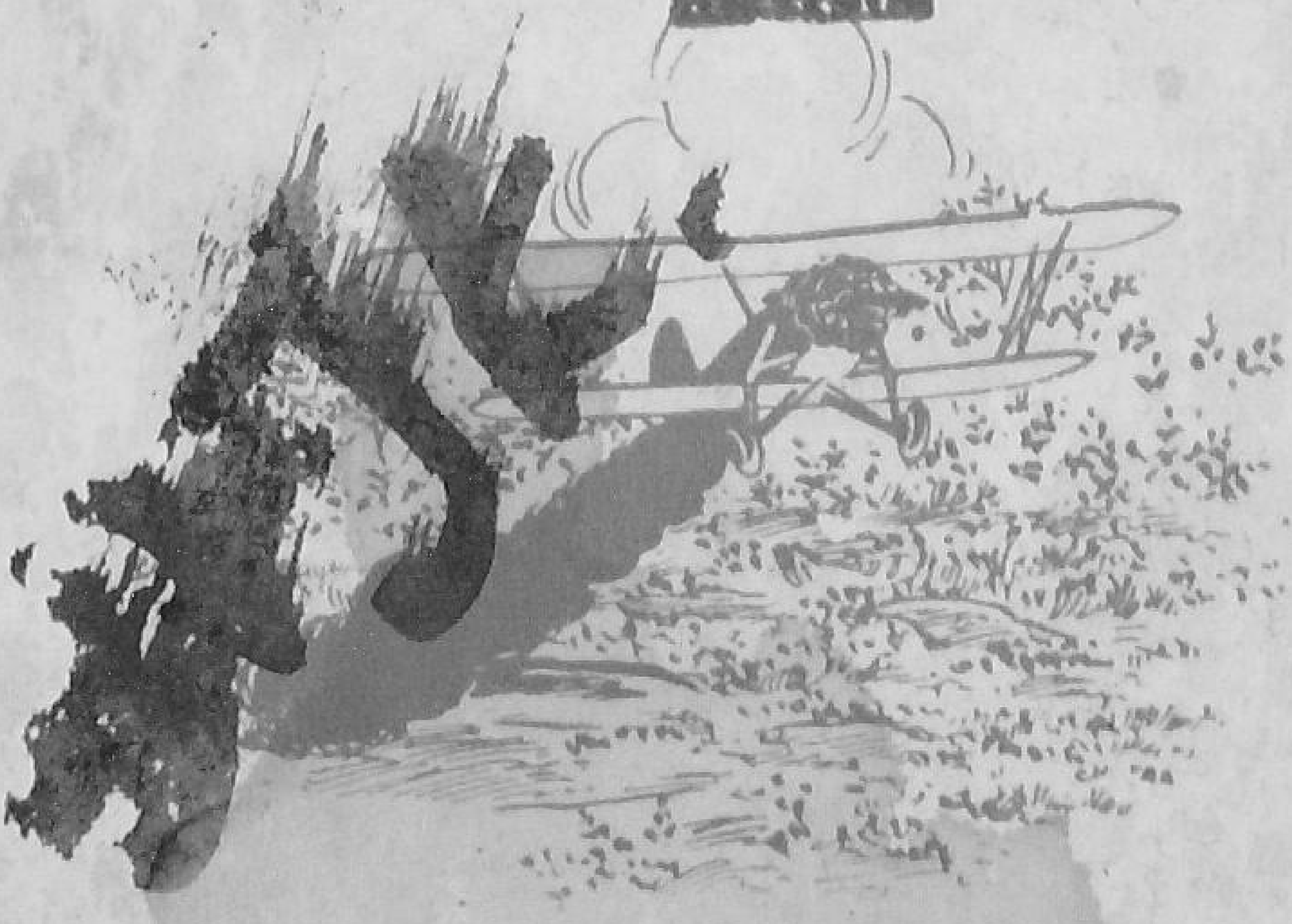
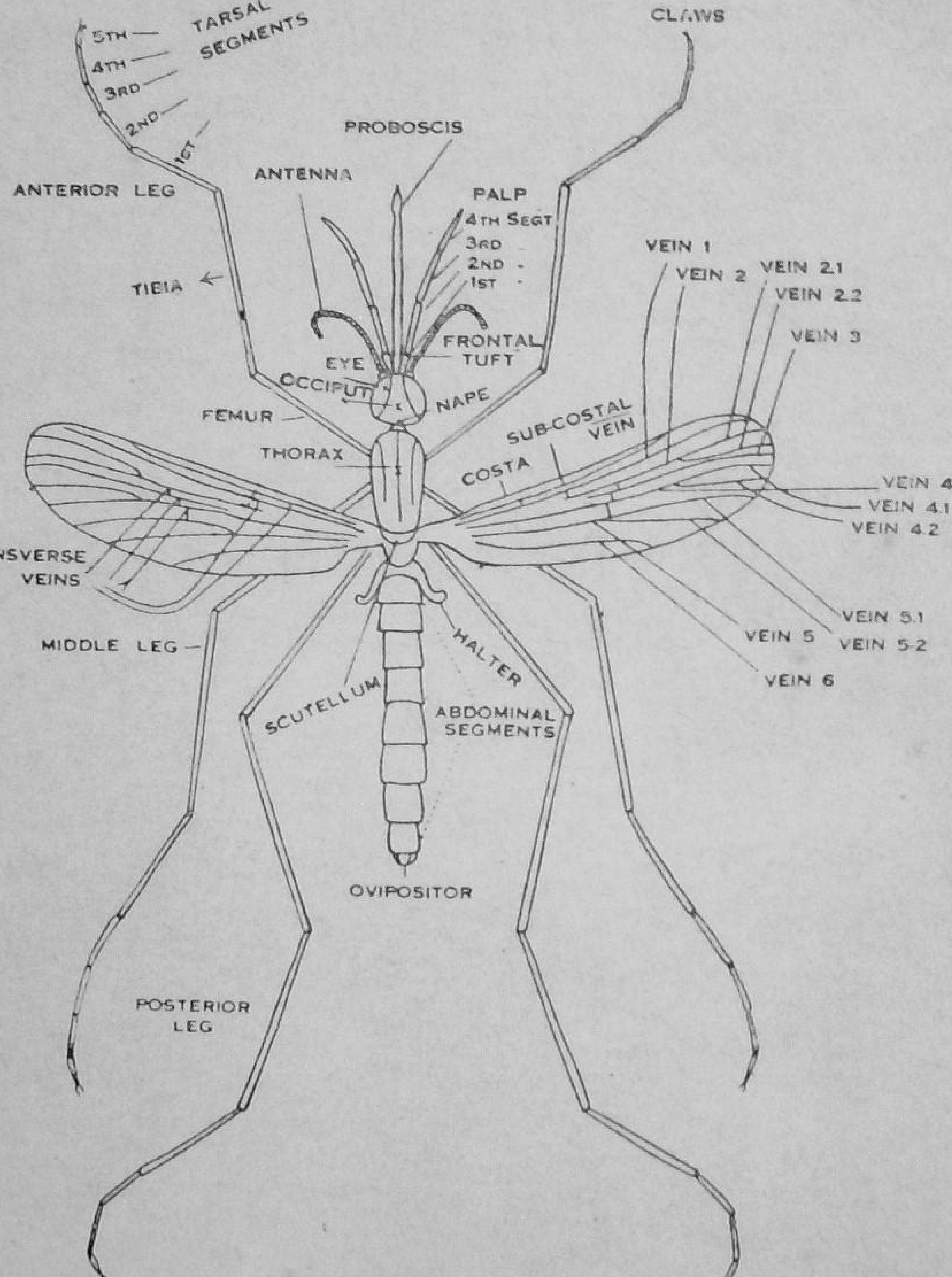
MOSQUITO
REDUCTION &
MALARIAL
PREVENTION



J. A. CRAWFORD &
B. S. CHALAM



DESCRIPTIVE DIAGRAM *ANOPHELES* (FEMALE)

MOSQUITO Reduction and MALARIAL Prevention

A PRÉCIS

BY

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THIS BOOK IS DEDICATED

TO

LT.-COLONEL S. R. CHRISTOPHERS,

F.R.S., C.I.E., O.B.E., I.M.S.

FOREWORD

THE Authors of this small book are quite correct when they point out the need of a work such as they now put forward. Many books, it is true, deal with anti-malarial work and many with various aspects of the study of malaria, entomological, parasitological, clinical, etc. There are also general treatises on malaria and works on the practical prevention of the disease. But the fact remains that it is very difficult to recommend a book to a beginner that will give him the simple facts and interests he requires to help him in commencing actual practical work in the field. The Authors have met the needs of a manager of a tea garden, or a malarial inspector, or the N.C.O. in charge of a regimental sanitary squad from their own experience of what such persons require. They give a brief but sufficient account of the nature of malarial fever, of the chief facts about mosquitoes and of how to find and identify mosquitoes, especially the Indian species of malaria carriers. They end with an account in some detail of practical steps to be taken in prevention, and, in the form of appendixes, with some helpful notes on the technique connected with mounting and preserving specimens. The Authors themselves have had the practical experience that qualifies them to write helpfully for others, and I wish their venture every success.

S. R. CHRISTOPHERS

PREFACE.

THE Authors, in placing before the public this volume, do so with the hope of filling a need long felt by the worker and inspector in anti-malarial measures. There are at present many tomes and excellent treatises dealing exhaustively with the life, habits and elimination of mosquitoes, and many are written with a view to controlling yellow fever and malaria—but the man who is too busy in other walks of life, or who has not the necessary technical education, cannot readily acquire the knowledge contained in these. We have only introduced such technical names and phraseology in this book as are absolutely necessary for the proper understanding of the subject, and where these are introduced they are explained as simply as possible. It has been our experience that the manager of a tea garden, or a malarial inspector, or the N.C.O. in charge of a sanitary squad dealing with anti-malarial measures begins to take a much keener interest in his work when he has acquired some knowledge of the habits and life-history of the mosquito, and it is primarily in the hope of quickening their interest that this work has been undertaken.

Our thanks are due to Lt.-Colonel S. R. Christophers, F.R.S., C.I.E., O.B.E., I.M.S., for his kindness in reading through our work and for his many valuable criticisms, and also for allowing us to include a Synoptic Table of Indian *Anophelini* issued by the Central Malarial Bureau, Kasauli, 1926. We also desire to thank all who by their kind criticism have encouraged us in our work.

BOMBAY,
June, 1926.

J.A.C.
B.S.C.

PREFACE TO THE SECOND EDITION

THE favour with which this work has been received and the demand within a few months for a second edition are evidence that the public is interested in anti-malarial work.

Some of our well-wishers made a few kind criticisms on the first edition of this book, and in this edition we have attempted to meet such criticisms and make necessary additions or amendments. We have added as an appendix a chapter on the action and uses of 'Paris Green', which is a chemical used for killing *anopheline* larvæ, and opens out great possibilities in anti-malarial field work. We have also added as much information as we could gather about the use of larvacidal fish, and have illustrated in a separate chart some of the paraphernalia that will be ordinarily required in anti-malarial field work.

We are greatly indebted to the Indian Research Fund Association for considerable financial help in the publication of the first edition of this book. We should be grateful to all our readers for any suggestions they may offer, bearing in mind the class of persons this work is intended for.

J.A.C.
B.S.C.

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CHAPTER I

THE FACTORS CAUSING MALARIA

MALARIA is probably the commonest disease that affects mankind, and its ravages are spread over large areas of the world. Nor is it a disease of comparatively recent origin, for we find reference to it in the writings of ancient Greece and Rome. Its ravages are evidenced in manifold directions; for not only does it in certain instances destroy the life of the individual infected, but also, from its chronic nature, debilitates him and thus exposes the unfortunate person to attacks of other and more grave disorders. In India alone it is estimated that some four millions of people apply annually for treatment for malaria, and there must be many others who do not apply for treatment. If we add to that number the vast army of sufferers outside India, we shall have some idea of the widespread character of this disease.

The economic and financial loss, which arises as a direct and indirect result of the ravages of malaria, can only be touched upon here. Many a day's labour is lost to those who employ people suffering from this disease; and the employees themselves, broken in health by recurring bouts of fever, cannot be productive of the same amount, or of as high a quality of work, whether mental or physical, as those who labour under conditions where malaria does not exist. The financial loss to the employers of labour in malarious districts is immense, and in this direction one cannot but refer the reader to the literature dealing with the subject. If this disease were to be eliminated the gain to mankind from a humanitarian and economic standpoint would be beyond belief, and it is from this point of view that we must approach the subject. We must first of all try to discover what essential factors are necessary to bring about this disease, and where, if possible, we can break in upon and destroy either all or one of these factors.

As we have already mentioned, this disease is to be found described by the ancient Greek and Latin authors, and even in those days the relationship between marshes and malaria was recognized. In the middle ages a type of mosquito-net was mentioned as the only safeguard to those living near marshes. This would seem to correlate for the first time fever, marshes, and insects.

The next real advance made was the discovery of Cinchona. By its use the physicians in the eighteenth century were able to distinguish between those fevers which reacted to Cinchona (i.e. quinine) and those that did not.

The name Malaria is derived from two Italian words, 'Mal' and 'Aria', meaning 'bad air', and refers to the belief that the cause of the condition was due to bad air arising from marshes.

It was not, however, until 1881 that the really first big step was made in solving the problem of its cause. In that year the French surgeon, Laveran, demonstrated that malaria was caused by a minute organism which attacked the blood corpuscles. Following quickly upon this, the workers in the subject established three distinct organisms which caused three distinct types of fever. These organisms are called *Plasmodium vivax*, which causes Benign tertian malaria; *Plasmodium malariæ*, which causes Quartan malaria; and *Plasmodium falciparum*, which causes Malignant malaria.

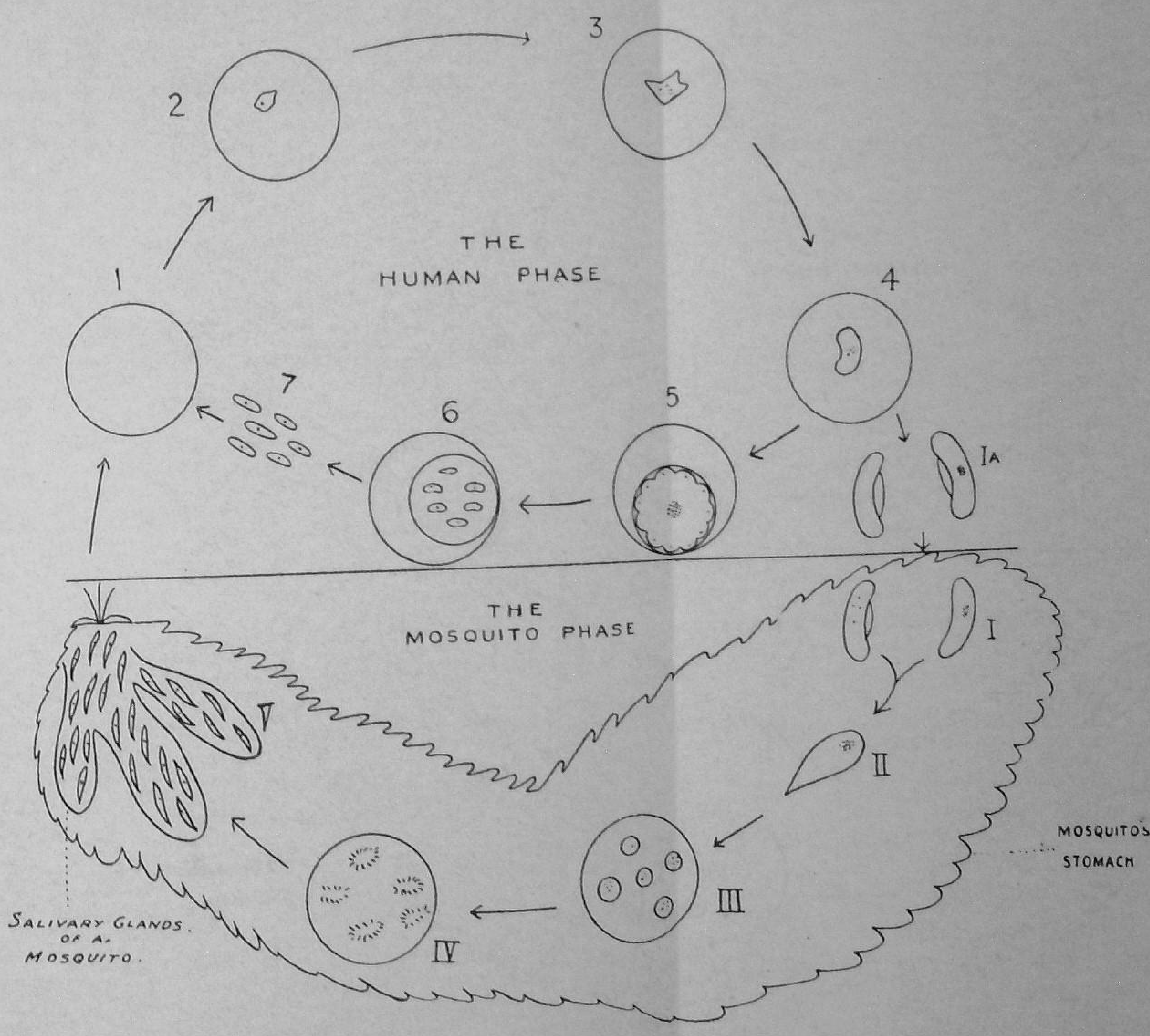
Up to this time we had two of the three great factors in this disease—namely man and the plasmodium. Having found that malaria was caused by these organisms, it yet remained to be discovered how man became infected or how the disease spread; and it was not until 1898 that Sir Ronald Ross, working on a hypothesis put forward by Manson, demonstrated that mosquitoes spread the disease from man to man by their bites. Thus were the three great factors, man, mosquito and plasmodium, linked up, and the cause and method of spread of malaria definitely settled.

In order that we may arrive at a full comprehension of the manner in which these three factors are linked together, we must have a knowledge of how the plasmodia infect man.

We will consider the plasmodium itself. This organism comes very low in the scale of animal life, seeing that it consists of one cell only. It is classed as a 'Protozoon'. The substance, called protoplasm, of which this unicellular organism is composed, has the same properties as have cells used in building up the tissues of higher animals; that is to say, it grows, moves, assimilates food, and reproduces itself by division. Its reproduction is of two distinct types, asexual and sexual. It also has the power of producing a variety of chemical substances. The organism itself has a nucleus situated in the midst of protoplasm, which is the substance of which all living cells are built up. In its methods of living it is entirely parasitical, that is to say, it lives at the expense of other animals which are called its 'hosts'. Like all true parasites, the plasmodia must adapt themselves to life inside their hosts and must be able, in order that the species may be maintained, to pass from one host to another. Thus it is that the parasites grow and multiply by one method in one host—man—and by another method in mosquitoes. The former is called the asexual life and the latter the sexual life of the plasmodium.

The three species of malarial parasites, the *Plasmodium vivax*, *Plasmodium malariæ*, and *Plasmodium falciparum*, produce three distinct types of fever. These are the Benign tertian, Quartan, and Malignant fevers. The sexual forms of the Quartan and Benign tertian—that is to say, those adapted for life and development in the mosquito—are spherical. This form of Malignant tertian is crescentic. There are male and female spherical forms, and male and female crescentic forms. The male sexual forms fertilize the female forms in the stomach of the mosquito, and a cyst is produced which imbeds itself in the wall of the stomach. Many such cysts are formed there, and 'these appear in the walls of the stomach like raisins in a pudding'. The contents of the cysts divide and form spores or young parasites, which find their way to the salivary glands of the mosquito. This whole process, which constitutes the sexual life of the parasite in the mosquito, takes about twelve days to complete. Now the mosquito is ready to infect the other host. Suppose she bites; then down the proboscis, or mouth-parts, travel these spores in the saliva of the mosquito and become injected into the man's blood stream. The spores then attach themselves each to a red blood corpuscle, enter, and proceed forthwith to destroy it by feeding on it. The question of male and female forms does not here arise, as we are now dealing with the asexual life of the plasmodium. The plasmodium becomes bigger and bigger inside the red blood corpuscle until the time comes for it to divide. The division goes on until instead of one parasite in the cell we get many, which form clumps of spores known as rosettes. This is now the full ripe stage of the parasite. The red cell bursts and all these tiny spores are thrown free into the blood stream, only again to enter fresh red cells and there begin once more the non-sexual cycle. Now this cycle takes time to complete. In some cases seventy-two hours are required. Then the fever is called Quartan; in other cases forty-eight hours suffice for the completion of the cycle and then the disease is called Tertian, and again the cycle may take place in under forty-eight hours, as is the case in Malignant or Sub-tertian fever. It is these forms that cause the symptoms of the disease. The main symptom is fever, which occurs when the rosettes burst and the parasites are thrown into the blood stream. Therefore the fever will recur every third day with Quartan malaria and every second day or every day in the Tertian fevers.

In process of time certain of the non-sexual elements of the plasmodium become differentiat-



LIFE CYCLE OF THE PLASMODIUM

I. Male and Female Gametes. II. Travelling Vermicule. III. Zygote IV. Oocyst. V. Sporozoits.

1 Normal red cell. 2 and 3. Red cells containing young parasites. 4. Red cell containing a mature parasite. 5, 6 and 7. The parasite dividing asexually into several younger ones and again invading a red cell. Ia. Some parasites develop into the sexual forms in the blood—the male and female gametes.

ed and form themselves, while in the red corpuscles of the blood, into spherical shapes called spheres, and into crescentic shapes. There are male and female spheres and male and female crescents, according as the type is Quartan or Benign tertian in the former case, or Malignant tertian in the latter case. These forms do not cause any symptoms of fever, and their sole function is to await the arrival of a certain mosquito which sucks them up into her stomach when she bites the individual, and there they commence once again the sexual cycle as has already been described.

It is in this manner that the complete cycle which causes the disease known as malaria, carries on between the mosquito and man. With this knowledge gained it remains for us to discover in what way we can endeavour to eradicate this disease. We could, for example, turn our attention to the individual, and by giving appropriate drugs kill out the plasmodium in his blood. Unfortunately, we have no known drugs on which we can depend for this ideal method of dealing with the disease. Quinine, which is excellent for controlling the disease, has no action on the sexual forms in the blood. We are, therefore, forced to look to the other host, and find out if it can be dealt with in such a way that we can break the link in the chain necessary for the development of the plasmodium.

Where there are no mosquitoes there is no malaria. Hence, if malaria exists in a locality and you want to free that locality of malaria, you must free it of mosquitoes. Thus our attention is directed to that enemy of mankind, the mosquito, which must be dealt with rigorously, firmly and unscrupulously. If one nation goes to war with another it strives to gain as complete a knowledge as it can of that other nation and of the armies of that nation, in order that it may supply sufficient fighting forces to overcome them. And so it is with the mosquitoes. If we are going to eradicate and exterminate the mosquito we must get to know which mosquitoes carry the disease, what their habits and environments are, what is the life-history of these mosquitoes, and at what stage in the life-history are they most easily attacked.

Other diseases have also been traced to these pests, two of which are very important, namely yellow fever and filariasis; while the common fever called dengue is also known to be spread by mosquitoes.

CHAPTER II

THE LIFE-HISTORY OF MOSQUITOES: EGG, LARVA AND PUPA

BEFORE commencing the study of mosquitoes it is as well that we should have some knowledge of how these creatures are classified in the animal kingdom, and by what means we can distinguish them from other animals. At the same time, we can acquire a rough working knowledge of how mosquitoes are divided up into their several families, tribes, groups, and so on.

The mosquito belongs to the class of animals called INSECTA, which are distinguished from all others by certain well-defined characteristics. Within this class certain groups of animals show common features. Each of these groups is called an ORDER. Mosquitoes belong to the order DIPTERA (flies), and their particular peculiarities are that they have one pair of membranous wings; that their mouth-parts are so constructed as to enable them to suck; and that during their existence they pass from an egg to a larval, then to a pupal, and then to an adult stage, or, in other words, exhibit complete metamorphosis.

Again, the order of Diptera is divided up into a large number of FAMILIES according to dissimilarities between certain of the creatures forming the order. The family that includes all mosquitoes is called the *Culicidæ* and it is characterized by its members all having long slender antennæ, consisting of never less than six portions or segments, having a definite arrangement of the veins on the wings, and carrying scales on their wings. This family is too large to treat as a whole, so it has to be divided up into lesser families called sub-families. One sub-family has long mouth-parts, often nearly as long as the body. They bite, and the veins on their wings carry scales. This sub-family is called the *Culicinæ* and in it are included all the mosquitoes with which we have to deal.

The *Culicinæ* are divided into four TRIBES—the *Culicini*, the *Anophelini*, the *Megalorhini* and the *Sabethini*. The *Megalorhini*, or Elephant mosquitoes, are large insects with long tapering mouth-parts bent downwards and backwards like a hook, and the *Sabethini* are forest-living mosquitoes which are regarded as harmless to man, but the *Anophelini* include all those which carry malaria, and the *Culicini* all those which carry filariasis, yellow fever, and dengue.

The last two tribes are once again divided up into GENERA. The *Anophelini* have only one genus, *Anopheles*; while the *Culicini* have at least two—the *Culex* and *Aedes*. The latter is usually spoken of as the genus *Stegomyia*.

Very fine characteristics common to groups within the genera finally cause them to be separated up into different species. These characteristics are always constant in the members of the same species. Take, for example, the genus *Anopheles*. There are some hundred and twenty different species recognized. In the same fashion there are numerous species of the genera *Culex* and *Aedes*, and among them attention must be paid to the *Culex fatigans*, which spreads the infection of filariasis, and to the *Aedes argenteus* (*Stegomya faxiata*), which transmits yellow fever. Dengue fever also is transmitted by the bites of *Aedes argenteus* and possibly of *Culex fatigans*.

With regard to the naming of a mosquito there are certain principles laid down. First of all, the name must be in Latin, and if the words used are not Latin they must be latinized. Secondly, there are always two parts to the name of a mosquito, the name of the genus followed by the name of the species. Thirdly, all names must be written in italics and the name of the genus begins with a capital, while the name of the species commences with a small letter. It is in this way that the names of the mosquitoes *Anopheles stephensi* and the *Culex fatigans* are arrived at. These are usually written shortly thus—*A. stephensi* and *C. fatigans.*

Having acquired some knowledge of the position occupied by mosquitoes in the animal kingdom, and of the names of the tribes and genera which are of immediate importance to us, we are now in a position to study in more detail their life-history and to bring out those details which are characteristic of the various genera.

The mosquito, before it emerges as the full-blown winged insect as we know it, passes through a complete metamorphosis. That is to say, it begins life as an ovum or egg. It then becomes a larva, and from that passes to the pupal or nymph stage, finally ending up as an adult mosquito, or, as it is technically called, the imago.

The Egg or Ovum (see Diagram).—The female mosquito lays its eggs on or very close to the surface of the water. These eggs hatch out into small wriggling animals called larvæ. The eggs when first laid are white in colour, but rapidly change to brown or black. If submerged in water or kept in a dry place, they do not hatch out. Mosquitoes of the genus *Culex*, before depositing their eggs collect them at first in the angle formed by the crossing of the hind-legs, and when several hundreds of eggs are thus collected they deposit them on the surface of water in the form of an egg-raft, which floats as a boat-shaped body raised at each extremity. Each egg-raft consists of about two hundred to four hundred eggs. These egg-rafts are easily distinguishable and once seen cannot be mistaken. *Anophelini* and some species of the genus *Aedes* lay their eggs separately on the water surface. They do not stick together and form an egg-raft, as in the case of the genus *Culex*. Eggs of the *Anophelini* float by means of an air-cell along the centre of each side of the egg, which is necessary to prevent them from being submerged and destroyed. These air-cells are absent in only two species of the genus *Anopheles*, viz. *A. turkhudi* and *A. azriki*. The eggs of the genus *Aedes* also are surrounded by small air chambers, while those of the genus *Culex* have no such arrangement.

The eggs of the *Anophelini* are difficult to detect in nature, as they are laid separately on the water surface and look like very minute specks of dust. With the aid of a hand-lens they may, however, be seen on the margins of small pools where larvæ are found. Owing to physical causes, these eggs sometimes form regular and beautiful patterns on the surface of the water. A typical egg is shaped like a boat and is about 0·7 to 1·00 mm. in length. One end of the egg is slightly fuller than the other, and it is towards this end that the

FIG. 1

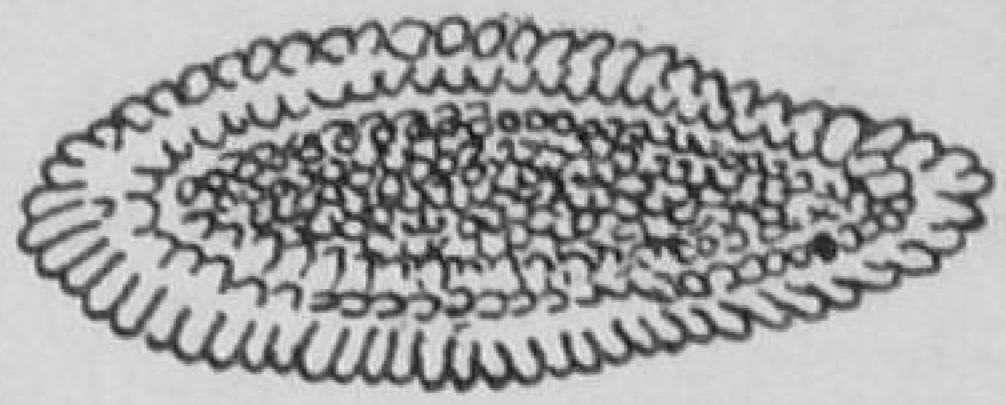


FIG. 2

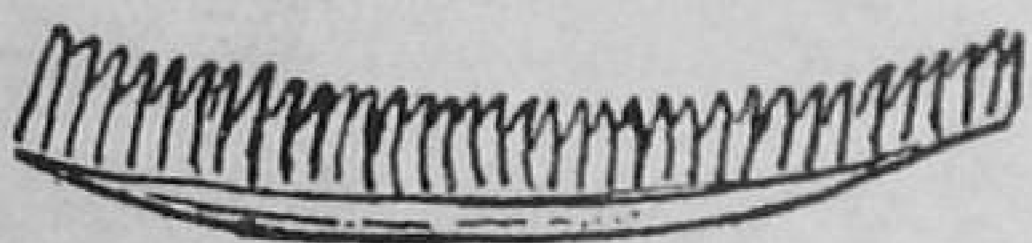


FIG. 3.

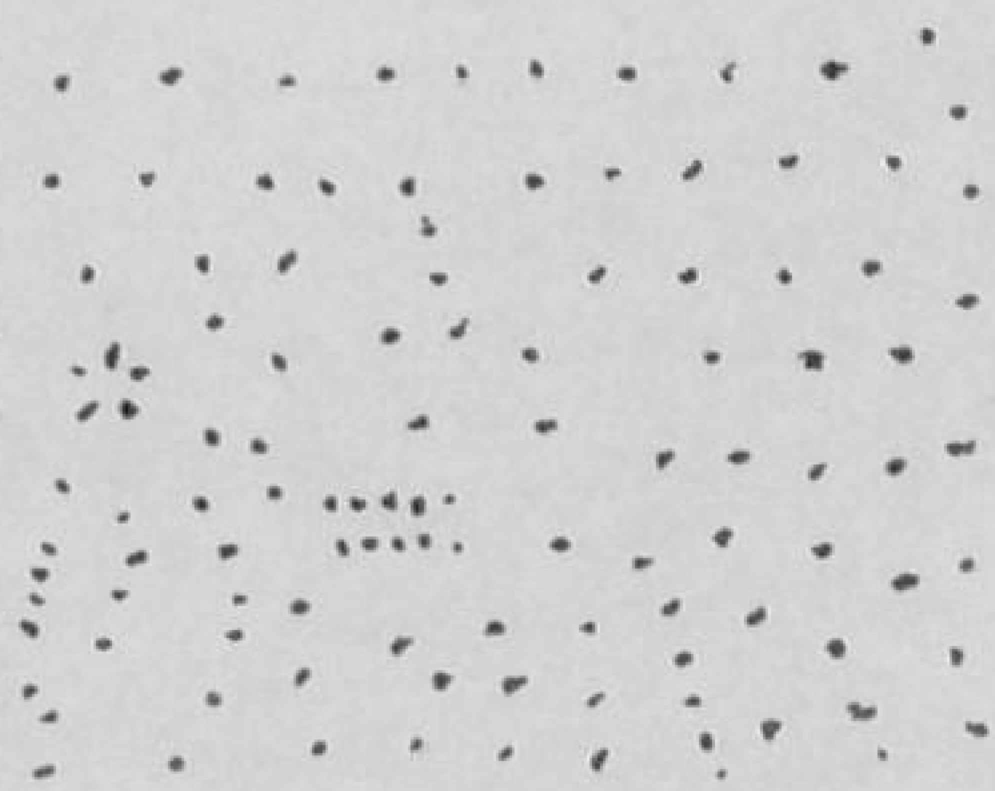


FIG. 4.

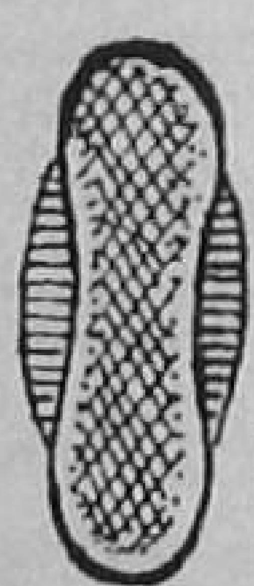


FIG. 5

FIG. 6

THE OVUM OR EGG

FIG. 1. Culex egg-rafts (natural size).

FIG. 2. Culex egg-raft (magnified).

FIG. 3. Lateral view of FIG. 2.

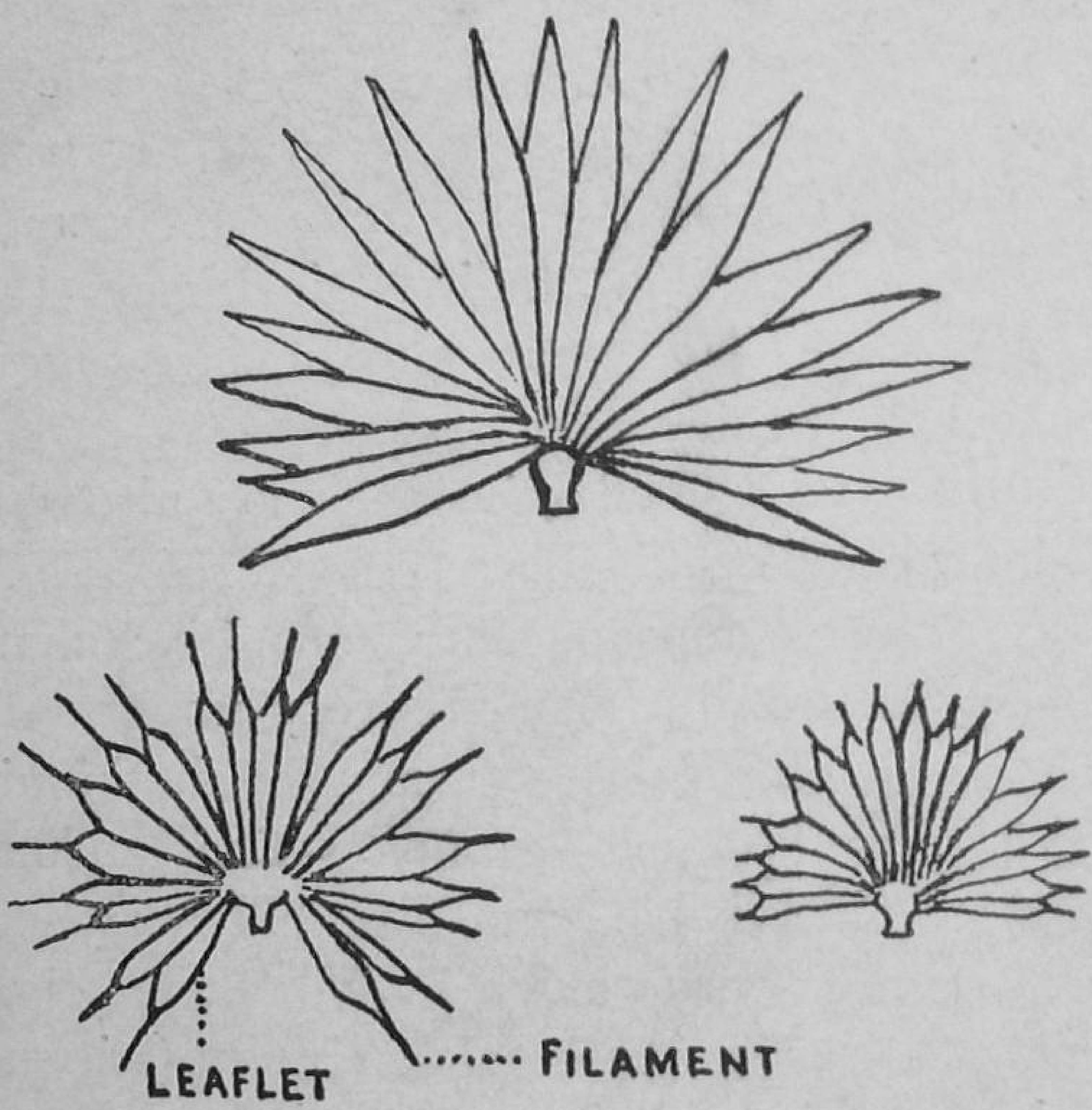
FIG. 4. Anopheles eggs (natural size).

FIG. 5. Anopheles egg (magnified).

FIG. 6. Patterns formed by Anopheles eggs.

head of the embryo is directed. The air-cells or floats, along the centre of each side of an egg, differ in shape and position in different species of *Anophelini*, and it is possible to some extent to distinguish between the eggs of some species of *Anophelini* by such characteristics. The egg or ovum stage usually lasts from two to four days, but may be a little less or a little more in different species, and at different temperatures, and then they hatch out into small wriggling animals called Larvæ.

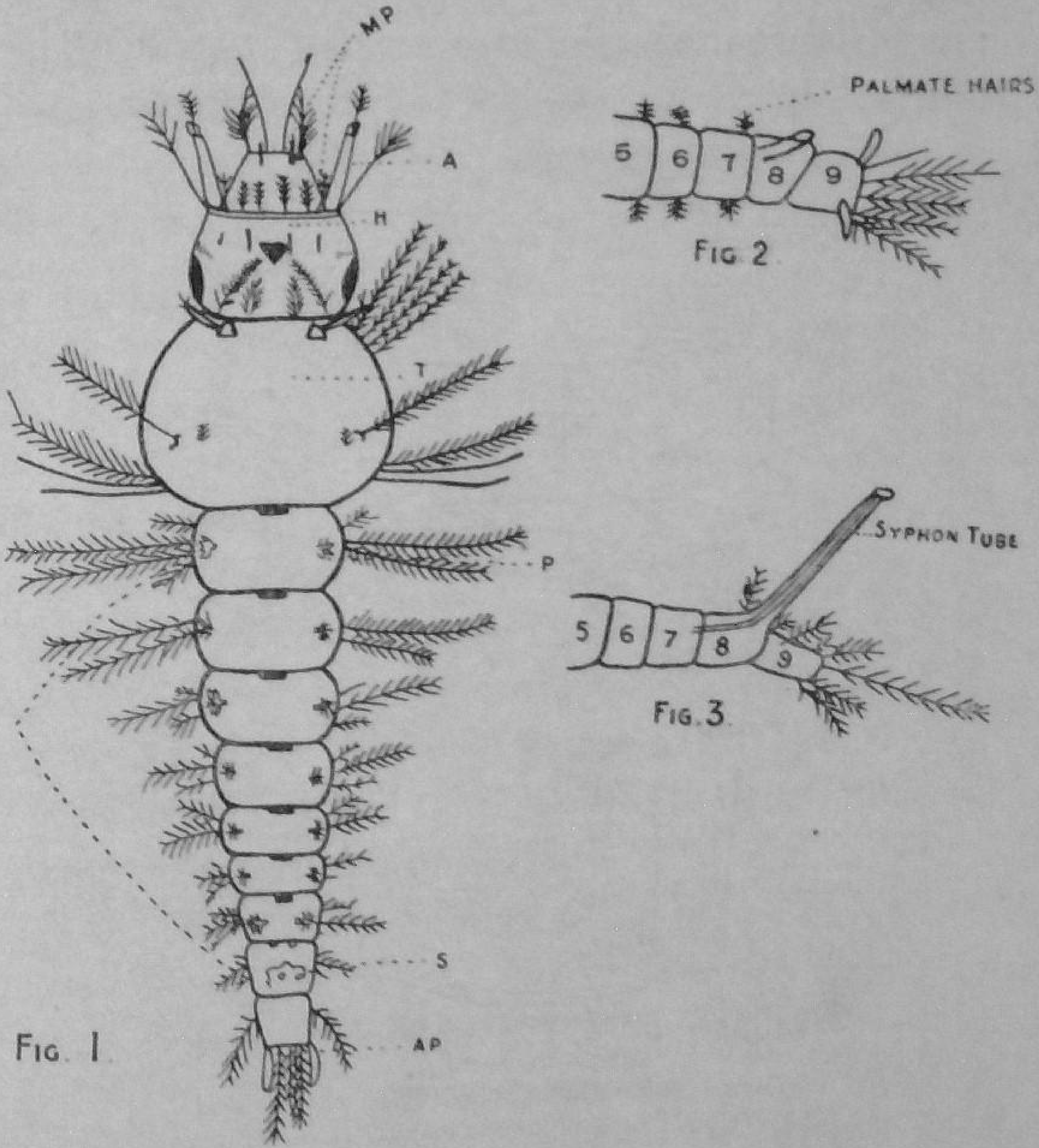
The Larva.—The larvæ of mosquitoes are well-known objects. They consist of a head, thorax or chest, and an abdomen. The characteristics of the abdomen are very important in that they give the readiest means of distinguishing between the main groups. The abdomen consists of nine visible segments. The first seven segments are very much alike. The eighth segment carries the external openings (stigmata) of the respiratory tubes, which serve to supply oxygen to the tissues of the larva. In all *Anophelini* the larval respiratory tubes open directly upon the upper surface of the eighth segment. The respiratory tubes of the larva of the genera *Culex* and *Aedes* do not open directly upon the eighth segment, but are prolonged from it into a projection which is known as the syphon tube. The absence of a syphon tube is characteristic of the larvæ of the *Anophelini*. The length and character of the syphon tube is of importance in distinguishing between the larvæ of the genera *Culex* and *Aedes*; it is short and thick



PALMATE HAIRS

Note the resemblance to the leaf of a cocoanut palm; note the leaflets and their termination into filaments, which varies in different species but is the same in the same species.

in the larvæ of the genus *Aedes*, while it is long and thin in those of the genus *Culex*. The ninth abdominal segment carries the anal opening, around which is arranged four large papillæ, called the anal papillæ, which are well supplied with air



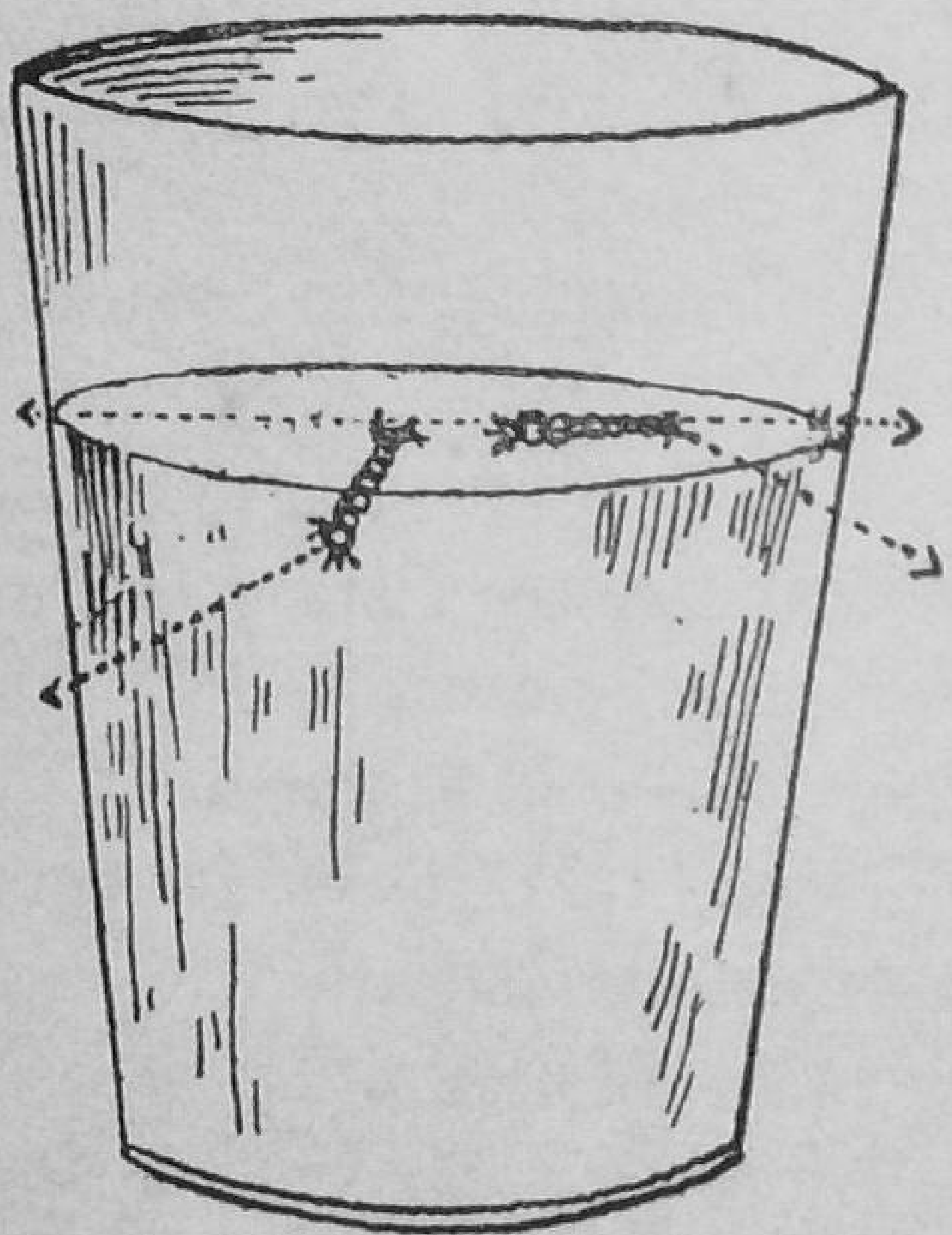
THE LARVA

Fig. 1. General appearance of an Anopheline larva: H, head; A, antennæ; T, thorax; P, palmate hairs; AB, abdomen; S, stigmata; AP, anal papillæ; MP, mouth-parts.

Fig. 2. Tail of an Anopheline larva showing abdominal Segments 5 to 9; note the presence of palmate hairs, and the absence of a syphon tube on Segment 8, and compare it with next figure.

Fig. 3. Note the absence of palmate hairs and presence of a syphon tube on Segment 8 in Culex larva.

tubes and long curved hairs. The most important appendages of the abdomen of Anopheline larvæ are certain fan-shaped structures called 'palmate hairs'. Each of these hairs is attached by a short stalk to the outer dorsal portion of some of the segments. To the apex of the stalk is joined a



Showing the position of Culex and Anopheline larvæ at the surface of water; note the slanting position of *Culex* and the horizontal position of the *Anopheles*.

number of leaflets which, when spread out, look like the leaf of a cocoanut palm. These palmate hairs are not present on the larvæ of any kind of mosquito other than those of the *Anophelini*. Owing to the presence of palmate hairs, and to the absence of a syphon tube, the larvæ of *Anophelini* float in the water just beneath and parallel to the surface film. Owing to the presence of a syphon tube and the absence of palmate hairs, the larvæ of other kinds of mosquitoes float below the surface film and at an angle to it.

The Head.—The head consists anteriorly of the rather complicated mouth-parts. The eyes are situated laterally, and in front of each eye is an eminence from which arises a prominent lateral protrusion called the Antenna. Each antenna is a rod-shaped, unjointed, structure. The antennæ as well as the head possess certain hairs which are of use in distinguishing between different genera and species. At the back there is an opening into which the neck is inserted. The upper surface of the head is largely occupied by a chitinous plate called the Clypeus.

The Thorax.—The thorax or chest in full-grown larvæ is broader than the head or any of the abdominal segments. It also possesses a number of branched hairs, and in some species there is a single pair of well-developed palmate hairs similar to those found on the abdominal segments. The presence of these palmate hairs on the thorax is of use in identifying certain species of larvæ.

The following points should be carefully noted in order that the genera *Anopheles*, *Culex* and *Aedes* may be readily distinguished.

Larvae of the *Anophelini.*—When hatched out these larvæ are minute creatures with black heads and transparent bodies. They change their position at the surface of the water by jerking or darting movements, and when floating in the water they take up a horizontal position. They possess palmate hairs and the respiratory tubes open directly on the surface of the eighth abdominal segment and, consequently, they have no syphon tube. The antennæ terminate in two leaf-shaped bodies, between which a branched hair arises. In most species of *Anophelini* a single unbranched hair arises at the junction of the proximal and middle thirds of the antennæ.

Larvae of the Genus *Culex.*—These larvæ form an angle with the surface film of the water and assume a hanging attitude. The degree of this angle varies in different species ; for instance, the *Culex concolor* assumes a very acute angle and lies nearly parallel to the surface film. These larvæ have a long thin syphon tube, but have no palmate hairs. They have a large branched hair projecting from the side of the antennæ.

Larvae of the Genus *Aedes.*—These larvæ are long and worm-like, and have a wriggling mode of progression through the water. Their syphon tube is short and thick, and when hanging from the surface film of water they assume an almost vertical position. They have no palmate hairs. Compared with the rest of the body the head is small, and it is not easy to say where the thorax ends and the abdomen begins. They have short inconspicuous hairs, sometimes as many as three, projecting from the sides of the antennæ.

The larval stage usually lasts from eight to twelve days in the tropics, and this is determined by at least two factors, viz. temperature and food. In colder climates it lasts much longer. Larvæ living under natural conditions in collections of water grow much more quickly than those kept in the laboratory in dishes of tap water.

Larvæ are free swimming animals, eat voraciously and grow rapidly. During the process of their growth they cast their skins several times until they reach their final development. At this stage they become much quieter, and are very easily killed by merely agitating the water in which they are found. The change from the larval to the pupal stage is sudden. With a few rapid motions the larval-skin is cast off and the worm-like larva assumes a characteristic comma shape, and becomes the pupa or nympha (see Diagram).

Certain larvæ of other insects may be mistaken for mosquito larvæ because they bear a superficial resemblance to them. There are, for instance, larvæ of certain flies called Chironomus, Ephemera, Dixa and Corethra. They can, however, be easily distinguished from mosquito larvæ by certain peculiar characteristics of their own.

Chironomus larvæ are commonly known as blood-worms. They are bright-red, worm-like creatures, often found in large numbers when the mud at the bottom of a small pool is stirred up. In general appearance they bear no resemblance to mosquito larvæ.

Ephemera larvæ may at first glance be mistaken for mosquito larvæ, but there is no real likeness. Their air tubes do not open externally and they obtain the necessary oxygen from the water by means of gills, the presence of which renders them easily recognizable. Also the tail end of Ephemera larvæ terminates in a tri-radiate manner, which marks them off distinctly from mosquito larvæ. These Ephemeridæ are commonly known as May-flies.

Dixa larvæ rather closely resemble *Anophelini*, though not other mosquito larvæ. They move along the surface of water like Anopheline larvæ, and they also rest horizontally just beneath the surface film. But in Dixa there is no globular thorax; all the segments are almost equal in size and the whole larva is longer and thinner than the mosquito larvæ. They have no palmate hairs, possess four legs by which they climb up the sides of the vessel in which they are kept, and are in the habit of resting in a loop with the head and tail downwards. These characteristics should prevent any difficulty in distinguishing these from Anopheline larvæ.

Corethra larvæ are very transparent and are for this reason known as 'Phantom-larvæ'. They have an exceedingly small head and possess no respiratory syphon. There is a swimming fan on the last segment, and they lie horizontally rather deep in the water.

The Pupa or Nymph.—The pupæ of mosquitoes are characteristic creatures, comma-shaped in appearance, with a large globular body and a small tail. The globular body includes the head and thorax. The tail includes the abdominal segments. When disturbed they dart downwards with great speed, but soon reappear on the surface. They sink in the water by making violent exertions with the tail, and once the movements of the tail cease, the buoyant pupa floats up to the surface. Just before the hatching of the mosquito, the pupa becomes less inclined for active movement, and the tail may be extended horizontally. Then a crack appears in the chitin[1] of the back of the thorax, and the adult insect emerges through this crack and sits for a while on the empty pupa case, drying its wings, and then flies away as the full-blown mosquito.

[1] Chitin is a hard impermeable substance, forming the covering membrane.

In order to differentiate between the genera *Anopheles*, *Culex* and *Aedes* in the pupal stage, great attention must be paid to difference between the syphons of these genera. In

FIG. 1.

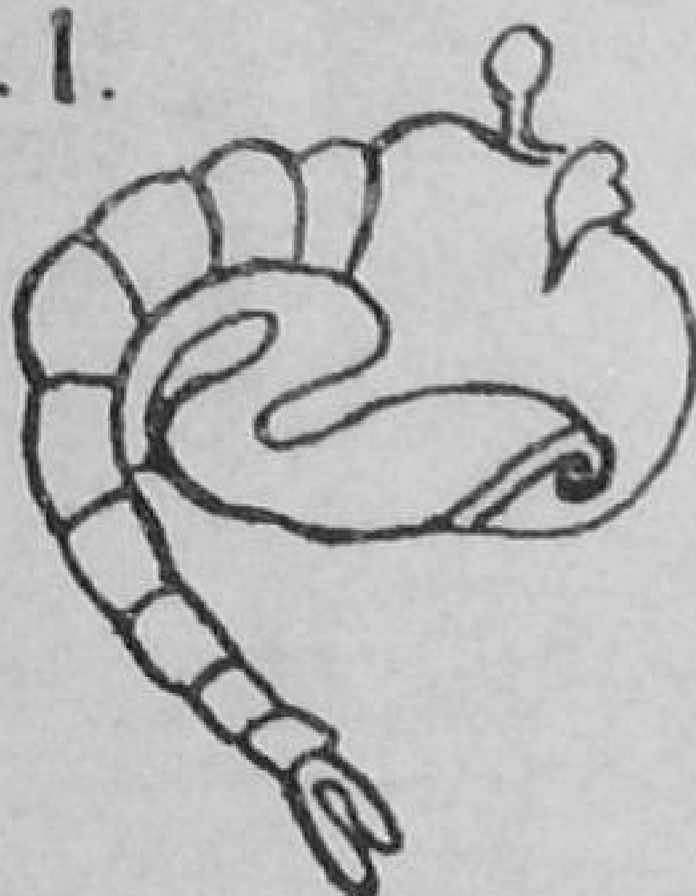


FIG. 2.

FIG. 3.

FIG. 4.

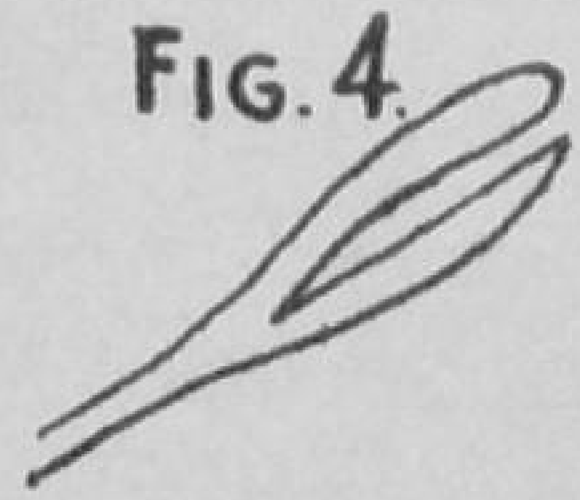
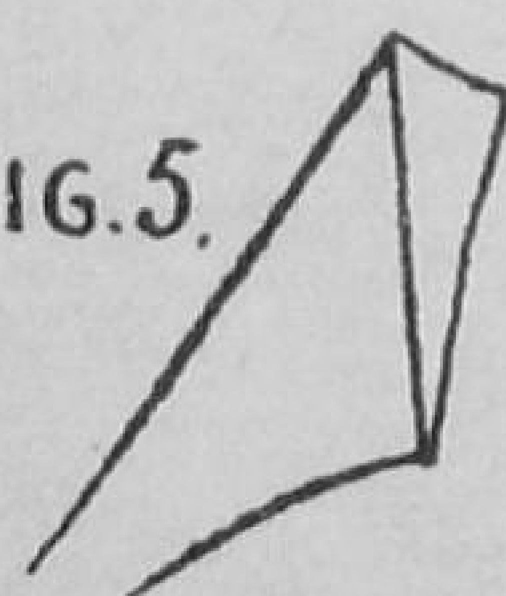


FIG. 5.



THE PUPA

FIG. 1. Pupa of *Anophelini*.
FIG. 2. Pupa of *Culex*.
FIG. 3. Syphon tube of *Anophelini*.
FIG. 4. Syphon tube of *Culex*.
FIG. 5. Syphon tube of *Aedes*.

the genus *Anopheles* they are stumpy, and proportionately much shorter than in the genus *Culex*. They have a square truncated end, and project from the middle of the thorax, while in the *Culex* the syphons are long and slender, have an oblique opening, and project from the posterior portion of the thorax. In the genus *Aedes*, on the other hand, the syphons are triangular and broad, and hence are very characteristic. The pupæ of the *Anophelini* lie less vertically in the water, and are longer and narrower than those of the genera *Culex* or *Aedes*.

In the tropics the nymphal stage lasts about forty-eight hours.

CHAPTER III

THE ADULT MOSQUITO OR IMAGO[1]

THE Imago is the winged insect well known to those living in the tropics. As in all other insects, the body of a mosquito consists of three distinct regions — the head, the thorax and abdomen.

The Head carries the sensory and suctorial organs. It is more or less globular in shape, and is attached to the thorax by a narrow neck. The upper surface of the head is mainly occupied by the two large compound eyes. The portion of the head which lies between the eyes is called the vertex, while the frons is that part which lies in front of the vertex. Immediately behind the eyes lies the occiput, while the nape is the portion behind the occiput at the extreme back of the head. The prolongation of the frons anteriorly is spoken of as the clypeus. Immediately in front of the eyes, on either side, arise the antennæ. These are long jointed structures provided with hairs, and consist of fourteen visible segments. Beneath the clypeus arises the proboscis. The proboscis is a collective term given to the highly specialised mouth-parts, which consist of the upper

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[1] See *Frontispiece*.

lip, the lower lip, the tongue, two mandibles, two maxillæ and two maxillary palpi. The lower lip or labium is a grooved structure enclosing the other mouth-parts, and forms the thick scaly proboscis as usually seen. The two maxillary palpi lie on either side of the proboscis, and are of generic and specific importance. Each palp commonly consists of four segments.

The Thorax carries the locomotory appendages, in the form of one pair of wings and three pairs of legs. The anterior portion of the thorax is a collar-like piece of chitin and is called the prothorax, while the middle portion is called the mesothorax, and forms the large globular mass of the thorax. Behind the mesothorax a prominent ridge, called the scutellum, runs between the bases of the wings. Behind the scutellum a horseshoe-shaped area, called the post-scutellum, can be readily distinguished. The scutellum and post-scutellum are of importance in the classification of mosquitoes.

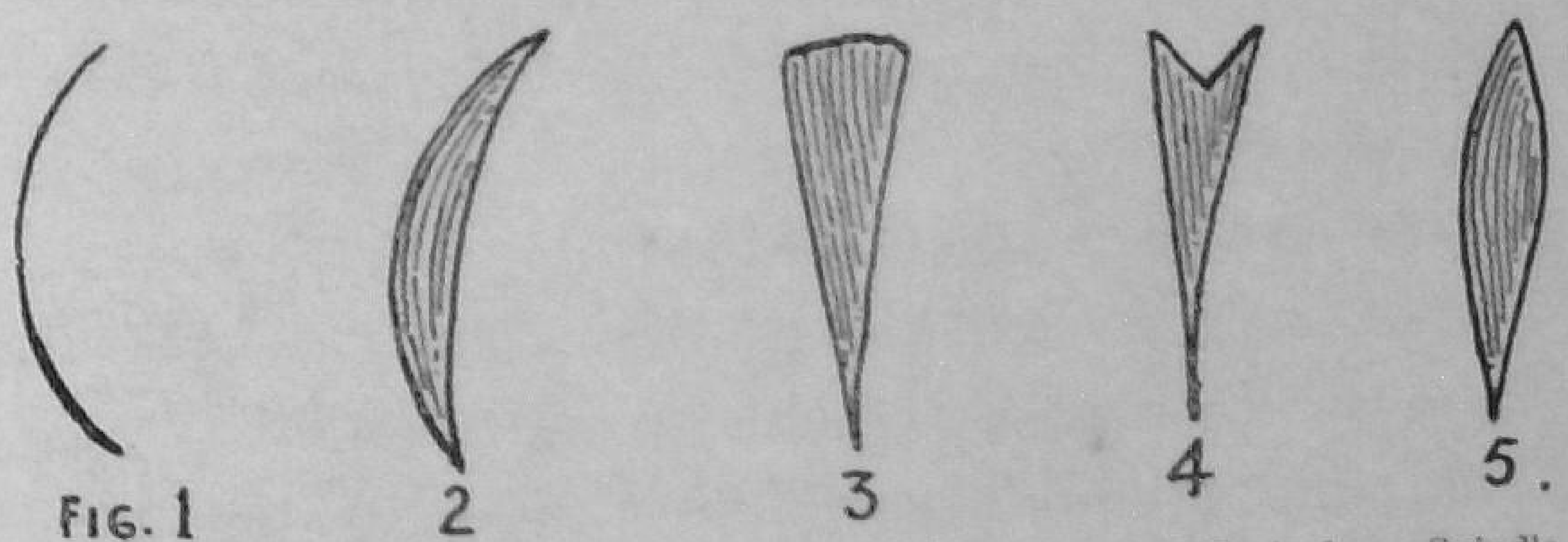
The wings of mosquitoes are long, with an anterior straight border called the Costa, which in *Anophelini* is usually covered with white and black scales forming the spotted margin. There is also a posterior curved border, fringed with long scales, forming the 'wing fringe'. In *Anophelini* this has also light and dark portions, the extent and position of which are made use of in the identification of species. The wings are mapped out with veins covered with scales. There is a costal vein forming the wing margin, and six longitudinal veins running from the base to the apex of the wing. These are named vein 1, vein 2, vein 3, vein 4, vein 5 and vein 6. Veins 1, 3 and 6 do not branch; veins 2, 4 and 5 each divide into an anterior and posterior branch, which are named vein 2.1 and 2.2, vein 4.1 and 4.2, and vein 5.1 and 5.2, respectively. Joining these longitudinal veins one with another are certain transverse or cross veins. There are six such cross veins:

1. The sub-costal vein arises near the origin of vein 1, and joins the costal vein.
2. One cross vein joins vein 1 to the sub-costal vein.
3. One cross vein joins vein 1 to vein 2.
4. One cross vein joins vein 2 to vein 3.
5. One cross vein joins vein 3 to vein 4.
6. One cross vein joins vein 4 to vein 5.1.

The areas enclosed by the anterior and posterior branches of veins 2 and 4 are termed Fork-cells. The mosquitoes are the only members of the order Diptera (flies) that have scales on their wings and bodies. The shape and character of the various scales are made use of by entomologists in the classification and identification of genera and species.

It will be of use to have a general idea of the different kinds of scales in mosquitoes. They are usually described as narrow curved, upright forked, flat, spindle, and hairlike curved (see diagram).

There are six legs, an anterior, middle and posterior on each side. These are attached to the under-surface of the thorax. Each leg consists of a number of segments jointed together



Hairlike Curved. Narrow Curved. Flat. Upright Forked. Spindle.

VARIETIES OF SCALES

and they occur in the following order from above downwards. The Coxa and Trochanter are small segments at the origin of the legs, and they lie close up against the under-surface of the thorax. This is followed by two large segments, the Femur and Tibia. Next comes a group of five small segments, called the Tarsus. The last segment carries a claw.

The Abdomen consists of nine visible segments. The last segment carries the anus and genital organs.

The male adult mosquito can be readily distinguished from the female by observing, with the aid of a hand-lens, that, whereas the male antennæ are markedly feathery or plumose, the female have only short lateral hairs, and, whereas the male palpi are long and hairy, the female are much less conspicuous. Another difference lies in the fact that the female feeds on blood, whereas the male prefers to suck vegetable juices.

There are some members of the order Diptera (flies) which may be mistaken for mosquitoes. Mention will be made of the chief ones, which can be distinguished by noting a few characteristics of each. First there are the *Chironomides* (Midges), which do not possess the characteristic proboscis of mosquitoes. Their legs are long and slender and the veins of their wings do not have scales. Then there are the *Tipulidæ* (Daddy-long-legs), which have no distinct proboscis and possess long slender legs; the *Simulidæ* (Sand-flies), which are tiny insects with a short, stout proboscis; and, lastly, *Rhyphus fenestralis*, a fly often seen on windows, which may be mistaken for *Anophelini*, as its wings are spotted, but there are no scales on the wings and the second longitudinal vein is not forked.

In the identification of mosquitoes it is necessary, in the first instance, to observe whether the insect under consideration belongs to the order

Diptera (flies). This is determined by observing whether the mouth-parts are constructed for biting or sucking, and whether they have one pair of membranous wings. Once it is decided that the specimen belongs to that order, the possession of scales on the wings and body and the characteristic wing venation will place it in the family *Culicidæ*, while the sub-family *Culicinæ* will be chosen if the specimen carries scales on the veins of the wings and if the mouth-parts are made for biting. If the specimen is a *Culicinæ* it is necessary still further to determine its correct tribe, whether it be *Anophelini* or *Culicini*. It will be sufficient for our purpose if we observe the distinguishing features between these two tribes, it being understood that, should the specimen not fulfil these conditions, it probably comes under the heading of some other tribe.

It is essential in distinguishing the *Anophelini* from the *Culicini* to observe the wings. As a rule those of the former are spotted, while the latter are not. These spots are caused by areas of white and dark scales on the veins, and always occur with *Anophelini* except in certain species, three of which are found in India and must be carefully noted. They are *A. aitkenii*, *A. barianensis* and *A. culiciformis*. Whereas nearly all the species of the *Culicini* have uniform dark wings, the *C. mimeticus* has costal spots. As a rough guide this differentiation is exceedingly valuable. Again, the proboscis of the *Anophelini* continues in a straight line with the body, while in the *Culicini* it forms a distinct angle. This accounts for that characteristic attitude adopted by these tribes when resting on the wall. The body of the resting *Anophelini* forms a distinct angle with the wall, whereas the *Culicini* appear either parallel to it or have a 'hunchbacked' appearance. There is, however, an exception, as the *A. culicifacies*, a common mosquito in India, holds its body horizontally, as do members of the *Culicini*. Again, the palpi are long in both the male and female *Anophelini*, whereas they are long in the male but very short in the female *Culicini*. The most accurate and scientific distinction between these two tribes lies in the fact that the scutellum of the *Culicini* is trilobed, whereas the scutellum of the *Anophelini* is simple and never trilobed. This observation, however, is not easy to make with any degree of accuracy with a hand-lens, and requires repeated and constant practice to become expert, but with a microscope this difference can readily be seen.

As there is only one universally recognized genus of the tribe *Anophelini*, once a mosquito is placed in that tribe it naturally becomes classed in the genus *Anopheles*. There are, however, at least two genera of the *Culicini*, the genus *Culex* and the genus *Aedes*, which must be distinguished.

Mosquitoes of the genus *Aedes* are popularly known as 'tiger mosquitoes' on account of the prominent alternating white and dark stripe-like areas seen on the abdomen and legs of some species of this genus. Unlike other mosquitoes, they can be seen feeding during the day; but

FIG 1

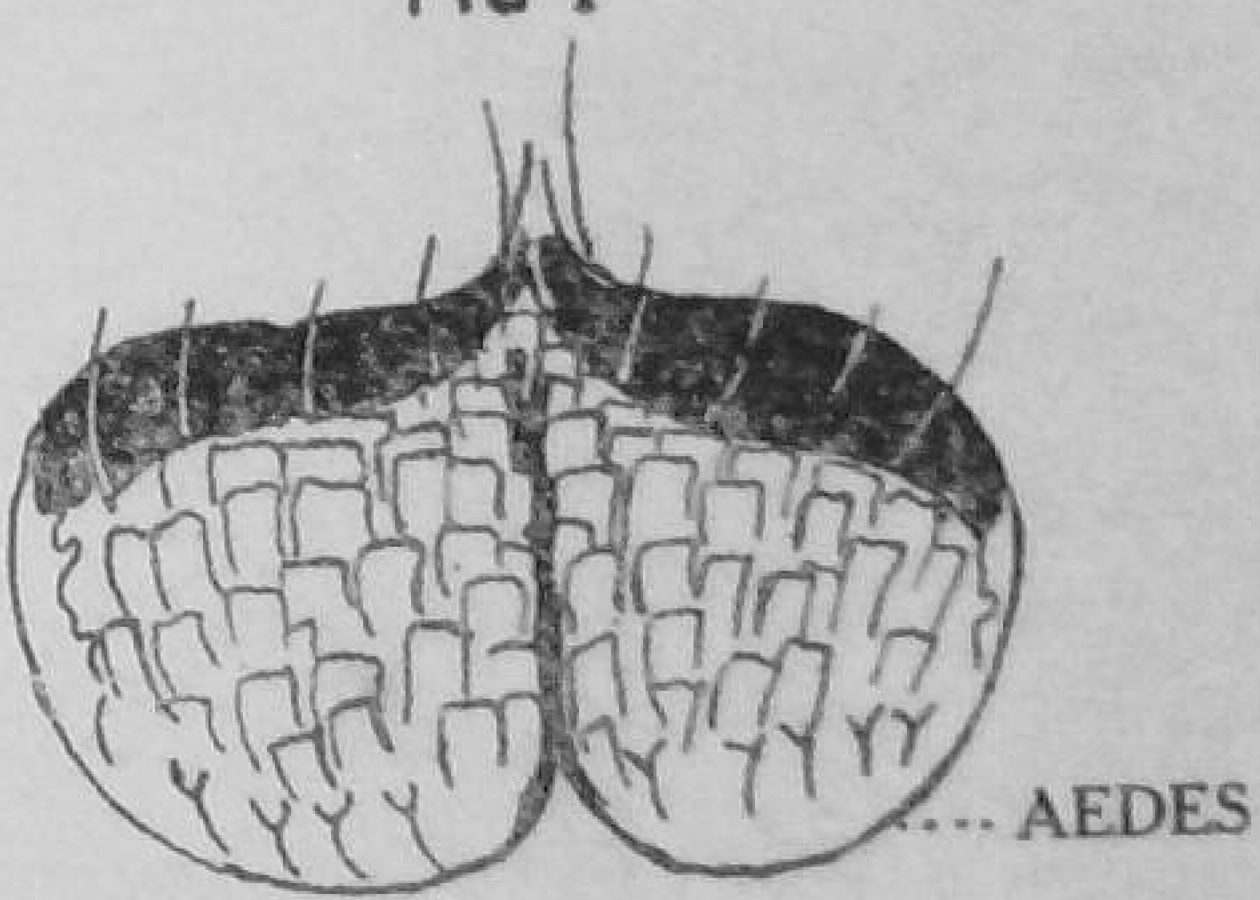


FIG 2

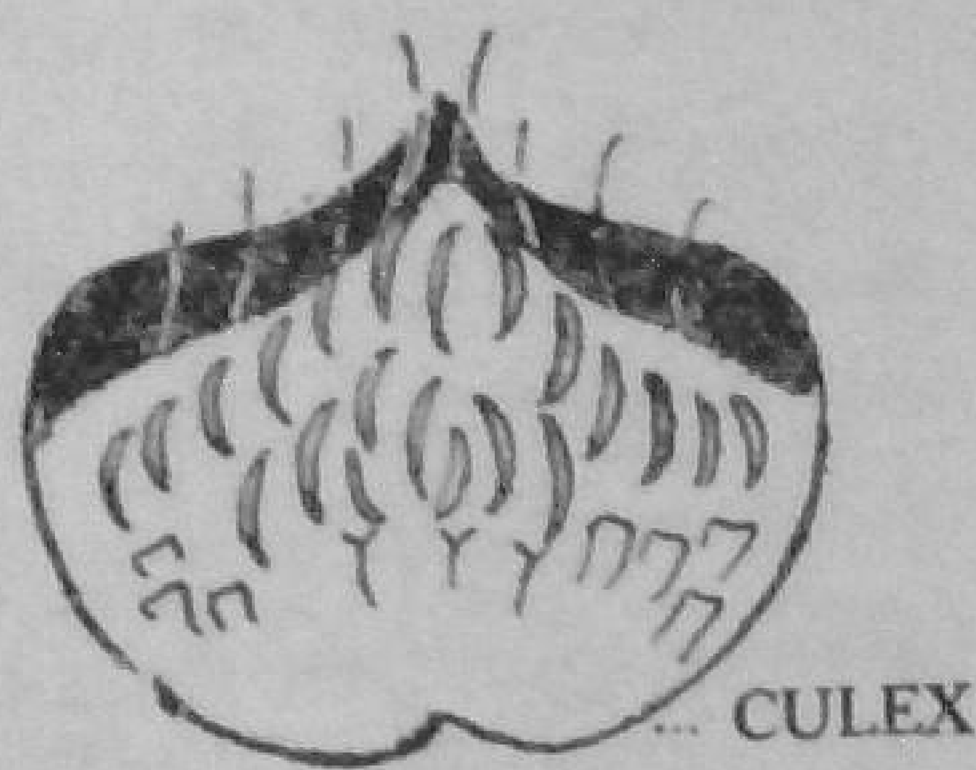


FIG. 1. HEAD SCALES OF *AEDES*

Note the absence of narrow curved scales. They are all flat scales with a few upright forked ones.

FIG 2. HEAD SCALES OF *CULEX*

Flat scales are very few and only at the sides. They are mostly narrow curved scales and some upright forked ones.

these features can by no means be relied upon as an accurate and scientific means of distinction. Although these two mosquitoes are obviously distinct, yet many mosquitoes which at first sight appear to be identical are often found to be quite different on examining their scales. The head scales in the genera *Culex* and *Aedes* are quite different, and are of importance in the identification of these two genera (*vide* plate).

All mosquitoes of the genus *Culex* have on the head mostly narrow curved and upright forked scales, but only a few flat scales laterally; whereas all mosquitoes of the genus *Aedes* have on the head practically all flat scales with only a few upright forked, and no narrow curved scales at all. Further, the clypeus in the genus *Aedes* is scaly, while in the genus *Culex* it is hairy. These differences can only be made out with the aid of a microscope.

Having now determined the exact genus to which a mosquito belongs, it is necessary to proceed to the final step of the identification of the species. As, so far, only *Anophelini* have been incriminated in the transmission of malaria, it will, therefore, only be necessary in this book to deal with that genus. The most important distinguishing features are the following, and one should get thoroughly acquainted with what they are, and where to look for them, so that deviations can be easily detected, and the species therefore identified. Each inspector should, by practical experience, make himself thoroughly familiar with the use of the hand-lens before he can hope to become expert at distinguishing these minute characters.

The Costal Spots.—On examining the wings of *Anophelini*, dark and white areas are usually observed along the costal vein, the sub-costal vein and vein 1. These areas are formed in the former case by dark scales and in the latter case by white scales, and are known as Costal Spots. They are fairly constant in each species, and the number and extent are of considerable importance in the determination of species.

The Palpal Bands.—Here again patches of white scales, occurring at the junction of the palpal segments, give the appearance of white bands. They are called palpal bands. These are also fairly constant in each species. The presence of such bands, their number and extent, are all made use of in the determination of species. In *A. barbirostris*, for instance, there are no white bands, the whole palp being dark-scaled. In *A. kochi* there are five white bands; in *A. hyrcanus* there are four white bands; and in *A. culicifacies* there are three white bands; so that each individual species has invariably got definitely marked palpi.

The Wing Fringe.—At the points of junction of veins 1 to 6 with the costal vein, which passes right round the wing, sometimes light areas occur, due to the presence of white scales. These light areas are called pale fringe spots.

Such pale fringe spots differ in different species, but are fairly constant in the same species. In *A. culicifacies*, for instance, there are not more than two pale fringe spots, while in the *A. listoni* there are six of them.

The Wing Veins.—Here again the presence of dark and white scales on the wing veins causes definite dark and light areas in the wing-field, which are fairly constant in the same species. In *A. culicifacies*, for instance, vein 3 is almost entirely dark except for a small white area at its commencement, whereas in *A. stephensi* the third vein is almost entirely white except for two small dark areas, one near its commencement and the other near its termination.

The Legs.—Banding of the legs, like those of the palpi, is also of specific importance. It must be noted whether banding is present in each segment, and, if so, whether it is apical, basal or both; whether any segments are completely white, and so on. In *A. subpictus*, for instance, the front tarsal segments are distinctly and broadly banded. In *A. theobaldi* the last two hind tarsal segments are completely white, while in *A. culicifacies* none of the tarsal segments is white.

Speckling.—This is a condition which in some species is present on the legs or on the palpi, or on both. When such a condition exists, the palpi or legs look as if they are distinctly marked with white and dark spots; the best way to get familiar with this condition is actually to look at a specimen with speckled legs or palpi, and, when once seen, it cannot be mistaken. *A. stephensi*, for instance, has speckling on the legs and palpi. *A. theobaldi* has only speckled legs, while *A. subpictus* has neither speckled legs nor palpi.

All these conditions could invariably be made out by means of a hand-lens (10 to 20 times magnification) and with a little practice the identification of species with the aid of a synoptic table is a simple procedure in the large majority of cases. Such synoptic tables have been published by different authors, and as an appendix will be found the synoptic table issued by the Central Malarial Bureau, Kasauli, 1926.

CHAPTER IV

THE HABITS OF MOSQUITOES

BEFORE entering any given district for the purpose of taking anti-mosquito measures, the squad, with its inspector at its head, will have been made acquainted with the types of mosquitoes that they are likely to encounter. This gives the key to the solution of the problem which faces them as to where they are to look, not only to encounter mosquitoes, but to discover where they are breeding. This information is received from what is known as a survey of the district, and is generally undertaken by expert entomologists and their trained assistants. A catch is made of all mosquitoes that can be found in the district, and also any larvæ discovered are carefully preserved. These catches are made throughout a whole year, and months which show a large increase in numbers are noted. The mosquitoes are classified and preserved under their several names, and large numbers are dissected to discover in what proportion the various mosquitoes carry malaria in nature. As a result of this information, a plan of campaign is put forward which will aim at the elimination of the breeding places of such mosquitoes; for if mosquitoes are not allowed to propagate, they will be gradually eliminated.

Armed, then, with a complete list of the various kinds of mosquitoes, the inspector will be put well on the way to discover their whereabouts, because experience has taught us many of the ways in which the various species live and propagate.

It is common knowledge that marshes breed mosquitoes, and operations on a large scale have been undertaken at great financial outlay to drain them, but sometimes without any diminution in the amount of malaria in the surrounding country. In some of these cases it was not until more careful observations had been made of the habits of the mosquitoes carrying malaria that the channels themselves, built to drain the marshes, were found to be the offenders, as they harboured the larvæ of a mosquito which bred in running water. Thus the object of the undertaking was not fulfilled through lack of a thorough knowledge of the habits of the various species of mosquitoes in that district.

We approach the subject of the habits of mosquitoes first of all from a general aspect. These insects, whose persistent annoyance is the source of much inconvenience and distraction to all who have lived in areas where they abound, usually pester their victims in the night, and one of two courses, both very apt to prove a false security, is available as a protection during sleeping hours. Either the individual must cover himself with a foul-smelling oil, which, although repugnant to the none too refined tastes of the mosquito, is much more repugnant to the unfortunate person trying to get a night's repose; or he must sleep under a mosquito net, which will, by the closeness of its meshes, keep out the cool, gentle night breezes, so refreshing on a hot, tropical night, and much of the current of air caused by an electric fan. Unless the utmost care is exercised that the net is properly used and kept in repair, he will awake in the morning, after a hot restless night, to find sitting in one corner of the net two or three of these pests, gorged with his own blood, too sleepy to fly away from the consequences of the savage wrath they engender in the breast of their victims. Far better it would be to sleep without a net in a bungalow not hampered by mosquito proofing, and awake refreshed from a sleep in the open air in the cool breezes, untroubled by the attacks of these winged pests.

Generally speaking, we divide the mosquitoes into two great bands. We have those which inhabit the vicinity of houses, stables, cattle sheds, and so on. They live and breed in and around them, and their life is lived in a very circumscribed area. These we may call 'Household' mosquitoes. Then we have those which live in the surrounding marshes, rivers, and streams, and fly to houses for protection from the heat of the day and for the purpose of sucking the blood of mammalia — these we may call 'Country' mosquitoes. Although it is not arbitrary, these two classes may roughly be said to include, in the former, the *Culicini* and a few *Anophelini*, and in the latter, most of the *Anophelini* and some *Culicini*.

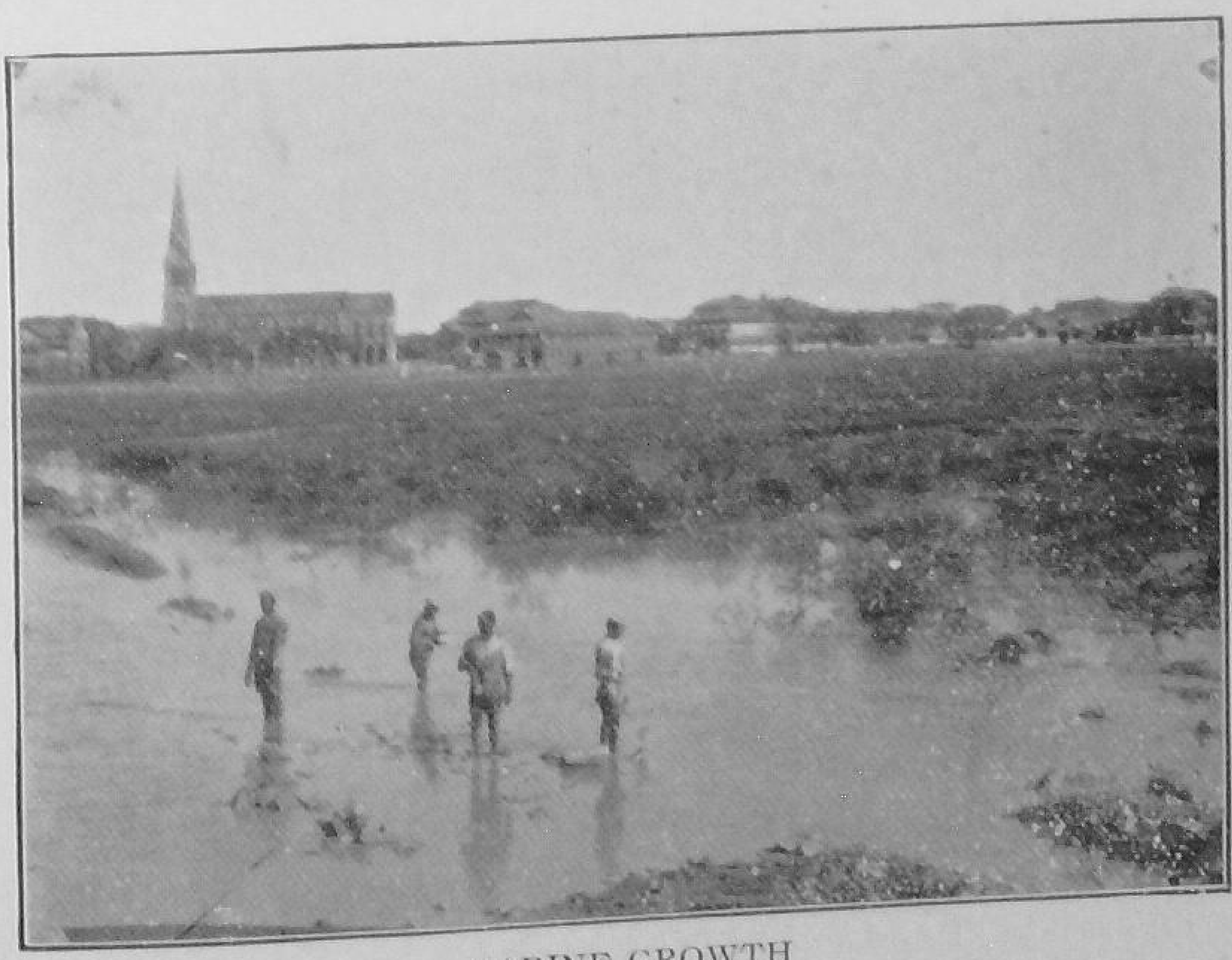
Again, it is not all mosquitoes which will bite human beings—only the females. The female will feed upon mammalia after she has become fecundated, as it is generally understood that blood is necessary to her for the true development of her ova. It is generally accepted that males never suck blood. The adult male remains, more or less, in the vicinity of the breeding place, and meets his mate after she has hatched from the pupal stage or has arrived and laid her eggs. Mosquitoes as a rule have many sources of food supply. Fruit and vegetables of various kinds, especially if they be over-ripe, and mammalian blood are their usual diet. The female will not select a spot for laying her eggs where there will be no food for her offspring. Thus dirty water, gully-traps and cesspools are popular breeding places of the *Culicini*; while clean water, marsh or ponds with vegetation, are frequented by the

Anophelini. Of course, when driven to it, they may deposit their eggs, and larvæ may hatch out, in water where no suitable food appears to be, but for preference the other more suitable sites are selected.

During the heat of the day mosquitoes will seek out sheltered spots to escape from the sun, which they do not like. Thus they are found reposing in the shade amongst long grass or under the leaves of trees, and it is this phenomenon which has given rise to the erroneous impression that long grass and undergrowth necessarily breed mosquitoes, and drastic operations have been undertaken to rid occupied areas of them, often rendering pleasant and beautiful districts desolate. Mosquitoes breed in receptacles concealed in grass and undergrowth, and in the hollows of trees where water can accumulate after rain. If these are properly dealt with, as will be mentioned later, it will be unnecessary to spoil beautiful gardens, and remove the benefits of shade by the destruction of trees. During the day mosquitoes may also be discovered hiding in houses from the heat and sun, especially in dark corners, cupboards, presses and among clothes hanging up. They are not generally found in the vicinity of cooking ranges, but *Anophelini* have often been found reposing on cobwebs looking like tiny little bits of dirt hanging downwards.

THE SEA SHORE AT COLABA, BOMBAY

A favourite breeding spot for the *A. stephensi*. The illustration shows the sea front being filled up with mud from a dredger two miles away.



MARINE GROWTH

A favourite breeding ground for *Anophelini*.

As evening approaches and the day cools they come out of their hiding places and feed, and in most species the female then seeks out warm-blooded animals. After having fed on them, and being ready to lay her eggs, she proceeds to the breeding water and lays them on its surface. There she finds the male awaiting her and once more she mates with him, and the whole process is repeated. It must always be remembered that if a number of male mosquitoes are discovered in any one locality, it is an indication that there are mosquitoes breeding nearby. Having grasped these few points, we will now pass on to consider the haunts of the various genera of mosquitoes.

The *Culicini* select breeding places which provide food for their young. For this purpose cesspools, gully-traps and collections of dirty water in and around houses, stables and cow-sheds are their favourite haunts, and here they are also near their mammalian food supplies. Except for the genus *Aedes*, which are day feeders, they mostly feed at night. During the day they hide themselves in cool corners, cupboards, amongst clothing, and so on, in order that they may escape the heat and glare of the tropical sun. As evening approaches, they come out to feed and they become annoying till dawn, when once more they seek shelter from the oncoming heat. The adults are most easily caught during the daytime if diligent search be made for their places of concealment. They are seen sitting patiently in their typical positions, and a glass tube can be gently and slowly passed over them. In the evening they fly about and are not so easily caught, but with nets they may be captured after a little practice. Their larvæ can be discovered in wells, gully-traps, open drains, cesspools, tanks and old tins which have been left lying about. Old barrels, motor tyres, cigarette tins and bottles will all hold water in the rainy season, and are favourite sites for ovipositing with many of the mosquitoes. In the compound, should you find trees, they should be searched carefully with a view to discovering whether there be any holes which retain rain water.

Long grass and rank vegetation in themselves do not breed mosquitoes, but they are splendid positions for mosquitoes to take up during the heat of the day, and they harbour all sorts of tins, bottles and rubbish, which catch rain and afford excellent cool water in quiet spots for breeding. Thus it will be found that when search for mosquitoes in and about a house has proved unsuccessful and just as you are about to abandon all hope of discovering any breeding places, your attention is arrested by that corner of the compound which in many households seems to be a sort of dumping ground for odds and ends. And there amongst the grass is an old rusted tin, with its brood of larvæ and pupæ. Nor do even the most innocent looking bamboo poles used as supports for sheds and lean-to buildings escape. The female bamboo is a hollow structure, and should there be any cracks or holes in it, rain water will collect and breeding will certainly result.

Within the house itself the careful inspector will generally find certain spots which are likely places for breeding mosquitoes. Among these the water cistern which has not been rendered mosquito-proof, and the water-seals of wash-down water-closets, which are not in daily use, may be mentioned. Flower vases and anti-formicas, or tins holding water, which are placed under the legs of tables to prevent ants from swarming up over food placed on them, have very often been discovered to harbour larvæ. The utmost care must be taken by the inspector to trace out all possible vessels containing water. These he must strive to have emptied daily, and among them are the earthenware vessels called *chatties*, which are in common use in India.

If one were to turn one's attention to the multiplicity of breeding places that can daily be discovered in cities, especially in factories and yards, volumes could be filled dealing with the inspector's work. Suffice it to say that on the principles evolved in this chapter the intelligent searcher will soon discover all the important breeding places, provided he has the co-operation of those living and employed in any establishment he may visit.

The *Anophelini* are usually found breeding in the country, although certain species, e.g. *A. stephensi* and *A. subpictus*, are frequently to be discovered breeding in water cisterns, and especially in wells in houses and compounds. But generally speaking the *Anophelini*, for example *A. maculatus* and *A. theobaldi*, live in marshes, river beds, and jungle pools. The female flies to the habitations of man and his domestic animals to feed upon blood, and thus during the day she may be found freely in infested houses in just those places where the *Culicini* are found. As a rule they attack their victims at night, but here again we may come across exceptions, as certain species bite during the day while others appear to reserve their energies until the early morning. Having fed upon blood she then flies back to her jungle pool, marsh, river bed, or seashore and there lays her eggs and, once again, in the vicinity she finds the male awaiting to mate with her and the whole process is repeated.

People often ask how far a mosquito can fly. With a wind behind them they can certainly travel great distances, but against a wind their range is naturally more limited. But some maintain that if the wind be not too strong, distance of flight is affected very little. Generally speaking, *Anophelini* live within a radius of one mile from their human food. The adults, in flying from their breeding beds, occasionally show most erratic habits. They will, for example, find their way not to the first house in a village but to the last, missing out houses in a curious manner. Adults are very conservative about their breeding haunts, and return to them time and time again. Most species show the extraordinary habit of keeping to the same type of breeding place. Certain species, for example, breed in the shady pools of jungles and will not breed anywhere else. Again, other species breed in the running water of streams and will not breed in still, shady pools. It is now very generally accepted that the different species will not alter their methods of breeding, and once the places have been eliminated the species dies out. They do not appear to be able to carry on as that species unless the conditions of breeding common to the species obtain. Thus it comes about that the inspector who knows the mosquitoes which are breeding in his district will also know where to look to find their breeding haunts.

It has often been stated that mosquitoes do not breed to any extent in sea water. This is not our experience in Bombay, where the *A. stephensi*, *A. subpictus*, *A. culicifacies* and *A. vagus* have all been discovered breeding in salt water on the sea-shore. On one occasion the water was three times as salt as sea water. However, there are strict limitations to their breeding on beaches. We have always found them in pools among rocks on that strip of the beach which lies between the high-water mark of spring tides and the high-water mark of neap tides. The presence of mangrove and other vegetation increases the likelihood of breeding in such areas. Mosquitoes have not been found breeding in the open sea or on that part of the seashore where the daily rise and fall of the tide take place.

The breeding places of mosquitoes can be divided into two great classes, permanent and temporary. Bentley, in his work on malaria in Bombay, has demonstrated that the chief carrier of malaria in that city is the *A. stephensi.* This mosquito is known to breed all the year round in wells, water cisterns and pools on the seashore. They are usually found in small numbers in these sites, and it is thought that their natural enemies prevent them from becoming too numerous. When the monsoon breaks, rainwater pools and a variety of collections of water become abundant throughout the city, and the mosquitoes spread from their permanent breeding places to these temporary ones, and this results in the appearance of multitudes of mosquitoes capable of carrying malaria. Within a short time malaria rages in the city. When the monsoon ceases and the temporary breeding places dry up and exist no longer, then the mosquitoes return to their permanent breeding sites, and consequently the incidence of malaria drops. Our experience in Colaba confirms these observations. Permanent places where breeding occurs are those positions in which water can be found throughout the year. They include wells, water cisterns, garden tanks, pools in river beds, streams, water channels, and so forth. Temporary breeding places are such as occur during rains, and include collections of water in storm water drains, sheets of water on the ground, and the numerous sites about a household already enumerated. We give at the end of this chapter a list of Indian *Anophelini*, and it is recommended to the careful study of every inspector. However, there is another way in which mosquitoes will remain alive when conditions are not favourable for their propagation. Should the weather be too hot or too cold to favour their continued existence, then adult females which are about to lay their eggs seek out some quiet cool spot, and there settle down and pass into a torpid state, in which they seldom, if at all, feed, and appear to be asleep. If this occurs during cold months it is spoken of as 'hibernation'. A similar condition may occur in hot dry months in the tropics, and then the mosquitoes are said to 'æstivate'.

The manner in which mosquitoes become distributed over a given area is interesting. They may be, and are, blown to considerable distances from their breeding haunts by strong winds, and, being unable to return, they are perforce obliged to seek out fresh collections of water in the neighbourhood; and though it is usual for mosquitoes to return to the vicinity where breeding abounds, yet it is not always so. Some may arrive at water collections which have a plentiful supply of food for larvæ, especially those to the leeward of the habitations to which the adult flies for its mammalian food. Again, irrigation channels can carry larvæ a long distance, and those surviving start new foci further down the channel. Also, mosquitoes may be transported to considerable distances by human agency.

The age to which an adult mosquito may live has not been worked out for each species. The males are generally shorter lived than the females. Although the females of some species are known to live through the winter in a torpid state, it seems probable that about six weeks to three months is the ordinary limit of active life.

TABLE OF *ANOPHELINI* (INDIA), SHOWING DISTRIBUTION AND BREEDING HABITS

Name of Species	Distribution	Breeding Habits	Remarks
A. aconitus—Donitz	Assam and Bengal.	Streams of running water edged with grass. Irrigation channels of paddy fields. Found in clear water.	Carries parasites of malaria in nature. Found in tea gardens.
A. aitkenii—James	Karwar, Frontier of Goa, Bengal Duars, Andamans, Burma, Assam, S. India.	Breeds in jungle pools.	Rests like *Culicini*. Feeds in shade during the day.
A. barbirostris—Van der Wulp	Throughout India and the Andaman Islands.	Breeds in shady pools in jungles, orchards and gardens.	Not commonly found in houses.
A. culicifacies—Giles	Widely distributed throughout India.	Pools of rain water, paddy fields, and pools in dry river beds. Breeds in wells or any collections of water, including brackish water.	Carries the parasites of malaria in nature. The *Imago* has an attitude on resting similar to *Culicini*.
A. culiciformis—Cogill	Bombay, Karwar, South India.	Breeds in holes of trees.	Adult rests like *Culicini*.

TABLE OF *ANOPHELINI* (INDIA), SHOWING DISTRIBUTION AND BREEDING HABITS—(*Contd.*)

Name of Species	Distribution	Breeding Habits	Remarks
A. fuliginosus—Giles	Throughout the whole of India and Burma up to 3,000 feet.	Pools, ponds and tanks with vegetation at sides. A swamp breeder.	Carries the parasites of malaria in nature. Found more especially in cattle sheds.
A. gigas—Giles	A hill species found in the Nilgiri Hills and hills of Southern India, also Himalayas.	Breeds in ponds and the 'dew ponds' of Simla Hills.	A wild mosquito, but rarely seen in houses.
A. hyrcanus—Pallas	Bengal, Punjab, Bombay and Madras Presidencies.	Breeds in swamps and water with much vegetation, and in rice fields.	Carries parasites of malaria in nature. Feeds mostly by day and not often found in houses.
A. jamesii—Theobald	Bengal, Central Provinces and parts of South India, Madras City.		
A. jeyporiensis—James	Jeypore Agency, Central Provinces, and parts of Southern India.	Breeds in streams, irrigation channels of rice fields.	

A. karwari—James	Bombay Presidency, Central India and Assam.		Has been infected with the parasites of malaria in laboratory.
A. kochi—Donitz	Assam.	Fresh water pools.	
A. leucosphyrus—Donitz	Burma, Assam, Bombay, South India.	Breeds beside forest streams.	Forest species found abundantly in coolie huts. Suspected to carry parasites of malaria.
A. lindesaii—Giles	Himalayas and hills of Southern India.	Breeds in streams in hills.	Hill species.
A. listoni—Liston	Berars, Central Provinces, Bengal Duars, Jeypore Agency, Goa, Bombay, Hyderabad Deccan, North Canara District, Ceylon, Assam.	Notorious stream breeder.	Carries parasites of malaria.
A. ludlowii—Theobald	Bengal, Burma, Andamans.	Chiefly a salt water breeder; found not far from seashore.	Carries parasites of malaria.

TABLE OF *ANOPHELINI* (INDIA), SHOWING DISTRIBUTION AND BREEDING HABITS—(*Contd.*)

Name of Species	Distribution	Breeding Habits	Remarks
A. maculatus—Theobald	Bengal Duars, North-west Himalayas, South India.	Breeds in streams.	Carries parasites of malaria.
A. maculipalpis—Giles	General throughout India.	Pools which may be connected with hill streams.	Carries the parasites of malaria.
A. minimus—Theobald	Assam, Bengal, Central India (rare).	Stream and pond breeder.	Carries the parasites of malaria.
A. pallidus—Theobald	Central Provinces.	Rice fields, borrow pits, but not flowing water.	
A. plumbeus var. *barianensis*—James	Western Himalayas above 6,000 feet.	In the hollows of trees.	During day found in hollows of trees. Enters houses morning and night to feed.

A. pulcherrimus—Theobald	North-West Frontier, Punjab, especially the west, United Provinces, Bombay Presidency.	In shallow pools, e.g. rainwater pools.	
A. rhodesiensis—Theobald	Baluchistan, Quetta, Kohat.	Similar to A. *culicifacies*.	
A. stephensi—Liston	Throughout India.	Notorious well breeder. Also any collections of fresh water; breeds freely in sea water.	Notorious carrier of the parasites of malaria.
A. superpictus—Grassi	North-West Frontier, chiefly Quetta.	Breeds in pools in stream beds.	Carries the parasites of malaria.
A. subpictus—Grassi	Throughout India.	Shallow pools, paddy fields, temporary pools, domestic pots; may breed in salt water.	May carry parasites of malaria, but is not thought to affect much the incidence of the disease.
A. tesselatus—Theobald	Rare in India, but may be found in Assam, Central and South India, West Coast, Burma.	Sugarcane brakes.	

TABLE OF *ANOPHELINI* (INDIA), SHOWING DISTRIBUTION AND BREEDING HABITS—(*Contd.*)

NAME OF SPECIES	DISTRIBUTION	BREEDING HABITS	REMARKS
A. theobaldi—Giles	West Coast and Central India.	Swamps and margins of lakes and streams.	
A. turkhudi—Liston	Berars, Central Provinces, Kashmir, Punjab, North-West Frontier.	Breeds in clear pools and pools in sandy river beds.	Larvæ rests like *Culex at* surface of water. Carries parasites of malaria.
A. umbrosus—Theobald	Assam.	Deeply shaded pools and swamps in jungles.	Carrier of parasites of malaria.
A. vagus—Donitz	Burma, Assam, Bengal, Bombay.	Clean fresh water and brackish pools on sea-shore.	
A. willmori—James	Foothills of Himalayas up to 6,000 feet, from east to west.	Breeds in streams and clear pools.	Carries parasites of malaria.

CHAPTER V

PREVENTIVE WORK

BEFORE describing in detail any measures on a large scale which may be undertaken to eliminate as far as possible the mosquito pest, let us consider for a moment the main criticisms with which the advocates of an anti-mosquito scheme are sure to be faced. Several aspects of the question are bound to be brought forward for criticism, and it is well that all who are more educated in these matters should have a ready answer. One of the first comments will be that it is a quite hopeless task to exterminate all mosquitoes, and therefore it is a waste of time and money to attempt it. It is difficult to convince the uneducated of the futility of taking up such a position. When the armies in France in the Great War were worried beyond measure by lice and fleas, it was not proposed to kill all the lice and fleas to free them of their troubles. Life was made wellnigh impossible for such parasites as require man as their host, by the free use of insecticides, frequent bathing, daily change of clothing, where possible, and disinfestation at properly prepared stations. And so it is with mosquitoes. We do not advise extermination out of hand, but a prolonged campaign, based on a sound knowledge of the life and habits of certain tribes of mosquitoes well known to be inimical to the health and comfort of man.

Another criticism, but one much more difficult to dispose of, is whether the large and oft-times vast expenditure which will be incurred by public communities and private concerns in the launching and future maintenance of an anti-mosquito campaign is worth while. This is too large a subject to be dealt with in this small book, but in all cases the pros and cons must be carefully weighed, and from this point of view all schemes put forward should be as economical as possible and should be adjusted so as not to overlap the work of other departments in a community—for example, the work of the Sanitary Department. The saving to a community of hours of labour and many valuable lives, besides the reduction of expenses in hospital maintenance, should be reckoned as valuable assets. In this connection one should be conversant with the work on *The Prevention of Malaria in the Federated Malay States*, written by Sir Malcolm Watson. Many laudable undertakings have ended in disaster through the neglect of anti-mosquito measures. The Panama Canal Scheme was attempted several times before a successful issue was achieved for this very reason, and loss of reputation, vast sums of money, and many human lives resulted from the neglect of not incurring an initial expenditure on anti-mosquito work. It was not until it was realized that due regard must be paid to the mosquito that large sums of money were forthcoming to undertake a campaign, and only then was it possible to see the completion of the Panama Canal.

Within our limited experience we know of several important business concerns which have come to inglorious ends because their directors failed to realize the part that the mosquito played in the success or failure of a commercial enterprise. In commercial houses established in India it is the custom to maintain their staffs on a basis of allowing annually for a very large percentage of sickness, almost wholly malaria.

As we have already explained, the links in the malarial chain are the plasmodium, the human reservoir and the *Anophelini*. These three links are absolutely necessary for the chain of malarial infection. If any of them be absent then malaria cannot exist; thus it follows that the lines of defence and offence should naturally be directed against the destruction of these links, thus rendering the chain impossible. All defensive measures will be based on the avoidance of human reservoirs and infected *Anophelini*, while offensive undertakings will be directed against the plasmodium in the infected individual, and prosecuted with a view to the destruction and, if possible, extermination of the *Anophelini* concerned.

Measures to Avoid the Human Reservoir.—The system of cantonments in India, where the troops are located away from the crowded quarters of the city, is a very good example of the advantage accruing from this method. The troops are thus frequently spared the risk of infection by *Anophelini* which have fed upon the human reservoir in the city, and it is well known that the malarial incidence in a cantonment is distinctly lower than that of the adjoining city. The moral that we learn from this is that in the location of new sites for human habitation, factories, mills, labour lines, and so on, one should always take into consideration the state of endemic malaria in the adjoining places, and then decide on a suitable spot. All houses situated in mosquito-infested areas should be rendered mosquito-proof by means of wire gauze, the mesh of which should never be larger than sixteen to the inch. In hospitals and houses persons suffering from malarial fevers should be screened, so as to prevent the *Anophelini* becoming infected, and thus transmitting the disease to others in the ward or household.

Measures to Kill the Plasmodium in the Blood of the Human Reservoir.—This virtually means treatment of infected persons by quinine, which is the only drug we know that will act on the plasmodium. Unfortunately, the success of this method depends on the regular and prolonged administration in suitable doses of a drug which, unless very strict precautions are taken to avoid loopholes, either in its preparation or administration, is liable to be abused; for quinine is an expensive drug and by no means an attractive medicine to swallow. Instances do exist, however, especially in Italy, where this method of malarial control has been used with success.

Measures to Exterminate the ***Anophelini.***—This method strikes at the root of the matter and will therefore constitute the ideal weapon in our hands. We can kill the enemy either in their stage of existence in water collections or when they are on the wing. It is obvious, however, that it is much easier to attack the mosquito in its aquatic period of existence than to hunt after it when it is flying. All living creatures have their enemies, both natural and artificial, and the study of these enemies may reveal a very efficient method of dealing with mosquitoes.

The Natural Enemies of Mosquitoes.—The adult mosquitoes can often be seen falling a prey to birds, bats, lizards, ants, etc., and certain species of fish also attack and devour them when they approach sufficiently near the surface of water. Though a number of mosquitoes can be destroyed in the adult state by such enemies, it is probable that this loss is small compared to that caused by the natural enemies which attack the insect in its larval state. Amongst such natural enemies fish take the first place. Unfortunately, all fish do not eat mosquito larvæ, but only certain species. Amongst the fresh-water fish that eat them are the following: *Anabas scandens*, *Haplochilus lineatus*, *Polyacanthus cupanus*, *Barbus stigmata*, a species of the genus *Ophiscephalus*, and *Macrones*. The sea-water fish that are known to eat mosquito larvæ are the *Therapon jarbua* and a species of the genus *Mugil*. It is probable that there may be several other species of fish which feed on them. Should any collection of water be met with where fish are present and mosquito larvæ absent, it is worth while testing whether the fish eat them. Put some of these fish in a suitable glass vase and put some larvæ with them and watch the result. As some fish do not eat the larvæ as soon as they see them, it is best to observe the experiment for twenty-four hours. It is best that experiments should be made with the local species and a selection made from them, for it may so happen that an imported fish may give up its larvæeating tendencies under a changed environment. Where there is much weed and floating vegetation in the water, mosquito larvæ take cover under them and defy the fish. The use of fish as larval eaters opens out immense possibilities of successfully preventing breeding of mosquitoes in permanent collections of water, especially where there is no vegetation. There is no easier method of dealing with the pest.

The sources from which these fish can be procured, their local names and other necessary particulars, can be obtained from the Departments of Fishery, wherever they exist. So far as we are given to understand, the Department of Fishery, Madras, is the only organization in India that can supply larvacidal fish at present, and the cost of supplying 100 specimens at a distance of 100 miles from Madras by railway is said to be about Rs. 4 only. Should the fish be required to be sent to greater distances, the cost will be proportionately greater, as it would involve the services of a trained assistant to look after the fish during the journey.

In using larvacidal fish great care should be taken to clear all weeds and overhanging vegetation and also to remove predaceous fishes, which otherwise will be destroying the larvacidal fish.

Certain aquatic insects, such as water boatmen, and some beetles and bugs, also destroy mosquito larvæ. Some plants, such as that which is commonly known as the rootless duckweed, are also said to be their natural enemies. The successful use of these natural enemies is a matter of individual discretion on the part of the person carrying out mosquito destruction.

The Artificial Enemies.—The artificial enemies of mosquito larvæ are what are known as larvacides. The most commonly used larvacide is oil, which, by blocking the respiratory passages of the larvæ, suffocate them. Kerosene, crude oil, castor oil, and gingelly oil are some of the oils that are generally employed, either alone or in different combinations. The most commonly used combination is a mixture of equal parts of kerosene and crude oil. A mixture of crude oil and crude carbolic acid (20 per cent.) in equal parts has proved highly satisfactory in our experience. Various disinfecting fluids, such as Cresol, Izal, and Newcol, are also highly larvacidal. The employment of disinfectants as larvacides is dependent on the correct strength of dilution of the disinfectant. An insufficient amount of disinfectant added to a collection of water will be far too dilute to be of any use as a larvacide. Hence it is preferable to use a disinfecting fluid like Cresol or Izal in shallow collections of water, and oil in large collections where a continuous surface film will and some beetles and bugs, also destroy mosquito larvæ. Some plants, such as that which is commonly known as the rootless duckweed, are also said to be their natural enemies. The successful use of these natural enemies is a matter of individual discretion on the part of the person carrying out mosquito destruction.

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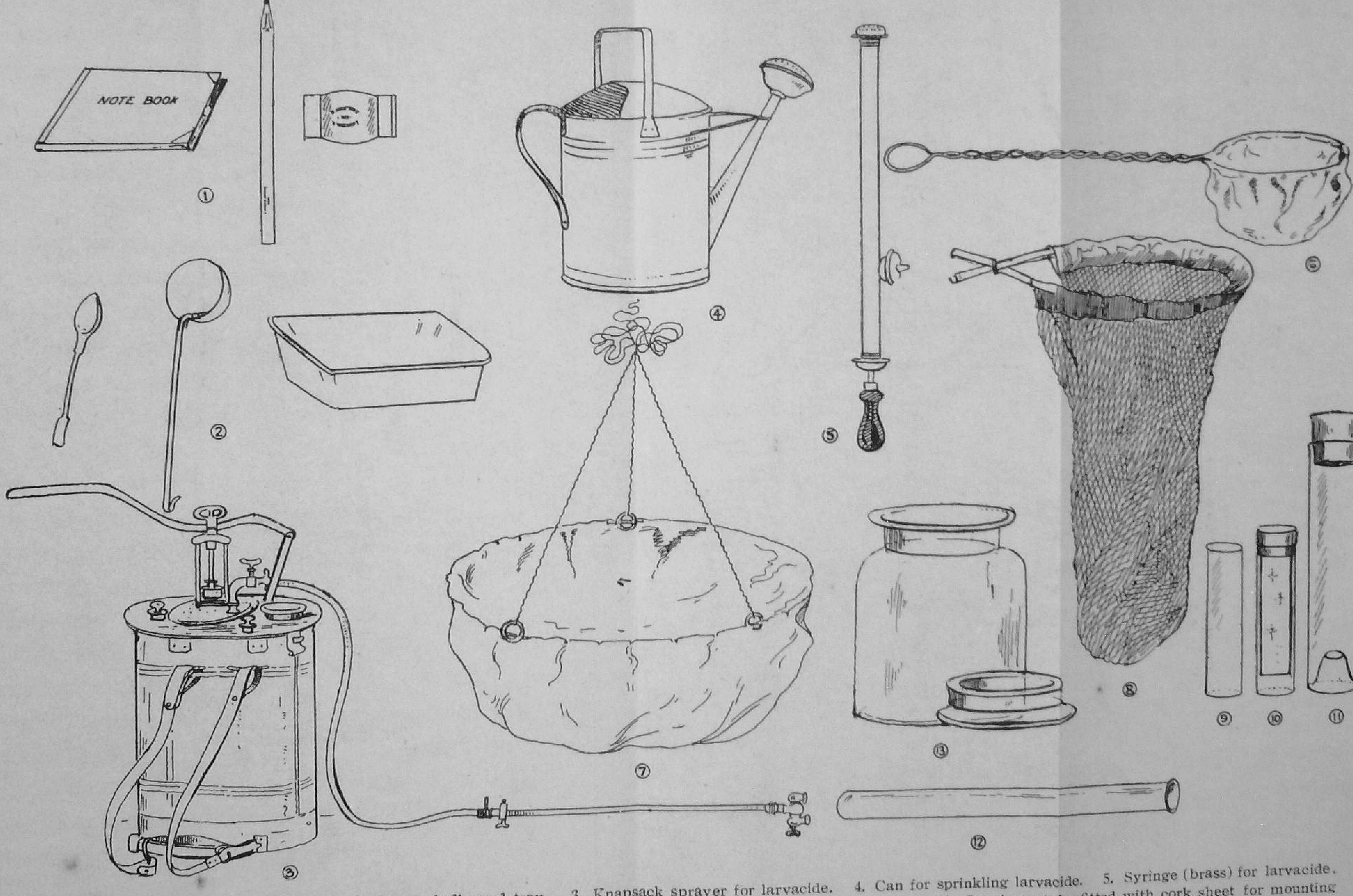

1. Note book, pencil and rubber. 2. Spoon, ladle and tray. 3. Knapsack sprayer for larvacide. 4. Can for sprinkling larvacide. 5. Syringe (brass) for larvacide. 6. Larvæ-catching net. 7. Well net for larvæ. 8. Hand net for catching adult mosquitoes. 9. Specimen tube. 10. Specimen tube fitted with cork sheet for mounting mosquitoes. 11. Specially designed specimen tube for catching adult mosquitoes. 12. Test tube. 13. Hollow stoppered glass bottles.

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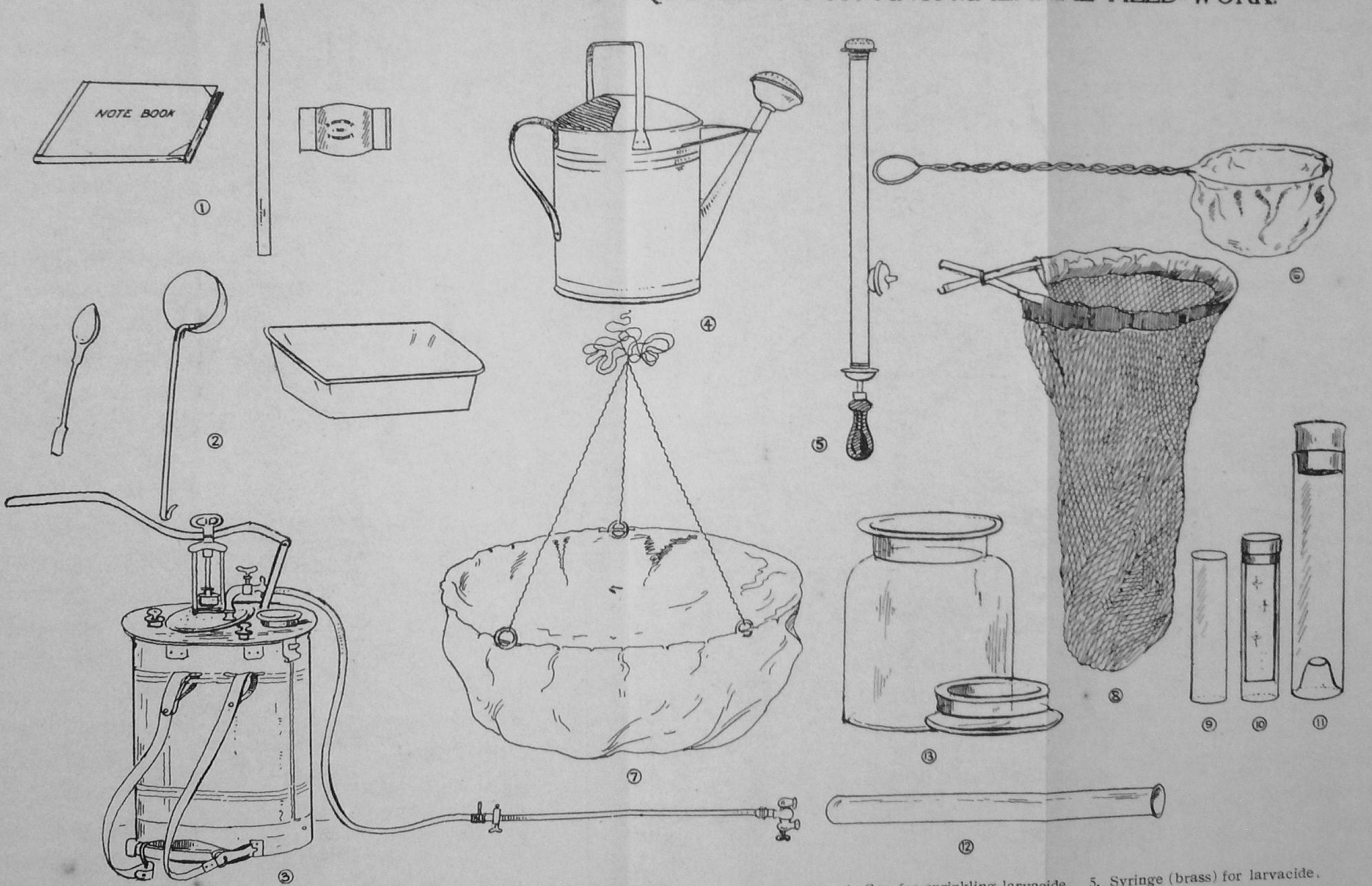

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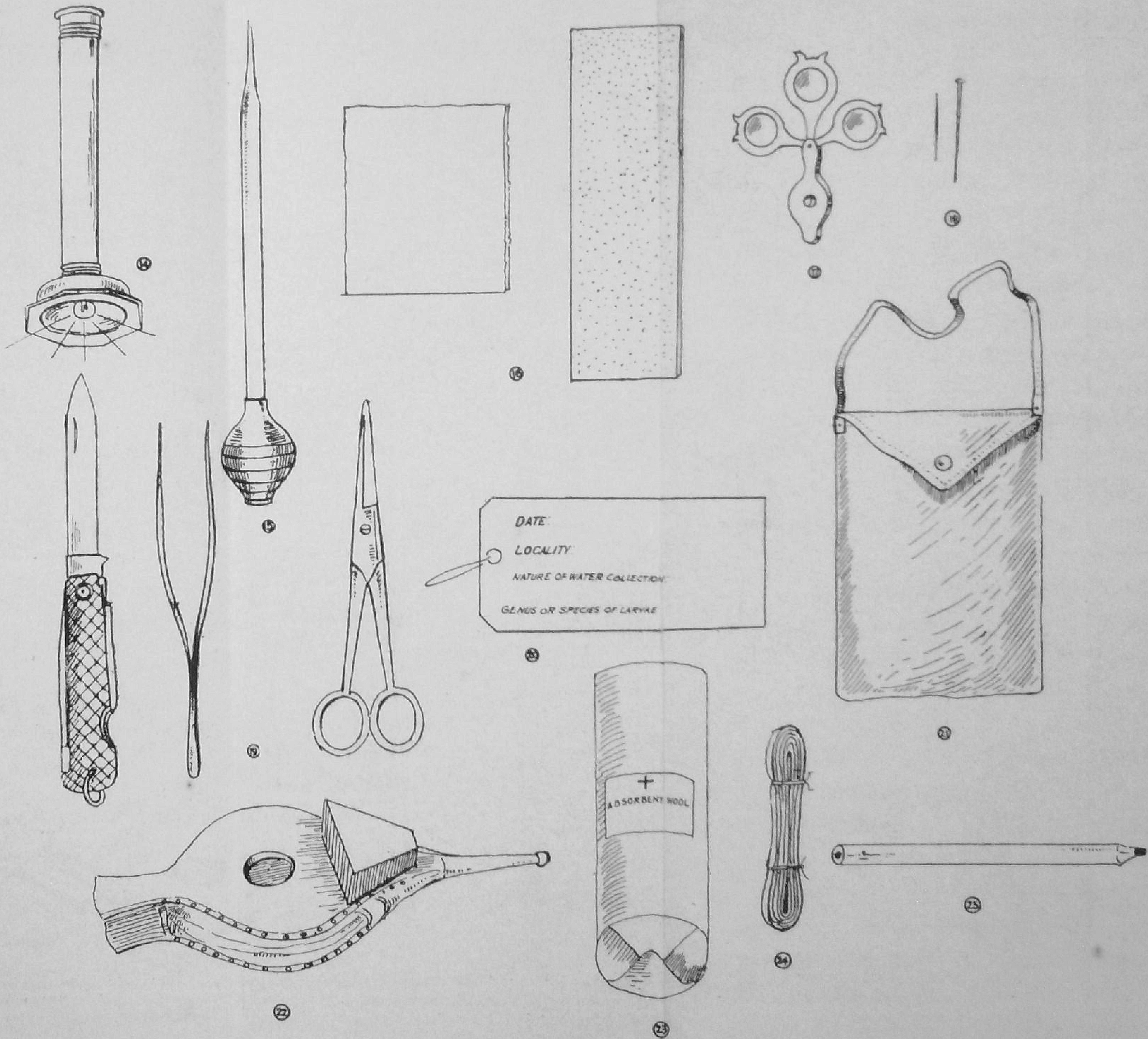
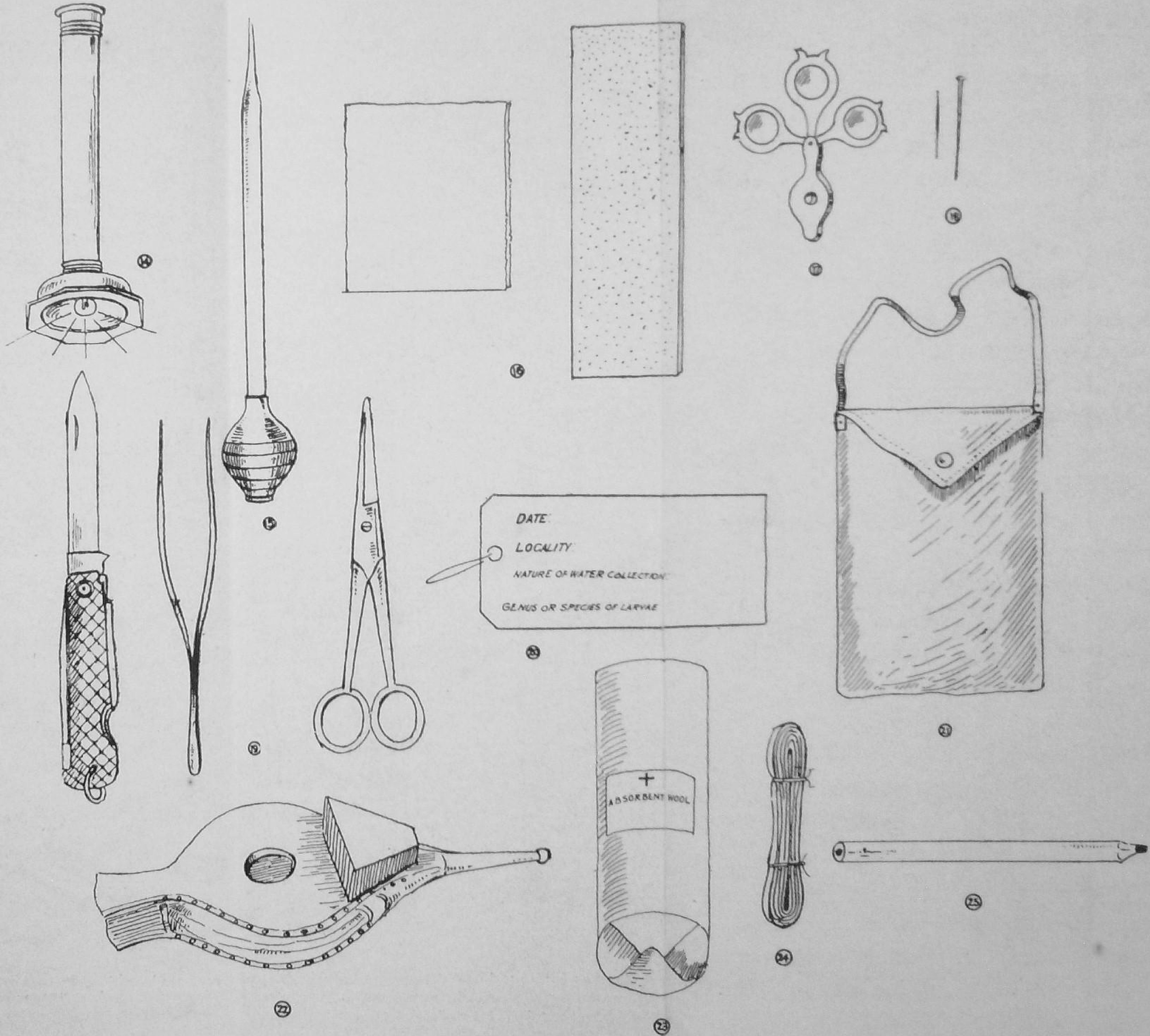


14. Electric torch light. 15. Pipette. 16. Card board and cork sheeting. 17. Hand lens. 18. Entomological and ordinary pins. 19. Jack knife, forceps and scissors. 20. Labels. 21. Haversack. 22. Paris-green blower. 23. Cotton wool. 24. Tape bundle. 25. Grease pencil.



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suffocate the larvæ and kill them. Certain chemicals, such as sulphate of iron and sulphate of copper, also destroy mosquito larvæ, when added in proper strength to the water in which they are breeding; but by far the best chemical we have come across is a substance called 'Paris Green'. This is an arsenical compound, and is diluted in one part in 100 parts of fine cork or road dust, and strewn over the surface of water where larvæ are to be found. This can be usefully employed in large collections of impounded water, such as tanks and ponds, where the use of oil or any other larvacide will be far too expensive to be practicable. (*Vide* Appendix VIII.)

In order to be able to detect breeding in collections of water every inspector should, by practical personal experience, be thoroughly conversant with the methods described below. Mere book knowledge in this very important section of his work is entirely useless. He should provide himself with an electric torch-light, a white enamel dish (10 in. x 8 in.), an ordinary table-spoon, an ordinary bath-tin, a hand-net and a well larval net. A well-net consists of muslin spread loosely over a loop of iron wire about 15 in. in diameter. To the loop are attached three chains about 2 ft. in length, which in turn are secured to a small ring above. To the suffocate the larvæ and kill them. Certain chemicals, such as sulphate of iron and sulphate of copper, also destroy mosquito larvæ, when added in proper strength to the water in which they are breeding; but by far the best chemical we have come across is a substance called 'Paris Green'. This is an arsenical compound, and is diluted in one part in 100 parts of fine cork or road dust, and strewn over the surface of water where larvæ are to be found. This can be usefully employed in large collections of impounded water, such as tanks and ponds, where the use of oil or any other larvacide will be far too expensive to be practicable. (*Vide* Appendix VIII.)

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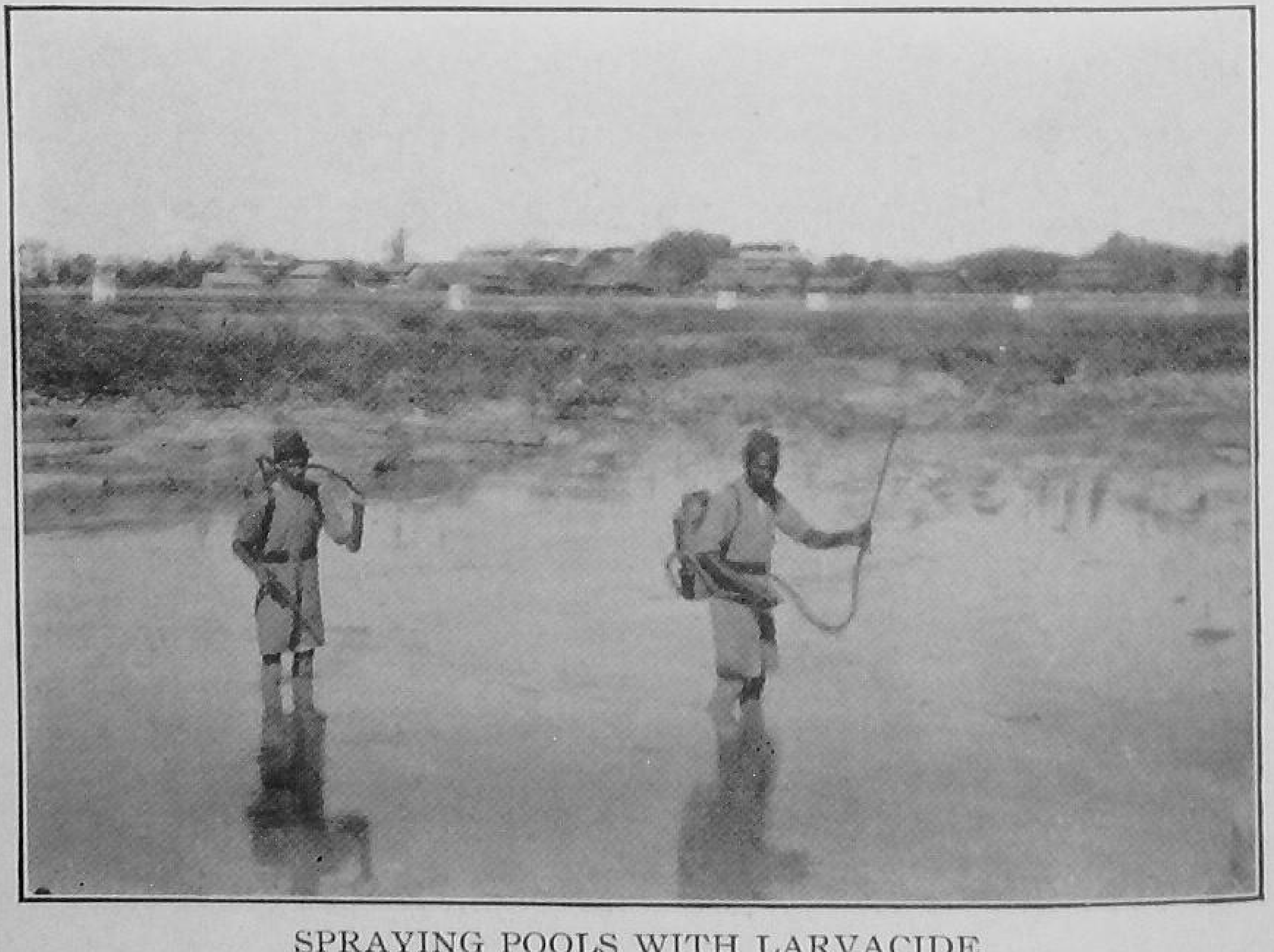
SEARCHING A POOL FOR LARVÆ



SPRAYING POOLS WITH LARVACIDE

tion, what is known as the 'dipping method' should be tried. By means of the bath-tin, the water, from as close to the vegetation as possible, is transferred, along with any vegetation, to the enamel dish. The water is allowed to remain a few seconds in the dish, when larvæ, if present, will be seen coming up to the surface. In using the hand-net for searching a pool, the method employed is to fill about half of the enamel dish with water free from larvæ and put the net in several places in the pool and search round, first at the surface, then at the edges, and finally deep in the pool. Care should be taken not to allow the larvæ caught in the net to escape. The net is then withdrawn and inverted into the enamel dish, when larvæ, if present, will be seen in the clear water. The operation should be repeated several times before a pool is pronounced free from larvæ. For wells, water cisterns, etc., where any of the above methods will not be satisfactory, the well-net is used by lowering it at several spots into the water and inverting it into the dish containing clear water. If larvæ are present they can be seen in the dish.

Larvæ have been known to thrive in all sorts of water collections, from the freshest rain water to pure sea water, from the tiniest collections of water between the axils of the leaves of certain plants to large ponds, swamps and rivers. Therefore, no water must be ignored, but each collection should be systematically searched, and experience will show in what surprisingly odd places mosquitoes will breed.

The Imago, or adult mosquito, can be captured in one of two ways. Either search can be made for him in his resting place, or else he may be caught on the wing. In the former case the apparatus required will consist of specimen tubes and cotton wool with which to plug the ends of the tubes. Having carefully observed the mosquito resting on a wall, in a cupboard or on clothes, the pledget of wool is removed from the end of the specimen tube, which is passed carefully but slowly over the mosquito, and then the pledget of cotton wool is slipped underneath the tube so as to block the entrance. If the cotton wool is pushed half way down another mosquito may be captured in the same tube if desired. By using a specially designed specimen tube, which was shown to us by Dr. G. Jameson Carr, late Member of the International Health Board, several mosquitoes could be caught in one tube without the necessity of putting a cotton plug every time a mosquito is captured. This consists of a large specimen tube, 8 in. x 2 in., one end of which is blown inwards like a funnel with a small aperture. The other end is kept corked. On putting the funnel-shaped end over the mosquito, it gets into the tube through the aperture, but cannot easily get out. Keep a finger over the aperture as a safeguard against any chance of escape of the mosquito, and put the same tube over the next mosquito, after removing the finger just before using the tube. When mosquitoes are flying about, a hand-net fashioned like a butterfly-net is required in addition to the glass tube. The net is passed over the flying mosquito by a sweeping movement, and the exit is immediately closed by gripping the outside of the net, near the entrance, with the free hand. With a little manipulation mosquitoes caught in this way can be passed into tubes and secured by a cotton wool plug, as has already been described. Should the specimens only be required for mounting it will not be necessary to catch them in a tube; simply place some chloroform on a pledget of cotton wool inside the net and all the specimens will be dead in a few minutes and will be ready for mounting.

A most thorough inspection must be undertaken before any building can be pronounced free of adult mosquitoes. In Indian villages all huts must be carefully examined. The thatch of these huts is a favourite resting place, and very often the colour of the thatch coincides with that of the mosquito and it requires careful searching for their detection. In almost every house in an Indian village a huge basket, in which grain is stored, will be discovered in one corner. The inside of the basket is smeared with cow-dung, which gives it a dull grey appearance. There appears to be some curious attraction for mosquitoes there, and usually large numbers can be discovered resting in these baskets. Adults should be destroyed wherever possible, but, unfortunately, no satisfactory trap has been devised that will attract them in really large numbers. Several situations may be mentioned where mosquitoes are likely to be found, and among them are to be noted all cow sheds and outhouses, under the eaves of huts, and in dark corners of houses, especially on any cobwebs discovered there. Mosquitoes have a curious fancy for dark and grey clothes and for the inside of leather boots and the under-surface of saddles. What the attraction is has not been satisfactorily explained. Some authorities think that the colour is the attraction, while others suggest that the odour of certain articles, for example boots, is what they like. Basements and cellars are likely places to find the Imago, and in certain countries they have been known to hibernate in them throughout the cold weather. The uses to which an adult catch can be put, besides the attempted reduction in total numbers, are the identification of species in a given area, the registration of houses, barracks, and so on, where the largest numbers can be caught, and at what periods of the year each species is most abundant. But there is a much more important observation to be made from such a catch. Large numbers of *Anophelini* thus caught are dissected with a view to determining what species carry the plasmodia of malaria and which of these species are the chief culprits. Having determined these facts, and knowing the habits of the species involved, we can locate their breeding places and make anti-mosquito plans.

In carrying through such a scheme there are several points which must be carefully observed. It must be remembered that anti-mosquito campaigns involve expenditure, and, unless adequate provision is made in the beginning to incur such expenditure, such schemes will only end in discredit to the personnel concerned. Half-hearted measures are worse than useless, and are more a pretence than an earnest attempt at the prevention of malaria.

An anti-mosquito campaign, once started, can never cease, just as much as conservancy arrangements cannot cease but must go on indefinitely. We cannot hope to exterminate mosquitoes once and for ever until we reach a state of civilization much higher than the present. In the meanwhile, war against mosquitoes has got to be continued without abatement, and then only shall we succeed in reducing their numbers to any appreciable extent. The officer entrusted with the conduct of the campaign should be made solely responsible for it. Undivided responsibility in anti-malarial operations is an asset, the value of which cannot be lightly ignored. Where different parties are concerned in a particular locality, and unification of responsibility cannot for various reasons be attained, a committee composed of the representatives of the different parties should be formed, and thus ensure the closest co-operation of all concerned.

One cannot too strongly emphasize the importance of selecting the personnel. Every endeavour should be made to get the right sort, from the chief officer down to the men of the anti-mosquito gang; on the intelligence and honesty of these much of the success or failure of a scheme will depend. The officer should not be hampered by too much office work and by other duties, but should have ample time for outdoor personal work to check the duties of those working under him. The subordinate staff should be well trained in a knowledge of mosquitoes, their life-history and habits; they should know how to detect the presence of larvæ, how to hatch them out and mount them, how to make an adult catch, and even to be able to recognize the commoner kinds of *Anophelini* in the locality. Anti-malarial schemes should be backed up by proper legislation, though this might be used as a last resource. Owing to the inadequacy of punishment given by legislators for sanitary contraventions, some wilful and recalcitrant people would rather undergo the punishment than obey sanitary rules. Deterrent punishments and the disallowing of endless petitions will soon put a stop to this.

The actual anti-mosquito campaign may be broadly divided into major and minor works.

Major works, such as large drainage schemes, diverting streams and channels, or filling up large swamps, will usually require a considerable capital outlay in addition to the recurring expenditure for their upkeep. Whether it will be more economical to do the major works or minor works in the first instance, should be decided at a very early stage of the campaign, in consultation with the engineers, taking into due consideration the species of *Anophelini* present, their known habits and the conditions under which they are found in any particular locality. Engineering skill exhibited in ignorance or in defiance of the knowledge of local *Anophelini* often ends in expenditure without any resulting benefit.

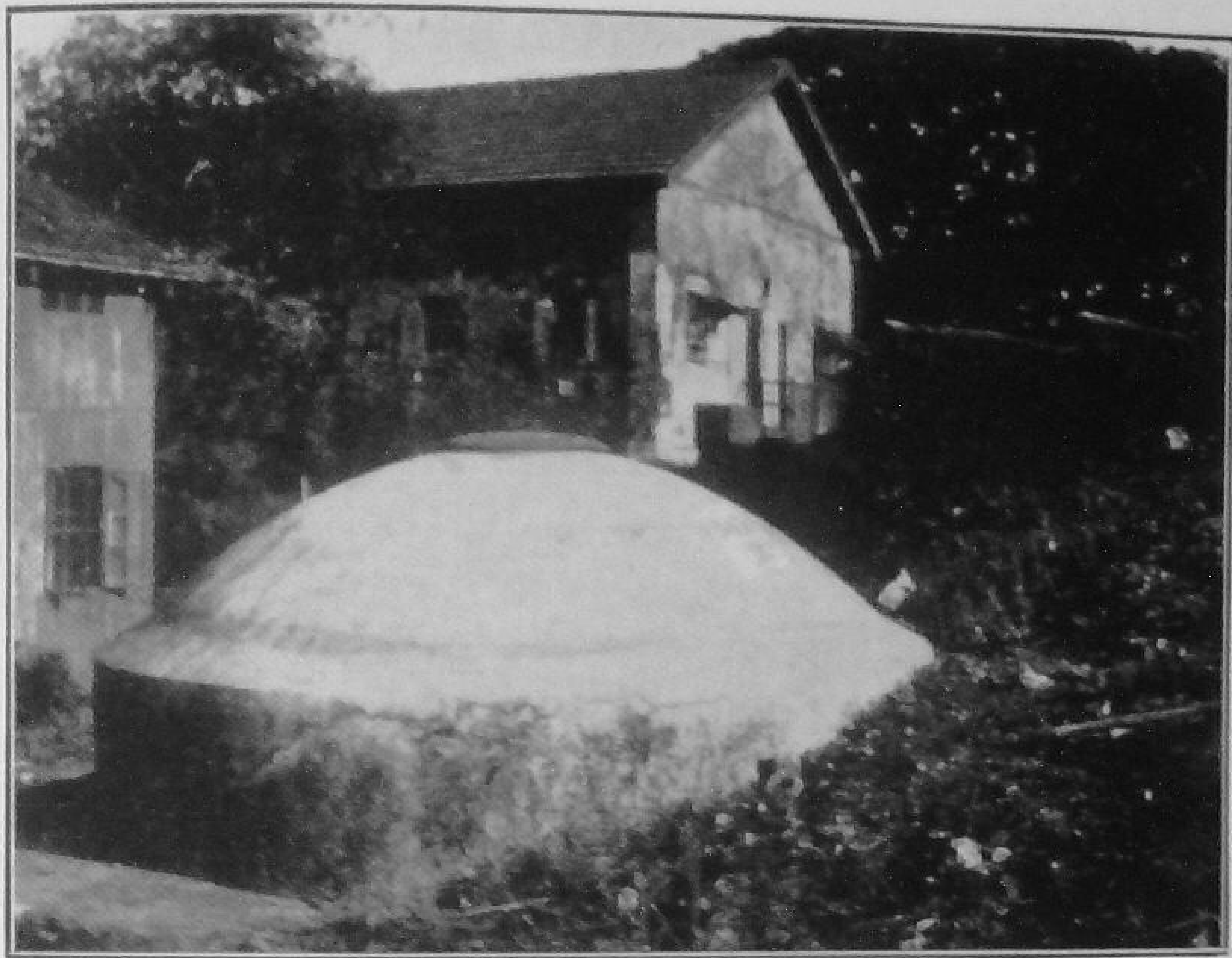
Under the heading of minor works we include such measures as systematic inspections and the use of larvacides, draining or filling up of casual water collections, rendering wells and water cisterns mosquito-proof by screening them, filling up tree holes, and so on.

The area to be controlled is divided into six sections corresponding to six working days of the week, and one section is dealt with on each day. By the end of the week the whole area is covered and the following week the process is repeated, and the different sections are inspected in the same order. Each such area is entrusted to one inspector who will have a certain number of men working under him, depending on the nature of the work to be done. If it is a large tract of country that is being controlled, there will naturally be several such areas, each under an inspector. The advantages of visiting the sections in a particular order are that there is less chance of omitting any section if such a routine method is followed, and the inhabitants, if any, of that particular section know exactly when to expect the visit of the anti-mosquito squad. During these inspections all possible breeding places are carefully looked for and dealt with as described. The inspector, who always carries with him a note-book and pencil, will carefully note down such places as he finds breeding and he will take samples of all larvæ. For this purpose he will have with him several numbered glass bottles, and in these larvæ will be sent back to the laboratory for identification. He will note such permanent places as wells, cesspits and water cisterns where he discovers larvæ, and report the fact to the officer in charge of his area. There are, however, many occasions where the breeding can be dealt with on the spot. It is then usually occurring in temporary breeding places. He will order his squad to spray oil on a cesspit, to drain away casual water, or to fill up a puddle with earth. He sees that all barrels or tins are emptied of any water they contain. The barrels he has turned upside down, and old tins and odds and ends are collected for disposal by the sweepers concerned.

The permanent breeding places are dealt with in various ways. The squad should clear up drains and water channels, freeing them from rubbish and undergrowth. If breeding is found in them they are sprayed freely with oil. Water channels should be emptied of water at least once a week and the channels cleaned out. In order to prevent water from accumulating in holes in such channels they should be constructed of cement or the water should be laid on in pipes. It must be carefully noted that when oil or cresol or any other such larvacide is used, a very essential part of the procedure will be the employment of a coolie to walk behind the person spraying the oil. He will intimately mix the water and larvacide by vigorously stirring up the water with a sweeper's broom. This is of the utmost importance if good results are to come from the use of larvacides. Garden tanks for holding water, with which the *mali* waters the garden, can be dealt with in various ways, but the first essential is that it must never, in whole or in part, be below the surface of the ground. If it is, then it cannot be properly emptied, and if it is not emptied it is sure to breed. The best type of tank is one built of masonry above ground. Its dimensions are of little importance, but one thing is essential, namely, the provision of an outlet pipe provided with a tap, placed low down so as to drain the tank. On his round every week the inspector must see all these tanks empty or else empty them himself. The householders will readily agree to see that the tank is emptied each evening by the *mali* and that there is no water in it on the day of the inspection. The substitution of hosepipes for tanks should be encouraged as much as possible. Ornamental fountains are the scourge of the inspector, but the addition of those fish which are the natural enemies of mosquito larvæ will usually stop any breeding occurring in them. Householders should be warned of the necessity of feeding those fish, but not to such an extent that they will prefer the food supplied and lose their appetite for larvæ. The inspector will make a point of seeing that they are alive and sufficiently numerous on his weekly round, and he should replenish them as may be necessary. The fountains should be kept clear of water-lilies and other vegetation which will provide protection for larvæ.

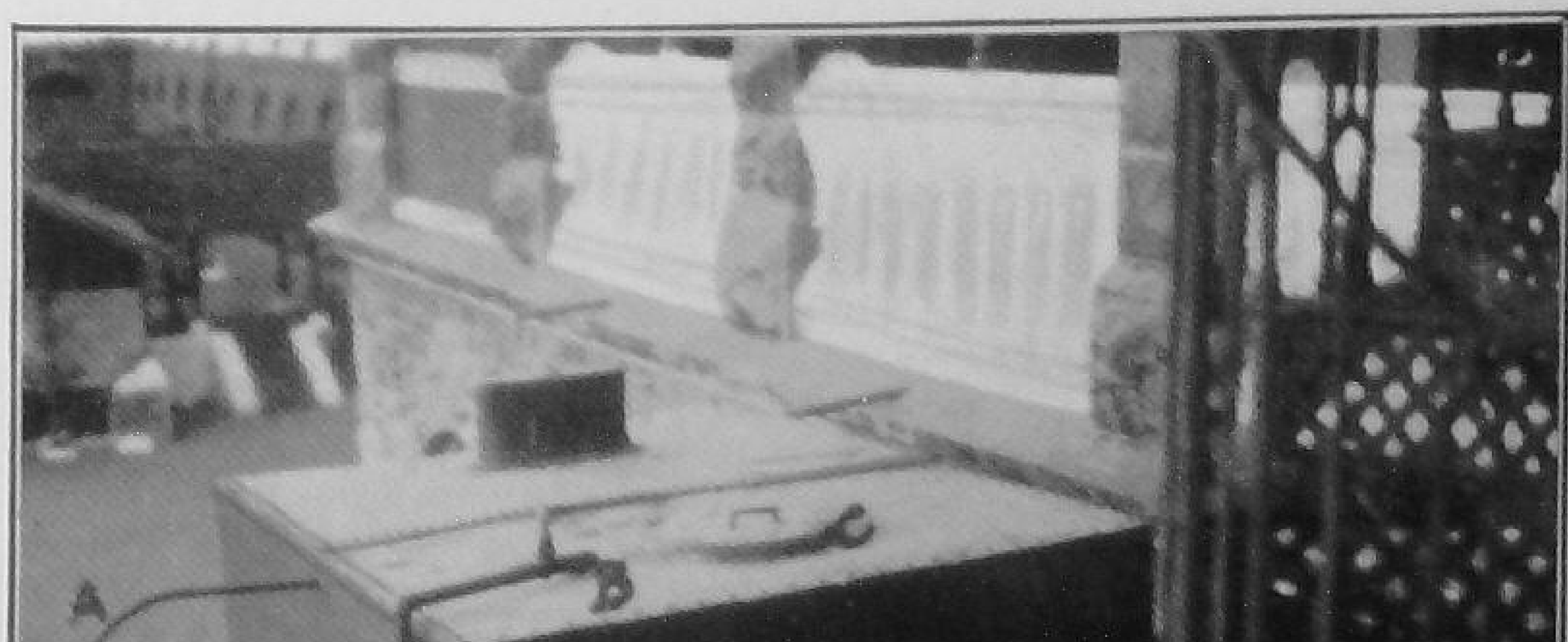
Where a laid-on water supply exists a cement platform should be built under each stand-pipe. The edge should be raised about six inches and the water tap should overhang this trough. The trough should be drained by a properly constructed drain with a gully-trap. The drain should be connected with the general drainage system, where such exists, or should lead to a properly constructed soakage pit. No puddles should be permitted to exist near a stand-pipe. This gully-trap is inspected and oiled every week as a routine measure. Cisterns are usually provided for each bungalow or group of bungalows where there is laid-on water. It is to be found either under the rafters of the roof or raised on a platform to the requisite height in the compound. These tanks should receive special care and should be rendered mosquito-proof. There are always two and sometimes three openings through which the Imago may gain entrance. There is the man-hole; this should be provided with a properly fitting lid, which is kept padlocked. If necessary, the edges of the lid may be cemented over so that no space can be left between the lid and the tank. The overflow pipe must be provided with wire gauze over the outlet so that no female mosquito can gain entrance by it. A third entrance may be discovered where the inflow of water takes place. This pipe should be bolted to the upper edge of one side of the tank, but sometimes it is thrust through a hole in the top. When this is so, cement should block up the gap between the pipe and the lid. All tanks not mosquito-proof will be reported on by the inspector.

Wells may present great difficulty in India, where they are in common use. In Colaba they have now been completely covered over by dome-shaped masonry work. This is a cheap and efficacious method, and has much to commend it. The well cannot be opened as the lid of the man-hole is bolted down, and the dome prevents either water or rubbish collecting on top of the cover. Wells have usually a semi-religious and semi-magic significance attached to them, and the complete closing of a well used for drinking purposes is objected to, because fresh air and light cannot gain admittance to the water. This difficulty may be overcome by raising the sides of the well some six or eight feet high and roofing it with wire gauze. The water is withdrawn from the well by some form of hand-pump similar to that employed in England. Wells which are



MOSQUITO PROOF

A well with cement dome.



A MOSQUITO PROOF TANK

A. Overflow pipe covered with wire gauze.
B. Inlet pipe cemented at junction with tank.
C. Close-fitting lid to manhole.

used for the provision of water for irrigating land present a much more acute problem, and the best suggestion we can offer is the covering of the well and the provision of an internal combustion engine geared to a centrifugal pump. Whatever solution there may be to this problem, one fact, from an anti-mosquito point of view, must not be lost sight of; and that is, that wells in India are the permanent breeding grounds of the *A. stephensi*, which is a notorious carrier of the parasites of malaria; and if anti-mosquito measures are to be successful such wells as breed this insect must be rendered mosquito-proof. During their weekly inspection it is the duty of the anti-mosquito gang to inspect the water seals of wash-down water-closets. Those not in daily use should be oiled and a film of oil should be spread over the surface of the water in the cisterns above them.

Vessels containing water inside houses should be emptied daily. Amongst them are not to be overlooked flower vases and *chatties*. Instead of water in antiformicas we would recommend cresol or, if the smell is objected to, oil. They are quite as efficacious in preventing ants swarming up on to tables or into meat-safes and they do not breed mosquitoes. They have the additional advantage of requiring very little attention. One of the most constant casual breeding places is the rain-water gutter which is very often found on buildings in India. During rains these become choked with dirt and grow weeds. Thus water collects in little pools in them. No building in India should have a rain gutter. The water should run directly off the roof to fall on a cement ledge on the ground level. The outside edge of this ledge should have a channel to lead away the water. Where there are flat roofs water often lies about on them during the rains. This water should be brushed off at least once in seven days.

All gully-traps connected with a drainage system must be oiled, and if a cesspit be found in the courtyard of a house, this must be inspected to see that it is properly constructed and rendered mosquito-proof. All inspection chambers should be inspected to see that the covers fit properly, and if they do not, then they must be opened and searched for mosquito larvæ. Defective covers are reported on by the inspector. The handle-grips in the lids of man-holes and other such covers are cup-shaped depressions crossed by a bar of iron. These depressions constantly become filled with rain water and form common temporary breeding places. They should be filled with earth or cement.

Gardens, especially untidy ones, require the attention of the inspector. Undergrowth and long grass should be forbidden anywhere near human habitations. They provide excellent shade for the Imago during the day and conceal all sorts of rubbish capable of holding water. Certain plants collect and store water at the junction of the stem with the leaf. The tiger-lily, commonly seen in Indian gardens, is such a plant; we frequently have found it breeding mosquitoes. Such plants should not be grown in gardens. Trees in the area under control should be inspected carefully once a year, and all hollows in them filled with a mixture of one part cement to two parts sand. When the holes are very large they are partially filled with stones and then covered with cement. Very seldom is it necessary to cut down trees. All trees inspected should be marked with a white cross while such trees as are found breeding should be indicated in addition with a red cross.

On the day preceding the inspection of a section one man is detailed to go round and collect all tins and odds and ends lying about. He deposits them so that they can be removed by the scavengers on their rounds. He also hands in at each bungalow a questionnaire card (*vide* Appendix VI) on which the occupant is asked to state whether he is troubled with mosquitoes or not. This card is dated and initialled. It is returned to the inspector when he calls next day on his inspection. These cards were started in Colaba with a view to finding out where mosquitoes were most troublesome. One surprising result has been the regularity with which they have been filled up by civilian and military inhabitants. There is no compulsion about these cards, and the housewife has, on many occasions, asked after her card should she not have received one. They usually give the first indication of any outbreak of mosquitoes. It is also a rough and ready guide to the inspector of the progress of his work, and informs him to what sections he should give special attention. If he is unable to detect any breeding place there, he reports accordingly to his officer, who takes the matter up and gives this particular area his careful attention. In a large majority of cases where complaints are made about mosquitoes, breeding can be detected in the immediate surroundings.

The inspector returning from his rounds will that day enter all records made in his note-book in the book at the office provided for that purpose. Each section of an area has a book, and under the date of the inspection he will enter the exact position of any breeding places discovered, the nature of the water where he found breeding; for example, a tin in the compound, a well, a cistern or a brackish water-pool, as the case may be. Matters he has noticed requiring attention beyond his power to correct will be entered up for the information of the officer in charge, who will take such action as he may deem expedient. The inspector also maintains a chart (*vide* Appendix V), which shows the division of the area into sections and the days on which each section is visited. This chart will be kept up-to-date. A spot map is maintained for each section concerned and whenever breeding is detected it is indicated by a distinctive spot, according as to whether the larvæ are of the genus *Anopheles*, *Culex* or *Aedes*. Such methods as the above lead to systematic work on the part of the inspectors, and tend to avoid confusion, which would be disastrous to the ends in view.

The progress of an anti-mosquito campaign is registered by the incidence of malaria occurring in hospitals and dispensaries. A more accurate estimation of the amount of malaria in a given district is shown by the incidence among the children of that area between the ages of two and ten years. One of the symptoms of malaria is an enlarged spleen, and children of these tender years are very susceptible to the disease, and when they are attacked by it their spleens become enlarged and so long as they suffer from it remain so, sometimes reaching an enormous size. The reduction in the percentage of children with an enlarged spleen is a sure indication that a campaign is progressing favourably. From rather complicated calculations a figure is arrived at which is called the 'Splenic Index'. This index shows the prevalence of malaria in a district. Also periodical catches of adult mosquitoes in a given area will indicate the progress of anti-mosquito work in that area.

In conclusion, we would draw attention to the subject of propaganda work, by which the interest of the general public may be aroused. Although it is not likely to be effective by itself, yet it might here and there appeal to the more intelligent who would press for greater co-operation between the public and sanitary authorities. While anti-mosquito measures must always be supported by public opinion, yet it is the duty of all who have knowledge of the ravages of malaria to educate and arouse that opinion, until we reach such a stage of civilization that we will look upon the mosquito as a noxious insect not to be tolerated in our midst. In the same way as we look back a few generations and wonder with disgust how our respected ancestors ever permitted themselves to be the hosts of loathsome bodily parasites, so will future generations be astonished at the many makeshift and ineffectual measures that we adopt today to avoid malaria and yet allow mosquitoes to dwell in our habitations.

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APPENDIXES

APPENDIX I

HOW TO SEND LARVÆ AND LARVAL SKINS FOR PURPOSE OF IDENTIFICATION AND DESCRIPTION

FULL-GROWN larvæ are isolated by placing them in tubes. Only one larva should be placed in each tube. When pupation takes place the larval skin is cast in the water complete with all the hairs and chitinous parts; the skin is carefully poured off with a little water into a clean petri dish, the pupa being left in the original tube with some water. The skin is carefully lifted from the water by means of a small slip of filter paper, and transferred to a small tube containing a mixture of formalin and water (about 10 per cent. formalin). This small tube containing the skin is numbered by placing a number on a small slip of paper in the top of the tube; a similar number on another slip is put in the top of the tube containing the pupa, being held in place by a plug of cotton wool; this plug also serves to prevent the escape of the mosquito when it emerges. When emergence has taken place the mosquito is transferred to a clean tube by holding the latter with its mouth to that of the former tube, after removing the plug. The plug is then pushed into the mouth of the tube containing the mosquito, and a few drops of chloroform poured upon it; the mosquito is then mounted in the usual way, and a small label attached to the pin corresponding to the number of the larval skin from which this mosquito resulted. The mosquitoes and the skins can be sent in their respective tubes by post. The small tubes containing liquid should be filled up to the cork, and if possible sealed with wax by dipping the top of each tube into melted wax.

APPENDIX II

HOW TO MOUNT AND PRESERVE MOSQUITOES

APPARATUS REQUIRED:

1. Specimen tubes with corks.
2. Fine double-pointed nickel pins, No. 3.
3. Cork sheets.
4. Cardboard.
5. Forceps with grooved teeth at the tip.

First prepare your specimen tubes as follows:

Paste white paper on to a cork sheet, and cut it into small strips just broad enough to go inside the specimen tubes. Attach a strip to the cork of the specimen tube by passing an ordinary pin on either side from the strip to the cork. The cork strip when thus fixed to the cork of the tube should not touch the bottom of the tube, but just clear it. Make a small triangular slit on one side of the cork of the specimen tube, so that a small groove exists between the cork and the glass, and into this groove fix a pledget of cotton wool. The tube is now ready for receiving the specimen. Place the mosquito upon its back on the cardboard. Hold the pin about the middle with the forceps, and push one end steadily though the thorax so that it just emerges from the centre of the dorsum of the thorax. The mosquito is now transfixed to one end of the pin; lift the pin and transfix the other end to the cork strip of the prepared specimen tube. In this way about ten mosquitoes can be mounted and preserved in each tube. Put a few drops of pure carbolic acid on the cotton wool plug. Put carbolic acid on the plug once a month and this will prevent the specimens getting mouldy.

APPENDIX III

HOW TO HATCH OUT MOSQUITOES FROM LARVÆ

Place the larvæ in a white enamelled basin containing some of the water in which they were found. Keep them there till they become pupæ, when they should be removed from the basin to wide-mouthed glass bottles filled three-fourths with water, and over the neck of which a piece of mosquito-netting is tied.

The mosquito-netting retains the emerging adults.

APPENDIX IV

HOW TO MAKE A CLEAR AND PERMANENT PREPARATION OF LARVÆ

METHOD I:

Put the larva in a test-tube and pour a few drops of caustic potash or soda (2 to 5 per cent.) solution in water.

Boil for a few minutes; when clear, transfer the whole into a watch glass, pour off potash solution, wash in distilled water two or three times. Then transfer the larva to 50 per cent. alcohol, keep for five minutes, then transfer it to 70 per cent. alcohol. Keep there for 5 or 10 minutes, then transfer to absolute alcohol, and keep for 15 to 30 minutes. During all these processes never allow specimen to get dry. It is better to change the absolute alcohol two or three times.

From absolute alcohol place it in a drop or two of clove oil till it is sufficiently clear (about 5 to 10 minutes); when clear, remove with a pin or brush to a slide and put a drop of Canada balsam over it, and with needles manipulate the position in which you want the larva; then cover with a cover slip.

METHOD II:

Put the larva in a watch glass containing 10 per cent. formalin. When dead, transfer it to another watch glass containing absolute alcohol so as to dehydrate it; then transfer it to clove oil or oil of winter-green, and when clear mount in balsam. Two strips of cardboard placed under the cover glass will support it.

APPENDIX V

DAILY ROUTINE OF ANTI-MALARIAL WORK FOR THE MONTH OF ....192 .

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Area 'A'																												
Area 'B'																												
Area 'C'																												
Area 'D'																												
Area 'E'																												
Area 'F'																												

APPENDIX VI

QUESTIONNAIRE CARD

Bungalow No.			
Occupant's Name			
'Are You Troubled by Mosquitoes?' On presentation of this card please state 'Yes' or 'No' and sign your name			
Date	Yes	No	Signature

APPENDIX VII

TABLE FOR IDENTIFYING THE FEMALES OF THE *ANOPHELINES* OF INDIA

N.B.—Always make certain that the specimen examined *is* a female *Anopheline*. Special attention is drawn to the Notes at the end of the table.

I. WINGS UNSPOTTED

A. Distinct White Knee Spots at Distal Ends of Hind Femora (Note 7).

A. plumbeus var. **barianensis**

B. No Definite Knee Spots.

1. Head scales very narrow, linear. Palps very thin. Anterior forked cell nearly double posterior (Note 7).

A. aitkenii

2. Head scales expanded as in ordinary *Anopheles*. Palps not very thin. Anterior forked cell relatively shorter (Note 7).

A. culiciformis

II. WINGS SPOTTED

A. Tips of Hind Legs White.
(If not white, see p. 98.)

1. Femora and Tibiæ not Speckled (Note 1).
(If speckled, see p. 97.)

a. At least the two terminal tarsal segments of the hind legs *completely* white (Notes 2 and 7).

(i) Dorsum of abdomen heavily clothed with pale scales, projecting at the sides to form tufts on all segments. **A. pulcherrimus**

(ii) Dorsum of abdomen not so clothed. No lateral scale tufts.

Fifth vein of wing pale in the greater part of its extent (Note 7).

Ventral aspect of most of the abdominal segments with scattered pale scales. Distal end of first hind tarsal segment never picked out with white (Note 7). **A. pallidus**

Ventral aspect of abdominal segments not so. Distal end of first hind tarsal segment variable, usually picked out with white (Note 7). **A. philippinensis**

Fifth vein of wing mostly dark. Distal end of first hind tarsal segment conspicuously picked out with white (Note 7). **A. fuliginosus**

b. Only the terminal hind tarsal segment *completely* white (Notes 2 and 3). Four white bands on each palp, including apical band (Note 7). **A. karwari**

2. Femora and Tibiæ Speckled (Note 1).
(If not speckled, see p. 96.)

a. Two or three terminal tarsal segments of hind legs *completely* white (Notes 2 and 7).

(i) Each palp with two broad pale distal bands, and one narrow proximal one (Note 7).

Three terminal hind tarsal segments completely *white* (*Notes 2 and 7*). *Palps prominently speckled* (*Note 4*).
A. maculipalpis var. **indiensis**

Two terminal hind tarsal segments only completely *white* (*Notes 2 and 7*). *Broad white band above this. Palps not speckled* (*Note 4*).
A. theobaldi

(ii) Each palp with one broad pale apical band, and two narrow more proximal ones (Note 7).
A. jamesii

b. Less than two terminal tarsal segments of hind legs *completely* white (Notes 2 and 7).

(i) Each palp with four well-marked pale bands, including apical band (Notes 5 and 7).

Three dark spots only on sixth longitudinal vein of wing. Conspicuous black scale tufts on ventral surface of all abdominal segments. Half of terminal hind tarsal segment only white (*Note 7*).
A. kochi

Five or six dark spots on sixth longitudinal vein of wing. Only extreme tip of terminal hind tarsal segment white (*Note 7*).

Tibio-tarsal joint of hind leg broadly and conspicuously banded with white.
A. leucosphyrus

Tibio-tarsal joint of hind leg without such broad band.
A. tesselatus

(ii) Each palp with three pale bands, including apical band (Notes 5 and 7).

Dorsum of most of the abdominal segments thickly clothed with scales.
A. willmori

Scales, if present, restricted to the last few abdominal segments only.
A. maculatus

B. Tips of Hind Legs Not White.

1. Femora and Tibiæ not Speckled (Note 1).
(If speckled, see p. 100.)

a. *Less than four dark areas on costa involving* both *the costa and the first longitudinal vein of wing (Note 7).*

(i) Inner half of costa without any distinct pale interruption (Note 7).

Broad white band on femur of hind leg.

With prominent scale tuft associated with the band. **A. annandalei**

Without such a tuft. **A. lindesaii**

No broad white band on femur of hind leg.

Palps with some pale bands. **A. hyrcanus** var. **nigerrimus**

Palps with no pale band.

With prominent scale tuft on ventral surface of seventh abdominal segment. **A. barbirostris**

With no such scale tuft. **A. umbrosus**

(ii) Inner half of costa with pale interruption (Note 7). **A. gigas**

b. *At least four dark areas on costa involving* both *the costa and the first longitudinal vein of wing (Note 7).*

(i) Front tarsal joints with broad pale bands (Note 7).
(If without, see p. 99.)

Palps with dark pre-apical area equal to, or nearly equal to pale apical band (Note 7). **A. subpictus (rossii)**

Palps with dark pre-apical area half, or less than half, the length of the pale apical band (Note 7). **A. vagus**

(ii) Front tarsal joints without broad pale bands.
(If with, see p. 98.)

Tips of palps black.

Dorsum of thorax with hairs or narrow false scales. Sixth wing vein with very indefinite markings (Note 7). **A. turkhudi**

Dorsum of thorax with obvious true scales. Sixth wing vein with very definite marking (three dark spots) (Note 7). **A. multicolor**

Tips of palps not black.

Third longitudinal wing vein dark (Note 7).

No pale spots on wing veins other than those on costa (Note 7). **A. rhodesiensis**

Pale spots present on other veins. **A. culicifacies**

Third longitudinal wing vein light (Note 7).

Each palp with two almost equal broad pale distal bands and a narrow proximal one (Note 7).

Proboscis pale in apical half. Sixth wing vein with three dark spots (Note 7). **A. aconitus**

Proboscis not so. Sixth wing vein with two dark spots (Note 7). **A. minimus**

Palps not so.

Inner quarter of costa without pale interruption (Note 7). Scales present only on the extreme front of dorsum of thorax. **A. listonii**

Inner quarter of costa with pale interruption (Note 7). Scales present over most of dorsum of thorax.

Longest pale area on costa less than half the length of longest dark area (Note 7). Tarsi of hind legs usually narrowly but distinctly banded with white. **A. jeyporiensis**

Longest pale area on costa very little shorter than longest dark area (Note 7). Tarsi of hind legs not banded thus. **A. superpictus**

2. Femora and Tibiæ Speckled (Note 1).

(If not speckled, see p. 98.)

a. Each palp with four well-marked pale bands, including apical band (Notes 5 and 7).

(i) Tibio-tarsal joint of hind leg broadly and conspicuously banded with white. **A. leucosphyrus**

(ii) Tibio-tarsal joint of hind leg without such broad band. **A. tesselatus**

b. Each palp with three well-marked pale bands, including apical band (Notes 5 and 7).

(i) Each palp with two broad distal and one narrow proximal band (Note 7). Palps speckled (Note 4). **A. stephensi**

(ii) Each palp with one broad apical and two narrow more proximal bands (Note 7). Palps not speckled (Note 4). **A. ludlowii**

NOTES TO PRECEDING TABLE

Note 1. A faint mottling is not considered as *speckling*. Seen under the microscope the spots constituting speckling are always clearly defined areas of pale scaling.

Note 2. Tarsal segments *completely* white are counted from the tip of the leg, *stopping at the first dark band*.

Note 3. In this case there are usually white areas forming bands higher up the tarsus.

Note 4. *Speckling on the palps* refers to white spots on their dorsal surface, usually between the middle and proximal pale bands.

Note 5. *Beware of speckling imitating a fourth band.*

Note 6. Species entered in more than one place in the table may show sometimes one appearance and sometimes another, or an appearance which may be overlooked. In either case the table will work out correctly.

Note 7. The *first tarsal segment* is that nearest to the tibia.

Terminal segments are those at the tip of the leg.

Hind tarsal segments, etc., are those of hind legs.

Front tarsal segments, etc., are those of front legs.

By *apical band* is meant one involving the extreme tip.

Distal means situated furthest from the body.

Proximal means situated nearer to the body.

The *costa* is the anterior border of the wing.

The *first longitudinal vein* runs parallel with the costa.

The *second longitudinal vein* lies behind the first, and divides into two branches.

The *third longitudinal vein* lies behind the second, and is unbranched.

The *fourth longitudinal vein* lies behind the third and divides into two branches.

The *fifth longitudinal vein* lies behind the fourth and divides into two branches.

The *sixth longitudinal vein* lies behind the fifth, and is unbranched.

The *anterior forked cell* is the part of the wing lying between the branches of the second longitudinal vein.

The *posterior forked cell* is the part of the wing lying between the branches of the fourth longitudinal vein.

Central Malaria Bureau, India, 1926.

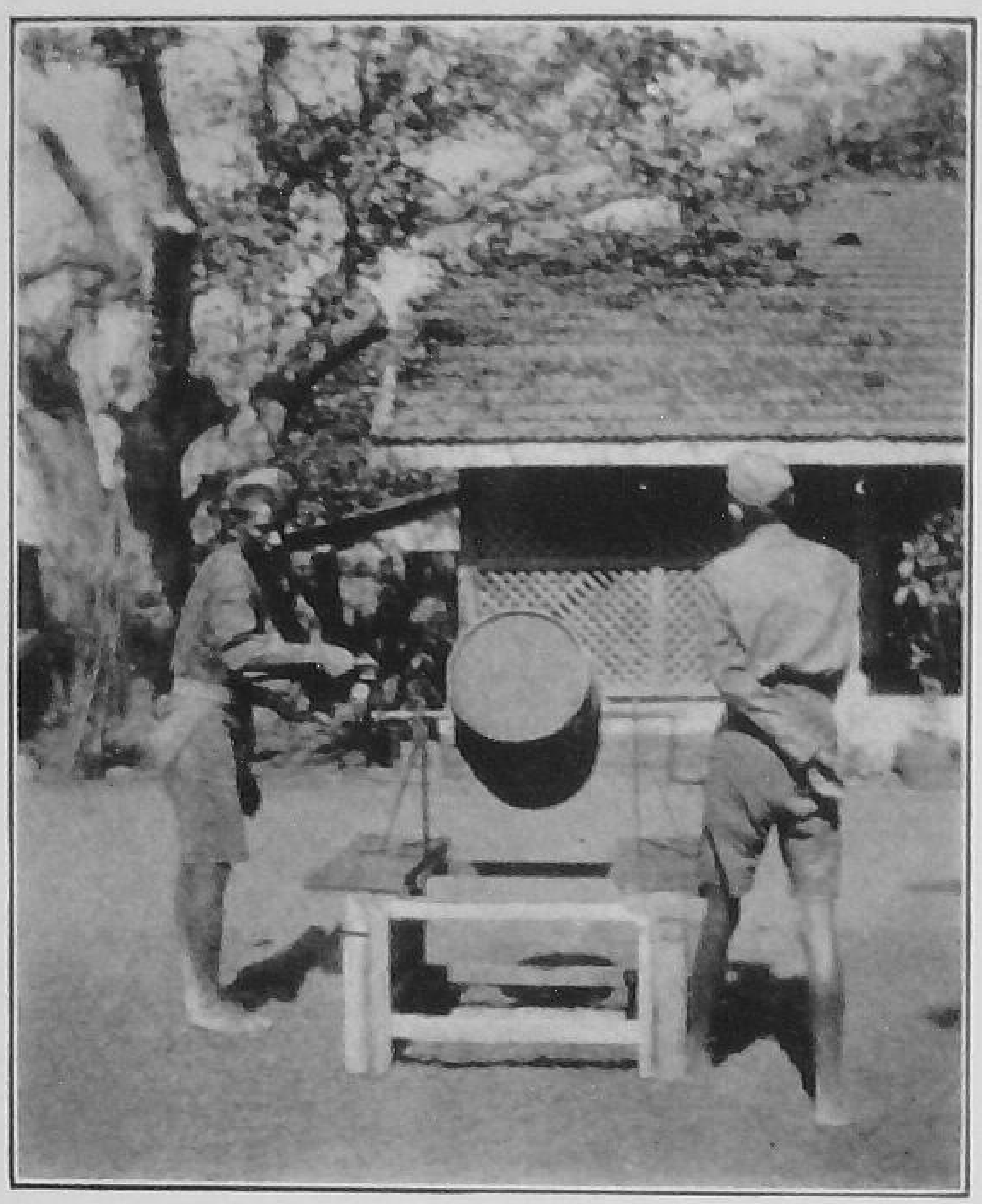
APPENDIX VIII

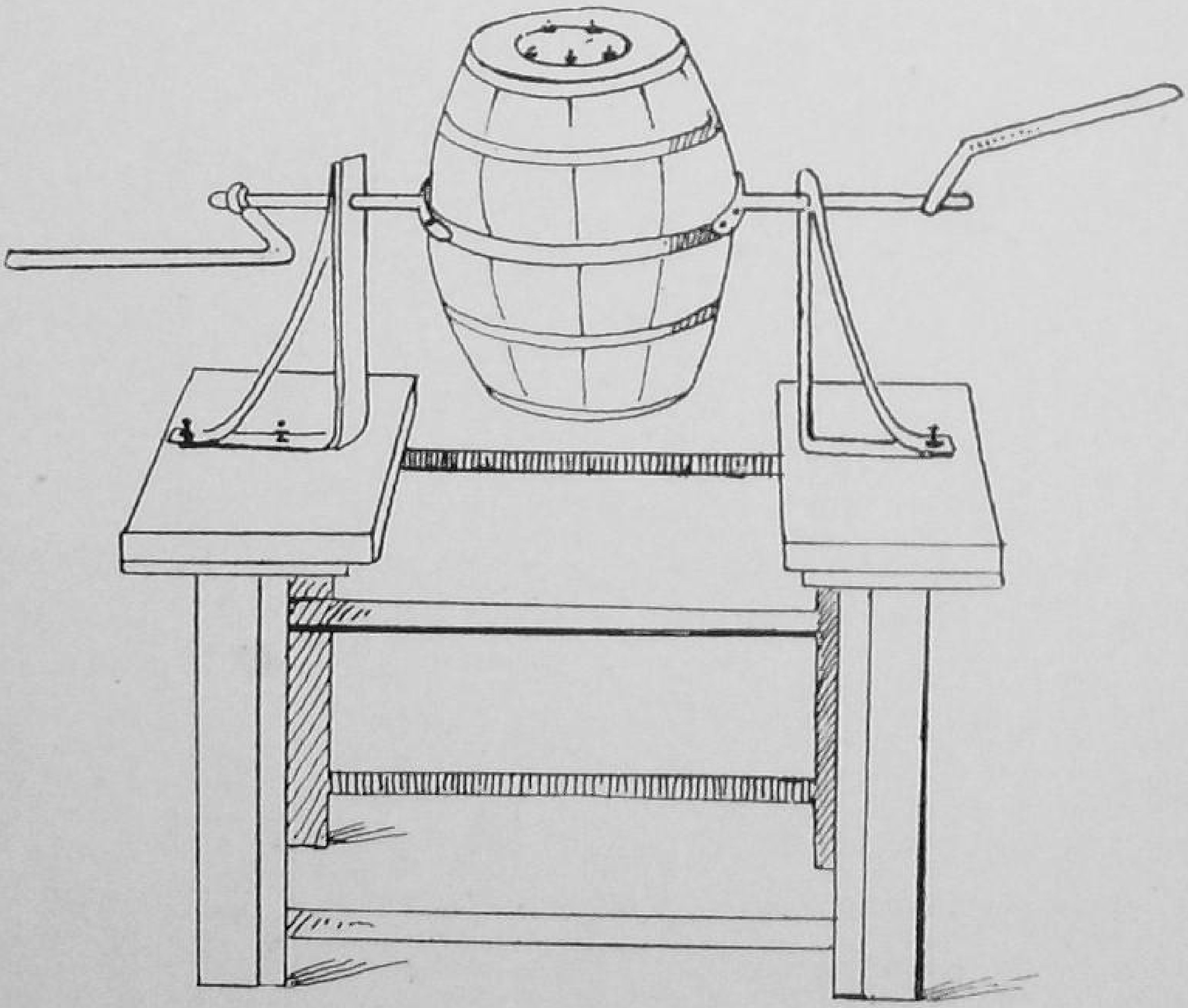
'PARIS GREEN': ITS ACTION AND USES

'Paris Green' is a recent addition to our armamentarium for malaria control, and its cheapness, simplicity of application and effectiveness, even in the presence of thick vegetation, are assets which are not even nearly approached by other larvacides. It is as well, therefore, that all interested in Anopheline control should know the action and uses of this larvacide.

'Paris Green' is the American name for a chemical which is aceto-arsenite of copper. In its pure state it is said to contain about 58·62 per cent. of arsenious anhydride. As the commercial product is liable to be subject to adulteration by various extraneous substances, it will be a wise precaution, when ordering it for larvacidal purposes, to specify its arsenite content, and also put every new consignment to a practical field test before accepting it for use on a large scale. 'Paris Green' containing approximately 40 per cent. of arsenic estimated as AS_2O_3 was found by us to be quite efficacious as an Anopheles larvacide. It is an exceedingly fine crystalline powder having a brilliant emerald green colour, and is practically insoluble in water.

'Paris Green' floats for several hours on the surface of water, and Anopheline larvæ, being surface feeders, swallow these floating particles, which act as a very powerful poison to them. Culicine larvæ, not being surface feeders, are not affected by this larvacide. It has no action on the pupal stage of Anopheline or Culicine mosquitoes, as pupæ do not feed. Eggs are unaffected by 'Paris Green', and hatch out into larvæ in the usual course. Fish and aquatic insects, like water-boatmen and water-bugs, are not affected by the use of 'Paris Green', and ducks feeding in some tanks where





PARIS-GREEN MIXER

this larvacide was used by us came to no harm. In both running and stagnant water, fresh or brackish, 'Paris Green' can be used with great benefit, even without removing any vegetation if present.

TECHNIQUE

Personnel.—Any ordinary Indian labourer will easily learn the method of dilution, mixing and distribution of 'Paris Green'. Highly trained labour is not required.

Dilution.—The best vehicle for dilution is fine road or clay dust. Cork dust, saw dust, fine sand or spoiled flour may also be used. The diluent used must be perfectly dry, since the least degree of moisture tends to cause the dust to sink. One part of 'Paris Green' mixed with one hundred parts of any of the above-mentioned diluents will be efficacious under nearly all conditions.

Mixing.—The figure opposite illustrates a very efficient method of mixing 'Paris Green' with a diluent. It consists of a barrel across which an iron pipe is passed in the middle for an axis, resting on a stand so that the barrel can be revolved with the greatest ease.

Quantity.—Fifteen grains of 'Paris Green' mixed with 100 parts of the diluent will suffice for every ten square yards of water surface. If the water surface is very densely covered with vegetation, it might be advisable to use a somewhat larger quantity, which can be easily judged after a few preliminary trials.

Intervals between Treatment.—Once in seven days is a safe interval for the application of 'Paris Green'; but since the development of mosquito larvæ depends a good deal on the existing temperature and other factors, the point to remember is that the interval should be shorter than the period required for the appearance of Anopheles pupæ.

Distribution.—The mixture can be thrown in the air by hand, so that it is carried by the wind and spread over the water surface. If, however, there is dense vegetation present, it is very likely that a good deal of the mixture will be delivered on the foliage of the plants instead of on the water surface. In such cases hand-bellows with a container and nozzle can be used with advantage, so that the nozzle can be thrust through the vegetation and the larvacide spread directly on the water surface (*vide* page 65).

Apart from the simple precaution of keeping to the windward of 'Paris Green' dust and taking a good bath after using it, we have taken no other steps to protect our personnel employed in mixing and distributing 'Paris Green', and have observed no ill-effects on them resulting from daily contact with it.

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