecticut work was earlier done at Pine Orchard and Ansonia, as well as at Bridgeport, Branford, Fairfield and Hartford; and in Maine at Old Orchard Beach. Excellent work was also done at a very early date at Lawrence, Long Island, largely against malarial mosquitoes, under the auspices of the Board of Health working with an appropriation of $1000 and with a privately contributed fund of $1678.54. A small crusade was also carried on at an early date under the auspices of the civics committees of the Twentieth Century Club at Richmond Hill, Long Island. In the Southern States the Boards of Health at Atlanta and Savannah began work in 1903 and certain regulations were enforced. At Talladega, Ala., work was also begun in the same year. The excellent work done at Morristown, N. J., under an improvement society in 1903 should not be forgotten.

The foregoing examples show what it is possible to do in the way of abating the mosquito nuisance and we trust the recounting of them will stimulate many to undertake the work. The matter is generally surprisingly easy when once the problem is well understood. The most important point to determine first of all is the exact species of mosquito concerned, for each species requires radically different treatment, as will have been evident to the reader from the foregoing. The principal object of the present work, therefore, is to elucidate, as far as at present is possible, the differences between all the known species in our region, not only the noxious species, but the far more numerous relatively harmless kinds, as well as the few actually beneficial ones. To this subject the following volumes are devoted.

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