LESSONS IN
PRACTICAL BIOLOGY FOR INDIAN STUDENTS.

THIRD EDITION.

BY

ARTHUR POWELL, B.A., M.Ch.,

PROFESSOR OF BIOLOGY, GRANT MEDICAL COLLEGE

FELLOW AND EXAMINER, BOMBAY UNIVERSITY.

EXAMINER, PUNJAB UNIVERSITY.

BOMBAY:

PRINTED AT THE TIMES PRESS.

1913.

CONTENTS.

PREFACE.

THE contents of this work were first printed some seven years ago. As the whole edition was sold in a fortnight, it may be fair to claim that such a book was wanted.

I am painfully aware of its many defects, and that its rapid sale was no evidence of its merit, but merely of the fact that there was no other better, or worse, on the market.

In 1910 it was reprinted with little alteration, in deference to the importunities of many teachers and students.

No apology is offered for the many repetitions to be found in the descriptions of the various types. They allow the student to examine the types in any order convenient to him.

I have been so obstinate as to stand by certain old names, such as *Perichaeta*, instead of *Pheretima*, mainly because many of our local *malis* have learned the former, and *Palinurus* instead of *Panulirus* on aesthetic grounds. A foot-note in the text gives an excuse for my crime. It is perhaps as well to say that the names *Panulirus* and *Linuparis* have been coined from *Palinurus* on "Transpontine" principles. I fail to see why, what would in social life be considered a vile pun or a contemptible "Spoonerism," should rank in zoology as "scientific nomenclature."

My best thanks are due to my friend, Mr. A. J. Kohiyar, for several photographs and for kindly correcting the proofs of the text.

AMŒBA.

Before looking for *Amœbæ* the student must first learn how and where to do so, otherwise he will waste almost as much time as in the proverbial search for a needle in a haystack.

Examine a drop of your own blood. Take some perfectly clean cover-glasses and slides. Clean the top of your finger with a rag dipped in spirit, let a friend grasp the finger pretty firmly, when the tip will become red, and then prick it with a clean sharp needle (the needle may be rendered absolutely clean by heating it in a spirit or gas flame and using when cooled). A minute drop not bigger than a pin-head should be squeezed out and touched with the cover-glass, taking care not to touch the skin. Let the glass then drop on the centre of a slide, when the blood will spread out in a thin film. In a well-made specimen the centre of the film should look as if there were no blood there. If the drop of blood that exudes be too big, wipe it off the finger with a clean rag or blotting paper and squeeze out a smaller drop.

If the drop be large, or if the surface of the cover-glass be dirty or greasy from touching with the fingers, the film of blood will be too thick and will not spread out evenly.

Examine under the highest power of your microscope. Note the pale yellow "*red corpuscles.*" Diminish the amount of light by using a smaller aperture of the diaphragm. Look for one of the *white corpuscles*. It will take some time for the novice to see them, but they are always present, and he will eventually recognise them as colourless, transparent finely-granular bodies of irregular outline somewhat larger than the red corpuscles. Watch one and you will see it slowly change shape and the minute granules slowly change their position by a flowing movement.

Vary the amount of light by altering the diaphragm. You will probably find that, with very little light, you will see them best. Gently tap the cover-glass with a needle so as to set up a current in the blood. You will see the red corpuscles tossed about by the flowing plasma, but the white amœboid corpuscle stands fast unless the tap be too violent.

Three facts learned by this preliminary exercise will help you much in your hunt for the *Amœba*.

The white corpuscle of the blood (*a*) exhibits amœboid movements, (*b*) is very transparent and invisible in too bright a light, and (*c*) is adhesive to a glass surface. *Amœba* resembles it in all these three properties.

Take some of the water and mud from the bottom of a fresh water tank, add some withering leaves and stalks and expose to the sunlight for a few days.* With a pipette take a little water and mud from the bottom, or with the edge of a knife scrape the surface of a submerged leaf. Examine under a cover-glass with a half-inch objective, *using*

* The medical student can obtain *Amœbæ* with little trouble in large numbers in the stools of certain cases of dysentery, especially when treated with salines. Great care must, however, be taken as there is a considerable risk of infection. When done with, the *Amœbæ* should be killed by heating the slide, and the hands should be disinfected.

very little or oblique light, and look out for an object resembling the white corpuscle. If in doubt about any object, *gently* tap the cover-glass. *If it flows away, it is probably not an amœba.* Watch for a *flowing movement of the granules.* When an *Amœba* is found, put on your highest power and note——

There is an outer clear marginal substance known as the *ectoplasm* (Gr. *ecto,* outer) so transparent that its margin may escape your notice. Move the mirror of the microscope to and fro slightly, and the margin may become more distinct. The central portion, of a ground-glass appearance owing to the presence of a large number of minute granules, is known as the *endoplasm* (Gr. *endo,* inner).

Watch the animal carefully and sketch it at short intervals. You will observe its outline change continually, and its position shift. At one or more places a little process of ectoplasm slowly projects. This is owing to a contraction of the rest of the animal, just as if you compressed some soft putty or dough in your hand, portions would be squeezed out between your fingers. At first only the ectoplasm takes part in this projection, but later the granular plasm will be seen to flow in with a fairly rapid rush. By this method the semifluid animal is able to change its position and move about with a slow flowing movement, so characteristic as to be known as "amœboid."

When the animal finds something it wishes to eat, it sends out one of these processes, known as *pseudopods,* Gr. *pseudes,* false, *pous, podos,* foot) on each side which then flow round and meet one another so as to completely engulf the particle of food. This becomes surrounded by a fluid which has the power of digesting or dissolving it. Any indigestible remnant is cast out in the same manner by the animal flowing away from it.

Should a grain of starch or globule of fat have been swallowed, it will be ejected quite unaltered, no matter how long it has been in the *Amœba*. From this it would appear as if the animal was capable of assimilating proteid food only.

Amœba requires oxygen and gives off carbon dioxide, so we may assume that it breathes. It also excretes other products of katabolism at all parts of its surface.

In many *Amœbæ* you may observe a clear round spot slowly form and increase to a certain size when it will suddenly collapse and disappear. This is known as the *contractile vacuole* (Latin, a little empty space). It again slowly forms and suddenly disappears rhythmically. Its formation is due to a collecting of fluid containing excretory matters, and its disappearance to the sudden rupture of the ectoplasm and the escape of this fluid. The vacuole is, as a rule, absent in the parasite Amœbæ.

A darker spot or nucleus may be seen in the endoplasm during the life of the animal; but even when not visible its presence can generally be proved by adding some substance such as carmine or iodine which stains the nucleus much deeper than the rest of the protoplasm.

The reproduction of *Amœba* is an extremely simple process, it simply divides itself into two, the nucleus always dividing first before the rest of the protoplasm. Each half becomes a new *Amœba* which feeds and soon grows to the size of its parent cell.

Under unfavourable circumstances, such as the drying up of the water in which it lives, *Amœba* becomes sluggish, and drawing in its pseudopods, assumes a globular shape. It then secretes a thin waterproof membrane on its outside, and goes into a state of rest in which its functions remain dormant. In this condition, called encystment, *Amœba* can be carried by the wind as a particle of dust to great distances till it again finds a suitable home. Sometimes instead of dividing into two (*binary fission*) the *Amœba* breaks up into a large number of small individuals when the process of multiplication is known as *sporulation* or multiple fission.

No *Amœba* can arise except as the offspring of another *Amœba*. This fact is as true, though not so obvious, of *Amœba* or any other animal or plant, no matter how minute or lowly, as of Man himself.

If some meat, soup or an infusion of vegetable matter be exposed to the air it is a matter of common knowledge that in a few days it will be found full of minute animal and vegetable organisms and in a state of decomposition. Not very long ago it was universally believed that animal and vegetable matters of necessity became rotten when dead and that this decomposition gave rise to new living organisms. Now we know that it is these low organisms that cause the decomposition and not *vice versa*. Canned vegetables and meat can be preserved for years; this might be attributed to the absence of air, but that it is not so can easily be proved. Take some cotton wool and a test tube and submit them to such a high temperature for some days that any living organisms would be killed. Place some broth in the tube, plug the neck of the tube with the cotton wool and boil the broth for a few minutes twice daily for a few days. You will find that the broth keeps clear and "sweet" for an indefinite period. If you examine a drop under the microscope you will find no living animal or plant.

If the plug of wool be removed, the broth will be found next day to contain many small plants, called *Bacteria*, and later will become turbid and rotten.

This experiment shows that it is not the presence of air that causes decomposition, for the air is able to pass in and out freely through the spaces between the cotton fibres. The cotton has acted as a filter, so that no dust has been able to pass through the broth. Almost all dust contains numerous spores of yeast, bacteria and other fungi as well as encysted *Amœbæ*. It is the entry of these organisms into the broth and their subsequent rapid multiplication that have caused the decomposition.

This is an experiment which with many others should satisfy you of the correctness of the modern theory of Biogenesis, namely, that there is no "spontaneous generation" of any animal or plant, be it *Amœba* or Baby, *Bacillus* or Banyan tree. Every cell, every animal, and every plant is the offspring of a previously existing cell.

Occasionally an *Amœba* has been seen to flow round and engulf another of the same species. This which formerly was looked upon as an act of cannibalism is now considered by many naturalists to be a primitive love scene or act of sexual conjugation. *Amœba* can be artificially multiplied by cutting it in pieces, provided there be a part of the nucleus in each fragment. Each piece develops into a new *Amœba*.

If a very diluted solution of some irritant chemical such as iodine or alcohol, be run in under the cover-glass, the *Amœba* will be seen to draw in its pseudopods proving that it is irritable or sensitive to a stimulus. Gentle heat or electric shocks will produce the same effect.

We must now consider more particularly the substance of which *Amœba* is composed.

It is known as *protoplasm* and is the basis not only of *Amœba* but of all cells, animal and vegetable alike. We have seen it to be a soft viscous, semifluid substance not soluble in, but readily permeated by water.

It is of an extremely complex chemical composition but is not a definite compound with a definite chemical formula. On the contrary, we shall find one of its chief characteristics is that its chemical composition is continually changing, certain constituents being continually broken down chiefly by oxidation and others being constructed. These processes are known as *metabolism* (Gr. *metabalein*, to alter); the constructive as *anabolism*, the destructive as *katabolism*.

This mixture of compounds, protoplasm, invariably contains complex substances known as *proteids* or albumens, into the composition of which carbon, hydrogen, oxygen, nitrogen and sulphur invariably enter. It is to these proteids that the chemical reactions of protoplasm are mainly due. Thus, like white of egg, a common proteid, protoplasm is coagulated by heat, by nitric, picric or chromic acids, by alcohol and other reagents.

It is soluble in weak alkalis and acids. In reaction it is slightly alkaline. When living it contains a large amount of water, abstraction of which causes its death.

Of its physical attributes *Amœba* has given us an illustration. We have seen it is capable—

(*a*) of growth,

(*b*) of assimilating food,

(*c*) of reproduction,

(*d*) of responding to impulses or stimuli, or, in other words, it is "irritable."

(*e*) That it is motile.

(*f*) That it breathes or respires, *i.e.*, that it continually requires oxygen to unite with its carbon and hydrogen, as it were in a slow process of combustion, by means of which energy is set free.

These are the characteristics which distinguish all living things, animal or vegetable, from inanimate bodies.

To the Teacher.

The Cultivation of Amœbæ.

Amœbæ may easily be cultivated by any one who has at hand the ordinary culture media used by bacteriologists. They cannot be obtained in pure culture but grow readily in symbiosis with many bacteria such as the Cholera vibrio or the Colon bacillus.

Take of dry agar-agar (sold in the bazaars as *sufed ghas*)	45 grains.
Common salt, Na. Cl.	3 to 5 grains.
Beef Extract, such as "Lemco"	10 to 20 grains.
Water	5 ounces.

Soak the agar in the water till dissolved; then add the salt, meat extract and enough carbonate of soda to render distinctly alkaline. Boil in a flask, plugging the neck with cotton wool. The boiling should be repeated twice daily for three days.

This culture material should then be poured in a thin layer into sterilised Petri dishes, or into test-tubes to form "slants." Plug the test-tubes with wool. Sterilise again the tubes and Petri dishes.

Frequently the amœbæ found in tanks and vegetable infusions can be directly transferred to and grown on the agar, but greater certainty of their growth will be insured by adding to half a pint of the tank water or infusion, an ounce of the broth made by boiling a drachm of the above culture material in an ounce of water. This will form a less sudden change of environment.

The next day you will probably find a scum on the surface of the water to which you have added the broth. Search this for amœbæ. If not found try again the second and third day. Make a sowing of the scum on the surface of the agar. Many bacteria as well as amœbæ will be found next day.

All precautions against infection must be taken if the amœbæ associated with dysentery be employed. Note that although in the human body the amœbæ as a rule have no contractile vacuole those found on the culture medium usually possess one. Either the presence or absence of a contractile vacuole cannot be looked upon as evidence of a distinct species or the amœbæ that appear on culture are not the true parasite but a foreign species that has been swallowed with the food.

Note also that on the second and third day the amœbæ are particularly active, many being of an elongated form moving rapidly with a vermicular rather than an amœboid movement.

Note that after the lapse of a week most of the amœbæ have become globular and motionless, while many are encysted. Make repeated transfers to fresh agar at intervals of three days.

Note that the encysted amœbæ of a first transfer from a tank to an agar surface often fail to grow when transferred after two or three weeks to fresh agar, whereas after many generations grown on repeated transfers to agar, amœbæ though dormant and encysted for many months, at once grow with great luxuriance when transferred to fresh culture material.

PARAMŒCIUM.

Paramœcium can be found in any of the weed-covered tanks, *jhils* or borrow-pits of this country. It will also be readily found in great numbers in the stale water of vases in which cut flowers have been kept for some days. Examine with a low power of the microscope a drop of water obtained from one of these sources. The animal will be recognised as a somewhat flattened elongated body, two to four times as long as it is broad, darting about the field in a lively manner. If they be very numerous, a higher power of the microscope may at once be used to observe their more minute structure, but their movements are so rapid that only a momentary glimpse may be obtained as they dart across the field of vision.

Place a minute drop of a $\frac{1}{2}$ to 2 per cent. solution of eucaine or cocaine hydrochloride close to the margin of the cover-glass and allow it to slowly run in.

It is best to use a large cover-glass, as the weaker solution takes a long time to narcotise, and a strong solution kills the animals too suddenly.

With a large cover-glass and a small drop of stronger solution of cocaine, the animals nearest the drop are rapidly killed and broken up by a process of molecular disintegration or diffluence, very characteristic of *Infusoria.* The animal is seen to come to a stand-still, the cuticle gives way at one or more points, a little granular matter exudes, and the process continues till in a few moments nothing is left but a patch of granular debris, in which no part of the animal can be recognised. As the cocaine slowly diffuses under the cover-glass, the animals at the far side will for a long time be unaffected, while those in the intermediate zones will be found in various stages of stupefaction. Long after locomotion has ceased, the movements of the cilia and contractile vacuoles can be seen.

The animal may also be studied by placing a drop of water containing *Paramœcia* on a slide, and spreading a few fibres of cotton over it, to restrict their movements. Put on the cover-glass and examine.

If well done, the cotton fibres will act as fences, dividing the field into a number of minute paddocks, from which the animals cannot escape, but the method requires some experience, as if the wool be too little, the paddocks are too large, if the wool be too much, the animals can escape through the gaps caused by the crossing of the fibres.

MORPHOLOGY.

Note the size of the animal. *P. aurelia* is about 200 to 250 mikrons in length, that is, about $\frac{1}{4}$ m. m. or $\frac{1}{100}$ of

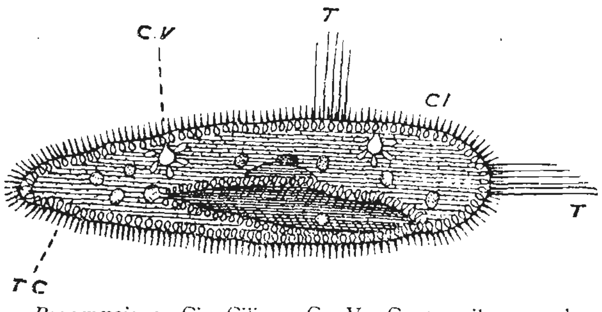


Fig. 1.—*Paramœcium*—Ci. Cilia. C. V. Contractile vacuole with radiating channels. F. V. Food vacuole. M. Mouth. Mi. Micronucleus. Meg. Meganucleus. T. C. Trichocysts. T. Discharged threads.

an inch, but smaller specimens are common in our tanks. Though extremely flexible, the animal, unlike *Amœba*, preserves a definite shape and outline, the body being elongated and somewhat flattened. The *anterior* end, that portion which keeps in front during progression, is rounded, while the posterior end is usually somewhat pointed.

On the ventral surface, we find an oblique depression known as the *oral* or *buccal groove*, beginning on the left side near the anterior end and reaching backward to the mouth, which is a little behind the middle of the animal's length.

The protoplasm is very clearly differentiated into an outer *cortex* (Latin, bark) or *ectoplasm*, and an inner granular *medulla* (Lat. pith or marrow) or *endoplasm*. Externally the whole body is covered by a thin cuticle, through which protrude numerous *cilia* (Lat. eyelashes) of approximately the same length.

These cilia are delicate hair-like filaments which vibrate to and fro without ceasing during the life of the animal. They arise from the ectoplasm, not from the cuticle through which they project. The movements of the cilia are extremely rapid, and somewhat resemble the rippling caused by the wind in a field of corn or rice. Their mode of action is also easily explained by this simile. In the one case the current of wind causes a sudden bending of the elastic corn which slowly recovers its erect position only to be again bent by the wind. In the case of the cilia, the cause and effect are reversed. Their sudden bending, followed by a more leisurely return, sweeps a continuous current of water with the particles of food contained in it into the buccal groove, which also is lined with cilia, all working inwards to the mouth.

The ectoplasm is elastic and much firmer than the endoplasm. It is the protective, sensory and motor layer. On its deeper surface may be seen indistinct longitudinal or oblique streaks known as the *myonemes* (Gr. *myon* muscle, *nema* thread) or *contractile fibrils* by which the various bending and straightening movements of the animal are performed. To the myonemes and the rowing action of the cilia the power of rapid locomotion is due.

Observe the two contractile vacuoles in the dorsal portion of the cortex.

One is about one-third of the animal's length from the anterior end, the other about the same distance from the posterior. Each is connected with a number of radiating channels which lead to it fluid for excretion. At the moment of contraction, or *systole* as it is called, these channels can be seen radiating out from the vacuole. After the collapse of the vacuole, the channels can be seen to fill gradually with fluid and then contract, discharging it into the vacuole, which becomes large and spherical in *diastole*. Both vacuoles then contract at the same moment and discharge the fluid externally.

Run a drop of weak iodine, safranine or osmic acid solution under the cover-glass. You will see a number of stiffish threads several times longer than the cilia suddenly shoot out. These are the threads of the *trichocysts*, (Gr. *trichos* a hair, *kystos* a bladder), stinging weapons used for offence or defence which are smartly discharged if the animal be irritated. The trichocysts are minute oval sacs arranged radially in the deeper part of the ectoplasm.

Run in a drop of 1 per cent. acetic acid. The same result will take place. Stain with Safranine, Dahlia, Bismark Brown or Carmine. The lashes of the discharged trichocysts are now well seen.

A little finely powdered indigo, or carmine should be suspended in the water to observe the action of feeding. Those particles which enter the buccal groove will be seen swept down by the action of the cilia to the mouth, where they pause for a moment. A sudden gulping movement is seen to take place, and the next moment the particle of indigo is seen in the endoplasm surrounded by a droplet of fluid known as a *food vacuole*. Many of these vacuoles may be seen circulating in the endoplasm till their contents are digested. You may see that starch grains and droplets of fat are digested as well as proteid matters—a considerable advance on the assimilative powers of *Amœba*.

The fæces, or waste food, from which the nutriment has been extracted, are discharged at a definite spot, a little behind the mouth. This is not a permanent opening and is called the *anal spot*.

The endoplasm is much more fluid and granular than the ectoplasm. The circulation of the food vacuoles and granules has already been noticed.

Observe the presence of the large nucleus with the small nucleus generally close by it.

Stain the specimen with carmine, with safranine and methylene blue. With an oil-immersion lens, observe that the large oval meganucleus stains uniformly, while the small micronucleus shows the chromatin strands seen in ordinary nuclei.

Sometimes the nuclei appear to be situated in the ectoplasm and some zoologists consider this their proper situation.

In many species of *Paramœcium* there are two micronuclei, and in others two meganuclei as well, throughout life and not only at the time of fission.

Reproduction is effected by transverse fission. The large nucleus divides into two by direct division, the small nucleus divides into two by the complicated process of mitosis. A transverse constriction appears and gradually deepens till the animal is completely divided into two, each new animal taking half of both large and small nuclei.

REJUVENESCENCE.

Reproduction by transverse fission cannot go on for ever. After several, perhaps a couple of hundred, generations produced by fission, the capacity for reproduction in this manner seems to become exhausted. You may then observe two individuals become attached to one another by their ventral surfaces. The protoplasm of their bodies becomes continuous, and they swim about for some time in this position of *conjugation*. They then part and become separate individuals again. Very important changes take place during this very elementary form of love-making, as a result of which both animals become "rejuvenated" and again capable of rapid reproduction by repeated fission.

During this conjugation the large nucleus breaks up into many fragments which disappear. Apparently some are absorbed, but in some cases they have been clearly seen to be extruded from the anal spot.

The micronucleus divides into two by mitosis, each of these again immediately divides into two, so that each of the conjugating individuals now possesses four micronuclei. Three of these disappear like the "polar bodies" of the higher animals, of which you will learn later on. The fourth again divides into two *pronuclei*, of which one is stationary, the other active. The conjugating *Paramœcia* then exchange their active pronuclei, which leave the animal in which they arose and cross over into the body of the other party, where it unites with the stationary pronucleus to form a single *zygote* nucleus (Gr. *zygotos* yoked, united).

Thus each of the conjugating cells comes to have a nucleus derived half from itself, half from its conjugating partner.

After separation the zygote nucleus gives rise to a normal mega--and micronucleus and the rejuvenated animal is able to give rise to further generations by fission.

This process of conjugation seems to come on at some definite "rutting period." For weeks you may not see a single case of conjugation, when suddenly a large number of *Paramœcia* seem to fall in love, and after a little preliminary flirtation quite an epidemic of conjugation takes place.

We have seen in *Amœba* little differentiation of structure; there are no special organs for special functions, except, perhaps, the contractile vacuole, and this is not present in many species, for example those parasitic on man.

There is no mouth, no hand, leg, stomach or lung; perhaps it would be correct to say it is all mouth, all hand, all leg, all stomach, all lung, as any part of the *Amœba* seems equally capable of taking in food, digesting it, or of acting as an organ of prehension or locomotion.

Each individual mass of protoplasm, containing a nucleus, such as *Amœba*, is called a cell. All animals and all plants are composed of such cells, some may be of a single cell such as *Amœba* and *Paramæcium* among animals or *Yeast* and *Bacteria* among plants; others are made up of many cells, but no matter how large or how complicated they may be, each Banyan tree, each Man himself begins his individual existence as a single cell, and it is only by the *multiplication* and *differentiation* of that cell and its daughter-cells that the higher animal or plant arrives at adult condition.

In *Paramæcium*, we find that though composed of only one cell, that cell maintains a definite outline, and that definite parts are set aside for definite purposes. We have a definite spot, the mouth, into which all food is received, contractile vacuoles in definite situations, cilia set apart as special organs of locomotion, and other special contractile fibrils, the *myonemes*.

In higher animals composed of many cells, we find special collections of cells, known as tissues, united in various ways to form organs for special purposes.

These organs, tissues and cells are constructed on different plans to fit them for their special duties or *functions* as they are called, so that from their appearance we can generally tell what is their purpose. This fact may be expressed as a rule in Biology, that a division of labour is always accompanied by a differentiation of structure. Furthermore we find that this division of labour among cells or tissues that have become experts tends to efficiency, and that those animals and plants that show least division of labour or differentiation of structure are the lowest and most primitive in the scale.

A parallel may be drawn with human social communities. In a savage or "primitive" state each man is a "Jack-of-all-trades." He does his own hunting, killing and cooking, he makes his own weapons, furniture, hut and clothes, he is his own doctor, law-maker and policeman to protect himself and his property. In a slightly higher state we find hunters, warriors, slaves as tillers of the soil, the women as cooks and rudimentary dressmakers and tailors, and our own prototype, the medicine-man who is not only druggist, surgeon and physician, but priest also in many cases.

In higher states of Society we find still further specialisation. For instance in most parts of this country the druggist, doctor and priest are differentiated into three personages. In large cities we find the medical man further specialised, the surgeon, the physician, the gynæcologist, the sanitarian, till finally in the great cities of Europe we have specialists for the eye, ear, throat and almost every organ in the body. A similar or even greater specialisation is found among the employés of our cloth, iron and ship-building trades.

History, even personal observation in countries like Japan, teaches us that the highest and most specialised form of civilisation is descended and developed from the more primitive. All the most civilised countries have passed by gradual development from primitive savagery to their present high estate.

SPIROGYRA.

In tanks and slowly flowing nullahs which contain clear water, you will often find slimy tresses of bright green, fine hair-like filaments which feel slippery to the touch. There are many genera of these water weeds, but under the low power of the microscope you can readily identify Spirogyra by the facts that it is unbranched and that its green colouring matter is arranged in spiral bands from which the plant takes its name.

The student should select a species in which the spirals are few and not so closely coiled as to obscure a view of the other contents of the cell.

Each filament is seen to be composed of a number of elongated cylindrical cells arranged end to end in a row. The essential part of each cell, as of all living organisms is protoplasm. As is the case in nearly all vegetable cells, the protoplasm is enclosed in a cell-wall of colourless cellulose

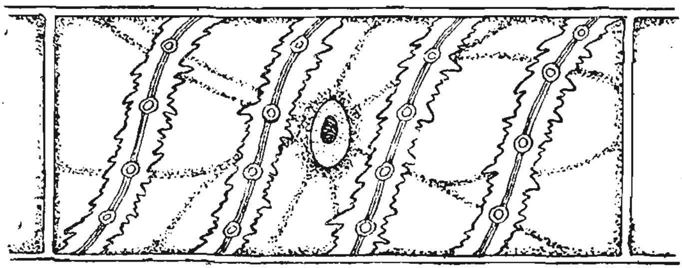


Fig. 2.

readily recognised by its double outline. Owing to the presence of a large vacuole and of the green bands, the firmer portion of the protoplasm is not always readily recognised at first, but by careful focussing you will find a nucleus, perhaps containing a brighter central nucleolus in the centre of the cell. Around this nucleus the cytoplasm can be recognised as a colourless granular substance sending thin processes out in all directions to the cell-wall and to certain spots in the spiral bands. Between these spidery processes is a large vacuole containing clear cell sap. A granular layer of cytoplasm lines the cell-walls and has received, rather unnecessarily, the name of the *primordial utricle*. Constant movement of the protoplasm can be recognised by watching the darker granules passing along the strands of cytoplasm. The structure of the cytoplasm can be well demonstrated by the process of plasmolysis which depends on the varying osmotic powers of the different cell structures and the withdrawal of its watery contents.

Mount some Spirogyra in water under a cover-glass. Allow a drop of solution of sugar or of table salt (5 per cent.) or of saltpetre (8 per cent.), which may be coloured by adding a little eosine to run in. The protoplasm will be seen to contract and withdraw from the cell-wall, beginning at the corners. At first the red colour passes through the cell-wall, but not through the protoplasm so that a layer of red fluid is seen separating the latter from the cell-wall. If now the saltpetre solution be removed and the Spirogyra be irrigated with pure water, the contracted protoplasm will recover and resume its original position. If, on the contrary, we allow the solution to remain, after an hour or two, you will see the protoplasm begin to die and become stained by the eosine. The vacuoles will however resist for a much longer time, and be recognised as colourless globules in the stained protoplasm.

The same phenomena can be observed by the use of any fluid, such as glycerine or alcohol which will withdraw by osmosis the cell sap, but these fluids kill the protoplasm more rapidly.

The cell-wall is composed of a colourless substance, cellulose, which like starch and sugar belongs to the group of substances known as carbohydrates, which contain only the elements carbon, hydrogen and oxygen, the two latter being in the same proportion as in water, *i.e.*, two of hydrogen to one of oxygen. Like starch it has the formula $C_6H_{10}O_5$, but is readily distinguished by the fact that iodine turns starch blue, while it stains cellulose slightly yellow. If in addition to the iodine cellulose be acted on by sulphuric acid, it turns blue. This test should not be applied by the young student as he is liable to injure his microscope with the strong acid. Most vegetable cell-walls are composed of cellulose or one of its modifications. Cotton fibre is almost pure cellulose, and the student can test the chemical reactions of cellulose by soaking some cotton wool in iodine solution and then treating with 50 per cent. sulphuric acid. Another useful test is Schulze's solution of chloro-iodide of zinc which turns cellulose blue. Cellulose allows water and substances held in solution to osmose freely through it. It is insoluble in dilute acids or alkalies. By the action of strong sulphuric acid, it is turned into dextrose. It does not, like starch, swell up on the addition of boiling water.

The green spiral bands, which are known as *chlorophyll* bands, *chloroplasts,** or *chromatophores,*† vary in number from one to ten. They owe their colour to a green pigment *chlorophyll,* which is present in all green plants. Each band is seen to have an irregular jagged margin and to contain at intervals round refractile bodies called *pyrenoids*. If the plant has been recently exposed to sunlight each pyrenoid is surrounded by small starch grains which can be demonstrated by running in a little iodine solution. The starch granules, if present, will become blue or bluish black in colour.

Note that all the cells which compose a filament of Spirogyra are alike ; there is no apex, no base, no root to the plant ; each cell is in size, structure and function almost exactly similar to its neighbours. Hence we may look upon Spirogyra either as a colony of unicellular plants arranged in a string or as a multicellular plant in which under ordinary circumstances, there is neither differentiation of structure nor division of function. Each cell absorbs its own food without the aid of its neighbours, each cell is capable of dividing and so multiplying independently.

REPRODUCTION.

Under normal circumstances Spirogyra reproduces it-lf by cell-division. This process usually takes place at ght, but if we put the plant in a cool place, or surround the ssel with ice overnight, we can delay the division till next

---

* Gr. *chloros* green, *phyllon*, a leaf.

† Gr. *chroma* color, *phorein*, to carry.

of strong sulphuric acid, it is turned into dextrose. It does not, like starch, swell up on the addition of boiling water.

The green spiral bands, which are known as *chlorophyll* bands, *chloroplasts,** or *chromatophores,†* vary in number from one to ten. They owe their colour to a green pigment *chlorophyll,* which is present in all green plants. Each band is seen to have an irregular jagged margin and to contain at intervals round refractile bodies called *pyrenoids.* If the plant has been recently exposed to sunlight each pyrenoid is surrounded by small starch grains which can be demonstrated by running in a little iodine solution. The starch granules, if present, will become blue or bluish black in colour.

Note that all the cells which compose a filament of Spirogyra are alike ; there is no apex, no base, no root to the plant ; each cell is in size, structure and function almost exactly similar to its neighbours. Hence we may look upon Spirogyra either as a colony of unicellular plants arranged in a string or as a multicellular plant in which under ordinary circumstances, there is neither differentiation of structure nor division of function. Each cell absorbs its own food without the aid of its neighbours, each cell is capable of dividing and so multiplying independently.

REPRODUCTION.

Under normal circumstances Spirogyra reproduces itself by cell-division. This process usually takes place at night, but if we put the plant in a cool place, or surround the vessel with ice overnight, we can delay the division till next

---

* Gr. *chloros* green, *phyllon*, a leaf.

† Gr. *chroma* color, *phorein*, to carry.

day and observe the process conveniently. While watching the process of cell-division you will observe the nucleus to divide first. Each half moves away from the centre of the cell, while a partition of cellulose is seen to creep in, gradually closing like the diaphragm of a microscope till it completely divides the mother cell into two new daughter cells.

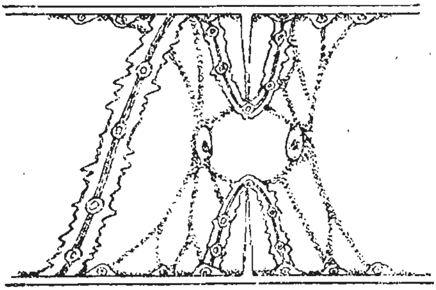


Fig. 3.

There is also a second, the *sexual* method of reproduction which comes into play when the conditions for normal growth and cell-division become unfavourable as, for instance, when the supply of food or water becomes insufficient. You can recognise when this process is about to take place by the filaments becoming tangled, losing their gloss, and changing their bright green colour for a dull yellowish green. You will also notice on handling the plants that they are less slimy and have become somewhat gritty to the touch.

On examining with the one inch power of the microscope you will see that several of the filaments have arranged themselves in parallel pairs. The cell-walls of most of the cells will have pouted out a protrusion which meets a similar protrusion from the cells of the neighbouring filament. The cell-walls where these protrusions meet give way, so that a passage is made between each pair of cells. The protoplasm of one cell will now have separated from its cell-wall, contracted into an oval mass and lost its vacuole. It then moves through the passage into the other cell and the protoplasm of both unites to form a *zygote*.* This zygote becomes globular in shape and secretes a thick cell-wall which latter may be seen to be composed of three layers, the outer and inner transparent, the middle yellowish brown. This coat is water-proof and prevents the protoplasm being killed by drought or frost.

The zygote can undergo a long period of rest and be blown about by the wind, till it finds a suitable place and temperature for germinating. The two outer coats then split, the protoplasm covered by the inner coat of cellulose then grows out into an ordinary filament of Spirogyra.

If you have difficulty in finding conjugating plants in nature, you can easily encourage Spirogyra by artificial means to conjugate. Place some filaments in very little water in a sunny position, add sugar to the extent of 2 per cent. and allow the water to slowly evaporate in the sunlight only just adding from time to time sufficient water to keep the plants alive. In a few days you will find conjugating filaments.

Our view of the nucleus and cytoplasm is usually much obscured by the presence of the chlorophyll bands, so we

---

* Gr. *zygotos*, yoked.

must study it further by fixing and staining specimens at successive stages of reproduction.

This may best be done by placing the plants for about twelve hours in a saturated solution of picric acid to which some strong solution of nigrosin is added till it becomes a deeply olive-green colour. Aniline blue may be substituted for the nigrosin. Next wash out the excess of fixing and staining solution and then mount in glycerine. If you wish to keep the specimens permanently, ring the cover glass with varnish.

You have already seen how glycerine and alcohol plasmolyse protoplasm. A similar distortion will take place n the fixed and dead cells, if they be transferred suddenly from one fluid to another of markedly different osmotic pressure. Hence we must always be careful to avoid this distortion by gradually changing the fluid. In this instance, we may use successively 15, 30, 45 and 60 per cent. glycerine till the material is sufficiently transparent. Or we may suspend the material in the upper part of a tall vessel containing at first 10 per cent. glycerine and at intervals add to the bottom of the vessel by a pipette pure glycerine which will slowly diffuse upwards. Or we may place the tissue in a weak solution of glycerine and gradually condense it by letting the water evaporate. This can be done cleanly and quickly in the vacuum of an air-pump.

NUTRITION.

Chemical analysis shows us that Spirogyra contains the elements carbon, hydrogen, oxygen, sulphur and nitrogen with smaller quantities of phosphorus, potassium, calcium and magnesium and a trace of iron. These elements are combined in various ways. For the chemical and physical attributes of protoplasm the student is referred to page 7.

We have seen that the cell-wall is composed of a carbohydrate, cellulose, ($C_6H_{10}O_5$) and that the protoplasm has other inclusions, such as starch, sugar and chlorophyll.

It is obvious that the food of Spirogyra must contain all the above elements C. H. O. N. S. P. K. Ca. Mg, Fe., and if we analyse the water in which it grows we will find, in addition to the H_2 O. a quantity of carbonic acid gas, CO^2 and salts, such as nitrates, phosphates and sulphates of calcium, magnesium, potassium and iron as well as chloride of sodium dissolved therein. If a bundle of Spirogyra be washed clear of all earth, etc., under a running tap of distilled water and then placed in distilled water we will find no growth take place.

Dissolve ten grains each of magnesium sulphate, potassium nitrate and potassium phosphate in a pint of distilled water. Dissolve forty grains of calcium nitrate in another pint of distilled water and then mix the two solutions. A certain quantity of calcium sulphate will be precipitated, but still we will have some salts of all the above metals held in solution.*

Wash some Spirogyra and introduce it into the above solution. You will find that it grows and multiplies freely when exposed to sunlight and air.

---

* This is known as Knop's solution.

It requires no further chemical analysis than burning some Spirogyra or any plant to tell us by its charring that carbon enters largely into the composition of all plants. But in the above solution carbon is the only essential element that we have omitted.* Whence does the plant then obtain its carbon ? From the carbonic acid gas, which is freely soluble in water and is universally present in the atmosphere. If we boil the above solution so as to expel all CO_2 and then see that all the air with which it comes in contact passes first through a solution of caustic potash so as to remove any CO_2 we will find no growth of Spirogyra take place under any circumstances. You will also find that no growth takes place in darkness. Sun-light is essential for the growth of Spirogyra or any green plant.

Take a bundle of Spirogyra filaments and wrap some tinfoil or lead paper round the central inch or two. Expose it to sunlight either in the above solution or in tank water. You will observe small bubbles of gas rise to the surface. Collect some of this gas by filling a test-tube with water, and inverting it over the Spirogyra. The bubbles will pass up into the tube displacing the water. On testing this gas you will find it is almost pure oxygen.†

After three or four hours' exposure to sunlight put the bundle of Spirogyra into a weak solution of iodine. You

* As the amount of iron required is the merest trace, there is always sufficient in the Spirogyra introduced to last several generations.

† A simple test for oxygen is that a taper feebly burning in air, if plunged into the test tube of O, flares up brightly. Another is that O is absorbed by a solution of caustic potash or soda to which pyrogallic acid is added.

will find a layer of blue starch granules around each pyrenoid that has been exposed to the light but none in that which has been kept in the dark under the tinfoil.

This proves that each chromatophore is a small laboratory in which, under the influence of sunlight, the protoplasm can construct carbohydrate material out of CO_2 and H_2O. What the exact process is, we cannot definitely say, but the result is usually the formation of starch and may be expressed by the equation

$$6\,CO_2 + 5\,H_2O = C_6H_{10}O_5 + 6O_2$$

This power of constructing all their substance from such simple food as water, simple organic salts like those contained in the above test solution, and CO_2 in the presence of sunlight is eminently characteristic of all green plants and distinguishes them from animals and fungi.

THE YEAST PLANT.

If a drop of the freshly drawn sap of a Toddy Palm be examined under the microscope no organised structure will be seen.

Examine the same sap a few hours later, and you will now see floating freely in the fluid a large number of globular or oval bodies somewhat smaller than human blood corpuscles. Each of these bodies is a small plant known as Saccharomyces or the Yeast plant, which is almost universally found in earth and dust.

On examination with a high power each plant is seen to be a small speck of colourless protoplasm surrounded by a cell-wall with double outline. In the protoplasm can be seen a number of fine granules and probably one or more vacuoles.

Allow a little Iodine solution to run in under the cover-glass. You will note that the cell-wall remains unstained while the central protoplasm stains brown. No blue dots are to be seen, therefore no starch is present. Stain another specimen with fuchsin, you will see the protoplasm stain red, the vacuoles being colourless or showing a faint pink colour, owing to a thin layer of stained protoplasm surrounding them. Stain another specimen with osmic acid solution. Many of the dots in the protoplasm turn black showing they are droplets of fat. No nucleus can be seen in these stained specimens or in the living unstained cells, but one is present and can be demonstrated in the following way.

Allow a thin smear of yeast to dry on a slide. Place the slide in alcohol for a few minutes, then in ether or petrol and again in alcohol. Then stain with Romanowsky's stain or hæmatoxylin. The nucleus will now be easily recognised as a central dark-stained spot.

You will have noticed that the toddy sap before the yeast plants appeared in it was sweet and non-intoxicating; shortly after the yeast has appeared, the toddy loses much of its sweet taste and acquires instead an alcoholic flavour and intoxicating properties. A quantity of gas is evolved and renders the liquid somewhat frothy.

What is the reason of these changes? They are due to the growth of the yeast and to the fact that yeast is a ferment capable of decomposing sugar into alcohol and carbonic acid gas. A ferment is a substance that has the power of setting up definite chemical changes in certain substances with which it comes in contact without itself undergoing chemical change.

That the fermentation of toddy is due to the yeast plant may easily be proved by carefully excluding any yeast plant from the sap when first drawn. Yeast cells and spores are so universally present in the earth, on the palm trees and in the air that to exclude them requires very particular precautions.

Take a number of test-tubes and plug the necks with cotton wool: there are probably many yeast cells or spores in the tubes and wool, so we must ensure their absence or death by heating both the tubes and the cotton to such a high temperature that the yeast or any other animal or vegetable would be killed. This we do by putting them for some hours at intervals of two or three days into a steriliser or stove at a temperature of 110° or 120° C.

We have now to tap the tree, but in doing so we must remember that its outer surface may hold many yeast plants. These we may get rid of by placing a piece of iron raised to a dull red heat against the spot we propose to tap and scorching a few square inches of surface. The knife with which we tap the tree must also be disinfected by boiling or heating for fear there should be some yeast on it. We must select a calm day and see that the leaves above us are not shaken or some dust containing yeast may fall into our tubes. The tree is then tapped and the sap rapidly collected in the tubes which must be at once plugged with the wool stoppers.

If all these precautions have been taken, the sap will remain sweet for months and no yeast and no alcohol will be found in it.

If later the plug be removed from one of the tubes some yeast plants will almost certainly enter the tube from the air, and in a few days we will find the toddy has fermented and contains thousands of yeast cells rapidly growing and multiplying. If we introduce a few yeast plants on the end of a wire and at once re-close the tube the same result will be found.

In actively fermenting toddy, the process of multiplication of the yeast can be easily observed. A small knob appears on the surface of the cell and gradually increases in size till it reaches that of the parent cell. What has happened is that the nucleus has approached the cell-wall, divided into two, one of which with the surrounding cytoplasm has grown out to form a bud. The cellulose soon forms a partition and the bud may fall off as a separate yeast plant. Frequently the daughter plant gives out a new bud before it separates from the mother cell and in this way chains of yeast cells are produced.

The process of gemmation or budding differs from the binary fission that we have already observed in Amœba, Paramœcium and Spirogyra, only in that the two daughter cells in these latter are from the first equal in size, while in the process of budding the daughter cell or bud is at first much smaller than the mother cell from which it has been derived.

In some circumstances, especially when the yeast is starved by an insufficient supply of food, a second method of multiplication takes place. To observe this make a slope of plaster of Paris or place a piece of unglazed fire-clay in a test-tube. On the surface of this make a streak of yeast from which the toddy has been filtered. Keep the slope thoroughly moist by immersing the lower part in water. The culture should be examined daily after the fourth day when spore formation may be observed. The nucleus and cytoplasm have divided into four new cells or spores each surrounded by a wall of cellulose and the whole enclosed in the wall of the original mother cell. These spores have a thick cell-wall and are especially able to withstand desiccation and starvation for long periods.

in size till it reaches that of the parent cell. What has happened is that the nucleus has approached the cell-wall, divided into two, one of which with the surrounding cytoplasm has grown out to form a bud. The cellulose soon forms a partition and the bud may fall off as a separate yeast plant. Frequently the daughter plant gives out a new bud before it separates from the mother cell and in this way chains of yeast cells are produced.

The process of gemmation or budding differs from the binary fission that we have already observed in Amœba, Paramœcium and Spirogyra, only in that the two daughter cells in these latter are from the first equal in size, while in the process of budding the daughter cell or bud is at first much smaller than the mother cell from which it has been derived.

In some circumstances, especially when the yeast is starved by an insufficient supply of food, a second method of multiplication takes place. To observe this make a slope of plaster of Paris or place a piece of unglazed fireclay in a test-tube. On the surface of this make a streak of yeast from which the toddy has been filtered. Keep the slope thoroughly moist by immersing the lower part in water. The culture should be examined daily after the fourth day when spore formation may be observed. The nucleus and cytoplasm have divided into four new cells or spores each surrounded by a wall of cellulose and the whole enclosed in the wall of the original mother cell. These spores have a thick cell-wall and are especially able to withstand desiccation and starvation for long periods.

The yeast or barm which the baker uses for raising bread and the brewer for brewing beer from malt infusion and that which causes the juice of the grape to become wine are closely allied to the toddy yeast.

The phenomena of fermentation and the growth of yeast were first elucidated by Pasteur, who found in the juice of the grape, much the same chemical substances as we find in toddy juice, *viz.*, water, sugar, soluble proteid and certain salts. By trying to grow yeast in media from which certain of these constituents were successively removed, he found out what were the essential forms of food without which yeast cannot grow.

He found the following fluid, hence known as Pasteur's solution, was sufficient to grow yeast ; but if any single item, except the sugar, was omitted no growth took place :—

		Per cent.
Water	H_2O	83.76
Sugar	$C_6H_{12}O_6$	15.00
Ammonium Tartrate	$(NH_4)_2C_4H_4O_6$	1.00
Potassium Phosphate	K_3PO_4	0.20
Calcium Phosphate	$Ca_3(PO_4)_2$	0.02
Magnesium Sulphate	$MgSO_4$	0.02

To test its powers of growth and nutrition wash some yeast on a filter and then introduce some into each of the following fluids :—

(*a*) Distilled Water.

(*b*) Knop's fluid with CO_2. (See page 28.)

(*c*) Pasteur's fluid without sugar.

(*d*) Pasteur's fluid with sugar.

(*e*) Pasteur's fluid in which the Ammonium Tartrate is replaced by Peptone.

(*f*) Fresh Toddy juice.

In (*a*) and (*b*) you will find no growth: in (*c*) little growth: in (*d*) good growth: in (*e*) and (*f*) luxurious growth. You will also find that the presence or absence of sunlight makes little difference in the amount of growth. You will find it grows best when the temperature is between 80° and 100°F. and that growth is stopped at very high or very low temperatures.

Analysis shows the yeast plant to contain the elements—Carbon, Hydrogen, Oxygen and Nitrogen with smaller quantities of Sulphur, Phosphorus, Potassium, Calcium and Magnesium. All these elements are to be found in the fluids (*c*), (*d*), (*e*) and (*f*), in which we have seen yeast grow. They are also all present in Knop's fluid that has absorbed Carbonic Acid gas from the atmosphere. We have seen Spirogyra and other green plants thrive in this fluid under the influence of sunlight, but yeast starves because having no chromatophores it is incapable of assimilating CO_2 as food.

We see that yeast thrives best when it obtains its Nitrogen in the form of organic proteids, but that it can, if necessary, obtain its Carbon and Nitrogen from simple organic salts like Ammonium Tartrate $(NH_4)_2 C_4H_4O_6$. From its mode of nutrition and the fact that its protoplasm is enclosed in a cell-wall of cellulose, it is classified as a plant and not an animal.

Collect in a test-tube some of the gas that is given off during the growth of yeast in toddy juice or Pasteur's fluid. A lighted match plunged into the gas is at once extinguished. If some of the gas be passed through lime water the latter becomes milky in colour, owing to a precipitate of Calcium Carbonate. The gas is therefore CO_2—not Oxygen which we have seen given off by Spirogyra and other green plants exposed to sunlight. Most of this CO_2 results from the decomposition set up by fermentation in the sugar, which may be expressed by the chemical equation—

$$C_6H_{12}O_6 = 2\,C_2H_5HO + 2\,CO_2.$$

Sugar = Alcohol + Carbon dioxide.

The quantity of CO_2 produced in the process of brewing beer is so great that men and animals have occasionally been suffocated in the vats of breweries.

A very small amount of the CO_2 is a result of the metabolic change known as *respiration*, taking place in the yeast plant itself. This process takes place in all plants and animals, but during the day-time green plants assimilate so much CO_2 and give off so much oxygen that the process of respiration ceases to be obvious. If, however, a green plant be kept in the dark, so that the process of assimilation is in abeyance, the CO_2 given off by its respiration can be readily estimated.

MUCOR.

If a piece of moist horse-dung or a piece of bread soaked in water be kept under an inverted tumbler, after two or three days you will find it covered with fungi among which will generally be found Mucor, one of the moulds. Mucor appears at first as white cotton-like filaments which soon produce erect, unbranched, pin-like stalks, terminated by rounded heads which though white at first, soon turn black and can be seen with the naked eye.

Examine first with a lens; next pick up with forceps a very small piece of the bread or dung; tease it out in water; put on a cover-glass and examine with the one inch objective.

Note (*a*) the *mycelium* consisting of threads or *hyphæ* which branch repeatedly in the substance of the bread.

(*b*) Certain stouter pin-like hyphæ growing up into the air, these are called *gonidiophores*, because they bear at their summits the spherical *gonidangia*, containing numerous *gonidia*.

Owing to the vast number of Mucor plants present on the bread, the mycelia are usually much intertangled. The student should isolate for study single plants in the following way.

Boil some horse-dung in water, filter the infusion, boil the filtrate for a long time to kill any bacteria or other fungi that may be present. Pinch off a single gonidangium with forceps that have been sterilised in a flame, shake a very few gonidia into a watch-glass of sterilised water. From this with a sterilised needle transfer still fewer gonidia to another watch-glass of sterilised water to which you have added a few drops of the dung infusion. Leave for a few hours, carefully covered by an inverted tumbler. On examining with a low power you will see the gonidia have swollen to several times their original size.

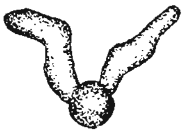


Fig. 5.

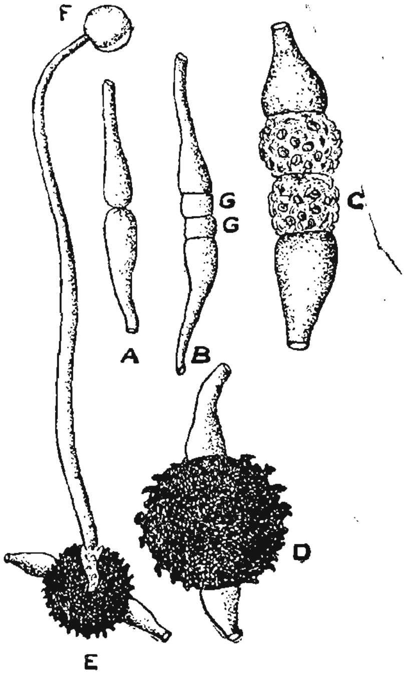


Fig. 6.

Fig. 5.—Gonidium germinating.

Fig. 6.—(*a*) Two hyphæ about to conjugate. (*b*) The gonads. (*g*) Now separated by cell-walls. (*c*) Later stage. (*d*) Zygote. (*e*) The Zygote has given rise to the sporophyte bearing a single sporangium, *f*.

Sterilise some slides in a gas or spirit-lamp flame; with a sterilised needle take a minute drop from the watch-glass containing the gonidia and spread it in linear streaks on the slides. With the help of a one inch objective remove from each slide all the gonidia except one by wiping off the rest with a sterile rag or blotting paper.

Add a few drops of horse-dung infusion to the slides and leave them for a few hours under a bell-jar or inverted finger bowls. In the course of twenty-four hours, you will find a well branched mycelium produced.

The hyphæ consist of protoplasm enclosed in a cell-wall of cellulose. Test this with chloro-iodide of zinc solution and you will find the cell-wall turn blue. With iodine we find no starch, but the protoplasm stains brownish. No nuclei are seen in the fresh specimen, but if we fix with picric acid or alcohol and then stain with safranine, methyl blue or violet, we find many nuclei at irregular intervals. The protoplasm is not divided into cells by septa or partitions in the young Mucor, but in old plants we find several septa of cellulose at irregular distances.

The first step you notice in the culture is that from the gonidium several hyphæ are pushed out which grow rapidly into a much-branched mycelium from which the gonidiophore grows out of the fluid as a thicker hypha. The first stage you notice in the formation of the gonidangium is that the free end of the gonidiophore becomes bulbous and ultimately globular, most of the protoplasm crowding into the swelling. Next a partition of cellulose cuts off the gonidangium from its stalk, the partition often bulges into the gonidangium as a *columella*. The gonidangium at first white, becomes dark-coloured, its very thin wall being often marked by bristling crystals of oxalate of lime. Its protoplasm becomes divided up into a large number of yeast-like cells, the *gonidia*, each being a nucleated piece of protoplasm enclosed in a cellulose cell-wall. A portion of the protoplasm is left over and forms mucilage in which the gonidia are imbedded. If some water be added to the gonidangia when ripe this mucilage swells up, bursts the wall and scatters the gonidia to a considerable distance. The gonidia are blown about by the wind and germinate on reaching a suitable soil. This is the usual method by which Mucor is propagated, but there is also occasionally a sexual method of reproduction.

Two neighbouring hyphæ are seen to approach one another till their walls touch. The tips of these contiguous hyphæ become swollen and filled with granular protoplasm. A cellulose septum cuts off each of these tips, so that they form gamete cells, each containing a single nucleus. The walls of the hyphæ which are in the contact disappear, the nuclei of the gametes unite and the two cells form a single zygote, which surrounds itself with a cell-wall covered with black warty projections. In this case we cannot see any distinction between the gametes or say which is male and which female.

The formation of these zygotes occurs at rare intervals, but we can encourage their formation by growing Mucor on a thin layer of compressed horse-dung, which is kept moist by water containing about 5 per cent. alcohol. The zygotes appear as little black dots on the dung and can be distinguished with the help of a lens from the gonidangium in that the latter resembles the head of a pin at the end of the stalk, while the former are either between the conjugating filaments or broken off, the points where they were attached, being marked by clear round spots.

The zygotes are heavier than water and can be isolated by suspending the dung on which they have grown in water, and pouring off the floating dirt, mycelium and fluid, while the zygotes remain sunk at the bottom.

The zygotes do not germinate for a month or two, and then, as a rule, give rise to a single hypha at the end of which is borne a sporangium resembling the gonidangium but smaller, and containing a few spores. The spores are oval or globular cells resembling the gonidia. On germinating they give rise to the ordinary branching Mucor.

We have here an irregular alternation of sexual and non-sexual generations. The generation which arises from the zygote gives rise to spores only and is hence called the sporophyte. The spores in turn give rise to a generation which bears the gametes and is hence called the gametophyte. In mosses, ferns and flowering plants there is a regular alternation of these generations, but in Mucor we have a complication in that the generation arising from the spore is only a *potential* gametophyte, that is to say, though it has the power to produce gametes, it, as a rule, suppresses this function and reproduces new generations by means of gonidia which in all respects resemble spores except that they rise on a gametophyte.

It will be noticed that Mucor contains neither chlorophyll nor chromatophores. Its manner of nutrition is practically the same as that of yeast, but you will have noticed that Mucor grows on the *surface* of the medium sending downwards hyphæ into its substance and other specialised hyphæ, the gonidiophores, upward into the air.

If Mucor be grown completely submerged in fluid, a peculiar change comes over the plant. The hyphæ become beaded like a necklace, septa are formed and each bead becomes a separate cell, the whole resembling a chain of yeast plants not only in appearance but also in its power of setting up alcoholic fermentation. Some gonidia should be sown on a thin layer of dung infusion or Pasteur's fluid with peptone, spread on a slide and covered with a large cover glass to see the formation of these "Mucor Yeasts."

THE HYDRA OF BOMBAY.

H. pentactinella.

Collect a quantity of floating water weeds, such as Water-Lilies, Lemnanthemum, Azolla and Duckweed from a tank or pond in which there is clean water all the year round.* In the cold weather a little of the mud from the bottom should also be collected, and the whole placed with plenty of fresh water in a large glass vessel, in a room not exposed to direct sunlight. Cover the top and sides of the vessel with a cloth or brown paper leaving only a small window at one side of the vessel near the surface of the water.

Next day examine the exposed part of the vessel and you will most probably find a few small yellowish white gelatinous-looking threads, from one to twelve millimetres in length, attached to the inner surface of the glass. With the aid of a lens you will see that these bodies bear at their free end five finer threads in continual slow movement.

This is a little animal known as *Hydra*. Further examination will show that it is attached by a basal *sucker* to the glass, and that the animal is able alternately to elongate and contract the body and also the five thinner processes or *tentacles*, so that at one moment it may exceed half an inch in length and the next moment, if irritated by touching with a needle, will contract so as to resemble a

* The tank near the elephant house in the Victoria Gardens is almost certain to contain specimens.

globule of jelly in which the tentacles are reduced to mere papillæ. In cold weather the room should be kept somewhat warm. As at this season *Hydra* does not show such a decided preference for light or the glass surface, some days may elapse before any come to the window.

Place one of these animals in a watch-glass or on a hollow slide with sufficient water to cover it and examine with a low power of the microscope.

The body will be seen as a *cylinder or tube composed* of an outer layer of clear cells and an inner layer of large yellowish brown or jelly-coloured cells. The body in fact resembles a test—tube in shape, there being no aperture at the fixed or sucker end. The tentacles are inserted near, but not quite at the free end of the body. Above their insertion is a slight conical process, the *hypostome**, in the centre of which may be seen the mouth, which serves not only for an entrance to the food, but also as an anus or aperture of exit for the fæces.

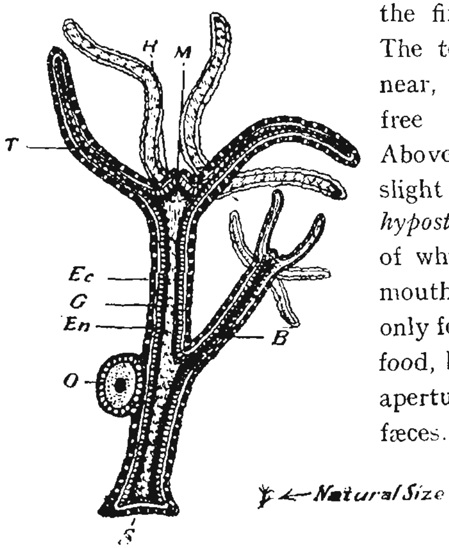


Fig. 7.

The *enteron*† or digestive cavity is continued into the hollow tentacles

* Gr. *hypo* below, *stoma*, mouth.

† Gr. gut.

which in the vast majority of Bombay Hydras are five in number. Of 549 specimens consecutively examined, 14 had six tentacles, 9 had four, 526 had five tentacles. Variation in the number of tentacles is not an indication of difference in species, as a six-tentacled bud has been seen growing from a five-tentacled parent.

Some small animals, such as water-fleas, should be placed on the slide with Hydra. These little crustaceans are very vivacious, darting hither and thither almost continually, but should one of them come in contact with the tentacles of Hydra, it will suddenly come to a standstill as if struck with paralysis. If the Hydra be hungry, the stunned water-flea is gathered into the mouth by the tentacles and passed into the enteron, where it may be seen causing a bulge as does a rat swallowed by a snake. This stunning of the little animal is due to certain stinging threads on the outer surface of the Hydra. You can demonstrate the effect by touching with your finger a jelly-fish, an animal closely related to Hydra.

To examine with the higher powers of the microscope a cover-glass should be placed over a Hydra on a hollowed slide. If you have no hollowed slide, a cell can be made by placing a thick cover-glass on each side of the Hydra, and a third over the animal with its edges resting on the other covers so as not to cause any undue pressure.

The tentacles and body will be seen covered with wart-like knobs, which careful focussing will show are due to collections of cells containing highly refractile* oval sacs, the *stinging capsules* or *nematocysts*.† When the tentacles are fully extended, spaces are seen free of stinging cells, when moderately contracted the tentacles are fairly uniform in diameter. When the Bombay animal is fully extended, the tentacles seldom exceed the body in length.

In the Hydras of Europe they may be three or more times, and in that of Bengal, according to Annandale, as much as six times the length of the body.

Some Hydras should be killed by pouring a little 1 per cent. osmic acid solution over them while fully extended. The ordinary fixing solutions, such as methylated spirit, picric acid, Perenyi's or Muller's fluid, if used should be poured on in a boiling condition, so as to kill the animal at once before it has time to contract. After fixing, washing and staining with carmine, picrocarmine or eosine and hæmatoxylin, they should be imbedded in paraffin, and both transverse and longitudinal sections made.

A comparison of the whole animal with these sections will show that body and tentacles are hollow tubes, their cavities continuous and their walls composed of two layers, an outer of smaller transparent cells, an inner of larger yellowish cells. The outer is called the *ectoderm*,‡ the inner,

* A body is said to be refractile when the rays of light passing through it have their direction altered, as a result of which alteration, focussing with the microscope causes the body to glitter and appear dark alternately, according as the centre or the surface of the refractile body is in focus.

† Gr. *nema*, thread ; *kystos*, a bladder.

‡ Gr. *ecto*. outer, *endo*, inner, *derma*, skin.

the *endoderm.** Between them is a very thin *supporting lamella*, not of cells but of a jelly-like substance called the *gloea*,† which in closely related animals is so thick and obvious, that they are popularly called "Jelly-fish." By some authors this layer is termed the *mesogloea*, Greek for "middle jelly," but as there is no outer or inner jelly, the shorter name, gloea, is preferable, especially as students are liable to confound it with the *mesoblast*, or middle *cell*-layer of higher animals. The important fact which the student should grasp is that this layer is not made of cells but is a jelly *secreted* by the cells of the cell-layers. Hence Hydra, Jelly-fishes and their allies are sometimes called *Diploblastic*‡ that is composed of two cell-layers, to contrast hem with the *Triploblastic*‡ animals,—all the higher Metazoa composed of three cell-layers epi—, meso—,and hypoblast, or epiderm, mesoderm and endoderm.

Another Hydra should be arranged on a slide under a cover-glass, a little safranine, methyl violet or 0·5 per cent. acetic acid coloured with fuchsin run in while the effect is watched by as high a power of the microscope as convenient. From the little projections on the surface slender threads are seen to be suddenly shot out from the nematocysts. These are the stinging threads.

The animal will probably break up into its individual cells or the process may be assisted by teasing with needles. When sufficiently stained the surplus fluid may be

---

* *Gr. ecto*, outer, *endo*, inner, *derma*, skin.

† Gr. *gloia*, jelly, glue.

‡ Greek, *diploos*, two-fold,double, *triploos*,triple, three-fold.

removed by blotting paper and the specimen irrigated with a little water.

An examination of these preparations will show that the cells of the outer layer are of three kinds :—

1. Large conical cells with their bases facing outwards, their narrow ends inward. At their inner ends may be seen long *muscle processes* which are arranged parallel with the length of the animal. The shortening of the tentacles or body is due to their contraction. Fig. 7a m.p.

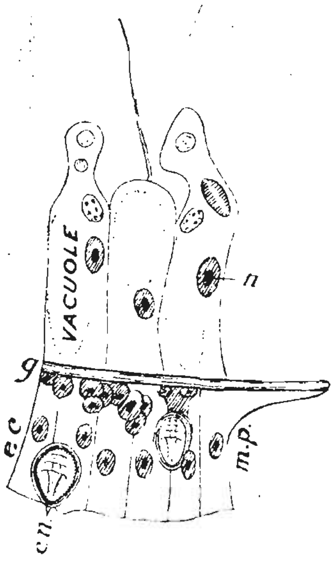


Fig. 7a.

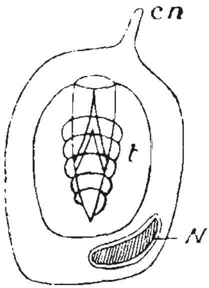


Fig. 7b.

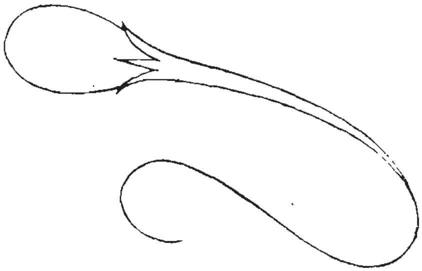


Fig. 7c.

Fig. 7d.

Fig. 7a. ec = ectoderm, en = endoderm, g = gloea. Fig. 7b. A cnidoblast. n = nucleus, t = nematocyst, cn = cnidocil. Fig. 7c. Large stinging thread. Fig. 7d. Small stinging thread.

(2) In the intervals between the apices of these cells will be seen smaller, more rounded, granular and deeply stained *interstitial cells.*

(3) Certain of these interstitial cells develope into *stinging cells* or *cnidoblasts** that make their way to the surface and in addition to the nucleus contain a *thread* capsule or *nematocyst* which has been likened to a glove with a single long-pointed finger ; the finger turned outside in and coiled up in the palmar portion of the glove. On the outer surface of the thread-cell can be seen a short hair-like projection, the *trigger* or *cnidocil.* The interior of the cyst is filled with fluid under considerable pressure. When a suitable stimulus irritates the

* Gr. *knide* a nettle, *blaste* a bud, development, hence applied to cells or tissues in or by which any structure originates.

sensitive trigger the cyst is compressed and the stinging thread forcibly everted.

The nematocysts are of two kinds :—

(1) A smaller containing a short thread folded in loops. When discharged the thread ends bluntly and often resembles a screw in outline owing to a spiral coil. The whole stains deeply and uniformly (Fig. 7d.)

(2) The large nematocysts containing a thread about ten times the length of the former, coiled round its base; when everted the thread is seen to be much thinner, ending in a fine lash, and bearing three barbs at its conical base. The lash and barbs stain deeply, the flask-like cyst feebly, with aniline dyes. (Fig. 7c.)

It is probable that the action of the stings is not merely mechanical, but that the fluid of the cyst also produces a poisonous effect on the animal struck. The threads when discharged remain embedded in the body of the prey, new nematocysts being developed to take the place of those used up.

The stinging cells are found not only on the tentacles but also on the body. They become fewer as the sucker end is approached. It will be noticed that the ectoderm cells near the sucker are much more granular than those elsewhere owing to an adhesive secretion by which the animal fixes itself to other bodies. The teased and stained specimens may be preserved by rapidly drying the slide by waving it in the air, and when apparently dry, heating the slide *gently* over a flame. Canada Balsam and cover-glass may then be dropped on.

Certain small cells with spidery processes in connection with the stinging cells are supposed to be nerve cells, through the agency of which Hydra can voluntarily discharge the threads. *Paramoecia* and other infusorians can be seen to creep over the tentacles without causing rupture of the stinging capsules from which we conclude Hydra is able to distinguish different kinds of stimuli and to select its prey.

The endoderm cells are much larger than those of the ectoderm. A small piece of a living Hydra should be examined under a cover-glass, when it will be noted the endoderm cells are actively amœboid, putting out or withdrawing long pseudopods. Some of the cells may be seen to put out one, two or three long flagella. These flagella are not seen in stained specimens as they are withdrawn in the act of death. The endoderm cells contain very large vacuoles. Many of those near the hypostome are long, narrow and much more granular than those elsewhere. They are of a glandular nature, probably secreting a digestive fluid.

It should be noted that digestion in this animal takes place in two ways (*a*) by the digestive fluids turning the food into soluble substances which enter the cells by osmosis; (*b*) by the amœboid endoderm cells engulfing solid particles.

Some of the endoderm cells exhibit muscle processes like those of the ectoderm but they are shorter and arranged in a direction transverse to the length of the body. Their contraction will therefore narrow the lumen and lengthen the body.

REPRODUCTION.

In an equable climate like that of Bombay Hydra multiplies all the year round by *budding*, provided it receives plenty of food. A little knob or projection appears on the side of the body, and gradually lengthens into a little tubular process, the cavity of which is continuous with the enteron of its parent. Tentacles and a mouth then appear at its distal end, and finally the connection with the parent body is severed by an ingrowth of the ectoderm. In the Bombay species of Hydra it should be noted that all the tentacles appear simultaneously. Sometimes we find a number of buds in different stages of development attached to the parent body, giving the appearance of a colonial organism.

If a Hydra be cut in two, each part is capable of regenerating into a complete Hydra, but it is doubtful if this is a natural method of reproduction.

Both these methods are *asexual*. There is also a *sexual* process of reproduction. If food becomes scarce, the temperature too cold or too hot, or if the tank or pond in which Hydra lives, begins to dry up, sexual reproductive organs develope. In Bombay these *gonads* are most common at the beginning of the dry season, October and November. One or more, or as many as five testes may then appear, as little breast-shaped outgrowths of the ectoderm in the distal half of the body. From the interstitial cells in these outgrowths *spermatozoa* with oval heads and vibratile tails are developed.

In most species of Hydra both testes and ovaries develope on the same animal, which is therefore *hermaphrodite* but the testes in such cases have always discharged their sperm cells by rupture of their walls before the ovum is matured. In this way self-fertilisation is prevented. In Bombay we have never yet seen testes and ovaries develope on the same Hydra, so that as far as observation has gone, this species is not hermaphrodite.

The ovary is larger and more rounded than the testis, usually extending over about half the circumference of the body, in a situation nearer the sucker than that in which testes are found. Like the testis, it is formed from the interstitial cells of the ectoderm. A number of these cells form the wall of the ovary. Those in the centre become potential ova, but one of them rapidly enlarges at the expense of the others, till finally we have a single large egg-cell or ovum left. If you find an egg-cell in this condition rupture the ovary by gentle pressure, and examine under a cover-glass with the higher power.

You will find the ovum is a very large amœboid cell putting out irregular pseudopods. In addition to a clear nucleus, the *germinal vesicle,* with a number of nucleoli or *germinal spots,* it contains many exceedingly large *yolk-granules.*

The ovum matures in the ordinary manner by successively casting out two polar bodies. The superficial cells of the ovary then rupture, allowing the spermatozoon to have access to the egg-cell and fertilise it.

This *zygote** or fertilised ovum, then divides into a number of cells to form a *mulberry*-mass or *morula,* † the outer cells of which form a hard tough water-proof shell, inside which the embryo can remain dormant throughout the cold and dry season. When the rains again set in, or the season becomes otherwise favourable, the embryo developes into a young Hydra.

You will have noted how Hydra resembles the *gastrula* stage of higher animals, consisting of two cell layers, an outer ectoderm and an inner endoderm, resembling the epiblast and hypoblast respectively, the mouth suggesting the blastopore, the enteron, the archenteron. The development of Hydra is however exceptional. The morula becomes hollowed out into a blastula. The cells become differentiated into an outer layer, the ectoderm, and an inner *solid* mass, the endoderm. Later a cavity, he enteron forms, by the endoderm cells separating from one another. Still later a mouth is formed. Hydra therefore differs in its mode of formation from the gastrula in that the *endoderm is not formed by an invagination of the blastula, the mouth therefore is not a blastopore but an opening formed secondarily.*

Classification and Nomenclature.

The only Hydra hitherto described in India has been called. *H. orientalis* by Annandale. This appears a distinct species for the following reasons,

* Gr. *Zygotos* mated, married.

† Lat. Mulberry.

H. orientalis has, as a rule, six tentacles which are commonly three times, frequently six times the length of the extended body. (Annandale.)

In the Bombay Hydra, all tentacles arise simultaneously. They are most commouly five in number and much shorter than those of H. orientalis.

PERICHÆTA POSTHUMA, A COMMON EARTHWORM IN INDIA.

Syn. Pheretima postuma.

Earthworms are to be found throughout almost the whole habitable surface of the globe. A certain amount of moisture and warmth being essential, arid sandy deserts the ice-bound regions near the Poles and summits of lofty mountains are the only places where we fail to find some representatives of the order.

In the cold and dry seasons which we experience in most parts of India, many species withdraw deep in the soil to burrows which they line with the slimy secretions of the body which dry into an almost water-tight covering that prevents the excessive evaporation which would prove fatal if the worm were exposed to our dry atmosphere.

The name Earthworm is fairly indicative of the animal's habitat and habits. Most burrow in the soil, living on decaying organic matter which they swallow with a large admixture of earth. The undigested residue or fæces is passed usually on the surface of the earth in the form of "casts." The size and number of these casts is very great, and in Bengal in particular they are a great source of annoyance to the *mali*, who during the rains finds his well-kept lawn each morning disfigured with large casts which he wrathfully describes as the fæces of a *Shaitan*.

Darwin estimated that the quantity of fæces brought to the surface by worms would amount in five years to a layer one inch thick over the whole surface of England.

The services thus rendered to the cultivator by Earthworms consist in a continual ploughing of the soil and bringing finely divided manure from the depths to the surface.

The Earthworm is nocturnal in its habits. It has no eyes and needs no light to guide it in the pursuit of food or a partner in its amours, so during the daytime it retires to its burrow.

The Earthworm is hermaphrodite, but the ova are probably never fertilized by the sperms of the same individual.

Copulation is effected between two animals by applying their anterior ventral surfaces together, in which position they are held by the sticky secretion of the girdle, and in some species, especially that more particularly described in this chapter, by suckers in the region of the genital pores. The sperms during connexion are passed out of the sperm-duct of the one worm into special sacs or *spermathecæ* (Gr. *theke*, receptacle), placed further forward on the other, and there stored up. After the worms have separated, the girdle secretes a tough tube of chitin, which forms a tolerably wide belt round the body. The worm gradually wriggles backwards out of this belt, and as it passes over the mouths of the oviducts and spermathecæ, eggs and sperms, as well as a quantity of nutrient albumen from certain glands in the skin, are squeezed out into the cavity of the belt. When the belt has finally been slipped over the head, its ends dry and contract to form a closed cocoon or capsule containing the gametes and albuminous fluid.

The sperms then fertilise the ova, of which there are at first several in each cocoon, but as a rule only one egg matures. On the other hand a single egg not unfrequently gives rise to twins. The embryo in the cocoon feeds on the milk-like albuminous fluid, and when hatched resembles the parent worm.

Select a large and stout worm. Draw it gently through your fingers from before backwards. You find it is smooth and "slippery as a worm." Draw it in the opposite direction, *i.e.*, from "tail" to "head," there is a distinct roughness which, on examination with a lens, you find is due to a number of bristles (Latin) *setæ* or (Greek) *chetæ*. These are functional as aids to locomotion, preventing the animal slipping backward when it progresses by alternate contraction and elongation of its body.

Select a worm with continuous rings of setæ round the anterior segments excepting the first. In Bombay this will probably be a *Perichæta*. Examine the ventral surface of the eighteenth somite. If you find a median depression, in which careful examination will show two openings placed close together, the worm is probably *Perionyx*. If the setæ be few in number—only four pairs on each segment—the worm does not belong to the Perichæte family.

In England all the native worms possess only eight setæ on each segment.

Should you find a worm with rings of setæ not quite continuous, there being gaps above or below, the worm is a *Megascolex* (Gr. *megas*, great, *skolex*, worm), of which there is a very large species in Ceylon and India. They measure up to three feet in length and are therefore excellent for dissection. Unfortunately they are rare in Bombay, probably being only accidentally imported, so we must take a more common species for study.

The genus *Perichæta* can be recognised externally by the continuous rings of setæ, the pair of openings on the eighteenth segment, and a girdle encircling the fourteenth, fifteenth and sixteenth somites only.

One of the commonest species in Bombay is *P. postuma*. Its male pores are raised on prominent nipples or papillæ; on the segments in front of and behind these pores we also find a prominent pair of papillæ or suckers, so that this species can easily be distinguished by these three pairs of prominences on the under surface of the 17th, 18th and 19th segments.

As this species can be so readily distinguished and is one of the most common in India, the details of the following description will specially apply to it.

Attention will be drawn here and there to the anatomy of other species, and even of other genera, so that if the studen is unable to ob ain this particular worm he can nevertheless gather the main facts in the structure of allied forms.

For practical dissection, therefore, choose, if you can, an Earthworm with continuous rings of setæ, with a girdle limited to segments XIV, XV and XVI having setæ on its ventral surface, with six papillæ in pairs on segments XVII, XVIII, and XIX.

Perichæta postuma.
B. Buccal cavity.
C. P. Copulatory papilla.
M. Male pore.
F. Female pore.
A. Anus.
P. Peristaya.

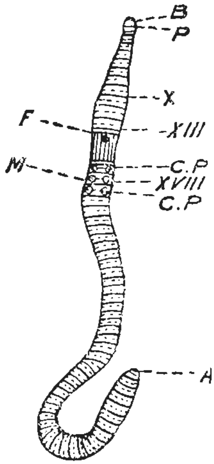


Fig 8.

EXTERNAL APPEARANCES.

The worm is about three inches long (50 to 120 m.m.), about 5 m.m. in diameter, cylindrical in shape, except that the posterior end is rounded off and the anterior end tapers like the end of a cigar. There is no trace of limbs or lateral head appendages, and no division of the body into head, neck, thorax and abdomen. Externally it is marked by ring-like grooves which divide the body into a number of segments closely resembling one another. Dissection will show you that this segmentation characterises the internal organs also, the nervous, alimentary, excretory, circulatory and to a less extent the reproductive organs of each segment, being a copy of those in the segments in front of and behind it.

In fact, if you cut up the posterior two-thirds of the body into its individual segments, it would be impossible for the most expert zoologist to place them in order, each one being so close a repetition of the same plan. These segments are technically known as *metameres* or *somites* (Gr. *meta*, behind, *meros*, a part, *soma*, body). Such somites are said to be *serially homologous* with one another, and such an animal is said to be *metamerically* segmented.

If you count the somites you will find these are about 110 or 120 in number.

Though the posterior region of the body is cylindrical, the animal has the power of flattening it from above downwards to a considerable extent, as you will find if you attempt to draw a worm from its burrow. By thus increasing the width of the body a "purchase" is obtained on the walls of the burrow.

Observe the manner in which the animal moves. Most worms crawl by a characteristic wriggling "worm-like" movement, but *Perichæta* and some species of *Perionyx* in particular, are very agile and move with great rapidity using their protrusible buccal cavity as a sucker, so that they can "loop" along after the manner of a leech.

Observe the most anterior segment which from the fact that it surrounds the mouth is called the *peristome* (Gr. *peri*, around, *stoma*, mouth). It bears no setæ and reaches further forward on the dorsal than on the ventral aspect. In the dead worm you must not mistake for the peristome the everted buccal cavity which the worm can protrude to a very considerable distance, at least 2 m.m. The everted buccal lining is wrinkled radially resembling a diminutive human anus. In some other Earthworms there is a small *prostomium* overhanging the mouth like an upper lip and dovetailing behind to a variable extent into the peristomium. It cannot be recognised in our species.

Note and count the bristles on the second segment. Observe there is no dorsal or ventral gap in any *Perichæta* (or *Perionyx*) and that there is a distinct ridge where they are inserted.

In an adult worm there is seen on segments XIV—XVI an enlargement caused by a thickening of the skin and a development of glands which assist in forming the cocoon and in some worms in forming a band round the pair of worms during copulation. In the Perichæte worms it forms a complete *girdle* (in Latin *cingulum*) round these segments and is therefore appropriately called by either of these names. Its prominence varies with the sexual activity of the worm. The colour is a different shade to the rest of the body, and usually becomes white in specimens preserved in spirit.

In many other worms this thickening does not extend all round, being deficient or absent below. It then resembles a little saddle on the dorsum of the worm and is called the *clitellum* (Latin *clitellae*, plural, a pack-saddle). The position and extent of this organ vary in different species. In *Perionyx* they are in some species the same as that described above, segments XIV to XVI, but more often they begin a segment earlier and may extend even to the XIX segment. In the Indian species of *Megascolex* the cingulum begins on segment XIII and extends to XVIII most commonly, but in the giant worm of Ceylon *M. caeruleus*, it reaches from XIII to XXI. While three segments of girdle is the rule in *Perichæta*, in *Megascolex* $3 + x$ may be laid down as a diagnostic feature.

In the *Lumbricidæ*, the common worms of Europe, the clitellum is placed very far back, from XXX to XXXVI or thereabouts, therefore well behind the male pores, not in front of them as in *Perichæta*.

Note also that in this species the rows of setæ on the three clitellar segments are limited to the ventral surface, being absent on the dorsum and sides.

Note the colour of the worm : dark-brown with perhaps a tinge of purple above ; paler, perhaps yellowish-brown, on the ventral surface. A narrow dark streak in the mid-dorsal line indicates the dorsal blood vessel. About segments XVI to XX two lateral white organs, the *spermiducal glands*, generally show through the integument.

OPENINGS OF THE BODY.

The mouth has already been seen at the extreme anterior end leading into the protrusible buccal cavity. The anus is a vertical oval aperture, also terminal, on the posterior aspect of the last segment.

GENITAL OPENINGS.

The openings of the sperm ducts or vasa deferentia are readily recognised on a pair of widely separated papillæ on the ventral surface of the eighteenth segment.

On segments XVII and XIX are seen paired papillæ in front of and behind the male openings. In the spirit-preserved specimen, depressions, looking more definite openings than the male pores, are seen on their summits. These do not open into the body cavity, but are of the nature of copulatory suckers formed by a depression of the epiderm lined by elongated pear-shaped epithelial cells, of a glandular nature. The glands are seen internally as rounded white elevations.

In *Perichæta* the oviducts open ventrally by a common median pore on the fourteenth segment at the anterior margin of the girdle.

Four pairs of openings, those of the spermathecæ, can be seen on the ventral surface of segments VI, VII, VIII and IX. They are very small and are best seen after drying the worm with blotting paper and then gently squeezing with the fingers. Small beads of moisture will exude and indicate the position of the pores.

In other species of *Perichæta* and in other genera the number of spermathecæ, and therefore of openings, varies. Other *Perichætæ* may have only one pair or as many as five. The openings may be furnished with papillæ.

In *Perionyx* the apertures are placed very close together near the middle line, and both pairs may open on the same, the eighth segment.

The female openings are double on the 14th segment in *Perionyx*, *Megascolex* and most Indian worms as well as in all the European family *Lumbricidæ*.

The *dorsal pores* are minute openings into the cœlom between the segments in the mid-dorsal line. They are best seen in specimens preserved in spirit, but can also be seen with a lens on squeezing the worm after drying as above advised.

They are simply holes through the layers of the body-wall and have no special lining of cells. They are absent from the first twelve segments, the first being found between segments XII and XIII.

The *openings of the nephridia* or excretory organs are very numerous in each segment in all *Perichætæ* and too small to be seen except in sections under the microscope.

DISSECTION.

The worm is best killed by dropping into methylated spirit for a few minutes. It should then be washed for about half an hour under a tap of running water.

Stretch it firmly, but gently, with the fingers. Pass flagged or coloured pins through the body-wall at the sides of segments V, XV and XXX, taking care not to injure the internal organs. With other pins fix the worm ventral side downwards in an extended position to a sheet of cork or soft wood weighted with sheet lead. Dissect in a dish under water.

Using coloured or flagged pins in definite segments will be a guide to the situation of the organs and will save much time and trouble in counting. They may be placed in any segment, provided a note is made of its number, preferably on the skeleton chart provided. With small fine-pointed scissors slit up the body-wall throughout its length close to the mid-dorsal line, avoiding the dorsal vessel and taking care not to open the alimentary canal. The latter accident will be readily recognised by the escape of earthy food;

should it happen, begin your incision more carefully at another point.

A sketch of all the organs should be made on the skeleton chart supplied.

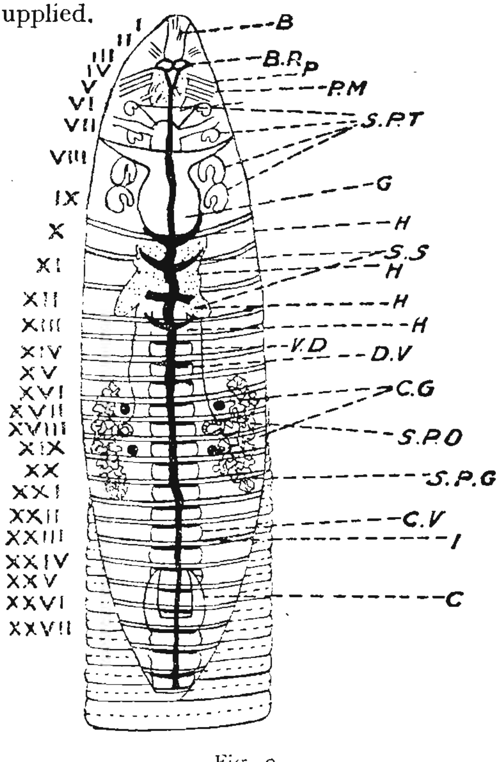


Fig. 9.

Fig. 9.—*Perichæta postuma. Anterior segments laid open*—B. Buccal cavity. Br. Brain. C. Cœcum. C.G. Copulatory gland. C.V. Commissural vessel. D.V. Dorsal vessel. G. Gizzard. H. Heart. I. Intestine. P. Pharynx. S. Septum. S.P.G. Spermiducal gland. S.P.D. Its duct. S.P.T. Spermatheca. S.S. Sperm sac. V.D. Vas deferens.

THE CŒLOM.

You have now laid open the body-cavity or *cœlom* (Gr. *koiloma,* a hollow), a large space in which the alimentary and other viscera are contained. It is divided into a number of compartments corresponding to the somites by transverse septa (Lat. *septum,* a partition). Above the nerve-cord the septa are incomplete and allow the cœlomic chambers to communicate with one another.

The anterior septa are incomplete, their place being taken by numerous muscles radiating to the body-wall from the pharynx. The septa behind segments V, VI, VII and IX are much thickened and muscular. There is none between VIII and IX, the segments occupied by the gizzard.

Posteriorly they are thin and membranous. Both surfaces of the septa as well as the inner and outer walls of the cœlom are lined by the cœlomic epithelium or *peritonenm.*

These lining cells are for the most part flat, being of the character known as tessellated, but on some portion of the gut the epithelial cells are large, globular and loaded with granules of pigment, which give them the name of *yellow cells.* They probably excrete material into the cœlom whence it is removed by the nephridia.

The cœlom communicates with the exterior through the dorsal pores, the genital ducts and the nephridia.

The whole worm resembles two tubes placed one inside the other, and continuous at both oral and anal ends. The inner tube is separated from the outer by a wide cœlomic space, and is maintained in position by the numerous transverse septa or mesenteries.

DEVELOPMENT OF THE CŒLOM.

In the embryo between the *hypoblast* or lining of the primitive gut, and the *epiblast* or primitive epiderm which are at first in contact, a third layer, the *mesoblast* (Gr. *mesos*, middle), arises. This consists of two layers,—the *splanchnic*, (Gr. *splanknon*, gut) or *visceral* layer and the *somatic* (Gr. *soma* body) or *body-wall* layer; the cavity between them is the cœlom. In the earth-worm embryo these cœlomic cavities first appear as a pair of sacs in each segment. These sacs and their walls continue to grow till finally they meet above and below the alimentary canal, and so form a ring-shaped space around the viscera. It is, therefore, obvious that no matter how thin the septa may be they are fundamentally made of a double layer of the cœlomic wall.

A cœlomic cavity is a characteristic of all higher animals, which are on this account called the *Cœlomata*, no matter how much the cœlom may be reduced or difficult to recognise.

The cœlom is thus not a mere slit or space between the various organs but a sac with its own proper wall of epithelial cells. From these cells always arise the mother-cells of the gametes or reproductive cells. Into the cavity open the nephridial tubes.

Examine the cœlomic fluid from a freshly chloroformed worm, making a smear, which should be rapidly dried in the air, fixed with alcohol, stained with eosin and methylene blue or logwood. The corpuscles will show blue nuclei surrounded by red cytoplasm.

Examine a specimen of the fresh fluid under a cover-glass, using your highest power. Observe the amœboid movement of the corpuscles, many of which contain vacuoles. Many of the cells soon run together and then break up.

ALIMENTARY CANAL.

We have already seen the large mouth placed anteriorly. In those worms which have a well-developed prostomium, the mouth will, of course, be placed more or less ventrally. The cuticle of the external surface is continuous with that lining the alimentary canal as can be seen on peeling it off from the anterior and posterior segments. The mouth opens into the thin-walled *buccal cavity* (*Lat.*, *buccæ*, the cheeks), which in *Perichæta* is much more protrusible than in most earthworms.

The buccal cavity ends in the third segment in a *pharynx* with strong muscular walls, from the outer surface of which powerful muscles radiate to the body-wall. In the dorsal portion of the groove which marks the junction of the buccal and pharyngeal regions lies the brain or supra-pharyngeal ganglia. In the fifth segment a small pair of glands open into the œsophagus. When examined with a lens they are seen to resemble a minute bunch of grapes. (Lloyd.)

From the pharynx the canal is continued as a comparatively narrow *œsophagus* to about the 14th segment where the intestine may be regarded as commencing.

In the 8th and 9th segments the œsophagus is greatly strengthened by an increase of its muscular, particularly the circular, layer. This portion, known as the gizzard, has a chitinous lining and can be readily recognised as a firm pea-like body when pressed with the finger. Attention has already been drawn to the fact that the septum on each side of the gizzard, that between the 8th and 9th segments, is absent or incomplete. You may also observe that the gizzard sometimes encroaches on the tenth somite, pushing the septum backward.

The soft portion of the œsophagus as well as the intestine is beaded where the septa pinch it. You will note that in many animals the gut is very much longer than the body and is coiled and twisted so as to pack into the body-cavity. By this great length a large amount of surface is able to act on and absorb the food. In other animals the absorbing surface is increased by the presence of folds or spiral valves, such as you see in the short-gutted dog-fish.

In the earthworms where the alimentary canal is quite straight and no longer than the body, an extra amount of surface is obtained by the septa nipping it so as to form a series of pouches like a string of closely pressed beads. In most earthworms there is a deep fold or gutter, called the *typhlosole* (Gr. *typhlos* blind, *solen* channel), on the dorsal surface of the gut, which forms a longitudinal ridge internally and so increases the absorbing surface. It is commonly stated that the *typhlosole* is absent or rudimentary in *Perichætæ*, but in this species at least, it is clearly present as a prominent longitudinal ridge in the latter half of the intestine, becoming less distinct more anteriorly.

In the 26th or 27th segment will be seen a pair of small pouches, the *cœca* (Latin, blind) which arise from each side of the gut and project forward for a distance of three segments. They are usually found empty.

These *cœca* are highly characteristic of *Perichœta*, being found in almost all species, while they are absent from all other Indian and European genera.

The intestine terminates at the anus on the posterior surface of the last segment.

VASCULAR SYSTEM.

The blood is a red fluid, owing its colour to hæmoglobin dissolved in the plasma and not associated with special red cells as we find in the blood of vertebrates. The white amœboid corpuscles are small, irregular and nucleated.

The blood is best examined by removing from a freshly chloroformed worm a large piece of vessel, such as one of the "hearts," pinching it between two pairs of forceps. Some should be examined fresh under a cover-glass. A smear should also be made and stained in the same manner as the cœlomic fluid.

In a recently killed worm the vessels are readily recognised by their red colour due to the contained blood. If the worm has been long preserved in spirit the vessels become yellowish white and less conspicuous, though firmer and more easily dissected. It is best to dissect a worm that has been killed from three to six hours as the blood has then clotted without losing its colour.

The blood is contained in a system of closed vessels, not communicating, as in the *Arthropods*, with the peri-visceral spaces.

The principal vessels are three *longitudinal*: (*a*) the *dorsal*, which can be recognised externally as a dark streak, (*b*) *ventral* or *sub-intestinal*, below the intestine, dorsal to the nerve cord; (*c*) the *subnervian*, placed close to the nerve cord on its ventral side. The dorsal and subnervian are united in each of the middle and posterior segments by (*d*) *commissural vessels*, one on each side, making a complete vascular ring in the body-wall.

In front of the twentieth segment the dorsal vessel becomes enlarged and its wall more muscular. In the 10th to the 13th segments it is united with the sub-intestinal vessel by four pairs of large and contractile vessels, generally known as the (*e*) *hearts*.

In smaller and moderately translucent worms the blood can be seen with a lens or the low power of the microscope to be driven forwards by rhythmical contractions of the dorsal vessel and in the hearts to be driven from above downwards. The blood is prevented from flowing in the opposite direction by numerous valves, which can be seen to cause a beading of the vessel if an attempt be made to squeeze the blood backwards. The walls of the ventral and other vessels are not contractile. The vessels break up in the various organs as well as in the intestinal and body walls into minute capillaries, extending even between the cells of the epidermis, which is the respiratory organ of the earthworm, where the blood is exposed to the oxygen of the atmosphere. From the dorsal vessel in each segment a short branch will be seen running to terminate dorsally in a small white fluffy ball of peritoneal cells probably of the nature of *blood-glands.*

The vessels differ considerably even in closely allied species. The subnervian may be absent. There is often a pair of lateral neural vessels, a supra-intestinal and an infra-intestinal longitudinal vessel, parallel with the dorsal and ventral vessels above described, but in closer contact with the alimentary canal. The number of hearts varies. The dorsal vessel may be double in the anterior region as in the giant *Megascolex caeruleus.* The manner in which the longitudinal vessels anastomose and terminate in the anterior segments varies greatly.

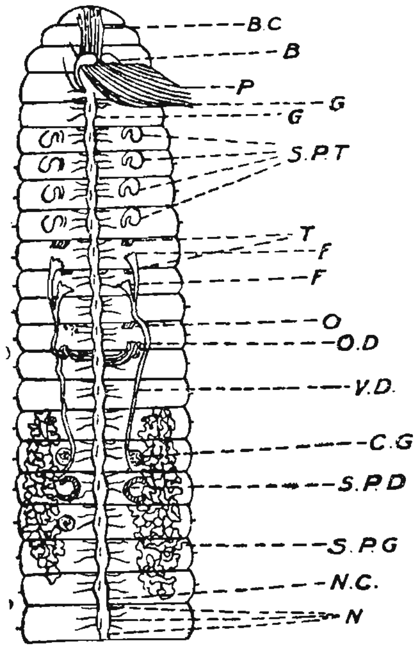


Fig. 10.—*P. postuma. Intestine and Œsophagus removed*—B. C. Buccal cavity. G. Ganglion. F. Funnel. O. Ovary. O. D. Oviduct. N. C. Ventral nerve cord. N. Nerves. Other letters as in Fig. III.

REPRODUCTIVE ORGANS.

To dissect these the worm should be pinned out under spirit in preference to water.

All earthworms are hermaphrodite, and multiply only by sexual processes, though their power of repair when mutilated is very great.

The essential organs are the *gonads* and their ducts. The gonads are arranged metamerically, one pair of *testes* in segment X, another pair in the following segment XI.

In the adult worm there is only one pair of *ovaries*, those in the thirteenth segment; but in the embryo of such forms as have been studied there is another pair in the 12th which soon disappears, and is only recognisable in abnormal adults. All four pairs of gonads arise (as in all *Cœlomata*) as thickenings on the wall of the cœlom. At first it is impossible to tell by their structure which will be testes, which ovary. The anterior pair of ovaries only makes its appearance to quickly disappear. The testes also in the young adult worm usually shed the sperm mother-cells into the *sperm-sacs*, where further development takes place, the testes meanwhile shrinking so that to see them properly a young worm should be selected for dissection.

The sperm-sacs or *vesiculæ seminales* (Latin seminal bladders) are seen in segments X and XI as two pairs of large irregular lobulated sacs which when fully developed extend up on each side of the œsophagus and meet dorsally above it.

These should be carefully dissected from the œsophagus, the intestine cut across about the 24th segment and carefully dissected from the body-wall by repeated snips of the scissors or touches of a very sharp knife. The ventral blood vessel and nerve cord should be left uninjured. Special care must be taken in the region of the sperm-sacs, as the œsophagus is very likely to break off from its connexion with the gizzard if roughly handled. When the whole anterior part of the alimentary canal as far as the third segment has been dissected up and turned aside examine the structures exposed.

In the thirteenth segment attached to the anterior septum close to the midventral line will be seen a pair of small granular patches, the *ovaries*, one on each side of the nerve cord. They are small flattened pear-shaped organs, the base attached to the septum, the apex pointing backwards. One should be removed, fixed in Muller's fluid, stained with logwood and eosine and longitudinal sections made; or it may be simply stained with eosine and examined at once.

Ova in all stages may be seen—at the apex ripe ova, large round cells enclosed in a *vitelline membrane*, the protoplasm containing a granular *yolk* (Lat. *vitellus*) with a large round nucleus and nucleolus, known as the *germinal vesicle* and *germinal spot* respectively.

At the attached base of the ovary is seen a mass of small undifferentiated cells, the *germinal epithelium*, while between the base and the apex ova are seen in all stages of development.

The *oviducts* can be seen as a pair of funnels or short trumpet-shaped tubes, piercing the septum between the 13th and 14th segments. The mouth of each funnel is ciliated and in the same line as the ovary of its side. On piercing the septum the ducts run inwards and slightly backwards to meet in the midventral line below the nerve cord and pass through the body-wall to open by a common aperture at the anterior margin of the girdle on the 14th segment.

The *spermathecæ* (Gr. *theke*, a receptacle) in which the sperm of the other worm is stored, are four pairs of pearly translucent sacs in segments VI, VII, VIII and IX. The thick muscular septa in this region should be cleared away to expose them. Each sac gives off from its median aspect a narrow process or diverticulum, about the same length as the sac itself. This is usually of a dead white colour and may have no lumen. Each sac opens by a separate small pore on the ventral surface of its own segment.

MALE REPRODUCTIVE ORGANS.

The sperm-sacs already described should be carefully removed from one side to see the *testes*. These are only recognisable in young worms, becoming atrophied in the adult. They are two pairs of minute white bodies attached to the surface of the septa in front of segments X and XI, close to the middle line.

The sperm-ducts or *vasa deferentia* arise as ciliated funnels on the anterior surface of the septa behind segments X and XI, there being a funnel for each testis. Each funnel is chalk-white in colour and its margins folded like those of a paper filter, the name "rosette" being sometimes given it.

The ducts of the ovaries, we have seen, open at once on the next segment. Those of the testes are long and traverse, several segments before opening by the well-marked pores seen on the 18th segment.

The ducts of the first pair of testes meet those of the second in the 12th segment where they become enclosed in a common sheath. They then run a somewhat contorted course on the body-wall close to the nerve cord till they reach the 17th segment, where they curve outwards behind the copulatory glands to enter the spermiducal duct just as it leaves the gland.

The *spermiducal glands*, sometimes called *prostates*, are a pair of large white lobulate racemose glands lying one on each side of the intestine from about the 16th to the 20th segment, more or less. Each consists of (1) a loosely lobulated glandular portion covered by peritoneum and lined with secretory epithelium, and (2) a muscular duct which is joined by the *vas deferens* of its own side and then curves inward in a sickle-shaped course to open as the male pore on the papilla already seen on the 18th segment.

The name "prostate" is objectionable as suggesting a false homology with the organ of that name found in Mammals. The term "spermiducal glands" is also unsatisfactory, as in a whole family of worms, the *Acanthodrilidæ*, they have no connection with the sperm-ducts but open independently on separate somites.

None of the European family, *Lumbricidæ*, possess these glands. They may be very small in some *Perichætidæ* occupying only one segment, or so large in *Hoplachætella* and a species of *Perionyx* as to reach from the 10th to the 40th segment. Their function is unknown.

In segments XVII and XIX in situations corresponding to the copulatory suckers two pairs of white knob-shaped glands may be seen projecting into the cœlom. Their structure has already been described.

NERVOUS SYSTEM.

The nervous system can be exposed by the same dissection as that described above for the testes and ovaries. The posterior portion of the intestine should also be lifted up when the whole ventral chain can be seen as a white cord close to the body-wall in the midventral line.

In the embryo the nervous system consists of a double chain of ganglia, a pair for each segment, united by a double cord. The first trace we find of it is two longitudinal thickenings of the epiblast on the ventral aspect. The thickenings gradually lose their connection with the ectoderm, and come to lie first in the thickness of the body-wall and ultimately for the most part quite in the body-cavity. In the most primitive Oligochæte we find the nerve system retains its connection with the epidermis throughout life.

This is *Æolosoma*, a pretty little transparent worm, marked with bright green, orange or other coloured dots, very common in fresh water tanks in Bombay.

The first pair of ganglia are dorsal in position and known as the *brain* or *supra-pharyngeal ganglia*. In the adult they have shifted back to the third somite where they can readily be found on the dorsal side of the groove that marks the junction of the buccal and pharyngeal portions of the alimentary canal. They form a two-lobed mass, each lobe being the shape of an elongated pear with the stalks continued as the *circumpharyngeal commissures,* downwards and backwards in the bucco-pharyngeal groove to unite below with the *first ventral ganglia.*

The brain gives off nerves to supply the integument around the mouth. The circumpharyngeal collar supplies the anterior two somites and also *visceral nerves* to the pharynx. The first ventral or *subpharyngeal ganglia* are in the fourth somite, and not only supply it, but send branches to the anterior somites also. Behind this in most worms the longitudinal connectives are enclosed in a common sheath and placed so close together as to look like a single cord with a ganglionic enlargement in each somite. In this species the ventral commissures can be seen in some specimens as a distinctly double cord in several of the anterior somites.

In each somite can be seen three pairs of nerves,—two given off by the ganglia and one anteriorly from the cord to ramify on the septum.

The nervous system of the Earthworm, as well as of all Annelids, is peculiar, in that the connectives contain nerve cells, as well as nerve fibres, whereas in higher animals the nerve cells are restricted to the ganglia. Three clear-looking "*giant-fibres*" are noticeable in the upper portion of the ventral cord.

SPECIAL SENSE ORGANS.

We can recognise no eyes or organs of vision in the Earthworm, but it is certainly conscious of the difference between light and darkness. If a flash of electric light be brought to bear on a worm during his nightly excursions, he will quickly withdraw to his burrow. Worms appear absolutely insensitive to sound, but here we must distinguish between the sense of hearing and the feeling of vibration. A window pane cannot hear, yet the sonorous vibration from a gun will shatter it. The shrillest whistle does not seem to disturb an Earthworm in the least. That there is a sense of touch or feeling is obvious : the trodden worm will turn ; tapping or hammering the ground in the neighbourhood causes the worm to retreat deeper in its burrow. In some Earthworms, not in Perichætes as yet, bodies resembling tactile or *Paccinian corpuscles* have been found in the epidermis.

The worm has probably a sense of smell. It is very fond of onions, and if one be placed near it at feeding hours, the worm is sure to find the onion. There must be a sense of taste also. If a number of odourless leaves of various kinds be placed in the neighbourhood of the worm, probably one kind will be quite consumed before the others are even touched.

THE NEPHRIDIA.

The *nephridia* (Gr. *nephros*, kidney), of whatever appearance they may be, are essentially tubular organs lined with an epithelium which excretes the nitrogenous waste. They are derived from the cœlom and communicate with its general cavity by one end, the exterior of the body by the other. The cœlomic opening in the Earthworm is a ciliated funnel known as the *nephrostome*, the external opening as the *nephropore*.

There is a considerable variation in the structure of the nephridia among the Earthworms. In *Perichætæ* the tubules form a diffuse network on the body-wall and the ciliated funnels are numerous in each segment ; the nephropores, also numerous, open all round the circumference. The pores are very small and can only be seen in sections. In *Perichæta* the nephridia, owing to the diffuse nature of their structure, are only visible to the naked eye as a roughness or fluffiness of the body-wall.

This type of nephridium is known as the *diffuse* in contradistinction to the *large* or *paired nephridia* found in most families of Earthworms.

Another type of nephridium is the *compound nephridium*, where a large number of tubules, each commencing with a ciliated nephrostome, unite to form a fluffy mass, resembling a mop. They are found in the pharyngeal segments and open into the alimentary canal.

Although the nephridia of *Perichæta* in the adult are always of the diffuse type, in the embryo we find the primitive nephridia are paired in each segment.

The paired nephridia are so called as there is usually one pair in each segment. They are large and visible to the naked eye. Each nephridium opens by a funnel into the cœlom, and is an unbranched tube, usually thrown into three loops, varying in width and character of the epithelial lining. The external pores of the paired nephridia are in definite sites.

Large looped nephridia can be seen in the Indian *Perionyx*, and in all the European family *Lumbricidae*. *Megascolex* has both large and diffuse nephridia. Some genera have two and even three pairs of nephridia per segment.

THE BODY-WALL AND GENERAL STRUCTURE AS SEEN IN TRANSVERSE SECTIONS.

The body-wall from without inwards is composed of:

(*a*) The *cuticle*.
(*b*) The *epidermis*.
(*c*) The *circular layer of muscle*.
(*d*) The *longitudinal layer of muscles*.
(*e*) The *peritoneal* lining.

The cuticle is not a layer of cells, but a secretion of the underlying epidermis. It readily peels as a thin film off worms that have been preserved some time. Under the microscope it is seen as a transparent colourless membrane, marked by fine lines or striæ and showing circles of openings through which the setæ pass. Frequently some of the setæ

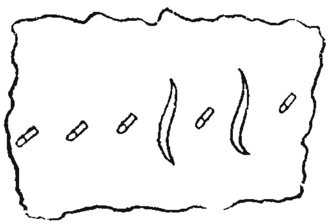


Fig. 11.
Cuticle of Perichaeta.

remain attached to the cuticle, and it is then seen that only about a third of the length of the seta projects above the surface. At the setal openings the cuticle may be seen turned in like small sleeves to surround the setæ when in position. Numerous minute openings for the nephridia may be seen scattered without any apparent arrangement. The setæ may be picked out with a fine pair of forceps or a portion of integument may be boiled in *liquor potassæ* to isolate them. They should be examined in water. They are seen to resemble an italic letter *f* in shape, the cross-bar being a very slight projection. Like the cuticle, they are non-cellular, a secretion of the epiderm composed of *chitin*.

The ectoderm consists of a single layer of epithelial cells, most of which stain feebly and have very small nuclei.

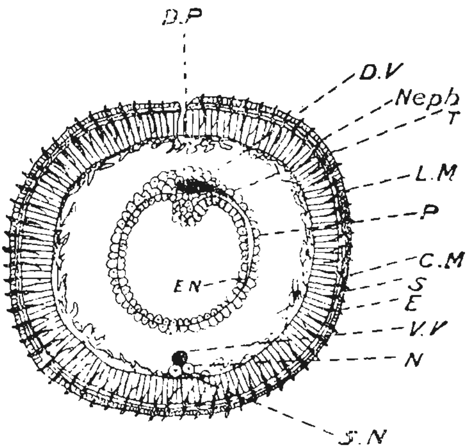


Fig. 12.

Fig. 12.—*Perichæta. Transverse section posterior region*—

D. P.	Dorsal pore.	S. N.	Subnervian vessel.
D. V.	Dorsal vessel.	V. V.	Ventral vessel.
Neph.	Nephridia.	P.	Peritoneum.
N.	Nerve cord.	T.	Typhlosole.

Between these feebly staining cells are seen glandular cells of a pear-shape, stalk-end outwards, containing deeply stained granules. These cells secrete the mucus which keeps the surface slippery.

Next is the circular layer of muscle. The muscles of the *Annelids* are peculiar and resemble those of the *Nematode* worms, in that each cell has a central unmodified portion of protoplasm enclosing the nucleus and surrounded by the striated contractile protoplasm.

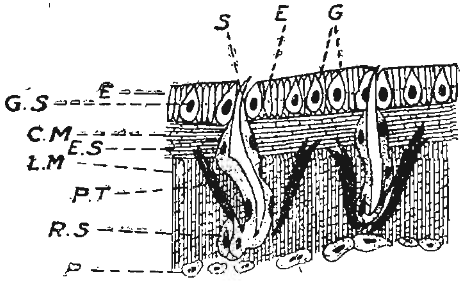


Fig. 13. P.

Fig. 13.—*Portion of Fig. 12, more highly magnified*—

S. Seta.
E. Epithelium.
G. Glandular cell.
E. S. Epithelium of setigerous sac.
R. S. Reserve seta.
C. M. Circular muscle.
L. M. Longitudinal muscle.
P. T. Protractor muscle.
P. Peritoneum.

The longitudinal layer is thicker than the circular.

The peritoneum is seen as a thin membrane internal to the muscles.

All these layers are continuous at the mouth and anus with similar layers of the alimentary canal. Thus the outermost layer of the canal is the peritoneum which, however in places is many cells thick forming the "yellow-cell tissue," the cells being, as already described, club-shaped and full of small refractive globules.

The muscular layers of the gut are feebly developed, the longitudinal layer is outer, the circular inner. The lining membrane is a single layer of epithelial cells, separated from the muscular coat by a thin layer of very vascular connective tissue, known as the sub-epithelial layer. It is probable that the whole of the epithelium lining the alimentary canal, except that in the buccal cavity and close to the anus, is derived from the hypoblast. (See description of stomodæum and proctodæum, p. 118 and p. 150.)

The ectoderm has been described as a single layer of epithelial cells. The region of the girdle is an exception, as in all the true Earthworms there are here two layers of cells, many of which are of a glandular character, to secrete the cocoon case.

The setæ will be seen set in sacs reaching inwards to the peritoneum, lined with a sheath of the epidermis, by the inner-most cells of which they are secreted. From the inner end of the sheath can be seen the *protractor muscle* of the seta passing obliquely outwards to join the outer circular layer of muscles. Young developing setæ, which will replace the functional ones when worn out, may be seen in their sacs or follicles close to the peritoneum.

RELATIONSHIP OF THE EARTHWORM.

In the English language the word "worm" is used colloquially to indicate any small cylindrical, soft-bodied animal devoid of conspicuous limbs. Linnæus classified the majority of these creatures in a sub-kingdom which he called *Vermes*, the Latin for "worm."

Further study of their structure and development showed such fundamental differences, that now-a-days most Naturalists divide the Worms into at least three *phyla* (Gr. *phylon*, a tribe) or sub-kingdoms.

Of these the most lowly organised phylum is known as the *Flatworms*, or *Platyhelminthes*, (Gr. *platus*, flat, *helminthos*, a worm). Many of them, such as the Tape-worms and Flukes are parasitic in other animals. They possess no cœlom or body-cavity, their internal organs being embedded in a mass of tissue or parenchyma. Some have no alimentary canal and those that have one are without an anus.

The *Nemathelminthes* (Gr. *nema*, thread) comprises several orders which really have few features in common, except that all are unsegmented, " vermiform " or thread-like in shape and devoid of any appendages except, in rare cases, bristles. They have no blood-vessels or special respiratory organs ; there is always a body-cavity containing fluid, but whether it is a true cœlom or not is doubtful. Many of them such as the round-worm, thread-worm, whip-worm and guinea-worm, are common parasites of man.

The Earthworms belong to the third phylum, *Annelida* (Latin, *annulatus*, ringed) or segmented worms. They are metamerically segmented, the viscera are separated from the body-wall by a cavity which is a true cœlom lined with epithelium. They do not possess jointed limbs like the *Arthropods*, but most of them are armed with setæ embedded in, and secreted by the skin.

The Annelids are divided into classes one of which, the *Chaetopods* (Gr. bristle foot) includes the *Polychætæ* (Gr. *polys*, many) or Marine worms, and the *Oligochæta* (Gr. *oligos*, few), which includes the Freshwater and Earthworms. The name Oligochæta was given as the Earthworms first studied were European genera, which possess only four pairs of setæ. As the name has been in use for so long, we may retain it, though the Indian species we have studied often has 140 setæ on some of its segments.

The Polychætes differ from the Earthworm in having their setæ arranged in lateral muscular processes or parapodia, in often possessing gills, and in that the sexes are usually separate.

The Oligochætes may be divided into two sub-orders—the *Limicolæ* (Latin, mud-dwellers) and the *Terricolæ* (Latin, earth-dwellers) or true Earthworms. In the former, which, as their name implies, live in fresh water or mud, the male pore is always in front of the female pore. The eggs are large, there are large egg-sacs and the clitellum is composed of a single layer of cells and never begins further back than the 11th segment.

The true Earthworms have small eggs and small egg-sacs, and except in one family (*Moniligastridæ*) a clitellum composed of two layers of cells; the ovary is in the 13th, female pore in the 14th segment, always in front of the male opening.

The families of Earthworms found in India are—

(1) *Moniligastridæ* (Latin *monile*, a necklace, *gaster*, stomach), so called because they often have several—four, even six—gizzards. They form a connecting link with the mud-worms in having an inconspicuous clitellum only one cell thick, placed far in front, on segments X—XIII and the male pores in front of it on segments X—XII. Only four pairs of setæ in each segment.

(2) *Perichætidæ*, (Gr. *peri*, around) of which we have studied one species. Setæ numerous in each segment. Male poreon XVIII segment. Spermiducal gland generally racemose or lobate. Indian genera, *Perichæta*, *Perionyx*, *Magascolex*.

(3) *Acanthodrilidæ* (Gr. *akanthos*, thorn). Setæ either 8, 12 or ∞ The spermiducal glands tubular, opening separately from the sperm duct on segments XVII and XIX. Male pore on XVIII. These worms are probably not indigenous to India, but one genus, *Benhamia*, is often found here, perhaps imported from Africa.

(4) *Lumbricidæ*. These are the common worms of Europe. Specimens may occasionally be found in botanic gardens in India. Setæ four pairs. Male pore on segment XV generally, perhaps in front of it. Clitellum far back, segments XXVII—XXXVIII, usually about XXX—XXXVI. No spermiducal glands. Gizzard far back.

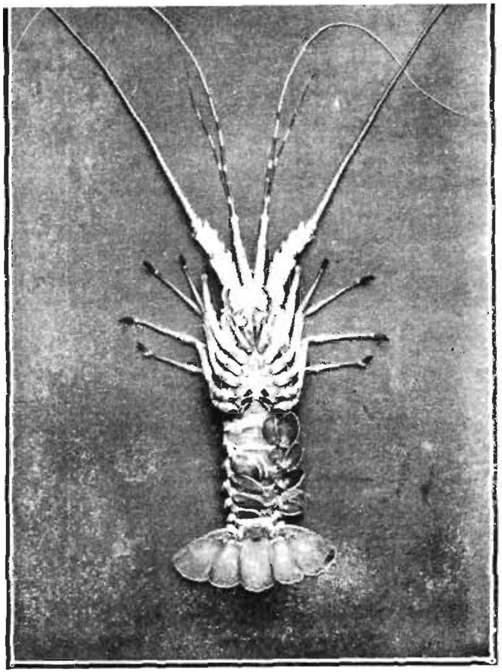


Fig. 14. Palinurus, Ventral View of Female.

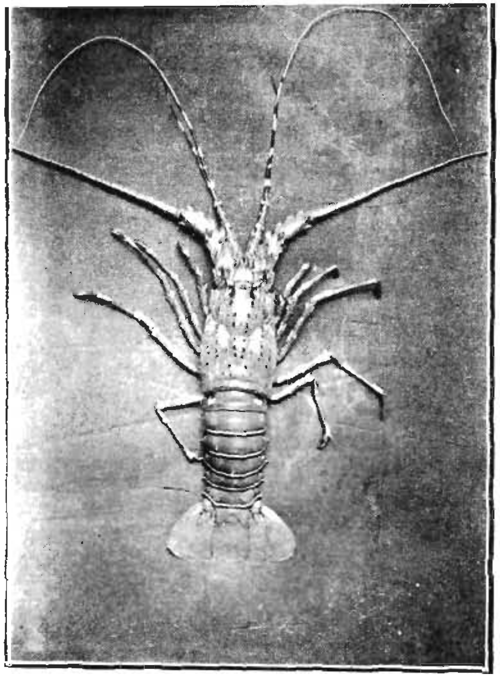


Fig. 15.—Palinurus, Dorsal View of Female.

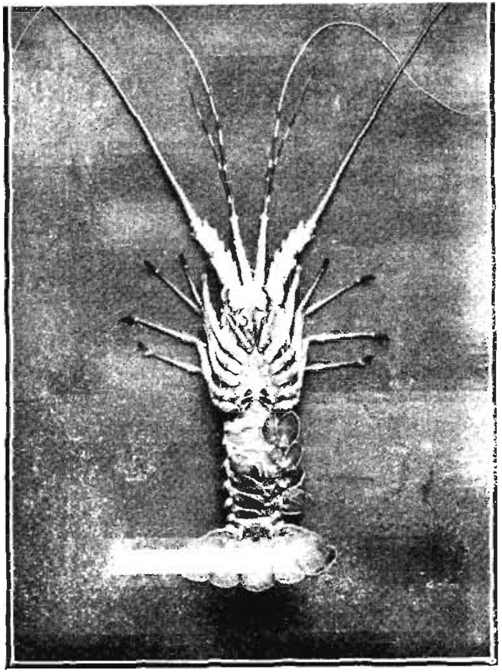


Fig. 14.—Palinurus, Ventral View of Female.

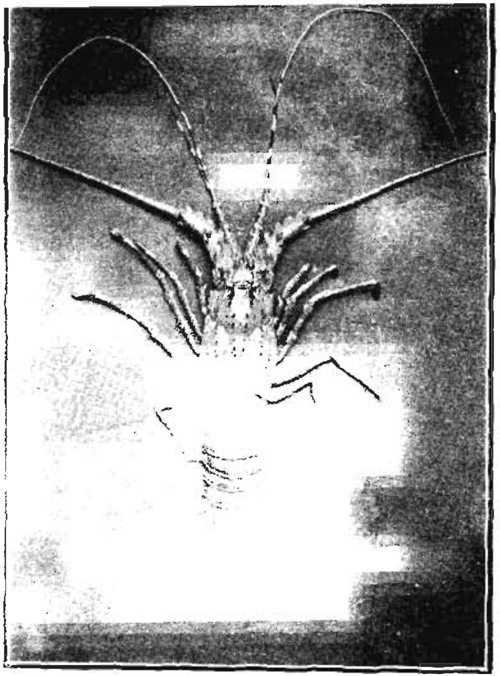


Fig. 15.—Palinurus, Dorsal View of Female.

* PALINURUS OR "THE SPINY LOBSTER" OF BOMBAY.

This animal is to be found in abundance all the year round on the coasts of Bombay.

Though locally called Lobsters, they do not belong to the same genera or even to the same family as the English Homarus or Norwegian Nephrops, and the inexperienced student attempting to study the anatomy of the Cray-fish or Lobster will soon become woefully muddled when he attempts to reconcile the accounts of the Lobster in English text books with his personal observation of Palinurus.

You may hold Palinurus in your hand with impunity as he possesses none of the powerful *forceps* with which his

---

* I have called this animal Palinurus though by many the oriental species are considered worthy of generic rank and called *Panulirus.* There has been some discussion as to who had the honor of inventing the latter epithet. Palinurus was the worthy pilot of Æneas' ship. He fell overboard and was drowned near a cape, to which and the "Spiny Lobster" of England, the "Langouste" of France, he has since stood god-father. "Panulirus," Greek for "wholly lewd," "without a trace of shame," "bilkul luchha," is a foul libel I would hesitate, without the most damning evidence, to apply to any gentleman, much less to the hero of this sketch.

My own impression is that the name was accidentally invented by a Babu from "Nucklow" who invariably transposes his "ls" and "ns." The first specimens received in Europe were packed and labelled by a Museum Babu in Calcutta.

European cousin, the Lobster, or some of the Indian Prawns can pinch and wound the unwary investigator.

If alive he will probably make a croaking noise as you lift him. This sound as you can verify yourself is caused by rubbing the first movable joint of the large feelers against the neighbouring fixed part.

He may perhaps startle you by forcibly flapping his tail against the under surface of his thorax. When in his native haunt, the sea, he is able to suddenly dart backwards by similar powerful strokes of the tail, but the usual mode of progression is swimming by gentle strokes of the flat tail fin, while the swimming feet all row together with an even swing like the oars of a boat. When on the bottom of the sea he half swims, half walks, on the long thoracic legs.

Note the movement of the jaw apparatus. Each jaw moves horizontally to and from the middle line of the body: not up and down as do the jaws of a dog or man.

Next look under the anterior edge of the large shield-like covering of the cephalo-thorax. You will notice a small scoop or paddle-shaped appendage moving rapidly to and fro two or three times a second. This is the paddle or *scaphognathite* (Gr. *scaphe*, boat, *gnathos*, jaw), by means of which the water entering the gill-chamber from behind is scooped out in front so that a continuous current keeps bathing the gills to enable them to absorb the oxygen dissolved in the water and get rid of the carbonic acid.

The course of the current is easily demonstrated by returning the animal to the water after it has been in the air for some time. On re-immersion, bubbles of air are for some time seen to come out from under the anterior edge of the gill-cover. Should this not satisfy you, if you put some finely powdered carmine or indigo in the water just behind the gills, you will soon see the coloured current pouring out in front of the scaphognathite.

The whole body of Palinurus is covered by an integument composed of a number of epithelial cells which correspond to the epidermis of man and higher animals. These cells secrete a substance which forms a continuous layer all over the surface of the body and limbs, and at the mouth and anus is continuous with the lining of the gullet, stomach and most of the intestine. This layer is known as the cuticle and throughout contains a substance known as *chitin* (Gr. *chiton*, a coat). Here and there it is impregnated with salts of lime to form the rigid armour-like portions of the exoskeleton. Any hardened portion is known as a *sclerite* (Gr. *skleros*, hard). By pouring a little strong acid on the hardened skeleton the lime will be dissolved with the ebullition of gas bubbles. You must clearly understand that the cuticle of the invertebrates is not homologous with your own cuticle or that of other vertebrates, which is composed of a number of flattened epithelial cells, that of the invertebrates being non-cellular, *i.e.*, only a secretion, and showing no nuclei or cellular structure.

Between each somite of the cephalo-thorax behind the mouth, there is an infolding of the cuticle, each such infolding being called an *apodeme* (Gr. *apodaio*, I partition), to form an internal skeleton, or *endophragmal* system, on the floor of the cavity. These sclerites form in the middle line a tunnel or series of archways over the sternal sinus, the nerve cord and sternal artery. Laterally they resemble the bulkheads of a ship and give attachment to the muscles.

The whole of this cuticular skeleton, including the apodemes and the lining of the fore and hind gut, is shed or moulted periodically.

The body is divided into two easily recognised regions, a posterior *abdomen* made up of six *somites* (Gr. *soma*, body), freely movable on one another in the vertical plane but having no lateral movement. These somites are all clearly homologous with one another and except the first each bears a pair of lateral appendages. Behind all is a seventh segment, the "tail" or *telson*, which bears no appendages and is not a true somite. Anteriorly is the *cephalothorax* (Gr. *kephale*, the head), covered dorsally and on the sides by a large rigid shield or *carapace*, in which there is little indication of segmentation. Ventrally however the presence of a number of transverse bars and of thirteen pairs of appendages will lead you to conclude that the head is composed of five, and the thorax of eight somites.

The structure of a somite may best be studied by taking as a type one from the abdomen, say the third of which Fig. 16 represents a transverse section, nearly semi-circular outline. The exoskeleton of the segment surrounds it as a ring, being hardened by calcification where rigidity or protection is required, and remaining soft where flexibility is necessary. Dorsally the hard exoskeleton forms a broad arch known as the *tergum* (Latin, the back); the lateral portions projecting downwards, and terminating in recurved spines are called the *pleura* (Gr. *pleuron*, side, rib). Ventrally the ring is completed by a narrow straighter bar to the outer ends of which the appendages are articulated. That portion of the bar between the swimming feet is called

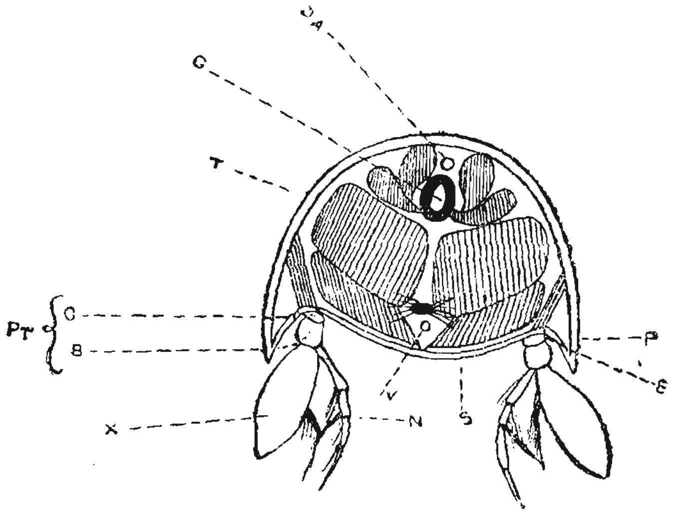


Fig. 16.

TRANSVERSE SECTION OF 3RD ABDOMINAL SOMITE.

C = Coxopodite } *Pr.* = Protopodite
B = Basipodite }
DA = Dorsal Artery.
E = Epimeron.
G = Hind-gut.
P = Pleuron.
N = Endopodite.
S = Sternum.
T = Tergum.
V = Sternal artery.
The black dot above it s the nervegangion.
The clear space around is the ventral sinus.
X = Exopodite.
The shaded portions are muscles.

the *sternum* (Latin, breast-bone). The very small portion of the bar external to the limb and internal to the pleuron is the *epimeron* (Gr. *epi*, upon or above; *meron*, the thigh).

Between these rings of sclerites the integument is soft and flexible to allow of free movement.

The terga of the successive somites overlap one another from before backwards like the tiles of a house; their movement is restricted to the vertical plane by very neat hinge-joints formed by a short peg on the posterior margin close to the pleuron, which fits into a corresponding socket on the anterior margin of the next tergum.

The appendages are attached by soft cuticle or arthrodial membranes to the margins of a circular opening in the ventral sclerite, between the epimeron and sternum as already described.

The appendages differ markedly in the sexes. In the female we find a basal stem or *protopodite* (Gr. *protos*, first,

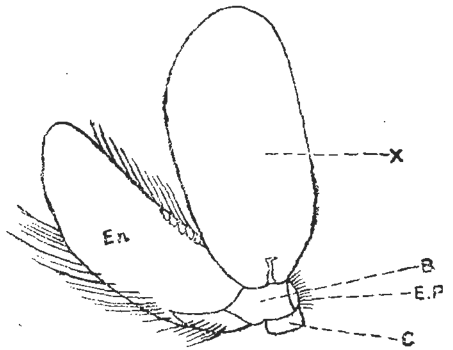


Fig. 17.—SWIMMING FOOT OF 2ND ABDOMINAL SOMITE OF FEMALE.
B = Baxipodite; *C* = Coxopodite; *En* = Endopodite; *X* = Exopodite.

podite from *pous, podos,* a leg or foot, signifying a leg segment), consisting of a very short proximal *coxopodite* (*coxa*, the hip) and a larger distal piece the *basipodite* (*basis*, the

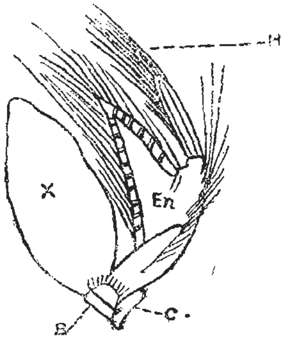


Fig. 18.

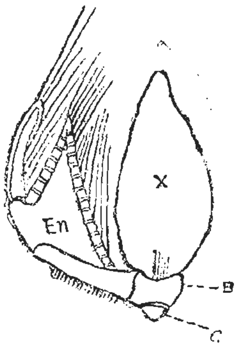


Fig. 19.

Fig. 18.—SWIMMING FOOT OF 3RD ABDOMINAL SOMITE OF FEMALE.
Fig. 19.— ,, ,, OF 4TH ,, ,, ,,
All are of the right side; Figs 17 and 18 are seen from front, Fig. 19 from behind, to show the epipodite-like sclerite.

base). To the distal end of this are articulated two flat leaf-like structures, an outer *exopodite* (Gr. *exo*, outer) and an inner *endopodite* (Gr. *endo,* inner).

The exopodite is shaped somewhat like a rabbit's ear. The greater part is membranous in character, being composed of a double layer of cuticle covering a little connective and muscle tissue; only the basal portion is calcified.

The inner margin of the endopodite is a calcified rod of three pieces united by membranous joints. In the appendage of the second abdominal somite the whole of the external portion forms a thin membranous leaf, very like the expodite in appearance but bearing on its margin a fringe of hairs.

The protopodites and exopodites of the next three segments, namely the third, fourth and fifth, resemble those of the second, but become progressively smaller. The leaf of the endopodite is however curiously divided. There is a triangular flap attached along the two proximal pieces; its free margin strengthened by numerous small white sclerites. The distal piece forms a calcified margin to a narrow plate. The margins of the whole endopodite bear numerous long silky hairs to which the eggs become attached when laid.

To the outer side of the protopodite of these swimming feet is attached a small white sclerite with a fringe of short hairs. It may be the homologue of a process known as the *epipodite* found on the thoracic legs, but it differs in being attached by membrane to the basipodite as well as to the coxopodite. Gills are attached to the abdominal appendages of certain Copepods, another order of the Crustaceæ.

In the male all the above appendages are much smaller and have only one leaf, the exopodite, as the endopodite is quite suppressed.

In both sexes the first abdominal segment is devoid of appendages. Its tergum has a large buttress on each side just above the hinge which prevents over-extension by coming in contact with the posterior margin of the carapace.

The lateral appendages of the sixth abdominal somite are very large and with the telson form the powerful five-leaved tail fin.

The protopodite consists of a single piece. The endopodite and exopodite form two large oval plates, each with a proximal stout calcified, and a larger distal membranous portion.

The telson may be regarded as a median appendage of the sixth somite. Ventrally it is for the most part uncalcified, and in its anterior portion is perforated by a longitudinal opening, the anus.

Two small oblique linear sclerites are seen on each side but somewhat in front of the anus. Dorsally the proximal portion is calcified but the greater part is membranous. The proximal part of this membranous surface as well as of the rest of the "tail-fin" is studded with minute spines.

Cephalo-thorax.

The dorsum and sides of the cephalo-thorax are covered by a large unjointed shield, the carapace, which dorsally terminates in front behind the eye-stalks by a broad crescentic notch limited at each end by a stout spine which projects forward above and internal to the eye.

In front of the eyes is a broad plate firmly attached to and looking like an extension of the carapace. This is not its true homology however, and we will later on see that it is part of the united basal joints of the antennæ. The dorsal part of the carapace bears a number of sharp spines which project forward and are most of them arranged in eight longitudinal rows. These sharp spines are some compensation for the absence of the defensive pincers which Lobsters and Prawns possess. They render Palinurus an ugly customer to attack and an uncomfortable mouthful to swallow.

About the middle of the dorsal surface we find a transverse *cervical groove* which runs downwards and forwards on each side of the carapace.

This groove (Latin *cervix*, neck) marks the junction of the head with the thorax and is the only evidence of segmentation in the carapace.

Behind the transverse portion of the groove is a quadrilateral space known as the *cardiac area* because the heart lies below it. The grooves that mark its lateral limits are continuous in front with the cervical and are also continued backward to form two longitudinal grooves, known as the *branchio-cardiac* grooves, because all the descending portion of the carapace below these grooves forms a cover for the *branchiæ* or gills and hence is known as the gill-cover or in Greek, *branchiostegite*.

This cover is homologous with the pleura of the abdominal somites.

The sterna of the cephalo-thorax are much more obvious in Palinurus than in the Cray-fish, Lobster or Prawn. Between the five pairs of walking legs is seen a large triangular or shield-shaped plastron, with its apex pointing forward. A number of transverse sutures show it is formed of the five sterna united together. On separating the foot jaws their three sterna are seen as a rod continuous with the apex of the plastron, stout tubercles marking the point of union between its segments.

The epimera of the thoracic segments form the inner wall of the gill chamber as a continuous delicate layer which at the dorsal limit of the chamber is continuous with the inner lining of the gill-cover.

The wall formed by the epimera is thin and but slightly calcified except just above the articulation of the appendages. Above the last walking leg it forms a specially strong plate bearing a stout process in shape and function resembling a shirt stud. The posterior margin of the carapace is tucked or reflected inwards and on each side of this reflection is an oval buttonhole into which the top of the epimeral stud buttons.

Were it not for this buttoning arrangement the posterior portion of the carapace might be tilted upwards and the gills exposed, as the articulating membrane between it and the first abdominal tergum is loose to allow of free flexion and extension.

We have seen that the abdominal appendages are paddle-shaped in accord with their function as swimming organs. The cephalo-thoracic appendages are formed on the same plan but with considerable modification in structure to adapt them for different functions.

Including the antennules they are from before backwards.

Appendages of the head.	I.	A pair of antennules	Main function organs of sense or "feelers."
	II.	A pair of antennæ	
	III.	A pair of stout mandibles	Jaws.
	IV.	A pair of first maxillæ	
	V.	A pair of second maxillæ	
Appendages of the thorax.	VI.	A pair of first maxillipeds	Foot-jaws.
	VII.	A pair of second maxillipeds	
	VIII.	A pair of third maxillipeds	
	IX.	A pair of first walking legs	
	X.	A pair of second do.	
	XI.	A pair of third do.	
	XII.	A pair of fourth do.	
	XIII.	A pair of fifth do.	

In Fig. 20A the appendages are indicated by these numerals.

Remove the gill-cover of one side with stout scissors, cutting from behind forwards a little external to the branchio-cardiac groove. Keep the scissors close to the gill-cover or you may cut the gills. Make a second vertical cut at right angles to the first, a little behind the cervical groove. Count the gills and note the position in which they are attached. You will find on moving the last walking leg to and fro that none of the gills are disturbed, but on moving any of the other walking legs or the second or third maxilliped, a gill and also a membranous flap is moved to and fro with the limb. These gills as they are attached to the legs are known as *foot-gills* or *podo-branchiæ* (Greek *pous, podos*, a foot; *branchia*, a gill).

Of the other gills you will find four are attached to the epimeron or inner wall of the chamber. As they are opposite the last four walking legs, it is obvious they belong to the last four thoracic segments. They are called the side-gills or *pleurobranchiæ* (Greek *pleuron*, side).

The remaining gills are eleven in number. The most anterior is attached to the membrane which joins the second maxilliped to the thorax. The other ten are attached in pairs to the inter-articular membranes of the last maxilliped and of the first four walking legs. From their attachment they receive the name of "joint-gills" or *arthrobranchiæ* (Greek *arthros*, a joint).

Remove the thoracic limbs one by one beginning with the hind-most. With the point of a knife cut the articular membrane close to the basal piece of the limb so as not to remove the arthrobranch, but be careful to remove the foot-gill and leaf-like flap. When the articular membrane has been cut all round, a gentle wrench will disengage the two little pegs and sockets by which the limb is hinged.

Number the limbs with a coloured pencil so that you can recognise to which segment each belongs.

The second maxilliped is perhaps the most complete of the limbs and you had better study it first as a type of the biramous appendage.

Like the swimming limbs, it is made up of a proximal stem, the protopodite, consisting of coxopodite and basipodite to the latter of which are attached two terminal divisions, the endopodite and exopodite. Attached to the

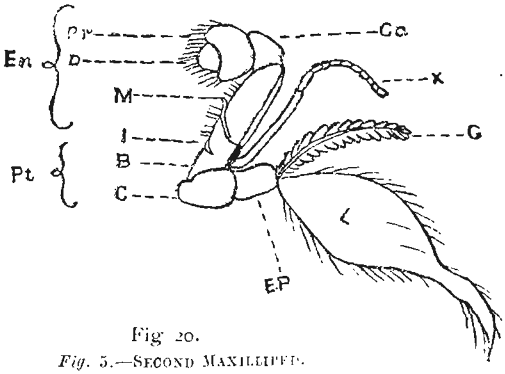


Fig 20.

Fig. 5.—SECOND MAXILLIPED.

B = Basipodite	*Pt.* = Protopodite.	*P* = Propodite.
C = Coxopodite		*X* = Exopodite.
En = Endopodite.		*G* = Gill.
I = Ischiopodite.		*Ep* = Epipodite.
M = Meropodite.		*L* = Lamella or leaf.
Ca = Carpopodite.		*D* = Dactylopodite.

outer surface of the coxopodite we find a new structure, a lateral development which runs up into the gill chamber and bears at its extremity a gill in front and a thin membranous lamella behind.

The whole of this lateral structure, including the basal calcified podomere articulating with the coxopodite, the gill and the leaf or lamella is called the *epipodite*. The surface of the lamella and especially its margins bear a number of hairs. It is formed of a double layer of chitinous cuticle.

Its function is unknown but it may prevent the filaments of contiguous gills becoming entangled.

The basipodite is movably articulated with the coxopodite, but distally it is firmly united with the proximal joint of the endopodite so that it may easily be mistaken for a portion of the latter limb-segment which is known as the *ischiopodite* (Greek *ischion*, the hip). A well marked notch at the inner margin indicates the point at which the two segments are fused.

That this is the true homology or explanation of the structure will be at once admitted on comparing the corresponding limb of a Cray-fish or Lobster in which there is a distinct movable articulation between the basipodite and ischiopodite, of which we have only a notch left as a vestige in Palinurus.

This ankylosis or immovable union of the basipodite and ischipodite is characteristic of all the thoracic limbs of Palinurus whereas in the Lobster we find the joint ankylosed in the great pair of chelæ or pincers, and in the third maxilliped only; the second maxilliped and all the walking legs have a freely movable joint between the basipodite and ischiopodite. To the latter is movably articulated the *meropodite* (Greek *meron*, a thigh), the longest segment of this limb. Next comes a short triangular piece, the *carpopodite* (Gr. *karpos*, wrist), next a *propodite* (*pro*, in front), a broad flat segment with a concave distal margin to the centre of which is articulated the terminal *dactylopodite* (Gr. *dactylon*, a finger). All these podomeres of the endopodite are more or less flattened to form horizontal plates, the inner margins of all being covered with stiff bristles or *setæ*.

The exopodite is a long many-jointed palp-like flattened filament, of which the proximal piece is as long as all the others—about seven—taken together.

We may regard a typical appendage as made up of a proximal stem or protopodite of two segments, coxopodite and basipodite. The coxopodite bears laterally an epipodite with its gill and lamina. To the distal end of the basipodite an endopodite and exopodite are attached, the latter of a variable number of segments, the endopodite of five, ischiopodite, meropodite, carpopodite, propodite and dactylopodite, enumerating from base to tip.

All the appendages may be regarded as built on the same biramous plan, and all their variations in appearance and function are due to one or more of three factors—

1. Suppression or atrophy of a part or parts.
2. Union or coalescence of parts.
3. Modification of a part or parts.

The third maxilliped much resembles the second, but is considerably larger and stouter. The exopodite is however completely suppressed, though in the Lobster and Prawn it is well developed.

The epipodite has both gill and leaf. The basipodite is firmly ankylosed with the ischiopodite as in all the thoracic limbs of Palinurus, the line of union being better marked than in the second maxilliped by a constriction forming a complete ring. The meropodite is in this limb the longest segment. All pieces of the endopodite are somewhat triangular in transverse section, being less flattened than the second maxilliped. The apex of the triangle forms the outer margin of the endopodite, the base being flat and well covered with bristles. The dactylopodite is much longer than that of the second foot-jaw and is covered with hairs.

The maxillipeds and maxillæ are all directed forward in the horizontal plane, so as to overlap one another, below the opening of the mouth.

The first maxilliped is much modified. The two segments of the protopodite have become broad thin plates with an inner thin cutting edge fringed with stiff setæ. The epipodite has become a thin membranous plate with no trace of a gill.

The endopodite is a small oval plate, its inner margin setose. The exopodite is relatively very large. Its proximal joint forms more than half its length ; the remaining nine joints are much broader than long, and together form an oval plate fringed with setæ, and twisted at the base through an angle of about 150 degrees, so that the anatomical inner surface looks outward.

The walking limbs are much alike. The first is the shortest and stoutest. The coxopodite, short and irregular in shape, bears at its outer dorsal angle an epipodite, the proximal portion of which is calcified and bears a gill and leaf. The basipodite is firmly ankylosed with the ischiopodite, the two together being about as long again as the coxopodite. The meropodite in this limb is the longest segment, the carpopodite is short, the propodite long, bearing a few setæ on the inner surface of its distal extremity. The dactylopodite forms a sharp claw or talon and is almost covered with setæ.

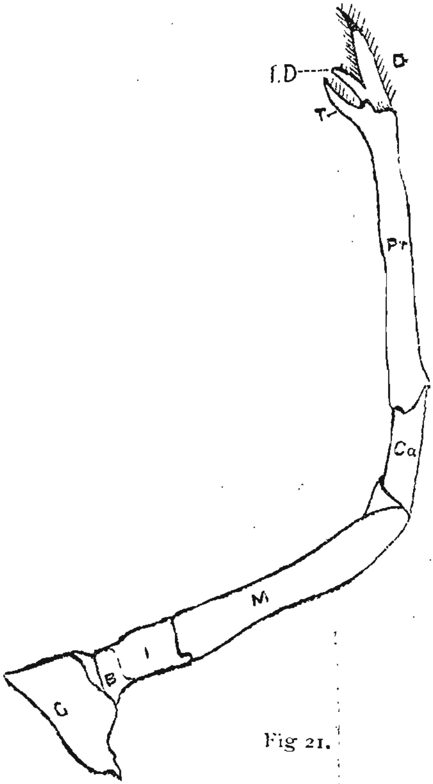


Fig 21.

LAST WALKING LEG OF FEMALE.
D = Dactylopodite.
ID = Inner opposable process of Dactylopodite.
T = Inner distal process or "Thumb" of Propodite.
(Other letters as in Fig 20).

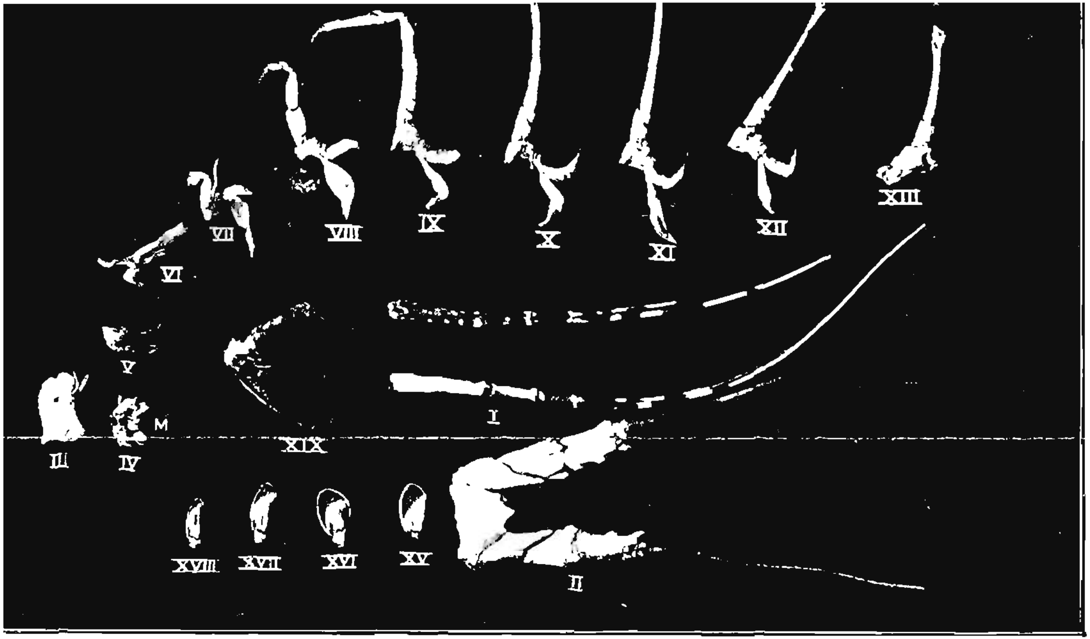


Fig. 20a.—APPENDAGES OF MALE.
M. Metastoma, which has not been separated from IV, the 1st pair of maxillæ.

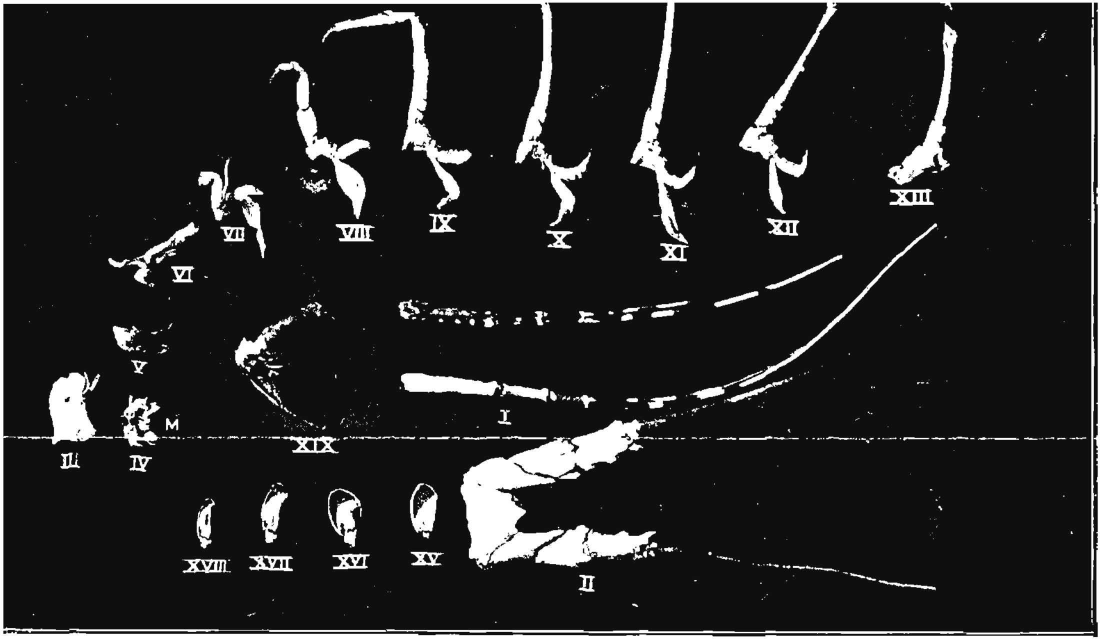


Fig. 20*a*.—Appendages of Male.
M. Metastoma, which has not been separated from IV, the 1st pair of maxillæ.

The second leg is longer and more slender, but otherwise resembles the first.

The third is the longest of the legs. There are fewer hairs on the propodite. On the dactylopodite the hairs form two lateral fringes. In the female the ventral surface of the coxopodite close to the sternal articulation shows a small pin-hole which is the orifice of the oviduct.

The fourth resembles the preceding.

The fifth differs from the other legs in having no epipodite and consequently no gill. In the male the ventral surface of the coxopodite has a large opening for the vas deferens. The propodite is about the same length as the meropodite. The dactylopodite is claw-like.

In the female, the propodite is the longest segment and the inner angle of its distal end is prolonged to form a spine against which the dactylopodite can be opposed so as to form a small pincer or forceps. The dactylopodite is somewhat bifid having a large outer claw and a short inner one which forms the uter blade of the forceps. See Fig. 21.

This is the only representative in Palinurus of the powerful forceps so characteristic of Cray-fish, Lobsters, Prawns and Crabs, and it is worthy of note that while all these Crustaceans have the anterior walking legs chelate, it is only the posterior limb of the female Palinurus that is chelate, while the male has no trace of forceps.

THE APPENDAGES OF THE HEAD.

To the parts of the antennæ special names are given, the termination "*podite*," *i.e.*, a "leg piece," being changed to "*cerite*" in Greek, signifying a "horn piece" or feeler piece.

In the case of the jaws the termination "*gnathite*," Greek for "jaw piece," is often used, *e.g.*, protognathite, scaphognathite, etc.

The second maxilla is so overlapped by the first maxilliped as to be almost concealed from view. It presents the appearance of two thin plates, the inner of which is soft and membranous, its inner margin fringed with hairs and divided into three serrations. The proximal of these represents the coxopodite, the second, the basipodite, and the third possibly the endopodite. The outer chitinous flap which lies under the cervical groove is the rapidly moving paddle by means of which water is continually baled out of the gill chamber. It is the epipodite probably united with the exopodite. It has received the name scaphognathite from its boat-shaped outline. The function of this limb being mainly to assist in respiration, its masticatory portion is uncalcified, feeble and degenerate.

The first maxillæ are more obvious than the second in the living animal, being more exposed and nearer the middle line. Each resembles the Prince of Wales' crest in shape and is firm and well calcified. The middle "plume," the largest, is the basipodite, the inner, the coxopodite, both having a cutting edge set with stiff setæ. The outer piece is the endopodite, an oval plate fringed with short soft hairs.

In front of the maxillæ and looking like another softer pair of jaw appendages is the *metastoma* (Gr. *meta*, behind, *stoma*, the mouth) (Plate B, fig. M), which forms a soft lip and consists of one median and two lateral lobes, the former being strengthened by two pairs of small sclerites.

Before removing the mandibles open and close them repeatedly to observe the points about which they move. Note on the cleaned skeleton that the lateral bulge of the carapace in front of the cervical groove is almost filled by the outer portion of the huge mandible. In front of the mouth you will see a small soft flexible upper lip or *labrum*, in which are two small symmetrical sclerites; above this is a small triangular space, part of the *epistoma*; in front of it you will see two small pointed processes of the mandible meeting in the middle line and articulating with the epistoma by a membrane throughout their whole length. On the outer hinder portion of the mandible, diagonally opposite the pointed process, you find a large pointed peg, which fits into a corresponding socket at the base of the epimeron which is here specially strengthened and calcified. On examining the endoskeleton you will find this point specially supported by stout transverse stays or apodemes, reaching from side to side of the cephalo-thoracic cavity.

On the diagonal line joining this pivot with the anterior pointed process the mandible rotates

The whole of this large rounded piece is the coxopodite. Close to the origin of the anterior tooth-like process is a three-jointed palp. The proximal segment represents the basipodite, the distal two, the endopodite. This we learn from a comparative study of certain lower Crustaceæ, in whom we find the basal joint of the palp bearing both endopodite and exopodite. In the dried skeleton the calcified tendons of the adductor muscles remain attached to the mandibles.

We have already seen a small portion of the ventral surface of the epistome. In front it is reflected back dorsally on itself so that the whole is a flattened cone which forms part of the anterior wall of the head. The epistome is homologically the sternum of the antennary somite, but in this case owing to its reflection it forms part of the dorsal surface of the head.

To understand the structure of the antenna, you should compare it with that of the Prawn or the Cray-fish. In these latter animals you at once recognise the homologue of the protopodite (here called the *protocerite* from the Greek *keras*, a horn or feeler), with a short *coxocerite*, on the ventral surface of which is a small nipple-like projection perforated by an opening. This opening you find on dissection leads into the duct of the kidney or "green gland." Then you have an obvious *basicerite*, to which are articulated an *exocerite* in the form of a scale or flat plate, very large indeed in the Prawn. You will readily recognise in the rest of the long feeler an *endocerite* with two large basal segments, and a long annulated terminal portion or *flagellum* (Latin, a whip).

In Palinurus you find no trace of the exocerite. You find a very long annulated feeler, sometimes a yard long, with apparently only three large basal joints. The two distal belong to the endocerite. The first movable joint has no opening for the green gland. This opening you will find on each side on a prominent little nipple near the outer angle of the large somewhat triangular plate in front of the epistoma. You find dorsally behind the antennules and in front of the eye a large plate which you do not find in the Lobster, Cray-fish or Prawn. Hence you are driven to the conclusion that the coxocerites of the two antennæ are firmly fused together and that these two plates represent the dorsal and ventral surfaces of the united coxocerites, and therefore the first movable joint is the basicerite.

Though we have for convenience numbered the antennules as if they were the appendages of a somite, they really belong to the prostomium. Those who hold the contrary view believe the sternum of the "antennulary somite" is fused with the coxocerites of the antennæ. The stem of the antennule, you will note, consists of three cylindrical segments, which therefore do not correspond to the pieces of the protopodite, only two in all the other appendages.

The basal segment is the largest. There are two rows of setæ on its inner and dorsal surfaces. At the proximal nd of the dorsal surface is seen the auditory opening. Both ilaments are annulated and much longer in the Indian han in the European members of the family The inner ilament is the longer.

The eye-stalks or *ophthalmites* have each two segments movable on one another. They are articulated to a median oval membranous space which looks directly upwards. In this membrane are two small median sclerites, one in front of the other behind the insertion of the eye-stalks. Those who claim an ophthalmic somite would call these the ophthalmic sternum and tergum respectively. They are sometimes united to form a single piece.

Circulatory Organs.

To examine the heart and greater vessels cut with stout scissors along the outer side of each branchio-cardiac groove. Join these cuts by a transverse one along the cervical groove. Remove the calcified portion. Note the underlying skin spotted with red and yellow pigment. Remove this skin carefully, and you will have opened into a large cavity filled with blood, the *pericardial sinus* (Gr. *peri*, around, *kardia*, the heart).

In this sinus lies the heart, which will be found beating for some time in a recently killed animal. Its walls are thick, muscular and perforated by three pairs of openings. the *ostia* (Latin, *ostium*, a door), guarded by valves that admit the blood from the pericardium, but do not allow it to flow back when the heart contracts. Two of these ostia can be seen on the dorsum of the heart, the others are on the lateral and ventral aspects and can be seen better on further dissection.

If desired the blood vessels may be injected with thin Plaster of Paris coloured with Prussian blue, or carmine, inserting the nozzle of the syringe into one of the ostia. The injection should be done slowly.

From the front of the heart a median *ophthalmic artery* is seen to run forward over the stomach to supply the ophthalmites and anterior part of the head. On each side of the ophthalmic is an *antennary artery* which passes forward to supply the green gland, antennæ, antennules, etc., of its own side. A little below and external to the antennary arteries are the pair of *hepatic arteries* which supply the digestive gland. Posteriorly the heart gives off a single large median vessel which almost immediately divides into a large *dorsal abdominal artery* which runs backwards above the intestine to supply it and the dorsal muscles, and a median *sternal artery* which runs directly downwards, sometimes to the right, more often to the left of the hind gut, to enter the sternal canal, and after passing through an opening in the large thoracic ganglion, divides into two branches, one to run forward below the nerve cord and give off branches to the legs, jaws and neighbouring structures; the other to run directly backward beneath the nerve cord and supply the abdominal appendages and ventral muscles.

All these arteries divide in the tissues they supply into smaller and smaller arteries till finally they become *capillaries* (Latin, *capillares*, hair-like) microscopic in size.

In the Vertebrates, as you are aware, the capillaries unite to form small veins, which by further union become progressively larger and return the blood to the heart. In the Crustacean this is not the case, the capillaries terminate by open mouths and allow the blood to pass into large spaces between the viscera and muscles, known as *blood-sinuses* (Latin *sinus*, a fold of a garment, a pouch or a bag). These sinuses all eventually communicate with a large median longitudinal passage, the *sternal sinus*, in which the nerve cord and the two branches of the sternal artery lie. In the thorax the sternal sinus sends a vessel to each gill, which runs up the outer side of the gill-stem as an *afferent* (Latin *affere*, to bring to) *gill vessel*. In the gill the blood is only separated from the water by a thin diffusible membrane, so that an interchange of gases between the blood and the water readily takes place. Carbonic acid is given off, oxygen is taken in, and the purified blood is brought back by an *efferent* (Latin *effere*, to carry away from) vessel or vein on the inner side of the gill-stem. The efferent veins from the twenty-one gills unite into six larger vessels, the *branchio-pericardiac canals*, which pour the blood into the pericardiac sinus, whence it enters the heart during diastole and so the circulation is completed.

The efferent and branchio-pericardiac vessels can readily be injected with ink from a finely pointed medicine dropper, by cutting across the base of a gill and injecting the inner vessel. The course of the circulation in these vessels may also be demonstrated by blowing in air from a blow pipe. The air can be seen to bubble into the pericardial sinus if the sinus be filled with water.

The General Relations of the Viscera.

Remove the whole carapace and the terga of the abdomen with the underlying integument. Also the extensor muscles of the abdomen.

Note the *alimentary canal*, a straight tube near the dorsal surface running the whole length of the body. Throughout the greater portion of its length it is brownish in colour and about as thick as a crow-quill. In front it is much enlarged to form the *stomach*, which fills the greater part of the head. Below the "cardiac area" of the carapace you find the *heart*, a dirty white or slightly yellowish somewhat translucent organ, lying dorsal and posteriorly to the stomach in the *pericardial cavity*. Note the dorsal *abdominal artery*, a translucent tube running from the posterior end of the heart along the dorsal surface of the hind gut, also the three arteries running from the anterior part of the heart.

The *gonads* (Gr. *gone*, seed or reproduction) or reproductive glands lying below a thin membrane, the floor of the pericardial sinus, and partly covered by the heart. They vary in size and colour with the seasons. In the male the testes, two long white masses, joined near the middle by a transverse median piece. In a full grown, lusty individual they extend up on each side of the stomach in front, and behind reach into the abdomen below and at the sides of the hind gut. In shape the united testes resemble an elongated H. They are white in colour and a little irregular in outline.

In the young female or in the adult out of the breeding season the *ovaries* are whitish in colour and in the same position as the testes in the male. They also consist of two long lateral lobes joined by a median bridge. In the breeding season they become very large, extending into the first abdominal somite, and deepen in colour to a salmon shade or deep coral red.

The Genital Ducts.

In the male the *sperm ducts* or *vasa deferentia* (Latin for "discharging vessels") are a pair of chalky-white very much convoluted tubes arising from the lateral lobes of the testes posterior to the median bridge. The distal loop of each is much thickened and runs forward some distance before turning backwards and downwards to its opening on the coxopodite of the last walking leg. In the breeding season the terminal portion acts as a sperm receptacle and becomes of a lavender colour and greatly distended with the cheesy, almost solid semen. Its walls contain many muscular fibres and it is said to be protrusible through the very wide opening, after the manner of a penis.

In the female the *oviducts* are short thin tubes which run directly from the outer margins of the ovaries outwards and downwards to their openings on the coxopodites of the third pair of legs. To see the oviduct properly the liver and ovary must be pressed over from the epimeron towards the middle line with the handle of the knife. The *digestive gland* or *hepato-pancreas*, commonly called the liver, is a large, soft, yellow mass which fills up nearly all the rest of the cephalothoracic cavity.

Except the oviducts all the above organs can be seen without further dissection than opening the cavity as described above

You should also note, on each side of the stomach, the large adductor muscle of the mandible, the attachment of which to the carapace you have cut. Separate the mandibles from one another; then with forceps pull the cut end of the muscle and observe how the mandibles are adducted or brought together in the middle line.

The Alimentary System.

The jaw apparatus has already been described and the student will have noted that the jaws are all external to the oral opening and not, as in the Vertebrates, inside it.

The mandibles have been noted as enormous in size even for a Crustacean. Lobsters, Prawns and Crabs have large forceps, by means of which they can crush and tear their food before swallowing it. Palinurus, not being thus gifted, has some compensation in the size and power of the mandibles.

The mouth, we saw, was flanked by the mandibles and bounded in front by the fleshy labrum, behind by the metastoma. It opens into a short wide gullet or *œsophagus*, running nearly vertically upwards to enter the large gizzard or stomach which occupies the greater part of the head cavity.

We may here remind you that in the embryo of the higher animals the primitive gut or alimentary canal is lined by the inner of the three embryonic layers, the *hypoblast* or *endoderm*. The original opening into this gut becomes completely closed and it is only at a later stage that the mouth and anal openings are formed. They are formed by a dimpling or tucking in of the outer layer, the *epiblast* or *epiderm,* till it meets the hypoblast, and an opening is made where they touch. This tucking in or invagination is very shallow in most animals, much the greater portion of the digestive canal being lined by the hypoblast, only a very short distance inside the mouth and anus by epiderm. In other words, the adult canal is mainly a development of the primitive gut.

In the Arthropods we have a striking contrast. The dimples in front and behind, known respectively as the *stomodæum* (Gr. *stoma,* mouth, *odaion,* a passage) and *procto-dæum* (Gr. *proktos* vent, anus) become deeper and deeper till instead of being mere pits they form long tubes that eventually meet the very short primitive gut or *mesenteron* (Gr. *mesos,* middle ; *enteron,* gut).

In Palinurus this mesenteron is less than a twentieth of the whole length of the alimentary canal. The œso-phagus and stomach are formed from the stomodœum ; the whole of the abdominal and the greater part of the thoracic gut form the proctodœum. All the epidermis we have yet studied in Palinurus both of the outer integument and of the apodemes is covered with a chitinous cuticle. That lining the alimentary canal is no exception, and is even in parts calcified to form stout teeth and plates.

The stomach is divided into a dilated anterior or *cardiac* portion and a smaller, posterior, *pyloric* portion (Gr. *pylo-rus,* a gate-keeper or durwan). In man and other Mammals the gullet enters the stomach just after it has passed through the diaphragm in a position quite close to the heart.

Hence as anatomy was first studied in the mammals, anatomists came to call the gullet end of the stomach the "cardiac" end. Later the name was continued in this sense in describing any stomach. I need not point out that in Palinurus the "cardiac" end of the stomach is that furthest from the heart.

The chitinous lining is thick. Its calcified portions are called ossicles. They support three large and two smaller teeth, which by the action of the muscles attached to the ossicles crush and tear the food. The whole apparatus is commonly called the "gastric mill."

The gizzard and intestine should be removed, emptied of their contents and boiled for a few minutes in a solution of caustic potash or soda. This will remove all muscular and connective tissue, leaving the chitinous structures only. Wash in water and open with scissors along the mid ventral line.

You will notice externally a pouch on the dorsal surface, between the pyloric and cardiac regions. Two white T shaped calcifications will be seen, the legs of the Ts meeting at the bottom of the pouch. The cross bars of the Ts are placed transversely on the top of the cardiac and pyloric walls of the pouch respectively, they may therefore be called the *cardiac* and *pyloric ossicles.* The tail of the anterior larger T is called the *urocardiac* ossicle (Gr. *oura,* a tail); of the posterior T, the *prepyloric* on account of its position. These four pieces are movably articulated with one another. The prepyloric ossicle terminates ventrally in a strong yellow *median tooth,* which curves round the end of the urocardiac ossicle where these two legs of the Ts articulate.

From the outer ends of the transverse cardiac ossicle a *pterygocardiac* (Gr. *pteryx pterygos*, a wing) ossicle runs backwards and downwards on each side along the margin of the pouch referred to above. From the end of the pyloric ossicle on each side runs down to meet the pterygocardiac another broader ossicle, the *zygocardiac* (Gr. *zygon*, a yoke or crossbar), the ventral portion of which appears from the interior of the stomach as a rough file-like surface and in front terminates in a large curved yellow *lateral tooth*.

Below the lateral tooth on each side is found a small pointed tooth borne on an ossicle, the inner aspect of which is setose. There are many other ossicles or sclerites in the stomach, but the above are the most important.

The transverse ossicles are acted on by muscles arising from the carapace in front and behind, as well as by muscles passing between them, which by their alternate action cause the teeth to clash together and again separate so as to thoroughly chew the food.

The passage from the cardiac to the pyloric chamber is narrowed by lateral folds and a large tongue-like valve covered with hairs on the ventral surface ; further back the pylorus is narrowed to a mere three-rayed chink by the pushing in of its roof and the presence of cushions on its sides, the whole being covered with hairs through which only very finely chewed food can filter. With the pylorus the cuticular lining ends, and the food passes into the mid-gut, the only part of the canal lined with cells of hypoblastic origin.

These cells are secretory in character and continuous with those lining the two hepatic ducts which are seen opening on the floor of the mid-gut. The large solid-looking yellow liver is in fact a tubular diverticulum or off-shoot of the mid-gut, which in the earliest embryonic condition is only a small pouch or tube on each side, but later on branches into an immense number of short blind tubes or *cæca* (Latin, blind), which being closely packed together form the apparently solid mass of the liver, or hepato-pancreas. The cells are of two kinds, *liver-cells* containing yellow oil globules and *ferment cells* which produce the digestive secretion.

The secretion is a slightly acid, yellowish fluid, containing many oil-globules, and possesses the power of—

(*a*) converting proteids into peptones,
(*b*) turning starch into sugar,
(*c*) emulsifying fats.

The short mid-gut is followed by the straight hind-gut or proctodœum which as already pointed out is lined with cuticle, which forms a number of longitudinal ridges set with small papillæ. The hind-gut opens on the ventral surface of the telson by a longitudinal anus.

The Excretory Organs.

The nitrogenous waste of the body is got rid of from the blood by the *nephridia* (Gr. *nephros*, kidney), a pair of "green-glands" whose apertures we have already seen on the ventral side of the basal joints of the antennæ.

Insert a bristle into this opening. You will find it enters a delicate thin walled sac or *bladder*, into which the secreting portion, a coiled tube lined with epithelium, discharges. The glands are of a light greenish-yellow colour and lie in the extreme anterior part of the head. The stomach should be pushed back a little to see them.

THE NERVOUS SYSTEM.

After examining the heart, alimentary canal and reproductive system, the gut should be cut across about its middle and each end turned aside. The abdominal muscles should be carefully removed, when the nerve cord will be exposed lying in the middle line close to the abdominal sterna. The thoracic portion is enclosed in the central canal or tunnel formed by the endophragmal skeleton which should be removed by forceps and scissors. The brain is seen in front of the œsophagus close to the origin of the ophthalmites.

When compared with other arthropods the nervous system of Palinurus presents a very interesting study with many useful lessons on the subject of development and the origin of species.

In the Earthworm you have seen a long nerve cord stretching throughout the length of the body with a small thickening in each somite, which from its likeness to a knot on the cord is called a *ganglion*—Greek for a knot. You learned that this cord and its knots were originally a pair placed side by side, but have become enclosed in a common sheath so as to appear single. The microscope shows that in the worm the structure of cord and knot is much alike, both containing nerve-cells and nerve fibres, but in different proportions.

In the Arthropods we have a specialisation of structure in accordance with a differentiation of function. We have a series of ganglia which alone contain nerve cells,

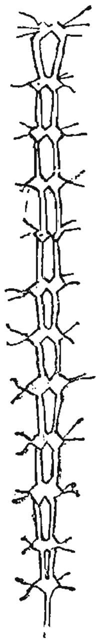


Fig. 25.
NERVOUS SYSTEM OF SANDHOPPER.

the function of which is to *originate* or *translate* nervous impulses, while in the connecting cords we have only nerve fibres whose function is simply to *transmit* impulses. Roughly the ganglia may be compared to the receivers and batteries of a telegraphic apparatus, the cords, to the wires.

If we take one of the lower Crustaceæ such as a Sandhopper, we find it has a "brain" or *supra-œsophageal ganglion* to supply the organs of special sense in the preoral region, and in each segment behind the mouth we find a double cord with double ganglia lying side by side in each somite.

In the higher Crustaceæ we find a pair of ganglia in each segment, but they have coalesced to form a median mass. The connectives have approached one another in the middle line, but a separation can still be seen in the cephalo-thoracic region.

In the Lobster we find a brain in front of the gullet; two commissural nerves pass back on each side of the gullet to join a large ganglionic mass which we find is the united ganglia of the mandibular, both maxillary, and the three maxillipedary somites and supplies all six pairs of jaws and foot-jaws with nerves. A double nerve commissure runs backwards to unite five other ganglia one for each of the posterior five somites of the thorax, and supply the five pairs of walking legs.

In the abdomen we find six ganglia, one for each somite. The cord joining them requires very careful examination to discover if it is really a pair of strands.

In Palinurus the concentration is still further marked.

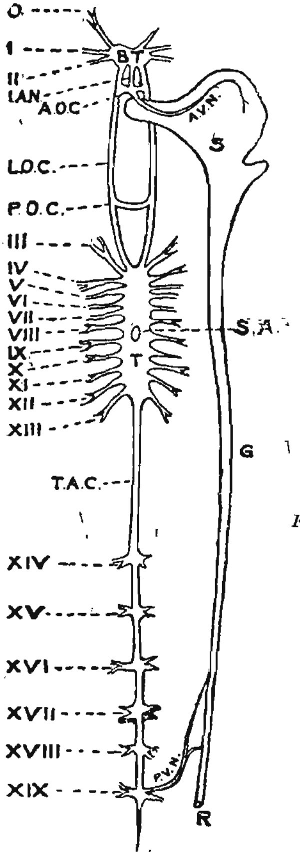


Fig. 26.

Fig. 26.—NERVOUS SYSTEM OF PALINURUS.

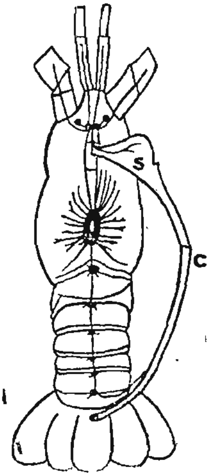


Fig. 27.

Fig. 27.—NERVOUS SYSTEM OF PALINURUS IN SITU.

O = Ophthalmic nerve.
I = Antennulary „
II = Antennary „
III = Mandibulary „
IV to XIX = Nerves to Segments.
BR = Brain.
T = Thoracic ganglion.
A V N = Anterior visceral nerve.
A N = Median root of anterior visceral nerve on azygos nerve.
A O C = Anterior œsphageal commissure.
L O C = Circum œsophageal. „
P O C = Post-œsophageal „
T A C = Thoracico abdominal „
P V N = Posterior visceral nerve.
SA = Opening for sternal artery.
S = Stomach } turned aside.
G = Gut }

The brain or supra-œsophageal ganglia form a large two-lobed mass close behind the eye-stalks. It sends out three pairs of large nerves, the ophthalmic, the antennulary and the antennary whose course is sufficiently described by their names. Posteriorly it sends a *para-œsophageal* (Gr. *para*, near, beside) commissure on each side of the gullet to join a large elongated ganglionic mass on the floor of the thorax.

This represents eleven of the post-oral ganglia, those of the three jaw somites and all eight thoracic somites united together with little indication of their metameric segmentation beyond the fact that the nerves radiate out from it to the eleven pairs of appendages. There is a large opening in the centre of these united ganglia through which the sternal artery descends before it divides into its anterior and posterior branches.

In the abdomen we find a ganglion for each segment, the last supplying the telson and giving a *posterior visceral* nerve to the hind-gut.

In front, the stomach is supplied by an *anterior visceral* nerve which arises by three roots,—a median one from the posterior surface of the brain, and two which arise, one on each side from the para-œsophageal connectives and run transversely in to meet one another and the median root and so form the visceral nerve. The lateral roots of the nerve meeting in front of the gullet are sometimes called the *anterior commissure*. Behind the gullet and in front of the thoracic ganglion is another transverse commissure, called the posterior.

In the Crabs, which are a higher race than Palinurus, we find a still further concentration of the nerves, all seventeen post-oral ganglia being united into a large central mass from which the nerves radiate like the spokes of a wheel.

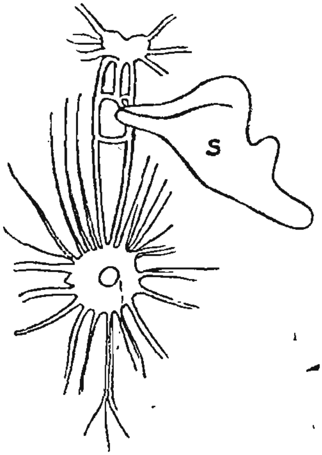


Fig. 28.

Fig. 28.—NERVOUS SYSTEM OF A CRAB. *Some crabs have no hole in the large* ganglion, the sternal artery passing to one side.

In the very young Palinurus we find the nerve cord double and the thoracic ganglia separate, and it is only as development proceeds that they amalgamate. Later when you study the Mosquito you will have another instance of a similar coalescence of the ganglia. In the Phantom larva you can actually see the separate thoracic ganglia of the larva rapidly closing up and amalgamating in the pupa in the course of a few hours.

We have now learned that in the course of development of the individual Palinurus, the separate ganglia of the somites of the larva coalesce to form the large ganglion of the adult. We have also seen that in the "lower," earlier or more primitive type of Crustacean like the Sandhopper the ganglia of each somite are separate and paired as is also the connecting cord. We have in the higher Lobster a further degree of concentration, the six ganglia behind the mouth having coalesced. In the Prawn, Palæmon, we have a stage intermediate between the Lobster and Palinurus, as the ganglia of the post-oral somites of the cephalo-thorax have all united, but the union is indicated by distinct indentations. Then above Palinurus we have in the Crab all seventeen post-oral ganglia united into a single mass with practically no indication of metamerism though in the larva it is distinct.

In Darwin's theory of the origin of species it is assumed that the higher types, such as the Crabs, have developed through past ages by a succession of stages through ancestors *resembling* or *common* to such *lower* animals as Palinurus, Prawn, Lobster and Sandhopper. In seeking to explain the origin of any species you will be greatly helped by the rule of which we have now seen an excellent example, that the *course of the development of an individual from the egg through its embryonic or larval stages up to that of the adult is an epitome of and furnishes a clue to the history of the development of the species.*

The Reproductive Organs.

These have been already described with the topographical anatomy of the cephalo-thorax. It should be further noted that the gonads are hollow organs continuous with their ducts. You have seen in the Earthworm, Frog and Rabbit types that the ova are discharged into the cœlom and taken thence to the exterior by their ducts.

You have seen in Palinurus the body-cavity is not lined with epithelium as in these three types, but is continuous with the cavity of the blood-vessels. It is therefore not homologous with the cœlom, and may be called the *hœmocœle* (Gr. *haima*, blood, *koiloma*, a cavity).

The homologue of the cœlom in Palinurus is to be found in the cavity of the gonads and of the green glands.

In some of the segmented worms, we find the nephridia utilised for the discharge of the generative products ova and spermatozoa. It is a characteristic of cœlomate animals that both the renal and reproductive organs are derived from the epithelium of the cœlom.

It is therefore not surprising, when we find such distinct evidence of serial homology between the gonads and nephridia in the sea worms, to find a certain homology between the green glands and the gonads of Palinurus, such as their cavities representing the cœlom and their ducts opening in homologous situations, the basal joints of appendages.

Development.

The female lays an enormous number of coral-colored eggs, probably about a lakh each season. The egg is a single large cell containing in addition to its nucleus and nucleolus a large amount of yolk granules. After fertilisation by the spermatozoon, segmentation commences. In many animals segmentation begins by the complete division of the cell including the yolk, into two new cells. This is known as *complete* division.

In Palinurus as in most Arthropods segmentation is *incomplete*. The nucleus divides and subdivides repeatedly till we have a large number of nuclei, the cytoplasm and yolk not being divided up into cells. These nuclei all approach the surface, and later with the cytoplasm around them give rise to a *germinal layer* of cells surrounding the yolk. This central yolk forms a number of cones the base of each being applied to the inner aspect of a germinal cell. The whole embryo is now a hollow bag, formed of a single layer of cells known as the *blastoderm* (Gr. *blaste,* a bud, sprout or development, *derma,* a skin or layer) its cavity stuffed with nutrient material.

At one pole of the blastoderm an oval patch, the *germinal disc* is formed by a thickening of the layer of cells. At one end of the disc a pitting or dimpling takes place and gradually deepens to form a small wide-mouthed pouch. This stage is known as the *gastrula,* (Latin, a little belly) and may be illustrated by pressing in one pole of a soft tennis ball.

This pouch, the *primitive gut* or *archenteron* (Gr. *arche,* origin, primitive state, *enteron,* gut) continues to deepen and its mouth to contract till we get a completely closed sac.

The cells lining the primitive gut are known as the *hypoblast* or *endoderm* (Gr. *hypo,* under, *endo,* inner). The remaining cells of the blastoderm are the *epiblast* or *epiderm* (Gr. *epi,* above) from which is eventually developed the epidermis of the integument, of the fore-gut, of the hindgut and the nerve system. A mass of cells appears between the hypoblast and epiblast near the blastopore, probably derived from the former; from it the muscles connective tissues, heart, vessels and reproductive organs are developed. It is called the *mesoblast* (Gr. *mesos*, middle).

In front of the blastopore, before it closes an elevation appears which lengthens in a forward direction. This is the rudimentary abdomen. In front of this again a pair of flatter elevations appear one on each side of the middle line called the *head lobes*. A median linear depression appears on the surface of the epiblast between these three elevations. Near its centre the groove deepens into a tubular ingrowth, the stomodæum, as already described. The primitive hind-gut arises in a similar manner on the abdominal papilla. A considerable time elapses before the partitions between the three portions of the gut disappear. The appendages appear as symmetrical pairs of buds of the epiblast and mesoblast. Those of the antennules, antennæ and mandibles appear early. The eye-stalks appear later as outgrowths of the head lobes.

The epiblast on each side of the median ventral groove thickens in two longitudinal strands to form the double nerve chain, which later severs its connection with the tegumentary epiderm.

The eggs of many Crustaceæ, for instance Penæus, one of the Prawns, are hatched in an elementary stage with only the three anterior pairs of appendages, which become very large and are used in swimming. This is known as the Nauplius stage. In Palinurus as in Lobsters, Crayfish, the Prawn, Palæmon, and most of the other *Macrura* (Gr. longtails) this stage is passed inside the egg.

Owing to the fact that the larvæ of Palinurus are inhabitants of the open sea, the full course of their development has not been studied. Only recently it has been recognised that the little *Phyllosoma* (Gr. *phyllon*, a leaf, *soma*,

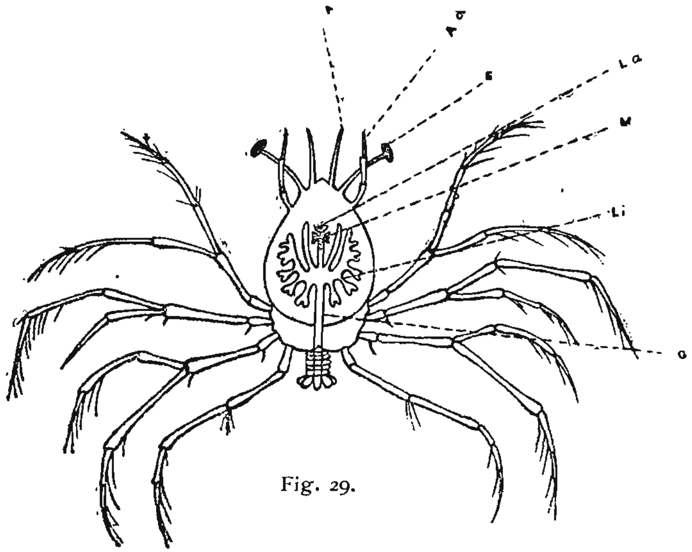


Fig. 29.

Fig. 11.—PHYLLOSOME.
A = Antennule.
Aa = Antenna.
E = Eye.
La = Labrum.
M = Mandible.
Li = Liver.
G = Gut.

body) is the larva of Palinurus or its near relatives. These larvæ were formerly thought to be a separate genus and are popularly known as "Glass-Crabs."

Both the scientific and popular names are very descriptive, as the animal is extremely flattened and the greater part of its body consists of two large transparent discs resembling small watch glasses.

These discs represent the carapace. The anterior corresponding to the cephalic portion, is oval or nearly circular and covers the stomach, liver and head appendages. The posterior is the thoracic region: it contains the heart and intestine, and bears the eight thoracic appendages, which it is interesting to note have both endopodite and exopodite at this stage. In earlier specimens the first maxilliped and last walking leg are rudimentary. The junction of the two discs is the cervical groove in which the scaphognathite can be seen moving.

The eyestalks are of great length; they, the antennules, and the antennæ are all borne on the anterior margin of the carapace. You will note the gradual shifting of the position of the eyes from the ventral surface of the embryo in the egg to the anterior margin in the phyllosome and finally to the dorsal surface of the adult.

The liver can be seen through the transparent disc as a more or less branched diverticulum of the mid-gut.

The abdomen is very small, and you can see six pairs of small appendages, the pair of the first somite disappearing before the adult condition is reached. In most phyllosomes the posterior margin of the hinder disc is notched to receive the abdomen.

The nerve cord is double; in the specimen sketche(there were six distinct thoracic ganglia. The reproductiv organs cannot be recognised.

The phyllosome stage lasts a month or two, durin(which time it moults repeatedly; at the last moult th discs are replaced by a carapace of the adult pattern.

MOSQUITO.

Mosquitoes are unfortunately only too readily found in India. In the day-time they should be searched for in dark corners, on curtains, in clothes-presses and on sheltered book-shelves.

They may be caught by quietly placing the mouth of a test-tube over them. A card or piece of stiff paper may be slipped between the mouth of the tube and the object on which the insect rests. As the mosquito flies to the depth of the tube, the latter should be closed with a cork or plug of cotton.

Anophelines may be found in dark huts especially on the rafters and on pendent straws of the thatch. In Bombay City they are particularly common in stables, cattle-sheds and coach-houses where they seem specially fond of resting on the blue lining of carriage-hoods. Leather-lined hats and caps seem to offer a special attraction to them as well as to Culicines.

Adult Mosquitoes can also be easily obtained by developing the larvæ.

The larvæ of Culex can be found in most collections of fresh or even brackish water, especially if containing decomposing leaves. Old neglected pots, tubs and disused tins are prolific breeding places.

Stegomyia is particularly fond of tubs and barrels in which rain water is collected.

Anopheline larvæ are to be found in the shallow pools at the side of slow running *nullahs*, small collections of clean water in rocks and in the beds of rivers during the dry season.

In Bombay City they are common in the rills caused by leakage from the reservoirs on Malabar Hill and at Mazagaon. One species, *A. stephensi** is to be found in clean water in tins, little-used jugs and *chattis* and in cisterns. At the time of writing they can be found in almost every well and pool in the Fort. The commonest species, *A. rossii* § is found in dirty roadside puddles all over the city.

Anopheline larvæ have a habit of keeping their "tails" close to the edge of the pool or vessel, with their heads pointing to the middle. They are best caught with a large spoon or ladle. If they cannot be seen, the bottom of the pool should be stirred up, when, if any larvæ be present, they will sink to the bottom for awhile. On rising they can readily be recognised on the surface of the muddy water. *A. stephensi* remains at the bottom for such a long time, that this method is not much use for this particular species.

Eggs can be recognised as small sooty-looking particles floating on the surface.

The Mosquito belongs to the Diptera or order of two-winged insects.

A typical insect like the Cockroach has two pairs of wings, but in the Diptera the posterior pair are absent or degenerated into mere vestiges known as the *halteres* or balancers. The anterior pair, which alone are developed as flying organs, are usually transparent and membranous in

---

* Nyssorhynchus stephensi. § Myzomyia rossii.

character. In the adult, the mouth is adapted for sucking and often for piercing. In the course of development there is a complete metamorphosis. The larva is often destitute of legs and aquatic in habit.

The Culicidæ or Mosquitoes are distinguished from all other Diptera by—(*a*) their proboscis which is long and formed for piercing as well as sucking; (*b*) the arrangement of their wing-veins; and (*c*) by the fact that these veins are covered with scales, the interspaces remaining naked and membranous.

The Mosquitoes are divided into four sub-families:—

I. THE MEGARHININA.

These are big brightly coloured Mosquitoes with a metallic bluish or greenish sheen. They are found in forests

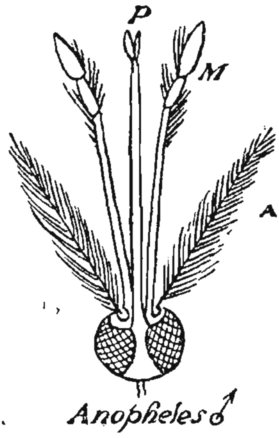


Fig. 29a.
A. = A. Antenna. *P.* = Proboscis.

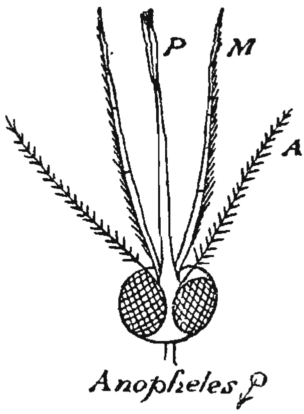


Fig. 29b.
M. Maxillary Palp.

and jungles. The palps are about the same length as the proboscis which is curved, and so long as to give the name to the sub-family, *Megas*, great ; *rhinos*, snout or proboscis.

2. ANOPHELINA.

(Greek *anopheles*, hurtful, noxious)*

These are dull-coloured insects, usually with spotted wings. The maxillary palps in both sexes are about as long as the proboscis. The insect usually stands head downwards, its body forming an acute angle with the surface on which it rests. The proboscis and the body are in nearly the same plane. See Fig. 30.

The larva has no respiratory syphon and generally lies in a horizontal position on the surface of the water owing to the fact that the two respiratory openings are almost flush with the dorsum. There are a number of palmate scales on some of the segments of the abdomen. Fig. 42.

The eggs of all the common species possess special floats and frills, and are not united into egg-rafts.

3. CULICINA.

The maxillary palps though long in the male are very short in the female. When resting, the head and posterior end are about the same distance from the surface on which the insect rests. The head and proboscis are not in the same

* This name was given by Meigen ninety years ago, long before the cause of malaria was discovered. He little knew how appropriate was the name. Probably lightning, volcanoes, earthquakes and wild beasts, such as lions and tigers, all combined, do not slay a tithe of the human victims this small insect can claim.

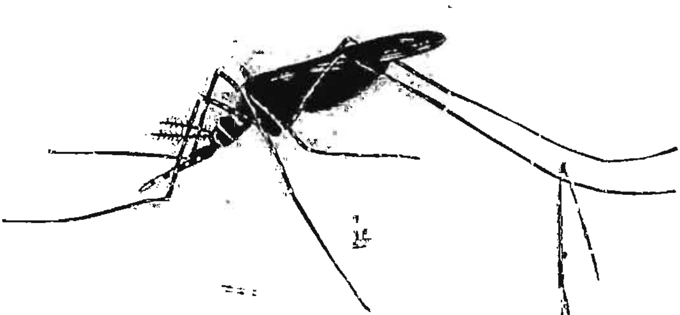


Fig. 30.
NYSSORHYNCHUS STEPHENSI.

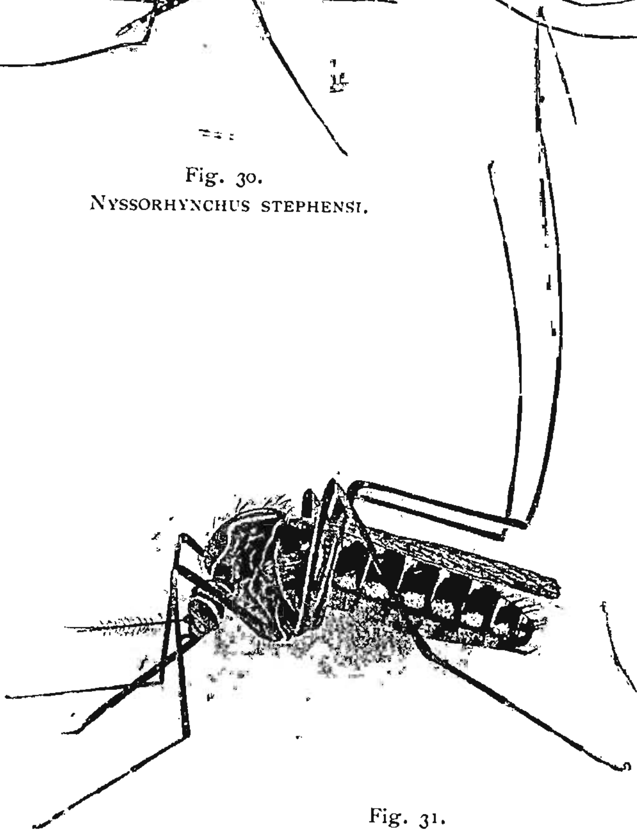


Fig. 31.
STEGOMYIA CALOPUS, THE CARRIER OF THE YELLOW FEVER GERM.

plane as the abdomen, but form an angle with it giving a hump-backed appearance to the animal. See Fig. 31.

In the larva the tracheæ end in a long syphon through which respiration is carried on. The larva hangs head downwards in the water, the syphon opening at the surface.

There are no palmate scales. The eggs are provided with neither frills nor floats but are usually united into rafts. Those of Stegomyia have frills but no floats and do not form rafts.

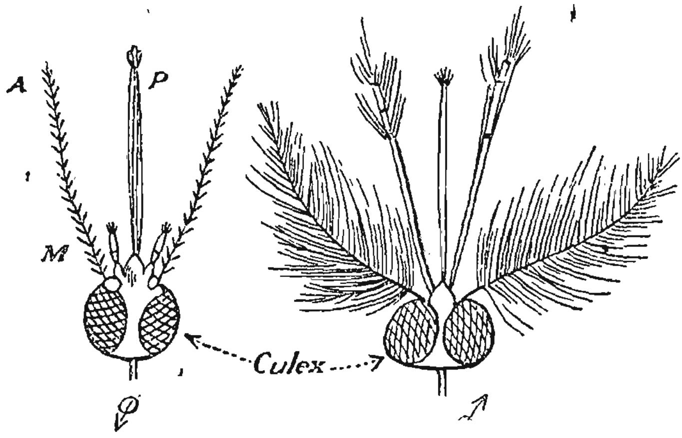


Fig. 32. Fig. 33.

A. = Antenna. *P.* = Proboscis. = *M.* = Maxillary Palps.

4. ÆDEOMYINA.

(Greek : *aides,* invisible ; *muia,* a fly).

The maxillary palps are very short in both sexes

The medical student is chiefly concerned with the Culicine and Anopheline Mosquitoes, which act as carriers of the parasites that cause Elephantiasis, Malaria and Yellow Fever.

In the following description it is assumed that the student has already studied the anatomy of the Cockroach or the Locust.

Like other insects the Mosquito's body is composed of three easily recognised regions—the head, thorax, and abdomen.

THE HEAD.

The compound eyes are very large and round, covering the greater part of the head. There are no ocelli in the adult insect.

As in the Cockroach the rest of the surface of the head is covered by chitinous plates. The EPICRANIUM is divided into certain ill-defined but easily recognised regions. Thus we have the *nape*, extreme back of the epicranium where it joins the neck; the *occiput*, the posterior region behind the eyes; the *vertex*, the part between the eyes above; the *frons*, that part between the eyes in front. The cheek pieces or GENÆ below the eyes. The CLYPEUS projects well forward instead of being in the same plane with the frons as in the Cockroach. Note that it is covered with hairs in Culex, with scales in Stegomyia.

The LABRUM is a long grooved organ in form resembling a surgeon's director and presents little resemblance to the overhanging lip of the Cockroach.

The paired APPENDAGES OF THE HEAD are—

(1) The ANTENNÆ.

(2) The MANDIBLES.

(3) The FIRST MAXILLÆ.

(4) The SECOND MAXILLÆ fused throughout the greater part of their length and usually called the LABIUM.

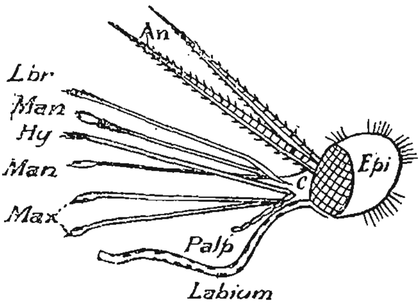


Figure 34.—

Epi.	=Epicranium.	*Man.*	=Mandible.
An	=Antennæ.	*Max.*	=Blade of Maxilla.
Lbr.	=Labrum.	*C.*	=Clypeus.
Hy.	=Hypopharynx.	*Lb.*	=Labellum.

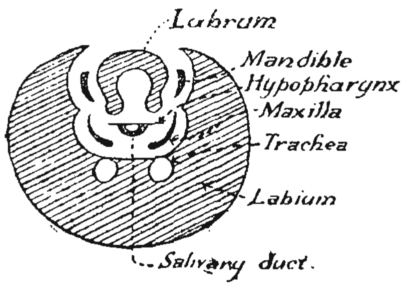


Figure 35.— Transverse section of proboscis.

The antennæ are clothed with silky hairs and consist of fewer segments than those of the Cockroach. There are generally fourteen, the basal joint being very much larger than the others, and articulated with the head by means of a membrane, which some consider to have auditory functions. The antennæ of the male are much more plumose than those of the female and offer a ready means of distinguishing the sexes.

On examining the head in its normal condition, the maxillary palps will be seen, but all the other mouth parts are concealed in the labium which forms a sheath or spout to enclose the piercing apparatus. The whole is known as the proboscis.

To see the parts of the proboscis, brush the head carefully with a camel-hair pencil to remove the scales. Cut off the antennæ and maxillary palps. Then cut off the clypeus with the proboscis. Mount in saline solution, press the cover-glass down firmly with the point of a pencil, watching the effect under a low power. If successful, the various parts will be separated from one another. If unsuccessful, try again, separating the parts with a pair of needles. Another head should be boiled in *Liquor Potassæ* and stained with fuchsin.

The proboscis consists of—

(*a*) The LABRUM or upper lip.

(*b*) The HYPOPHARYNX or tongue.

(*c*) The MANDIBLES.

(*d*) The ENDOPODITES OF THE FIRST MAXILLÆ, * commonly called the maxillæ.

The above are all enclosed in the groove of—

(*e*) The LABIUM OR SECOND MAXILLÆ united to form a sheath.

(*a*) The LABRUM has already been likened to a surgeon's director. The groove is, however, deeper, so that a cross section would occupy more than three-fourths of a circle, and resemble the Greek letter Ω or the cover of a motor tyre in section. The tip is bevelled off to a sharp point.

(*b*) The HYPOPHARYNX or tongue.
In the Cockroach the salivary duct opens at the base of the tongue. In the Mosquito the duct is continued to the tip of the hypopharynx as a very minute tube. The tubular portion bears two lateral flanges so that the whole hypopharynx forms a long flat strip which can be applied to the under surface of the labrum, converting its groove into a tube up which the blood or other food of the insect is sucked.

(*c*) The MANDIBLES are a pair of very fine rods or stylets of chitin. In some Mosquitoes the tips are toothed like a saw.

(3) The FIRST MAXILLÆ consist of a short proximal joint, the protopodite, concealed by the base

* The homology with the parts of the same name in Panulirus is not rtain.

of the labium. This bears an exopodite easily recognised as the maxillary *palp* which does not enter into the formation of the proboscis.

(*d*) An endopodite which is reduced to a very fine chitinous rod or lacinia usually known as the maxilla. The pair of these resemble the mandibles and with them form the four lancets of the proboscis. In the males of some species they are not developed.

(*e*) The LABIUM or lower lip which is formed of the two second maxillæ united to form a grooved sheath or spout in which the piercing organs rest.

The labium is the part of the proboscis usually seen when that organ is undisturbed by pressure or dissection. Its under surface is rough, and scaly. Two small leaf-like LABELLÆ attached by a joint to the distal end of the labial spout, are commonly regarded as homologous with the labial palps of the Cockroach, but some naturalists look on them as representing the laciniæ.

The labium does not penetrate in the act of biting, but serves as a guide to the rest of the proboscis, becoming doubled up on itself into a loop, while the stylets, labrum and hypopharynx pierce the skin.

The MAXILLARY PALPS are most commonly five-jointed. On their length relative to the proboscis, the number of joints, which is best seen after brushing off the scales, the colour, shape, and arrangement of the scales and hairs, is chiefly based the classification of Mosquitoes. The student should note *these points in each specimen.*

As the hypopharynx often sticks closely to the labrum and its lumen is not evident when looked at longitudinally, transverse sections of the proboscis should be made to properly understand its structure and relations.

Dehydrate the Mosquito in absolute alcohol, with two changes, place for a couple of minutes in clove oil, then in xylol-parafin, finally in parafin. Cut transverse sections. Note the large labium, concave on its upper surface. Observe two large tracheæ near the middle line. In the groove note the other parts of the proboscis, *viz.*—

(1) The labrum, above, like an inverted U.

(2) Below the labrum, closing its groove is the hypopharynx, looking like a transverse section of a blade of grass, its mid-rib being pierced by the salivary duct.

(3) The mandibles, crescentic in section.

(4) The first maxillæ, larger than the mandibles.

THE THORAX.

The three segments—pro, meso, and meta-thorax are easily recognised from the ventral and lateral aspects. Dorsally, however, only two thoracic terga are visible. Of these the anterior is large, covering much the greater portion of the thorax. It is the MESONOTUM. Its posterior margin presents a lip known as the SCUTELLUM, which is of importance to entomologists in classification, the hairs or scales being of different kinds in different species.

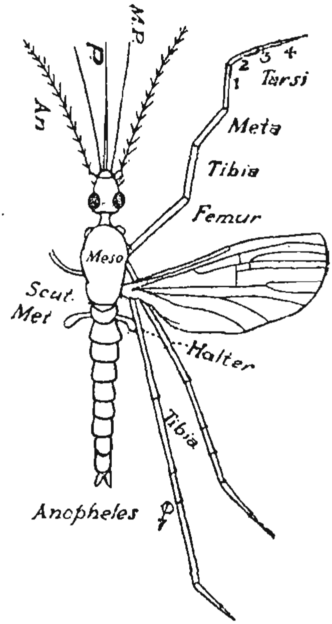


Figure 36.—Female Anopheles—

An.	= Antenna.	*Meso.*	= Mesonotum.
M. P.	= Maxillary palp.	*Scut.*	= Scutellum.
P.	= Proboscis.	*Met.*	= Metathorax.

Behind the scutellum is seen the small METANOTUM to which the halteres are attached.

The PRONOTUM is scarcely recognisable except its oute movable ends known as the PATAGIA. Ventrally the exo skeleton consists of a PROSTERNUM, MESOSTERNUM anc METASTERNUM. Each pleuron consists of two plates.

The MESOPLEURA and METAPLEURA bear large stigmata.

The APPENDAGES of the Thorax.

These are (A) THREE PAIRS OF LEGS attached ventrally, one pair to each segment.

Morphologically they resemble those of the Cockroach, and consist of the following joints :—

(*a*) A short stout COXA.

(*b*) A very short TROCHANTER.
These joints are so short that they are not seen on looking down on the insect from the dorsal aspect.

(*c*) A long straight FEMUR.

(*d*) A long straight TIBIA.

(*e*) A TARSUS of five joints, the last of which is variously clawed or hooked, and differs in the male and female.

Remove the three legs of one side, place them in order on a slide, cover with a drop of balsam, put on a cover-glass, and note the above points.

(*B*) The WINGS, dorsal appendages springing from the side of the mesonotum. *Note that it is the first pair* of wings with which the Mosquito flies, while in the Beetle and Cockroach these appendages have no flying function, but are hard wing-cases for the protection of the functional wings,—the second pair. Remove the wings as close to the thorax as you can and place dorsal surface upwards on a slide. Put two minute dots of thick balsam on the slide just where the edges of the cover-glass will overlap them. See that the wings are not touched by the balsam, the object of which is to hold on the cover-glass. Press down the cover-glass; ring with hard parafin.

Note the "veins" or "nervures" of the wing covered with scales, while the intervening spaces or "cells" are naked and membranous.

Observe the spots on the wings of Anophelines.

The arrangement of the veins on the wings is characteristic for the Mosquitoes, and to each vein a name is given as indicated in the diagram Fig. 37.

The border is called the *costa*, anteriorly it is straight and strong, posteriorly thin, curved and fringed with scales.

Note that the second, fourth and fifth longitudinal veins are forked at their distal ends.

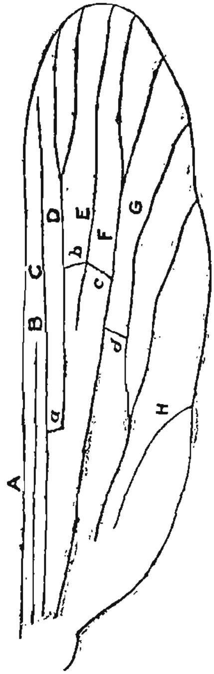


Fig. 37.

Venation of Mosquito's Wing. A = Costa, B = Subcostal, C = First, D = Second, E = Third, F = Fourth, G =

Fifth, H = Sixth longitudinal, a = First, b = Second, c = Third, d = Fourth cross-vein.

(*C*) The HALTERES or balancers will be seen attached to the metanotum on each side as small club-shaped processes, the vestiges of the second pair of wings usually found in the Insecta.

THE ABDOMEN.

The abdomen consists of eight segments, each covered dorsally by a tergum, ventrally by a sternum.

These chitinous plates are laterally united by a third continuous pleural membrane in which may be seen the openings of the abdominal spiracles, a pair for each segment.

The anus with the genital aperture below it opens posteriorly on the last segment between the gonapophyses or appendages used in facilitating copulation or the laying of eggs, and which therefore differ in the sexes. They will be described with the genital organs.

THE ALIMENTARY CANAL.

To dissect the alimentary canal kill the Mosquito with chloroform or with tobacco smoke. Fix the thorax by piercing it with a needle, pick off the wings and legs. Brush well but gently with a camel-hair pencil to remove the scales. Place in a drop of saline solution on a glass slide over a board or card painted half white, half black.

Gently flatten out the hinder portion of the abdomen about the seventh segment. With a sharp-edged needle or cataract knife make two lateral nicks through the abdominal wall. This will so weaken the wall that you can break it completely by laying the needle flat on the segments you have partly detached and steadily but gently pulling them apart from the anterior segments.

Shift the slide over to the black part of the board. You will now see against the dark background the white intestine and Malpighian tubes.

Slowly and patiently continue your traction, till all of the white opaque mid-gut appears, and you see the hinder part of the. œsophagus recognisable by its thinner and more translucent character.

Now move the needle up to the exposed part of the œsophagus and with its shaft gently pull out the remainder of the œsophagus.

The transfixing needle during this last manœuvre may be driven into the board and both hands set free. While traction is kept up, a little teasing or cutting of the exoskeleton under the microscope will help to remove a more complete œsophagus.

In your study of embryology you have learned that the cavity of the gastrula lined by the hypoblast becomes the archenteron or primary alimentary canal. The original opening into this cavity becomes obliterated, so that at one stage, the enteron is a completely closed sac.

In the epiblast, at each end of the body, a dimple forms which deepens till the epiblast meets the hypoblast, and finally the opposed portions becoming absorbed, the dimples or pits become openings into the archenteron.

The anterior or oral depression is known as the STOMODÆUM (Greek: *stoma*, mouth; *odaion*, an entrance) or primitive fore-gut; the posterior is known as the PROCTODÆUM (Greek: *proctos*, anus) or primitive hind-gut.

In the vertebrates these depressions are comparatively shallow, so that only the mouth and the anus are lined by epiblast—in man and the rabbit, for instance, not one hundredth part of the length of the alimentary canal—all the remainder being lined by cells derived from the hypoblast.

In the Mosquito as well as in the Arthropods generally only a relatively small proportion of the lining of the alimentary canal—the mesenteron or mid-gut—is derived from the hypoblast.

The invagination of the epiblast at both oral and anal extremities is very extensive, so that all those portions known as the fore-gut and the hind-gut are lined by epiblast, the former being the stomodæum and the latter the proctodæum.

The alimentary canal consists of the following parts:—

The MOUTH	STOMODÆUM.
The PHARYNX with bulb	
The ŒSOPHAGUS and diverticula ..	
The MID-GUT, commonly called the "stomach"	MESENTERON.
The HIND-GUT	PROCTODÆUM.

The mouth parts have already been described.

The mouth and pharynx are lined with chitin, not so the œsophagus or the hind-gut, though they also are derived from the epiblast.

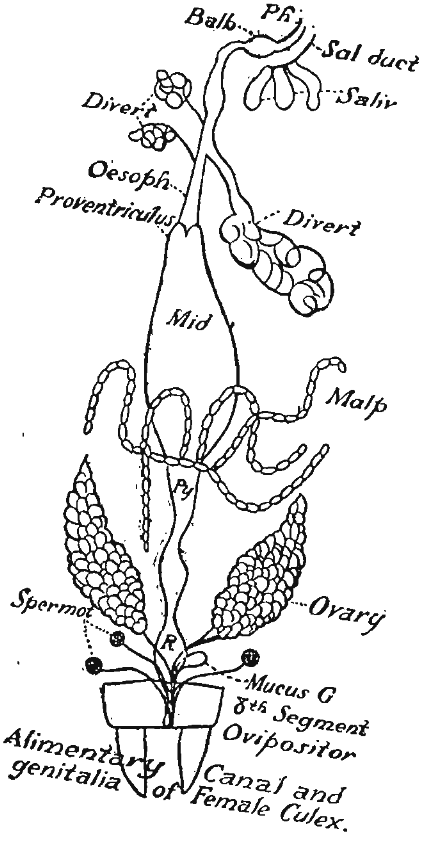


Fig. 38.

In the head the anterior portion of the pharynx is narrow and surrounded by the "œsophageal" nerve ring. Behind this it dilates into a pumping or suctorial bulb acted on by powerful muscles. Behind it again becomes narrow and makes a sharp bend which acts as a valve where the chitinous layer ceases and the œsophagus begins.

The ŒSOPHAGUS is very thin walled. From it three DIVERTICULA arise, recognisable to the naked eye as white dots, but under the microscope looking like a number of dark air bubbles entangled in a thin membrane. In the newly-fledged Mosquito they are small, but they rapidly increase in size *pari passu* with the insects' powers of flight. One extends backwards into the abdomen. Probably they act like the air sacs of other flying insects in ballooning the animal up to diminish its specific gravity. They are obviously neither homologous nor analogous with the hepatic cæca of the Cockroach. They usually contain many bacteria.

There is no gizzard which would be of no use to an animal living like the Mosquito on fluid food, such as blood and the juices of plants. The mid-gut extends backwards to the origin of the MALPIGHIAN TUBES. Its anterior portion is narrow, the posterior portion dilated in proportion to the amount of food it contains, when full distending almost the whole of the abdomen.

It will be noted, that the whole of the fore-gut is usually found quite empty of blood or other food even immediately after feeding.

The posterior opening of the mid-gut possesses a well-developed muscular PYLORUS.

Immediately behind this the MALPIGHIAN tubes open. Behind this for a short distance is a narrow portion, then a short dilatation, separated by a slight narrowing from the wider RECTUM. Three pairs of PAPILLÆ, each supplied by a large tracheal vessel, project into the lumen of the rectum. The anus opens on the posterior aspect of the last abdominal segment.

THE DIGESTIVE GLANDS.

To dissect the salivary glands, remove the wings, legs and scales as before described. Place the insect on its side. With a needle or cataract knife slice off the "hump" of the thorax on a plane joining the surface of the first abdominal tergum with that of the occiput. Make a vertical cut at right angles to this just in front of the attachment of the second pair of legs.

With needles pull apart the head from the portion of thorax thus separated. The salivary glands will be drawn out of the thorax in a tolerably isolated condition. They will be recognised as transparent lobes whiter and more glistening than muscle or fat-body. The presence of the three ducts uniting to form the main duct will set all doubt at rest. The duct may then be cut across when the glands will be left free. *Good specimens may also be obtained by simply pulling the head off by gentle steady traction with needles.*

If the lobes be fairly well separated from one another and clear of fat-body, they may be simply dried on the slide, fixed in alcohol and stained with logwood and eosin.

If you want to look for malarial parasites, squash the glands with a cover glass, smear, dry, and fix in alcohol. stain with Romanowsky's stain.

The salivary glands lie one on each side of the œsophagus. Each consists of three lobules with their ducts. The three ducts soon unite into right and left ducts which join below the subœsophageal ganglion to form a common duct which as already seen traverses the whole length of the hypopharynx.

You may note that all these lobules are secretory in function, but that usually the lumen of the middle lobule is larger and the cells lining it clearer and less granular than those of the upper and lower lobes, showing an approach to the cystic condition found in the Cockroach.

There are no hepatic cæca or diverticula in the imago.

THE EXCRETORY SYSTEM.

The MALPIGHIAN TUBES are five in number opening into the commencement of the hind-gut. They are lined with large opaque granular cells with large nuclei, the lumen presenting a zig-zag appearance.

Their function is analogous to that of the nephridia or kidneys of other animals, namely, to excrete the nitrogenous waste.

THE CIRCULATORY SYSTEM.

This in all insects is but poorly developed. A dorsal vessel can be seen running longitudinally close beneath the abdominal terga.

Remove a piece of this vessel and tease it with needles. Observe some very large pear-shaped cells with many nuclei, lying on each side of the vessel. From their position they are called the PERICARDIAL CELLS.

THE RESPIRATORY SYSTEM.

There are two main longitudinal tracheæ which run parallel throughout the body and communicate with the external openings by ten pairs of lateral branches, the thoracic spiracles being two, the abdominal eight on each side, as already described.

At the origin of the lateral branches, dorsal and sternal branches are given off in each segment and ramify through the whole body. Their chitinous lining is marked by a spiral thickening. Under the microscope they appear dark by transmitted, white by reflected, light.

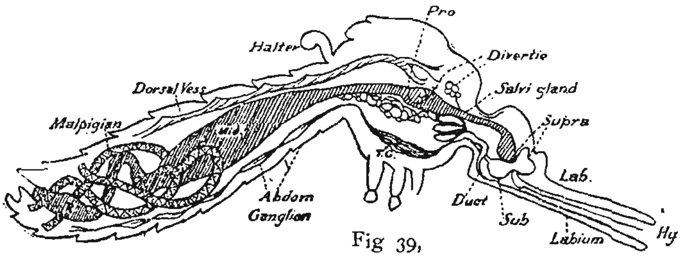


Fig 39,

THE NERVOUS SYSTEM.

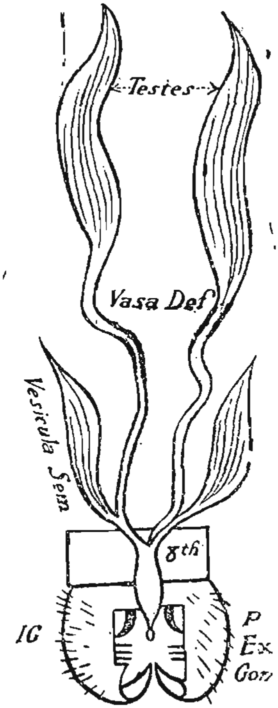
The nervous system is arranged on the plan usual among insects. The supra-and infra-œsophageal ganglia are very large in proportion to the intelligence displayed by the

Mosquito. They are united by commissures which complete the ring of nerve tissue around the pharynx.

The chain of ganglia are united by two longitudinal connectives extending from the head ganglia to the last abdominal ganglion.

The three pairs of thoracic ganglia are united to form one large mass. They and the abdominal ganglia lie close to the sterna. The last abdominal ganglion supplies the reproductive organs and in the ordinary manner of dissecting is usually pulled away with them and may be seen lying in the angle formed by the union of the oviducts.

The visceral nervous system resembles that of the Cockroach, but is too minute to be dissected by the student.



Male Genital Organs.

Fig. 40.

E. = Ejaculatory duct.
P. = Penis,
I. G. = Internal gonapophysis
Ex. Gon. = External „

THE GENITAL ORGANS.

To dissect these, cut partly through the anterior portion of the last segment, instead of the sixth or seventh, as you did to expose the alimentary canal, and proceed as in that dissection gently pulling out the genital organs and as much of the alimentary canal as you can.

In the male the TESTES are a pair of elongated somewhat spindle-shaped whitish or yellowish bodies, their anterior portions or tips appearing less granular under the microscope than the opaque posterior part. Posteriorly they are attached to the VASA DEFERENTIA, a duct for each testis. Just before their termination each communicates by a short duct with a SEMINAL VESICLE.

The vasa unite to form a short muscular EJACULATORY DUCT which terminates in a short fleshy PENIS projecting from the last abdominal segment below the anus.

On each side of the penis are two GONAPOPHYSES' backward projections of the last segment, by some regarded as constituting a ninth segment.

The outer pair are the two stout processes which to the naked eye give the bifid appearance to the posterior end of the insect. They bear on their inner or opposed surfaces a stout, sharp pair of chitinous hooks used as claspers for holding the female during copulation. The median pair of gonapophyses are much smaller.

In the female we find a pair of spindle-shaped OVARIES. In the newly-fledged insect they are very small and contained in a single segment of the abdomen, but they rapidly grow, so that in the living impregnated female they are easily seen with the naked eye, extending into several segments, as large, white patches contrasting with the dark-red gut when full of blood.

Each is made up of a cluster of spindle-shaped follicular tubes, commencing as fine filaments and opening by their bases into the OVIDUCT.

Their structure can be best seen in the anterior tubule, which forms the apex of the ovary. In a mature female eggs in all stages, can be seen in each tubule, the youngest being at the filamentous end. The oviducts pass backwards from their respective ovaries to unite in a COMMON OVIDUCT, which opens below the rectum. Just before it opens the common duct is joined by the ducts of three SPERMATHECÆ, small dark vesicles in which the spermatozoa are stored after copulation. It is also joined by the duct of the cement or MUCUS GLAND, the secretion of which forms an outer coating for the eggs and helps to glue them together to form the egg-rafts. Anophelines have only one spermatheca, *Mansonia* a Culicine genus, has only two.

Projecting from the posterior part of the last segment are the gonapophyses, or ovipositors, a pair of somewhat trowel-shaped flattened processes, which are utilised in launching the egg-boats.

DEVELOPMENT.

Copulation probably takes place while the insects are on the wing. The external gonapophyses of the male form a powerful pair of claspers which facilitate accurate intromission of the semen, which is then stored in the spermathecæ of the female, so that a single act of copulation may suffice to fertilise more than one batch of eggs.

In the ovarian follicles the nucleus of the egg can be clearly seen, but it soon becomes obscured by the accumulation of yolk.

The ovum or egg-cell proper is covered by a vitelline membrane derived from the ovum itself, and by an outer egg-shell or chorion derived from the follicle.

The female is able to stand on the surface of the water with her front four legs, owing to the tension of the surface film. The female culex crosses the two hind tarsi and with the help of the ovipositors holds the eggs vertical with the thicker end downwards in close apposition. The eggs are covered with the sticky secretion of the cement glands which quickly sets on exposure to the air. In this way two or three hundred are united to form a boat-shaped raft, which is lowered on to the surface of the water as soon as the cement has set.

The eggs of the Culicines with the exception of *Stegomyia* are much elongated, and broader at the lower pole to which is attached a clear round process which is easily broken off, sometimes leaving a small spine exposed. They have no air cavities in the form of either frills or floats.

Stegomyia, the Tiger Mosquito, does not build rafts. The eggs are oval and surrounded by a frill of small air-spaces formed by a reticulation of the outer cover, which serves to keep them afloat, but they sometimes become obliterated and allow the eggs to sink to the bottom. This submersion does not however prevent the eggs of the Tiger Mosquito from hatching, though it will kill the eggs of other genera.

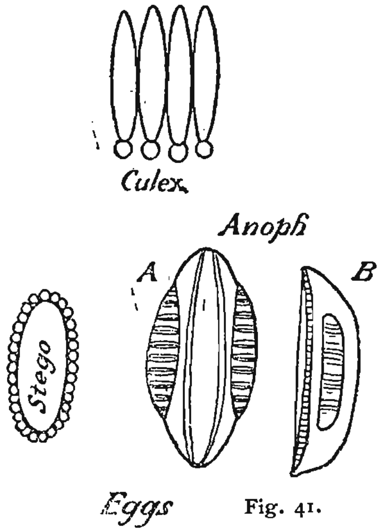


Fig. 41.

Stego = Egg o Stegomyia. *A* = Dorsal view ot Anopheles' egg.
Culex = Four eggs of Culex. *B* = Lateral view of Anopheles' egg.

The eggs of Anophelines are not united in'o rafts. They are very beautiful objects of a definite boat shape. The flat or concave upper surface or deck is surrounded by a gunwale or frill like that of *Stegomyia*, but has in addition in all species except *A. turkhudi* a pair of lateral floats which ensure its buoyancy.

The time taken by the eggs to hatch varies with the species and with the conditions of the weather and other environments.

In development the nucleus divides in the centre of the yolk and the resulting cells come to the surface of the egg to form a peripheral blastoderm enclosing a central yolk.

THE LARVA.

Examine a small larva in a drop of water under a cover-glass to restrain its movements.

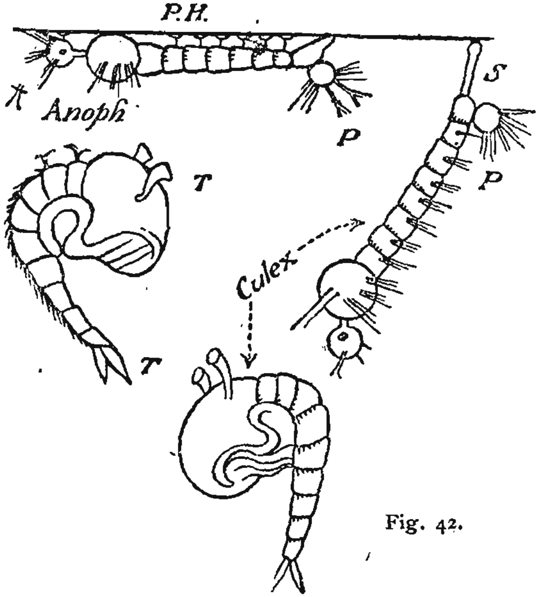


Fig. 42.

P. H. = The palmate hairs. *S.* = Syphon. *P.* = Anal papillæ. *T.* = Trumpet of pupa.

The body will be seen to be made up of head, thorax and abdomen, the whole being so transparent as to allow much of the internal anatomy to be made out without dissection.

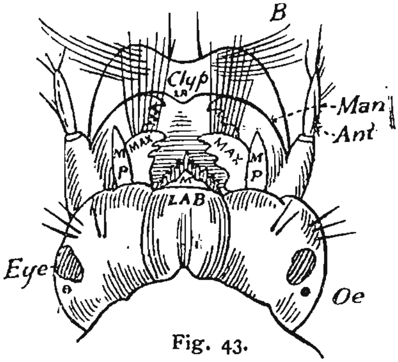


Fig. 43.

Figure 36.—Head of larva.—

B.	=Feeding brush.	*M. P.*	=	Maxillary palp.
C.	=Clypeus.	*LAB*	=	Labium.
LR.	=Labrum.	*M.*	=	Mental plate.
Man	=Mandible.	*Ant.*	=	Antenna.
Max.	=Maxilla.	*Oc.*	=	Ocellus.

THE HEAD.

The head is large and rounded. Its dorsal surface is covered by a chitinous plate, the epicranium, which is marked laterally by a pair of compound eyes. Behind these are the *ocelli* or simple eyes. In front arise the antennæ, much simpler structures than in the imago.

Anteriorly the head is covered by the clypeus, from the under-surface of which on either side arise the feeding brushes. These usually bear a striking resemblance to a pair of shaving brushes and may be seen rapidly sweeping in front of the mouth at frequent intervals. Their function is to sweep food material into the mouth, the serrations of the jaws acting as combs to remove entangled particles.

In the more voracious larvæ the brushes are replaced by stout chitinous rods which seize the prey as claspers or pincers.

In addition to the brushes the clypeus bears a few hairs, the number and character of which are of much importance in classification.

The mouth parts are adapted for seizing and tearing solid food and differ widely from those of the blood-sucking imago.

From the oral margin of the clypeus projects the labrum or "upper lip" unnoticeable in many young larvæ, but in some older larvæ growing into a rather prominent hairy beak. Posteriorly the mouth is closed by the pair of second maxillæ united throughout to form the labium, the anterior part of which is known as the *mental plate*, a dark dentated plate of chitin of very characteristic shape.

The inner margins of the mandibles form two series of strong chitinous hooks. From their anterior margin arises a number of chitinous processes resembling a comb, cockade, or brush, varying much in different genera.

The first maxillæ bear short conical maxillary palps as their exopodites. The endopodites are roughly quadrilateral plates which close in the mouth ventrally when approximated. Their inner margins are more finely serrated than those of the mandibles.

THE THORAX.

The thorax is more or less globular in shape. It bears no limbs or jointed appendages, and there are no separate terga or sterna for the three segments of which it is composed, but these three segments are clearly indicated by three lateral pairs of unjointed tubercles, each bearing a tuft of bristles.

THE ABDOMEN.

The abdomen consists of nine segments, each bearing a lateral tuft of bristles as well as numerous hairs. The Anopheline Mosquitoes have a pair of PALMATE SCALES on the dorsum of some of the segments, and in some species even on the thorax. These scales are shaped like the leaf of the fan palm and are very characteristic objects, having slight variations in shape in different species, which, as well as their distribution, are useful guides in classification.

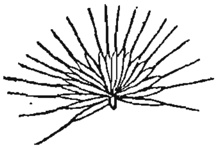


Fig. 44—Palmate scale.

The tracheæ open on the dorsum of the eighth segment. In Anophelines the separate openings of the two great longitudinal tracheæ are almost flush with the dorsal surface. In the Culicina, the eighth segment bears a projecting dorsal horn or syphon which gives the posterior extremity of the abdomen a forked appearance. The longitudinal tracheæ are continued up this syphon to open at its apex.

The ninth segment is traversed by the rectum, the anus opening on its posterior surface. Round the anus are two pairs of leaf-like processes known as the anal papillæ, into each of which a large trachea runs like a mid-rib. They probably act as respiratory gills. The last segment bears a pair of large tufts of hairs on each side.

THE DIGESTIVE SYSTEM.

The mouth parts have been described in connection with the head. They are best seen after boiling in *Liquor Potassæ*.

The buccal cavity opens into a short ŒSOPHAGUS followed by the MID-GUT, a straight tube that reaches from the middle of the thorax to the posterior part of the sixth abdominal segment where the five Malpighian tubes are given off.

At its origin in the thorax the mid-gut communicates with four pairs of digestive glands or HEPATIC CÆCA, which can be seen in the living larva as brownish lobules lying in the thorax, kept in constant motion by the communicated impulse of the dorsal vessel. In the dead larva they appear to have discharged their brownish contents into the gut and are hard to recognise.

The SALIVARY GLANDS lie close to the œsophagus, but are very difficult to demonstrate except in sections. Their common duct opens in the floor of the buccal cavity.

The hind-gut is a straight tube reaching from the seventh segment to the anus.

Most of these structures can be seen in the living transparent larva, but dissections should also be made as in the case of the imago, cutting partially through the eighth segment and dragging out the gut and tubules. The anterior portion should also be examined by cutting through the "shoulders" as it were, of the thorax, and dragging them with the contents of the thorax and abdomen out of the body-wall.

THE CIRCULATORY SYSTEM.

The dorsal vessel or HEART can be seen in the living larva as a delicate pulsating tube lying dorsal to the gut and extending from the head to the posterior extremity.

It is expanded in each segment and is held in position by alary muscles. The pulsations are transmitted to the tracheæ and other organs.

THE RESPIRATORY SYSTEM.

The main longitudinal tracheæ are of very wide calibre. They open to the surface only by the two stigmata already described, on the dorsum of the eighth segment in Anophelines; at the end of the syphon in Culicines.

The amount of anastomosis varies in different species. Lateral imperforate branches unite the tracheæ with the exoskeleton in the situation to be occupied by the stigmata of the adult.

THE NERVOUS SYSTEM.

This is not easily seen in the larval Mosquito and differs from that of the adult, in that the SUPRAŒSOPHAGEAL ganglion is much smaller and in that there are three separate ganglia in the thorax, eight in the abdomen.

THE EXOSKELETON.

The cuticle is repeatedly moulted or cast off during the growth of the larva. The inner lining of the tracheæ is also moulted at each of these periods of ECDYSIS. Very pretty specimens of the shed cuticle with the palmate hairs may be made permanent for microscopic study.

The horizontal position of anopheline larvæ should be noted, also the rippled line on the surface of the water made by the palmate scales. Observe the great range of rotation of the head and how the larva does most of its feeding at the surface turning the head ventral surface upwards. Observe also they are much more jerky in their movements than Culicines.

THE PUPA OR NYMPH.

In insects like the Butterflies a stage of rest known as the chrysalis takes place during metamorphosis. In the Mosquitoes the pupa retains its power of locomotion.

In the older larvæ certain changes take place. They become less active and cease to feed. Before the last moulting of the larva rudiments of the appendages appear as outfoldings of the hypodermis. There are eight pairs of these processes, six thoracic and two abdominal. Three of the thoracic pairs are cylindrical in shape and ventral in position, being the rudiments of the legs. The other three are dorsal; the prothoracic pair are the rudiments of the breathing trumpets of the pupa; the mesothoracic represent the wings, the metathoracic the halteres.

Of the abdominal outgrowths, one pair on the dorsum of the eighth segment becomes the tail fins of the pupa, and a pair on the posterior aspect of the last segment becomes the gonapophyses of the imago.

These rudimentary appendages are all covered by the cuticle of the larva till this splits in the last larval ecdysis. This split commences in the prothoracic region allowing the first dorsal pair of appendages to escape from the slit in the form of the breathing trumpets of the pupa. At the same time the abdominal tracheæ contract, so that the centre of gravity is altered and the tail end sinks, allowing the trumpets to come to the surface.

The second pair of dorsal folds become the wings, the third the halteres, while the three ventral pairs become the legs.

These five pairs of appendages rapidly develope and can be seen folded up beneath the pupa-case.

The outgrowths of the eighth abdominal segment or fins are a pair of thin oval plates bearing a chitinous mid-rib which is prolonged beyond the margin as a short spine.

The alimentary canal of the older larvæ can be seen surrounded by the adult gut, a fluid-containing space intervening. During the pupa stage the larval canal gradually disappears, being probably digested.

The pupa stage generally lasts only two to five days; yet within this short period the mouth apparatus quickly changes from the masticating type of the larva to the sucking proboscis of the imago.

LESSONS IN
PRACTICAL BIOLOGY
FOR INDIAN STUDENTS.

THIRD EDITION.

BY

ARTHUR POWELL, B.A., M.Ch.,

PROFESSOR OF BIOLOGY, GRANT MEDICAL COLLEGE.
FELLOW AND EXAMINER, BOMBAY UNIVERSITY.
EXAMINER, PUNJAB UNIVERSITY.

BOMBAY:
PRINTED AT THE TIMES PRESS.

1913.

Great changes also take place in the nervous system. The small supraœsophageal ganglia of the larva very rapidly enlarge. The three thoracic ganglia and, according to Hurst, the first abdominal ganglion all unite to form the large thoracic ganglion of the adult.

METAMORPHOSIS.

In all the Metazoa growth is not merely an increase in bulk, but is accompanied by development and considerable changes in structure from the fertilised egg-cell or zygote up to the adult condition.

In many animals, such as Man, Rabbit, Bird, Fish and Earthworm the more marked of these changes take place in the embryo or young animal before it is born from the womb or hatched from the egg. Throughout the rest of its existence the animal bears a considerable resemblance to its parent, as whose offspring it is readily recognised.

Other animals, such as the Frog, Crab, Spiny Lobster, Butterfly and Mosquito undergo striking changes after they have left the egg, and at first bear so little resemblance to the parent form that an inexperienced observer may well be excused for not recognising their relationship. Such young animals, when they leave the egg, are known as LARVÆ, and the changes in form which they undergo are spoken of as METAMORPHOSES.

From the fish-like tadpole feeding on vegetable matter and respiring by gills there is a gradual transition stage with mixed feeding and mixed respiration to the adult carnivorous Frog with ærial respiration.

In Crustaceans and Insects which possess a rigid armour of chitin, increase in bulk can only take place at the periods of ecdysis when the shell-like covering is thrown off. Something further is necessary in Insects like the Butterfly and Mosquito, where we have a worm-like larva with powerful chewing jaws formed for eating large quantities of bulky vegetable food, transformed into an imago with its mouth parts fitted for sucking liquid food only.

In these Insects the larva is chiefly engaged in assimilation and growth; the perfect Insect makes no increase in bulk and its principal function is reproduction.

Metamorphosis of structure is a necessary adaptation to change of habits and environment. To be able to fly it is essential that an animal should have powerful muscles, food easily absorbed, highly nutritious and containing little waste residuum. The bulky wood and coal that suffice as fuel for the railway train or ocean steamer must be replaced by pure hydrocarbons like petrol or benzol in the flying machine. The coarse, bulky food of the caterpillar and mosquito larva would be a heavy and unprofitable handicap to a flying insect, hence we need not be surprised to find during the process of metamorphosis a change of structure in the biting parts of the mouth and in the digestive apparatus to adapt them for sucking in concentrated and readily assimilable food such as honey or blood which leaves little residue.

Having reached a maximum of bulk after several ecdyses the larva enters on a period of apparent rest known as the CHRYSALIS or PUPA stage. This rest is however only in relation to the animal's surroundings, for internally very marked changes in structure are rapidly taking place. The amœboid corpuscles of the blood take on an extraordinary activity and well deserve their name of PHAGOCYTES (Gr. eating cells) by devouring the greater part of the animal tissues which they reduce to a creamy mass strongly reminding us of the yolk of the embryo, or the pus of an abscess. In this process of destruction or *Histolysis,** certain cells known as HISTOBLASTS are spared which are of embryonic character, like those of the blastoderm and proceed *to rebuild the insect into its imago condition, being fed by* the yolk-like mass.

Collections of these cells known as 'IMAGINAL DISCS or BUDS are found in definite situations and from them are formed the wings, legs and the greater part of the new head appendages which replace the old.

All Anopheline Mosquitoes do not harbour the malaria parasite. It is therefore necessary for the medical man to distinguish the harmful from the harmless species. This work would require a volume to itself, therefore only a few remarks will be made to enable the student to identify the Anophelines to be found in Bombay City.

At present three species of Anopheline are common, two rare in this city. The five are :—

Nysso-myzomyia rossii	.. ..	brown
Nyssorhynchus stephensi	.. ..	brown

* Gr. *histos*, tissue, *lyo*, to dissolve or destroy.

Nyssorhynchus jamessii	} black	
Myzorhynchus barbirostris		
Myzomyia culicifacies	small brown	

M. rossii, the most common, is incapable of transmitting malaria, and is therefore comparatively harmless. It is found all over the City and is the only Anopheline that breeds in foul water. It is very like *M. stephensi* and often mistaken for it. The latter is the next most common Anopheline and is to be found in about half the wells in the Fort. It also breeds freely in cisterns, unused cans, jugs and other vessels as well as in slowly running nullahs and pools.

N. jamessii is next in order of number.

M. barbirostris is rare and has only recently been found in the City by Dr. Bentley.

To identify these insects note first—

if they are brown they are :—

N. rossii	if black :—
N. stephensi	*M. barbirostris, large*
or *M. culicifacies* ;	or *N. jamessii, small.*

M. culicifacies derives its name from the fact that it resembles a Culex in its attitude. It does not stand head downwards like other Anophelines. It further resembles a Culex in that the thorax is distinctly humped, the proboscis and the abdomen not being in the same line. The larvæ are found in running streams or in the borrow-pits beside the B. B. & C. I. Railway line near Mahim and Parel. It is rare, I have not seen any for years.

The larvæ can be distinguished from all other larvæ found in Bombay by the presence of palmate scales on the metathorax, as well as on the abdominal terga.

N. stephensi can be recognised by its brownish grey colour, by the fact its tibiæ and femora are speckled with white and by the markings of the palps. The distal portion of the palps is marked by two broad white bands separated by a *narrow* dark band. See Fig. 30.

M. rossii on the other hand has no white dots on the legs except at the joints. The terminal white bands on the maxillary palps are separated by a *broad* dark band. The larvæ of *M. rossii* have the terminal hairs of their palmate scales longer than those of *M. stephensi*. Some experience is necessary to appreciate this sign.

The "deck" of the egg of *M. rossii* is open and oval; that of *N. stephensi* is narrow and encroached on by the large lateral floats which give the "gunwale" an elongated figure of 8-shape.

M. barbirostris can be easily recognised as a large black Anopheline, the palps and proboscis entirely black without any bands of white. The larvæ are big, black, lie in an S-shaped curve as a rule. The outer frontal hair is branched and brush-like.

N. jamessii is a small black mosquito; the palps are banded; it is readily recognised by the white "socks" on its hind-legs, *i.e.*, the distal three or four joints of the leg are pure white.

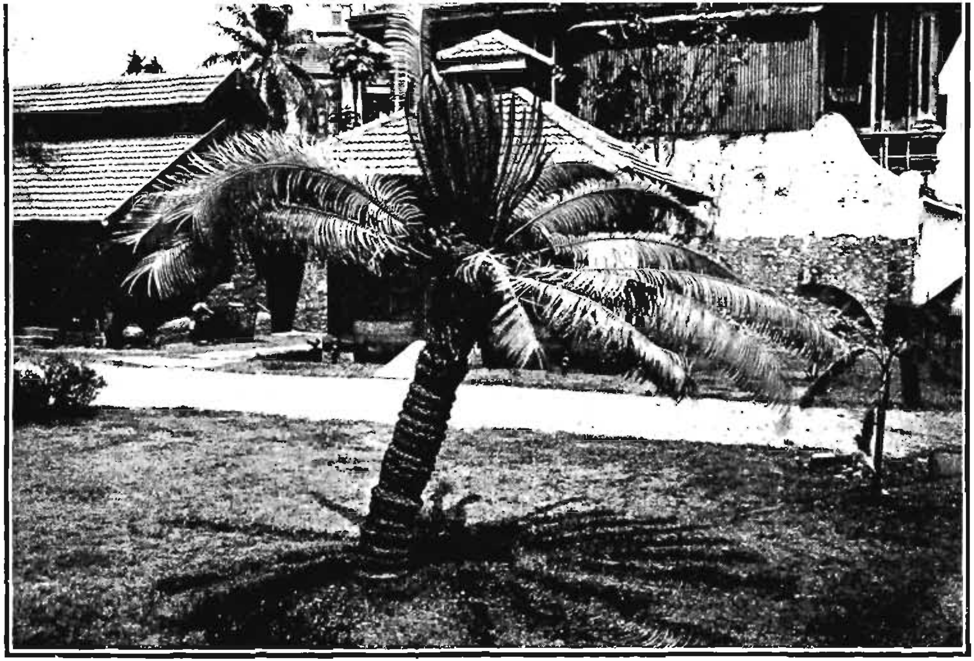


Fig. 45.—Cycas circinalis, Female Tree.

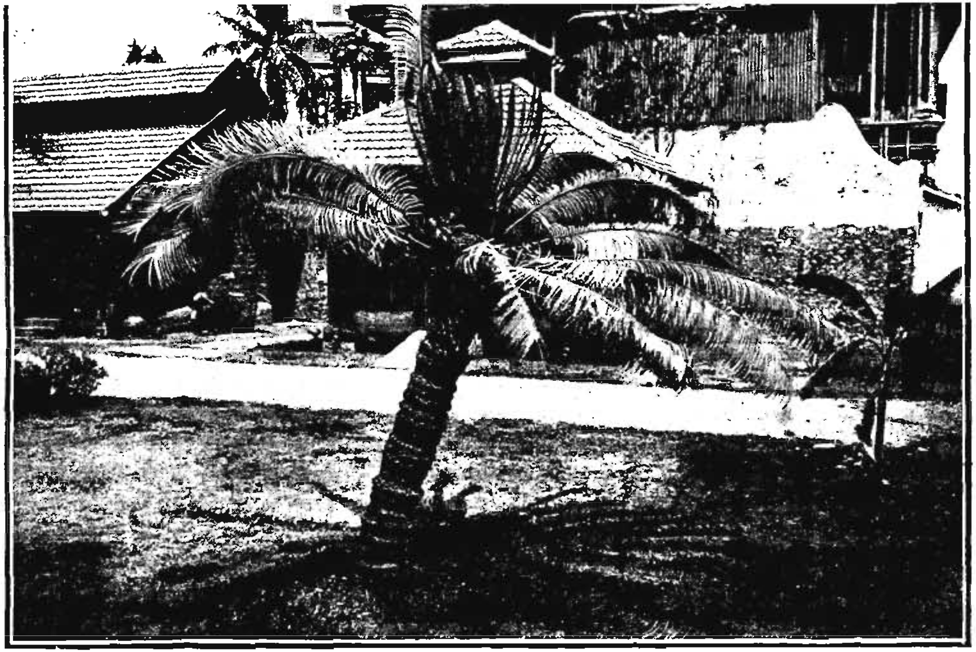


Fig. 45.—Cycas circinalis, Female Tree.

CYCAS.

The Oak, the Banyan and the Sequoia may have rival claims to the title of Monarch of the Forest, but among the flowering plants there is none to dispute that the Cycads are the absolute Aristocrats. Away back in the Permian period we find fossil Cycads differing but little from those of our own time. Like many an old human family the Cycads have failed to adapt themselves to their changing environment with the inevitable result that they have lost much of their first estate and are gradually dying out, making way for more enterprising or accommodating upstarts who push them aside and usurp their place in the struggle for existence.

They were the first flowering plants to appear on the earth and had so covered the greater part of its surface during the Mesozoic age that it is sometimes called the "Age of Cycads."

England and Europe generally, which were at that period covered with dense forests of Cycads, do not at the present day contain a single indigenous tree. Cycads are now comparatively few in number and restricted to certain tropical and sub-tropical regions.

Cycas is a handsome evergreen tree seldom exceeding twelve feet in height, so much resembling a Tree Fern or Palm in habit that Europeans often erroneously call it a "Sago Palm." The trunk is, as a rule, unbranched like that of a Palm and bears at its apex the leaves arranged in whorls like a rosette. The tree is diœcious, that is to say, the male and female spores are borne on separate plants. In the full-grown female tree a whorl of carpels or macrosporophylls is usually produced alternately with a whorl of foliage leaves as is seen in Fig. 45. The stem is cylindrical its surface rough with scaly leaves, and the stumps of fallen foliage leaves. Though usually unbranched, it contains a number of dormant buds which often sprout out close to the ground, and are utilised by the *mali* as a means of reproducing the tree.

The histological structure of the stem agrees in the main with that of the Dicotyledons, and as among the latter we can find stems of more convenient bulk, the student may postpone this portion of his study till he is familiar with the histology of the dicotyledonous stem.

The stem of Cycas contains a large amount of *central ground tissue* or pith composed of parenchymatous cells containing much starch from which an inferior sort of sago can be made. External to the pith we find the vascular bundles arranged as a circle of wedges with their apices pointing inwards. These bundles are collateral and open, that is to say, there is a layer of *meristem* or *cambium* separating the *wood* on the inside from the *phlœm* or bast on the outside. From this layer of cambium wood is continually being formed on the inside and phlœm on the outside. Between the vascular wedges are the *medullary rays*, layers of ground tissue connecting the pith with the parenchyma of the cortex. As the stem grows a little older, the layer of cells in the medullary rays between the cambium of the bundles acquires the power of growth, giving off woody tissue on its inner aspect and phlœm on its outer, so that we get complete cylinders of cambium, wood and phlœm, which in a transverse section of the stem appear as rings. This meristem is known as the *interfascicular* cambium.

After a few years this normal ring of cambium becomes exhausted, but a new meristem arises in the pericycle, and forms bast externally and wood internally. This secondary meristem in its turn becomes exhausted and is followed in turn by new layers.

The wood of Cycas differs from that of Dicotyledons in that it contains only tracheids. A tracheid (Greek, *trachelos* a neck or tube, *oidos,* like) differs from a vessel or trachea in that it is formed of a single elongated cell, while a vessel is formed by the union of several cells joined end to end. These tracheids are marked by dots and bordered pits which are mostly rounded, but may be elongated, in which case they give the cell a ladder-like appearance and are called scalariform tracheids (Latin, *scala,* staircase). The bordered pit gives the appearance of two concentric circles, which is due to the fact that the pit is lens-shaped, the inner smaller ring represents the opening into the cavity of the tracheid, the outer larger circle indicates the widest part of the pit. In the first formed wood some tracheids with spiral marking are to be seen.

The phlœm differs from that of the Angiosperms in that there are no companion—cells but only sieve tubes and parenchyma as in the Ferns.

The cortex is remarkable for the large number of mucilage ducts which it contains ; they are also found in almost all parts of the plant though in fewer numbers than in the cortex.

THE ROOT.

Fig. 46.

CARPEL OF C. CIRCINALIS.

The radicle of the seed persists, growing vertically downwards as a tap-root which like its branches increases in length by means of an apical growing point covered by a root cap and in its general features resembles the Dicotyledons.

THE LEAVES.

The leaves of Cycas are of three kinds, scale leaves, foliage leaves and sporophylls.

We have already seen the scale leaves which help to give the stem its rough appearance. Longer scale leaves may be seen in a whorl covering the inflorescence before it reaches maturity. The scale leaves are all dry and brown owing to the absence of chlorophyll.

that there are no companion—cells but only sieve tubes and parenchyma as in the Ferns.

The cortex is remarkable for the large number of mucilage ducts which it contains ; they are also found in almost all parts of the plant though in fewer numbers than in the cortex.

THE ROOT.

Fig. 46.

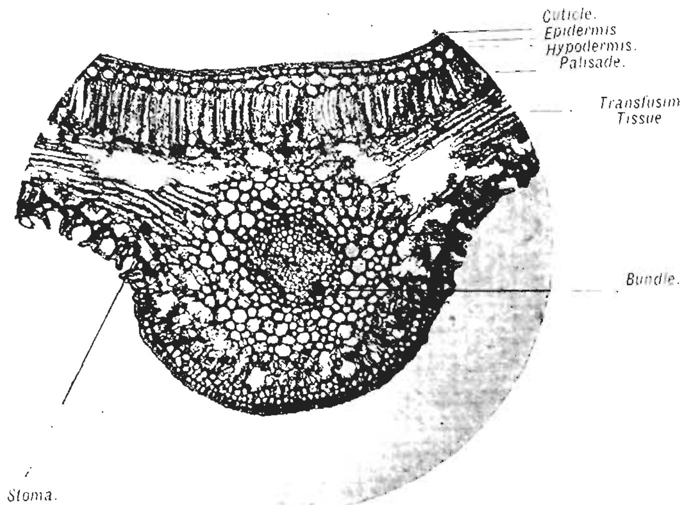
CARPEL OF C. CIRCINALIS.

The radicle of the seed persists, growing vertically downwards as a tap-root which like its branches increases in length by means of an apical growing point covered by a root cap and in its general features resembles the *Dicotyledons.*

THE LEAVES.

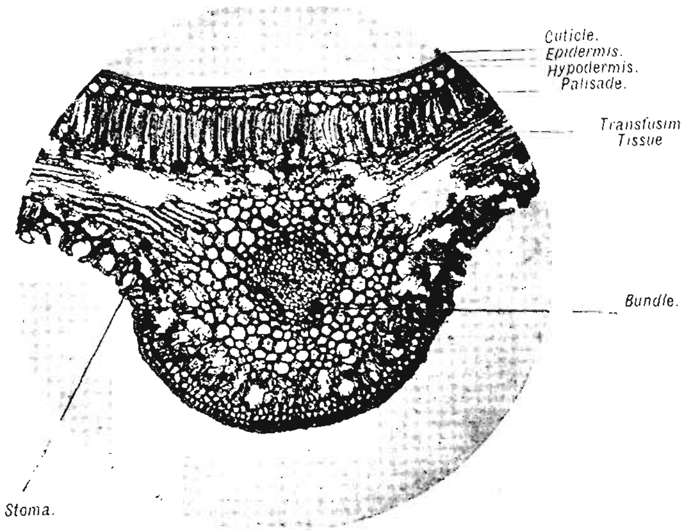
The leaves of Cycas are of three kinds, scale leaves, foliage leaves and sporophylls.

We have already seen the scale leaves which help to give the stem its rough appearance. Longer scale leaves may be seen in a whorl covering the inflorescence before it reaches maturity. The scale leaves are all dry and brown owing to the absence of chlorophyll.



Cuticle.
Epidermis
Hypodermis.
Palisade.
Transfusion
Tissue
Bundle.
Stoma.

Fig. 47.



Cuticle.
Epidermis.
Hypodermis.
Palisade.
Transfusion Tissue
Bundle.
Stoma.

Fig. 47.

The foliage leaves are large and pinnate (feather-shaped) with a central rachis to which the linear *pinnæ** are attached on each side. In the bud each of these pinnæ is soft and coiled up from apex to base in *circinnate* fashion. Note that the pinnæ near the base of the leaf cease to expand, developing into hard and sharp-pointed *thorns* while the more distal pinnæ are flattened in the horizontal plane and become leathery in consistence. A transverse section of a pinna shows a vascular bundle surrounded by a periycle of colourless cells entering the mid-rib of the pinna from the rachis. The surface of the leaf is covered by a single layer of *epidermal* cells with thick cutinised walls. Split a short portion of a pinna horizontally and boil the pieces for a minute in Nitric acid to which a few crystals of chlorate of potash are added. This will macerate the tissues and cause all the tissues of the leaf to separate into their constituent cells, except those which are cutinised as cutin resists the action of this fluid. Wash the *debris* and mount in water the epidermis which remains entire as a thin film. Note that the elongated cells on the upper surface of the leaf form a mosaic with their margins in contact with no interspaces. On examining the under-surface you will find numerous *stomata* at the bottom of pits formed by from ten to twenty elongated cells.

Below the epidermis we come on the *hypoderma*, a layer of thick-walled sclerenchymatous cells to which the leaf owes its leathery consistence. This layer varies in

---

* *Latin*, pinna, a feather.

thickness from five or six cells on the under-surface of mid-rib to one on the upper-surface of the lamina.

Below the hypoderma we come upon the *mesophyl* chlorophyll—containing tissue. This consists of an u] one-celled *palisade* and a lower *spongy* layer. The u] layer receives its name from the fact that its c ponent cells which contain many rounded chlorophyll bo are columnar in shape, five or six times as long as they broad, and arranged at right angles to the surface in c contact with one another like the planks of a palisade.

We next come on the spongy layer of the mesophy: which the chloroplast—containing cells are irregular in sh and loosely arranged, only touching one another here there, so that large intercellular spaces are left which c municate freely with the air through the stomata. R ning transversely through the spongy mesophyll from mid-rib towards the margin is seen the transfusion-tis composed of colourless cells, some empty with dotted w approaching in appearance and probably acting as trache others containing granular protoplasm which are suppc to carry away the elaborated sap like sieve tissue. ' absence of well developed vascular tissue, except in mid-rib contrasts with the condition found in the leaves Angiosperms in which the vessels usually ramify in lamina almost up to the margin.

The lowest layer of the mesophyll approaches the palis in character, but the cells are shorter, only two or th

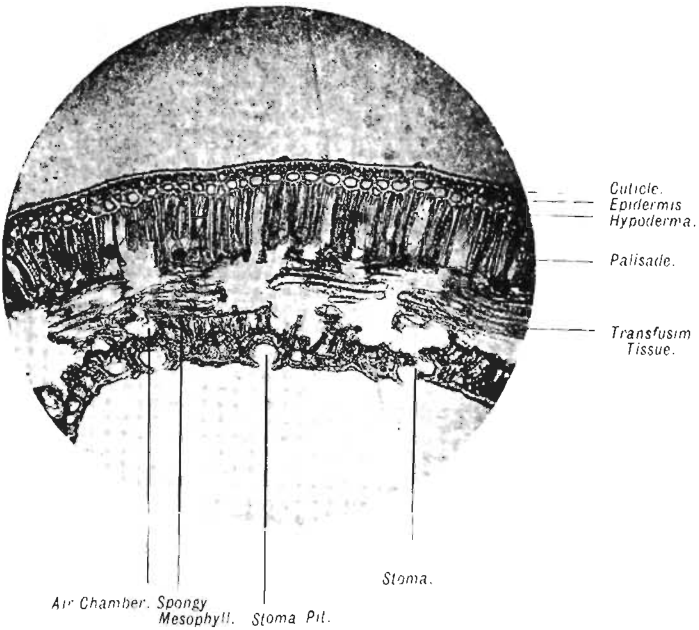

Cuticle.
Epidermis
Hypoderma.
Palisade.
Transfusim
Tissue.
Stoma.
Air Chamber.
Spongy
Mesophyll.
Stoma Pit.

Fig. 48.

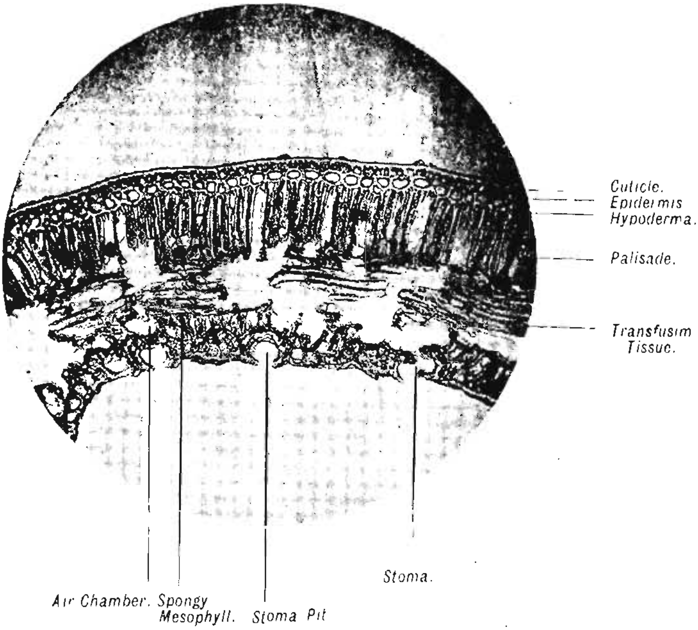

Cuticle.
Epidermis
Hypoderma.
Palisade.
Transfusim
Tissue.
Stoma.
Air Chamber.
Spongy
Mesophyll.
Stoma Pit

Fig. 48.

as long as they are broad and irregularly arranged with air-spaces between them into which the stomata open.

Fig. 40.—STAMEN OF C. CIRCINALIS × ½.

SPOROPHYLLS.

The macrosporophylls or carpels arise as whorls of modi-l leaves at the apex of the stem. At first they are closely essed together to form a large yellow dome-shaped bud, rrounded at its base by brown linear scale leaves; but the axis elongates the carpels become separated from one nother and assume the horizontal position. The axis ontinues to grow and the following year produces a whorl f foliage leaves above the carpels. Fig. 40, reproduced rom a photograph shows this alternation of whorls of sporo-phylls with foliage leaves. At the apex are seen the still ver-tical foliage leaves of this year, below a whorl of carpels, next the horizontal whorl of two-year-old foliage leaves, below which are seen hanging down the withered carpels of three seasons ago.

Each carpel bears from three to five ovules or macros-porangia, and is thick, succulent and yellow, in shape some-what like the blade of a spear. The homology of the car-pels with foliage leaves is shown not only by their alternation with the latter but also by an approach to the pinnate form at their apex. This is well seen in *Cycas revoluta* the carpels of which produce round cord-like pinnæ at their apex. In *C. circinalis* (see Fig. 46) we find only a slightly dentate condition of the margin which turns green from the presence of chlorophyll, to indicate this homology.

Each ovule or macrosporangium consists of a *nucellus*, from the base of which, the *chalaza*, arises a thick integument that grows up to entirely surround the nucellus except at its apex, where it forms a small nipple-like projection perforated by an aperture, the *micropyle*. This leads down to a cavity, the *pollen chamber*, at the apex of the nucellus. The ovule is sessile, that is to say, it possesses no stalk. The portion of the carpel to which it is attached is called the placenta.

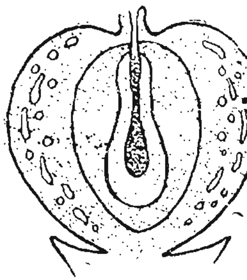


Fig 50.

In the nucellus appears only one spore-mother-cell, which divides into four daughter-cells, only one of which becomes the female spore or *macrospore*. In the flowering plants this spore has unfortunately for such a long time been known as the *embryo-sac*, that it is difficult to avoid the name. The macrospore is not discharged from its parent plant but proceeds within the ovule to divide into a large number of cells and form the female prothallus. The

Fig. 51.—*Cycas circinalis*, Cone of Male Tree.

Fig. 51.—*Cycas circinalis*, Cone of Male Tree.

archegonia, or female gonads, which produce the ovum or egg-cell, make their appearance in the upper part of the prothallus at the bottom of a hollow, which we may call the sperm chamber. The ovum of Cycas is about 2 m.m. in diameter and contains a remarkably large nucleus, about 0·5 m.m. in diameter, so large that when stained it is readily visible to the naked eye.

The male tree produces a terminal inflorescence in the form of a large cone from six to twelve inches high. The cone consists of a large number of woody scale-like leaves, the *microsporophylls*, arranged spirally on a central axis. This axis is the true upward continuation of the stem. The subsequent growth in height of the tree is maintained by a lateral bud, which as it developes pushes aside the cone and grows vertically in the same direction as the trunk.

Each microsporophyll or *stamen* bears on its under-surface some hundreds of *sori* or collections of *microsporangia*. In these sporangia the spore-mother-cells divide into four pollen grains or *microspores* so that in its earliest stage the pollen is a true spore consisting of a single cell enclosed in a two layered cell-wall. The outer layer, the exine, is cutinised; the inner, the intine, is of cellulose containing much pectin. When the pollen escapes from the sporangium we find it has already become a small prothallus, consisting of three or four cells. The first formed cells are called the vegetative cells ; from these later is cut off the spermatogenous cell which again divides into two, one of which breaks up, the other is the sperm-mother-cell. Fig. 54.

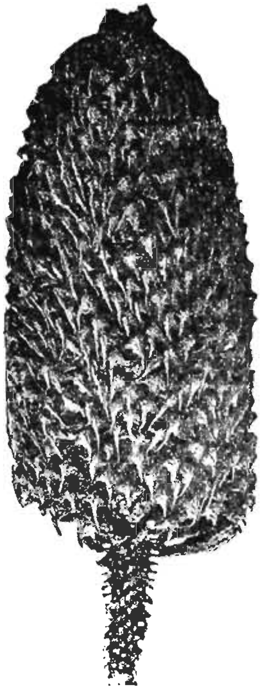


Fig 52.—CONE OF MALE CYCAS CIRCINALIS.

The pollen grains are produced in vast numbers and are carried about by the wind. In this way some of them find their way to the ovules of the female tree. This method is extremely precarious and involves an enormous waste. Some years ago a female tree in Esplanade Road, Bombay, bore several seeds, although, as far as I am aware, the nearest male trees are in Victoria Gardens with about four miles of city streets intervening. Pollinisation takes place when the carpels begin to separate from one another. The pollen falls into the micropyle which is continuous with the pollen chamber. In this is a quantity of fluid which slowly drying up draws the pollen grains down to the bottom of the chamber. Here the exine ruptures ; one of the prothallial cells grows out carrying the intine with it like a hypha. The sperm-mother-cell enters the pollen tube and there divides into two motile *spermatozoids* of a peg-top shape with a spiral band of cilia round their narrow ends. Figs. 55 and 56.

In the meantime the female prothallus has increased in size pushing aside the cells of the nucellus till the sperm

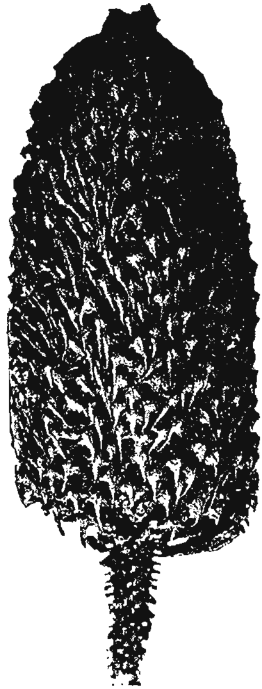


Fig 52.—CONE OF MALE CYCAS CIRCINALIS.

The pollen grains are produced in vast numbers and are carried about by the wind. In this way some of them find their way to the ovules of the female tree. This method is extremely precarious and involves an enormous waste. Some years ago a female tree in Esplanade Road, Bombay, bore several seeds, although, as far as I am aware, the nearest male trees are in Victoria Gardens with about four miles of city streets intervening. Pollinisation takes place when the carpels begin to separate from one another. The pollen falls into the micropyle which is continuous with the pollen chamber. In this is a quantity of fluid which slowly drying up draws the pollen grains down to the bottom of the chamber. Here the exine ruptures ; one of the prothallial cells grows out carrying the intine with it like a hypha. The sperm-mother-cell enters the pollen tube and there divides into two motile *spermatozoids* of a peg-top shape with a spiral band of cilia round their narrow ends. Figs. 55 and 56.

In the meantime the female prothallus has increased in size pushing aside the cells of the nucellus till the sperm

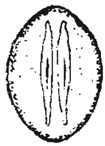


Fig. 53.

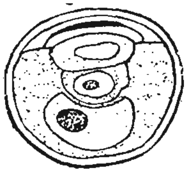


Fig. 54.

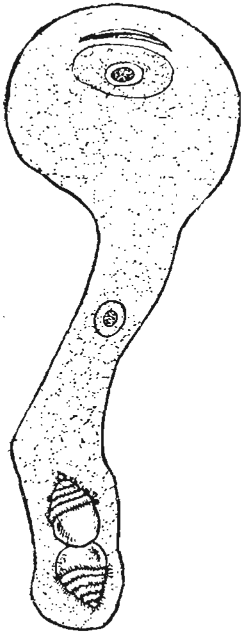


Fig. 55.

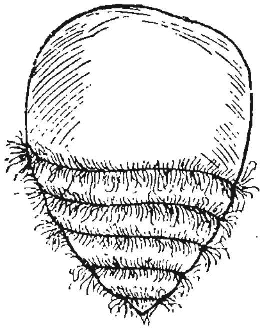


Fig. 56.

chamber with the archegonia at its base has come close to the bottom of the pollen chamber. The pollen tubes bore their way through the intervening soft-celled tissue, and on reaching the sperm chamber rupture allowing the spermatozoids to escape. The commotion caused by their spinning movement can be observed with a simple lens. They swim about actively in the fluid of the sperm chamber till they find the neck of the archegonium. Through this they pass and enter the ovum. The nuclei of the spermatozoid and of the ovum then unite to form the zygote nucleus.

The nucleus of the zygote divides successively into two, four, eight, sixteen, thirty-two, sixty-four, one hundred and twenty-eight and two hundred and fifty-six free daughter nuclei before their protoplasm separates and forms cell-walls. The embryo then becomes differentiated into an axis composed of a short radicle and a relatively large plumule with two large cotyledons. A large portion of the prothallus remains as the *endosperm* of the seed. The integument of the ovule becomes the seed-coat with an outer succulent and an inner hard layer. The ripe seed grows to the size of a small apple, and from its size and the character of the seed-coats is popularly mistaken for a fruit of the drupe kind.

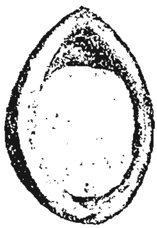


Fig. 57—SEED OF C. CIRCINALIS × ½.

To see the spermatozoids and pollen tubes examine some pollinated ovules about the month of September. With the naked eye you can see the pollen tubes projecting from about 0·5 m.m. to 1·5 m.m. into the sperm chamber of the nucellus. As a rule from four to eight tubes may be seen, possibly as many as twenty, or as few as one; sometimes unfortunately none. With a lens the united pair of spermatozoids may be recognised as an opaque white dot in the more pellucid tube.

Cut out this piece of nucellus and place it on a slide in some 8 per cent. solution of cane sugar. With the help of a dissecting microscope and a sharp knife cut off the ends of the tubes. Do not put on a cover glass, at least do not do so till you have examined with a 1 inch or ½ inch objective as you may crush the spermatozoids or restrain their movements.

If the spermatozoids are mature, they will soon begin to spin round and separate from one another. They usually keep up active movements for some hours. On an average the spermatozoids of *Cycas circinalis* are about 0·2 m.m. in diameter.

THE FERN PLANT.

Ferns show a considerable amount of morphological differentiation. At one stage in their existence all possess a stem bearing both leaves and roots, the tissues of which show marked histological specialisation. The general appearance or "habit" of a Fern depends largely on the character of the stem, which may be a vertical trunk, ten or twelve feet in height as in the Tree Ferns, or it may creep above ground or climb over rocks or the trunks of neighbouring trees. Most commonly it is a *rhizome* or underground stem, easily mistaken for a root from which however it can be distinguished with certainty by the fact that it bears leaves, of which at least the stumps or scars are present if the actual leaves have fallen off.

Before examining the adult plant in detail, we will first study its *ontogeny* or the life history of an individual, so as to get some clue to its evolution or ancestral history.

In the dry season on the back of most fully developed Fern leaves will be found certain brown patches from which can be scraped or shaken a brown powder. The grains of this powder are spores. Like all spores, each is a single cell and in this case surrounded by a double cell-wall.

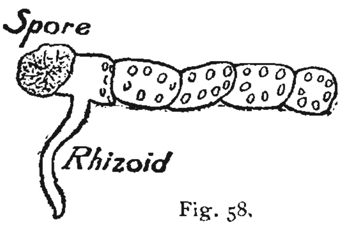


Fig. 58.

Germinating Spore.

When the spores are sown on damp earth they germinate, the outer cell-wall ruptures and the protoplasm of the cell covered by the inner coat protrudes as a filament, which divides by transverse walls into a number of cells, reminding us of Spirogyra.

Almost at once, however, we get a differentiation of both structure and function, as the proximal cell gives off a colorless root-hair or *rhizoid* (Gr. *rhiza*, root; *oidos*, like) which attaches the tiny plant to the soil and absorbs therefrom water and mineral salts, whereas the other cells possess chloroplasts and devote themselves to carbon assimilation.

Later on the distal cells multiply by dividing in both the transverse and longitudinal planes, so that we get a thin sheet of tissue, only one cell in thickness and usually shaped somewhat like the ace of hearts. Later still, by the growth of its cells in all three dimensions the central portion becomes thickened into a cushion several cells in depth. From the under surface of this little independent, self-supporting plant, now called a *prothallus* (Gr. *thallos*, a sprout), a number of unicellular root-hairs or rhizoids are given off.

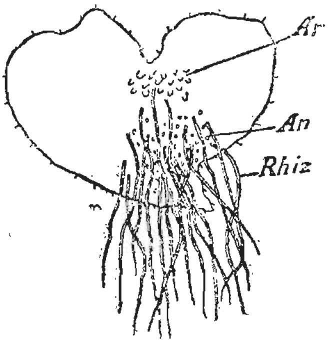


Fig. 59.
Prothallus of Fern. Ar=archegonia; An=antheridia; Rhiz=rhizoid.

In most green-houses or ferneries a plentiful supply of prothalli in various stages of development can be found growing on damp bricks or on flower-pots. They can be recognised by their heart shape; their dull green color contrasting with the lighter green of the young embryos which may be found growing from the older prothalli; and by their size, seldom exceeding a quarter of an inch in diameter. To ensure a supply of prothalli a number of spores should be sown on a soft piece of tile or brick laid in a saucer of water and kept constantly moist in a shady situation. In dry weather the whole should be covered by a bell-glass.

In cutting sections, you must be careful to remove all earth or sand from the prothalli or you will ruin both section and razor. For this purpose it is best to sow the spores on the dust of coir refuse, patted down firmly into a flower-pot saucer and kept constantly damp.

Most fern spores take a long time to germinate and usually some months elapse before the sexual organs are developed.

The prothalli of most ferns are hermaphrodite, that is to say, the same plant usually bears gonads or sexual organs of both sexes. The male gonads appear early and have generally withered by the time the female gonads are mature so that cross-fertilisation is assured.

Clean a young prothallus of all earth and sand by moving it to and fro in a basin of water. Place it in water, under-surface upwards, on a slide, and examine with a one inch objective. Note the root-hairs, that the periphery is only one cell in thickness, while the central cushion is several cells in thickness. Search near or between the origin of the root-hairs for the male gonads, called *antheridia*. They appear as small hemispherical elevations projecting from the surface of the cushion. To get a profile view, fold the prothallus double in the median line, under surface outwards, and examine the edge of the fold. Later confirm your observations by examining sections.

Each antheridium is formed of two superposed ring-shaped cells covered by another cell which forms a lid. In the cavity thus formed may be seen several small cells, the sperm mother-cells. (Fig. 60.)

The *archegonia* (Gr. *arche*, beginning : *gone*, development, womb), as the female gonads are called, must be looked for on olde[illegible] y-formed prothalli on the under surface between the apical notch and the origin of the root-hairs. Each is somewhat flask-shaped, the body or *venter* (Lat. belly) being sunk in the tissue of the cushion, while the long *neck*, the wall of which is composed of four rows of colourless cells in four tiers, projects from the surface. *The contents of the flask, filling its cavity,* are a large naked egg-cell or ovum, and above it two granular canal-cells, which later on break down into a refractive mucilage.

Profile views should be taken of the archegonia by folding the prothallus. Note the chimney-like projection of the neck, the granular canal cells in the young archegonia, the refractive appearance of the mature unopened and the *gaping mouth* of the opened archegonia. You can scarcely see the ovum except *in sections.*

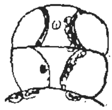


Fig. 60.
Antheridium after discharge of spermatozoids.

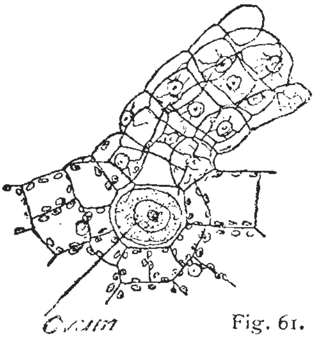


Fig. 61.

Archegonium opened.

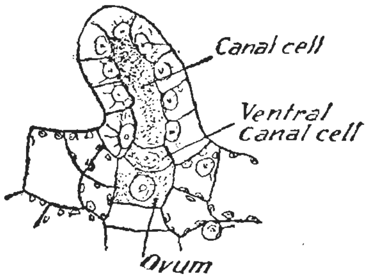


Fig. 62.

Archegonium un-opened.

To see the opening of the gonads and the process of fertilisation, some quite young prothalli bearing antheridia, and some fully-formed prothalli with various stages of archegonia should be kept moderately dry by omitting to water them for several days, and then placed together in water on a large slide and watched with a one inch or a half-inch objective. Watch an antheridium and you may see the lid-cell rupture and the sperm-mother-cells come out. These remain quiet for some time and you can recognise in each the coiled thread of a spermatozoid surrounding a number of fine granules. The walls of the mother cells dissolve in the water and the spermatozoid sets itself free with a jerk, and lengthens owing to the coils separating. They rotate and swim about so rapidly that at first it is difficult to make out their structure, but in about a quarter to half an hour their movements become much slower and finally cease. They can be artificially made to slow their movements by putting them in a tenacious medium such as a 10 % solution of gum arabic. They can be killed and stained by weak iodine solution. They are then seen to be composed of a cork-screw-like band of nuclear material. They bear a number of cilia or flagella at their anterior end, and at their posterior end for some time a thin vesicle containing small starch granules stained blue by the iodine in contrast with the brown of the nuclear spiral and the flagella.

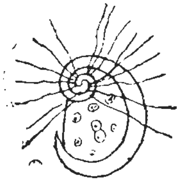


Fig. 63.

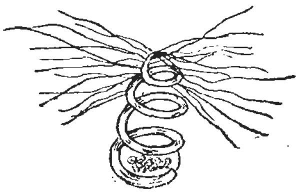


Fig. 64.

Spermatozoids of Fern.

Permanent specimens are best made by fixing in the vapor of osmic acid, or by running in a drop or two of 1 per cent. osmic acid solution. After washing, stain with logwood or fuchsin-iodine-green and mount in balsam. To observe the opening of the archegonia and the process of fertilisation, proceed as above ; on the same slide in water mount both full-grown and young prothalli which have not been watered for some time.

The archegonia nearest the notch are the youngest and their neck cells probably look granular. The oldest archegonia, possibly already fertilised, possibly opened and dead, of a withered brown color inside, are to be found nearest the root-hairs. Between these too old and too young archegonia will be found those ready to open and become fertilised. You will recognise them by the strong refraction of the contents of the neck. Watch such a one and you will be rewarded by seeing the four apical cells of the neck suddenly separate from one another, leaving a wide mouth through which the mucilage resulting from the breaking up of the canal-cells, escapes intermittently.

If there be any spermatozoids swimming about you will observe that though they took no notice of the archegonium before it had opened, they now swim toward it from a considerable distance and enter the neck. Here their movements are slowed by the mucilage as in your experiment with gum arabic. You will notice that the vesicle at the posterior end of the spermatozoid is left outside the neck.

Although several spermatozoids may enter the neck only one succeeds in wriggling down and fertilising the ovum. The resulting zygote soon surrounds itself with a cell wall so that any later-coming spermatozoids cannot enter.

In the mucilage formed by the canal-cells is to be found a small amount of malic acid, and it seems that this substance has the power of attracting the spermatozoids.

Heat to redness in a Bunsen flame a narrow piece of glass tubing and draw it out into a very fine capillary tube. Into a short piece of this capillary tube draw some solution of malic acid and malate of potash, each 0.02 per cent. Seal one end in the flame, place the open end on the slide under a cover-glass in some water in which spermatozoids are, and you will find they all swarm into the tube. This is a good example of sensitivity to chemical attraction or *chemiotaxis* as it is technically called.

DEVELOPMENT OF THE EMBRYO.

After fertilisation the zygote forms a cell-wall of cellulose, and soon divides into two cells which again divide and re-divide to form successively four and eight cells. In most Ferns in about a week or a fortnight after fertilisation the venter of the archegonium is found distended by this little embryo, while the neck has become brown and withered.

Of these eight cells one grows upwards to form the growing point of the stem, two others of the upper cells multiply to form a mass of parenchymatous cells called the *foot*, an organ peculiar to the Fern phylum, which is imbedded in the tissue of its parent prothallus and absorbs from it nourishment for the young embryo till it is able to take care of itself.

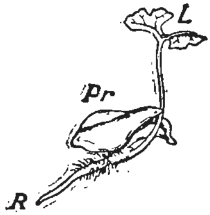


Fig. 66.

Embryo attached to Prothallus, Pr. ; R=Root ; L ;=first leaves.

Of the lower cells two develop into the primary leaf while another grows down to form the primary root. As the little plant grows the young stem develops and forms leaves, the root attaches it to the soil. The foot and prothallus wither away as the need for their services ceases to exist.

The Mature Sporophyte.

NAKED EYE CHARACTERS.

As already mentioned the Fern plant in the spore bearing stage consists of root, stem and leaves, which are lateral organs of the stem. The habit or external appearance of the different genera and species depends greatly on the character of the stem.

The following description, unless otherwise stated, will apply to the genus *Nephrodium* or *Aspidium*, species of which are common in gardens all over India. Dig up a well grown plant of *Aspidium* and wash the earth from its roots.

Note the short unbranched stem growing obliquely upwards, its surface covered by the stumps of fallen leaves. Above these stumps are the stalks of this year's fully developed leaves. Above these are next year's leaves curled up from apex to base in what is called *circinate* vernation. Note that these as well as the bases of the older leaves are thickly covered with yellowish scales easily brushed off with the finger. Nearest the apex of the stem may be seen still smaller rudimentary leaves which will become fully developed two years hence. Thus we learn that the leaves take three years to attain full development.

Examine a fully developed leaf. Note that it is composed of a long *leaf-stalk* or *rachis* nearly cylindrical, except for two longitudinal lateral ridges. From these ridges are given off on each side the leaflets or *pinnae* (Lat. feather, wing). Note that the leaf veins bifurcate. This forked vernation is a characteristic of Ferns by which many imperfect fossil remains can be recognised.

Late in the season circular brown patches will generally be found on the under surface of the *pinnae*. Each of these is a *sorus* (Lat. a collection), a group of several spore-cases or sporangia, covered by a thin kidney-shaped membrane, the *indusium* (Lat. a lady's under garment), derived from the epidermis of the leaf.

Note the roots which arise not only from the stem but from the bases of the leaf-stalks. They are therefore adventitious roots. Note also that you cannot recognise any persistent indication of the primary root of the embryo.

Trim off the leaf-stalks about 6 or 8 m. m. from their insertion on the stem. Cut off 30 or 40 m. m. of the older end of the stem by an accurately transverse cut, and boil in 20 to 30 per cent. hydrochloric acid till the ground tissue becomes soft.

Examine the cut surface of the other piece of the stem and note that the periphery of the section is a dark brown band of *sclerenchyma* surrounding the *ground tissue* of yellowish white parenchymatous cells. Seven or eight larger yellow dots will be seen arranged in a ring some distance from the centre (Fig. 67). These are the steles or vascular bundles. Outside these are scattered smaller yellow dots the *leaf-traces* or vascular bundles running to the leaves.

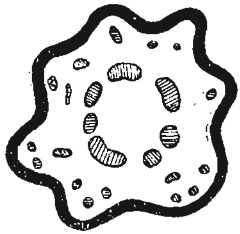


Fig. 67.
Aspidium. Transverse section of stem. Black line = Sclerenchyma. Shaded parts = Vascular bundles.

Split the upper inch of the stem including the apical bud into two equal halves by a medium longitudinal section.

Note that the large steles do not form continuous lines but are interrupted at intervals—the foliar gaps. One or two of the leaf-traces may be seen to arise from the stele and run into the base of the leaf stalk; if not, a little dissection by picking away the ground tissue should be made to demonstrate this continuity. Take the piece of stem you have boiled in HCl. and after careful washing, pick away with the point of a knife and by brushing with a nail-brush all the softened ground tissue so as to leave bare the vascular skeleton of the steles. Note that it forms a cylinder of trelliswork like a clothes "jamp" of which each mesh is opposite the insertion of a leaf and so called a "foliar gap" (see Fig. 69).

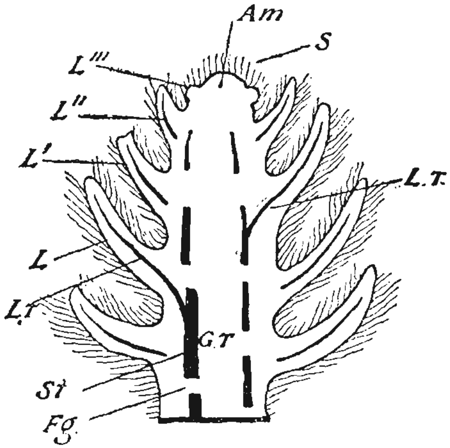


Fig. 68. Longitudinal section of stem. Am= Apical meristem; G T=ground tissue; Fg. =foliar gap; L=this year's leaf; L'=next year's leaf; L'' and L'''=rudiments of leaves of following years; L T=leaf-trace; St=stele.

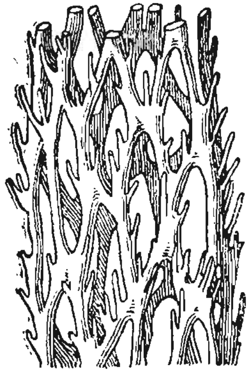


Fig. 69.

Vascular skeleton of stem of Aspidium.

Make some thickish longitudinal sections of the stem, boil them in nitric acid to which a few crystals of chlorate of potash are added. This should be done in the open air or in the verandah, as the fumes of the acid will corrode the metallic instruments in the laboratory. Wash the sections with several changes of water, tease the tissues with needles into minute fragments, mount in water and examine first with a low, then with a high power of the microscope. By this method the pectin which constitutes the so-called "middle lamella" between the cells of the tissues is dissolved so that they can be readily separated from one another by teasing.

Cut as thin as you can both longitudinal and transverse sections of the stem from material that has been preserved in alcohol. It is important that the sections be not oblique, but cut accurately at right angles to or parallel with the axis of the stem. Do not try to make a transverse section of the complete stem as it is too big; be satisfied with cutting a small area at a time, provided the section is *thin and in the right plane*. Mount some of your thinnest sections in glycerine, others in chloro-iodide of zinc solution.

Microscopic examination of these sections and of the macerated and teased cells shows that there is—

(*a*) An outer badly defined *epidermis*, composed of a single layer of cells with dark brown outer walls, bearing here and there *scales* one layer of cells in thickness.

(*b*) Internal to this is the *ground tissue* composed of

(1) an outer narrow band with relativelythick-walled cells placed in close contact with one another and containing protoplasm with starch granules, and (2) an inner central mass in which the steles are imbedded, composed of cells with thin cellulose walls containing much starch. In this central portion are many intercellular spaces into which project small spikes from the walls of the cells.

c) Between the outer and central portions of the ground tissue is a ring of *sclerenchyma* composed of elongated cells with thick, brown, lignified and stratified walls dotted with pits. In longitudinal sections they are seen to resemble long *fibres with tapering ends. There are no intercellular spaces.*

(*d*) The steles.

It is easier to cut good sections from the base of the leaf-stalk as there is not so much hard *sclerenchyma.* The tissues in general resemble those of the stem while the structure of the stele is the same. As the student can cut thinner and better sections from the leaf-stalk, he is advised to use it for study of the minute structure of the stele.

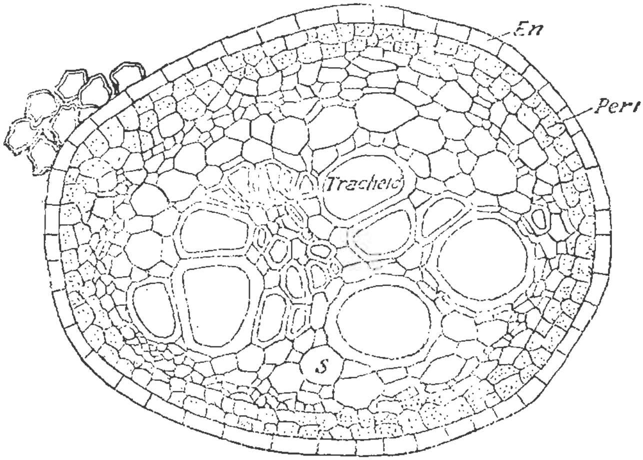


Fig. 70.
Stele of Aspidium.
En = endodermis ; Peri = pericycle ; S = Sieve-tube.

Examine a stele or vascular bundle with the $\frac{1}{6}$th objective and note that each is surrounded by a sheath or *endodermis*, a single layer of cells with yellow walls, yellow contents and no intercellular spaces. Internal to this is the layer called the *pericycle*, two* cells in thickness, the cells being rounded, with thin cellulose walls enclosing protoplasm with starch, and for this reason sometimes called the *starch-sheath*. (Fig. 70. peri.)

Internal to this is the *phloem* or *bast* consisting of—

(*a*) Sieve-tubes which in transverse section appear polygonal and in longitudinal sections are seen to have sieve plates arranged along their side walls. The tubes are lined with a thin layer of granular protoplasm. (Fig. 70. S.)

(*b*) The bast-parenchyma composed of thin walled cells rich in protoplasmic contents.

In the centre of the bundle is the xylem (Gr. *xylon*, *wood*) or wood, consisting of (*a*) starch-containing cells, the *wood parenchyna*, and (*b*) *tracheids* which in transverse section at once catch the eye as large oval or polygonal spaces from which the protoplasm has completely disappeared. In longitudinal section they are seen to be wide empty tubes, their walls are lignified and have transverse markings like the rungs of a ladder owing to the walls being unequally thickened. For this reason they are called *scalariform tracheids*. (Lat. *scala*, a ladder). (See page 177.)

They fit against one another by their obliquely bevelled ends. As a rule these ends are not actually perforated in Ferns, and so they are tracheids. Should they be perforat-

---

* In some Ferns only one.

ed and a communication be formed between two cells, this constitutes a true *vessel* or fusion of tracheids. At one or

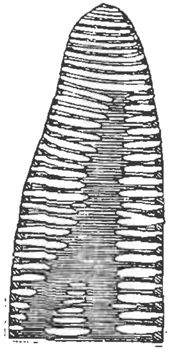


Fig. 71.
Portion of a Scalariform Tracheid.

two spots may be seen spirally thickened tracheids which as they were the first formed, are known as the ***protoxylem*** (Greek for "primitive or first wood.")

The arrangement of the sclerenchyma and of the vascular bundles varies much in the Fern family. The arrangement above described is that common in Ferns with erect or ascending stems. In climbing stems there may be several narrow black strands of sclerenchyma. In ***Pteris***, well described in many English text-books, in addition to the peripheral, there is an incomplete large brown ring of sclerenchyma half-way to the centre of the stem enclosing two or three large central steles. In Davallia there is no sclerenchyma: of the bundles which form a ring, one on the upper surface and another on the lower, are much larger than the rest.

In the very young stems of most Ferns there is a single central stele, a condition which persists in the *Hymenophyllaceae*.

Clear away from the apex of a stem the leaf-stalks and young leaves, carefully pick away with forceps as many as ed and a communication be formed between two cells, this constitutes a true *vessel* or fusion of tracheids. At one or

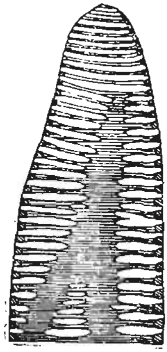


Fig. 71.
Portion of a Scalariform Tracheid.

two spots may be seen spirally thickened tracheids which as they were the first formed, are known as the *protoxylem* (Greek for "primitive or first wood.")

The arrangement of the sclerenchyma and of the vascular bundles varies much in the Fern family. The arrangement above described is that common in Ferns with erect or ascending stems. In climbing stems there may be several narrow black strands of sclerenchyma. In ***Pteris***, well described in many English text-books, in addition to the peripheral, there is an incomplete large brown ring of sclerenchyma half-way to the centre of the stem enclosing two or three large central steles. In Davallia there is no sclerenchyma: of the bundles which form a ring, one on the upper surface and another on the lower, are much larger than the rest.

In the very young stems of most Ferns there is a single central stele, a condition which persists in the *Hymenophyllaceae*.

Clear away from the apex of a stem the leaf-stalks and young leaves, carefully pick away with forceps as many as

Internal to this is the *endodermis*, a single layer of narrow cells enclosing a pericycle of two layers of thin-walled cells containing protoplasm.

In the centre we find the vascular bundles. In all roots, not only of the Fern phylum but of the flowering plants also, we find the xylem and phloëm groups alternating with one another in contrast to their arrangement in the stem. In the Fern we find two groups of xylem opposite one another, the largest tracheids being those nearest the centre.

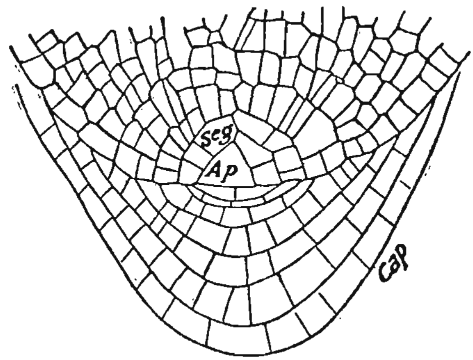


Fig. 74.
Growing point of Fern root.
Ap=apical cell ; Seg=segmental cell.

Two groups of phloëm consisting chiefly of sieve-tubes like those of the stem alternate with the strands of xylem instead of the concentric arrangement seen in the stem.

In the endodermis, at opposite points in the same diameter as the xylem strands, may be seen one or two cells larger than the rest ; these are the *root-forming cells* from which the young lateral rootlets develop.

THE ROOT APEX.

Examine the apex of the root and observe it is covered with a root-cap. (Cap. Fig. 74.)

Imbed in paraffin the apex of a root that has been fixed in alcohol, cut thin median longitudinal sections, mount in glycerine. One or two of these sections, which have passed through the exact anatomical apex will show a large tetrahedral *apical cell* looking triangular in section with its apex directed toward the older part of the root. Around this are the segmental cells that have been successively cut off to form the apical meristem, like that of the stem with the important difference that cells are not only cut off from the sides of the pyramid to form the body of the root, but also from its base to form the root-cap. The function of the root-cap is to protect the delicate growing point. As it bores through the soil the outer cells are constantly being rubbed off and replaced by the new cells cut off from the base of the apical cell.

A good general idea of a root-cap can be obtained from the large caps on the aerial roots of the Screw Pine.

THE LEAF.

Several steles run as "leaf-traces" from the stem to the rachis whence lateral ones run out to each pinna and there break up to form the characteristic forked veins.

To see their minute structure cut several narrow strips about 3 or 4 m.m. wide from pinnae free from sori. Sections should be made from both fresh tissue and that pre served in alcohol which not only fixes the protoplasm but dissolves out the chlorophyll. Place several of these strips together like the leaves of a book for mutual support, place in a slit in a piece of carrot and cut sections both parallel to and at right angles to the long axis of the leaflet. Mount some of the thinnest sections directly in glycerine and others after treating with iodine.

Hold a fresh piece of a pinna with the thumb and middle finger over the index of your left hand and peel off the epidermis from both the upper and lower surfaces. A very small piece will suffice. Mount in water and examine with your high power.

Note that the epidermis of the upper surface is composed of a large number of cells of very irregular outline placed close in contact with one another like the pieces of a jig-saw puzzle. They contain a few chlorophyll bodies in their otherwise colourless protoplasm. There are no intercellular spaces between them. The outer surface of the epidermal cells forms a thin waterproof *cuticle*. The epidermis of the lower surface resembles that of the upper except that we find a number of *stomata* (Gr. stoma, a mouth or opening.) Each stoma is an opening on the surface of the leaf allowing air to communicate with the intercellular air-spaces of the tissues. Each is bounded by a pair of kidney-shaped guard-cells with their concavities facing one another.

The guard-cells present a marked contrast to the other cells of the epidermis not only by their size and shape but also in color as they contain many more chloroplasts. The size of the stoma is regulated by the turgidity of these guard cells. If the plant be abundantly supplied with water the cells become turgid, the stoma is enlarged and watery vapor is freely transpired. If on the other hand the supply of water be lessened the guard cells become flaccid and their free concave margins approach one another and close

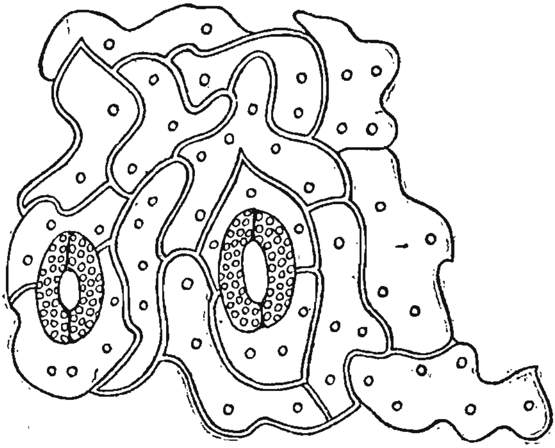


Fig. 75.
Epidermis of Fern leaf showing two stomata.

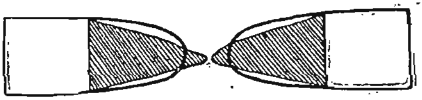


Fig. 76.

the stoma. This regulation of the size of the stoma can be understood by the help of diagram, Fig. 76, in which the shaded portion represents the flaccid cells almost closing the stoma, while the thick dark line represents the same cells in their turgid condition leaving a wide space between them.

In the sections note that the space between the upper and lower epidermis is occupied by *mesophyll,* here and there traversed by vascular bundles. The cells of the mesophyll are thin-walled and contain many chloroplasts; those near the upper surface have small intercellular spaces; those near the under surface are more irregular in shape and separated by large intercellular spaces.

Note that the Ferns being older and more primitive than the flowering plants, we do not find so great differentiation in the structure of the leaves. For example the differentiation into spongy and palisade layers of the mesophyll is not well marked, the epidermal cells have not yet lost all their chlorophyll, and the vascular tissue instead of true vessels contains tracheids. Each leaf is green and usually bears spores, fulfilling both vegetative and reproductive functions, which in the higher flowering plants are carried out separately on specially modified leaves, the foliage leaves and the sporophylls.

Examine a sorus with a low power and note that it is composed of a large number of sporangia covered by the *indusium,* a sheet of epidermal cells. In some Ferns, such as Pteris and the Maiden Hair, instead of an indusium, the sori are protected by the margin of the leaf folding over them. In Polypodium and others the indusium is absent and the sori naked. Scrape off some sporangia and mount in water. Each is composed of a stalk and a hollow capsule shaped like a bi-convex lens. The brown cells of which the capsule is formed are thin and membranous except round the margin where they are peculiarly thickened and form the *annulus* or *ring*. The inner and the contiguous portion of the lateral walls of the cells forming the ring

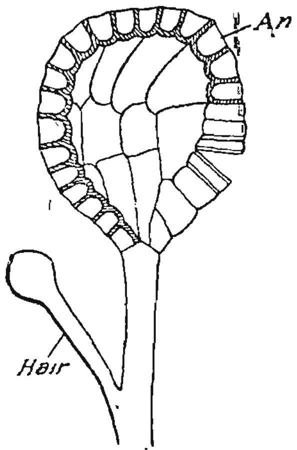


Fig. 77.
Sporangium of Aspidium. An = annulus.

are dark brown and greatly thickened while the free outer portion is thin and yellow. In dry weather the annulus loses its moisture and straightens out, thus rupturing the capsule and discharging its contents, the *spores*. This rupture can be seen by placing some ripe sporangia on a slide and gently heating it over a lamp. Rapidly place it on the microscope and you will see the process take place. The same result can be gained by mounting in glycerine which will extract the water from the annulus. Examine the spores with a high power. Each is composed of a single cell enclosed in a double cell-wall. The outer wall is cutinised and marked by an irregular net-work of raised rough lines.

KARYOKINESIS.

Although he has not yet sufficient knowledge of microscopical technique to verify the facts for himself, it is now necessary for the student to learn something about the method of nuclear division already frequently referred to as *karyokinesis* (Gr. *karyon*, a nut or nucleus ; *kinesis*, movement) or *mitosis* (Gr. *mitos*, a thread).

The essential part of the phenomenon is that shortly before dividing to form two daughter-nuclei, the substance of the nucleus called *chromatin*, (Gr. *chroma*, color) from the fact that it stains deeply with certain dyes, arranges itself in loops or rods called *chromosomes*, (Gr. *soma*, body.) The number of these chromosomes may be as few as two or as many as over two hundred, but is always constant in any one species of animal or plant.

In the ordinary process of division each chromosome splits longitudinally into two halves. The halves of each chromosome separate from one another and move, or are drawn, to opposite poles of the mother-nucleus to form the two new *daughter nuclei.* Thus each new cell possesses not only the same number of chromosomes in its nucleus, but the same quality of chromosomes, as it has a half of each chromosome of the mother cell, and it is reasonable to believe that each daughter chromosome possesses the same functions and attributes—whatever they may be—as its parent.

A striking modification of this process takes place during the formation of the reproductive cells such as the gametes of animals—spermatozoa and ova,—and the spores of the higher plants—Mosses, Ferns and Flowering Plants.

For instance in the spore-mother-cells of the Fern after certain manœuvres, half of the chromosomes without splitting go to one pole, the other half go to the opposite pole of the mother-nucleus and there form the daughter-nuclei, which have now *only half as many chromosomes as the spore-mother-cells and all the body cells of the sporophyte plant.* The chromosomes of the daughter-cells at once split into longitudinal halves, half of each going to form the nucleus of the grand-daughter cells which are the spores.

The result of this, hence called, "reducing division" is that the spores of Ferns, also of Flowering plants, that is to say, of pollen-grains and embryo-sacs, of the spermatozoa and of the mature ova of animals contain only half the number of chromosomes found in the "vegetative" or body cells of their parent. Only by the conjugation of the gametes or sexual cells is the original double number restored. In the case of animals this takes place at once, as the mature ova and the spermatozoa do not develope further unless they meet and conjugate. In their case the sperm and ovum are the only cells which (except in cases of disease) contain the reduced number of chromosomes.

In the Moss, Fern, and Flowering plant the spore divides to form the cells of the prothallus. It cannot increase the number of its chromosomes so that *all the cells of the gametophyte contain only half the number of chromosomes found in the cells of the sporophyte.* There is no need therefore for a reduction division in the formation of the pro-nuclei of the spermatozoids and ova of the Fern. As a result of the conjugation of these two gametes the number of chromosomes in the zygote nucleus is doubled, and this double number remains constant throughout all the cells of the embryo and adult sporophyte till in the formation of the spores a reducing division again takes place.

ALTERNATION OF GENERATIONS.

In our review of the life-history of the Fern we have seen that it passes through two generations, a sexual and an asexual, which occur in regular alternation. Twice in its life-history does it pass through a unicellular stage. The asexual generation—"the Fern plant" as popularly recognised, gives rise to asexual spores, and is hence called the *sporophyte* (Gr. *phyton*, a plant), which in turn give rise, not directly to a large sporophyte, but to the little prothallus, or sexual generation which, from the fact that it bears the gametes, is known as the *gametophyte*. The fertilised ovum or zygote gives rise in turn to the sporophyte. The number of chromosomes in the cell-nuclei of the sporophyte is double that in the nuclei of the gametophyte, the reduction taking place in the division of the spore-mother-cells. By the fusion of the gamete nuclei the double number is restored in the zygote.

This regular alternation of a sexual with an asexual generation is characteristic of all the higher plants, though owing to the diminution in size of the gametophyte phase in the higher Flowering plants it can only be recognised by the aid of the microscope.

THE COCKROACH.

Place before you a Cockroach and a Mosquito and compare them with Palinurus. You will notice that the bodies of all three are bilaterally symmetrical and divided from in front backwards into distinct segments or metameres, some of which bear a pair of appendages composed of distinct segments united by movable joints. These three external charactertistics unite all three animals in the sub-kingdom or Phylum, *Arthropoda.* *

Palinurus possesses two pairs of antennæ, and several appendages of the biramous type and breathes by gills. These are the characteristics of the class, *Crustacea.* The Cockroach and Mosquito on the other hand possess only one pair of antennæ, their walking legs are six in number and never biramous, they breathe by means of tracheæ and their body is made up of three readily distinguished regions, head, thorax and abdomen. They also, as a rule, possess wings. These are the general characteristics of the class, *Insecta.* †

About a thousand species of Cockroach have been described. Of these at least half a dozen have attached themselves specially to the dwellings of man and so usurped the

---

* Gr. *arthros*, joint ; *pous-podos* foot.

† Latin, *Insectus*, cut into : from the body being partite into head, thorax and abdomen.

title, "Domestic". The Cockroach rivals the Englishman in his travelling and colonising propensities so that a species that is common in a certain city or country to-day may in a few years be outnumbered by a new immigrant. It is said that England was free from the domestic Cockroaches till the reign of Elizabeth when *Stylopyga orientalis*, a native of India, invaded and colonised Europe. A little later *Periplaneta americana* arrived in the ships of Sir Francis Drake and others from America. Of late there has been a German invasion of England by a third species, *Phyllodromia germanica*.

In Bombay City we have all three of these insects firmly settled in much larger numbers than in any English city. Perhaps the most common is *P. Americana*. There is also a large Australian and three or four smaller species in the city, while in the jungle may be found a really handsome Cockroach, the piebald *Corydia*, with black velvety wing-cases marked with orange or white spots, the terga and under surface being of a bright orange color.

As either the American or Oriental Cockroach can be readily obtained and are of a large size for dissection the following description will deal with these species.

Cockroaches, like most thieves, are nocturnal in their habits, hiding in the day time and sallying forth at night in search of food. They are almost omnivorous, nothing animal or vegetable, even boots, saddlery and books comes amiss to their crop. They are often erroneously called "Black

Beetles" by lower class Europeans, but they are not black, and they are not beetles. Beetles belong to quite another order of Insects and can be readily distinguished as their wing-covers do not over-lap like those of the Cockroach, but when folded their inner edges meet accurately together in the middle line. In their development Beetles pass through a grub or larva and a pupa stage which the Cockroach order, Orthoptera, does not do.

Catch some Cockroaches and place them in a large glass vessel with some food to watch their movements and manner of feeding. Note how he uses his long feelers or antennae and also the palps of the maxillae to examine the surface over which he moves. Watch him eating and notice how the mandibles and maxillae work to and from the middle line like those of Palinurus and not up and down like the jaws of a Rabbit or Frog.

Observe the movements of the abdomen, how it is alternately expanded and contracted from above downwards. These are the movements of respiration by which air is alternately drawn in and expelled through ten pairs of openings known as stigmata, on the sides of the thorax and abdomen.

To kill the Cockroach pour a few drops of chloroform, petrol or benzol on it.

Observe that the body is covered with a cuticle which in definite situations is hardened into sclerites like those of Palinurus except that they are not calcified. In the abdomen we can count ten metameres, each of which is covered dorsally by a *tergum* and ventrally by a *sternum*, which overlap one another from before backwards like the tiles of a roof. Between each of these sclerites the cuticle is soft and allows of considerable movement in the dorso-ventral plane. Laterally between the edges of the terga and sterna the cuticle is soft and known as the *pleuron*. You will note that this is not homologous with the pleura of Palinurus where this name is given to the lateral margins of the terga.

On stretching the abdomen and bending it to one side you will be able to see the *stigmata* or respiratory openings in the pleura, eight on each side of the abdomen, two on the thorax, one behind, the other in front of the mesothorax.

Of the terga you will note that the last, the tenth, is prolonged backwards as a thin plate deeply notched behind. In the male *S. orientalis* all the terga can be seen without dissection, but in the female of this species and in both sexes of *P. Americana* the eighth and ninth are so telescoped forward as to be completely overlapped by the seventh. By pulling the tenth backwards with forceps the eighth and ninth can be seen. On lifting up the tenth tergum the anus can be seen, flanked on each side by a sclerite called a *podical plate*. Some biologists regard this pair of plates as homologous with the tergum of an eleventh segment. A pair of many-jointed styles or feelers, called the *cerci*, can be seen in both sexes projecting backwards from under the tenth tergum.

Of the sterna the first is rudimentary in both sexes. In the male nine are visible. To the posterior free margin of the ninth are attached a pair of slender unjointed, bristly *styles*, which are not found in the female. On cutting away the tenth tergum and the podical plates we expose the *gonapophyses*, a number of asymmetrical chitinous plates and hooks which represent processes of a tenth sternum and are used in copulation to hold and open the female genital aperture. You will note that the abdomen of the male is not so broad as that of the female.

In the female only seven sterna are visible externally, the posterior three being modified for sexual purposes and telescoped forward under cover of the seventh to form a genital pouch. The seventh is large and shaped like the bow of a boat, its posterior portion is split longitudinally into two thick chitinous halves united by a thin flexible membrane which allows them to separate during copulation and the laying of the egg-case. The latter is often carried about for a considerable time protruding from the genital pouch.

The eight and ninth somites are telescoped into the cavity of the seventh sternum, their terga are reduced to narrow bands ; the sternum of the eighth is a plate pierced by a vertical slit, the opening of the vagina ; the ninth is a small curved plate on which the spermotheca rests. Two pairs of gonapophyses, an anterior belonging to the eighth, a posterior bifid pair to the ninth somite, act as ovipositors and hold the egg capsule while it is being formed and hardened.

THE THORAX.

In all Insects the thorax is composed of three, and only three, segments, named from in front backwards, prothorax, mesothorax and metathorax. These are covered dorsally by terga called pronotum, mesonotum and metanotum respectively. Observe that the pronotum which in the Mosquito is scarcely recognisable, is the largest of the three terga in the Cockroach and overlaps the head in front, and the mesonotum behind. To the margins of the mesonotum are attached thewing-covers or first pair of wings, which are much firmer than the second pair to which they act as covers for their protection when at rest. The second pair of wings which are those with which the insect flies, are attached to the metanotum. They are thin and flexible membranes strengthened like the forewings by numerous radiating and cross "veins" or nervures which act as supports like the ribs of an umbrella. When not in use the wings are folded up fan-wise under the wing covers.

The student must remember that these veins or nervures are not homologous with the veins or nerves of the vertebrates. They originate as channels through which the blood circulates and usually contain a trachea and a stiff rod or "rib".

In the female *Stylopyga orientalis* the wings are rudimentary. In the young of both sexes in all species, they are absent and only appear at the last moult. The wings are not true appendages: they are outgrowths of the skin covered by cuticle and may be regarded as homologous with the thoracic pleura or gill-covers of Palinurus. This homology can be readily recognised in the rudimentary wing-covers of the female Oriental Cockroach which are obviously extensions of the tergal margin.

The thoracic sterna being covered by the proximal joints of the legs do not need to be large or stout. The prosternum is small; in the male the mesosternum is partly, in the female, completely divided into lateral halves; the metasternum is completely divided in both sexes. As in Palinurus we find an endoskeleton formed by certain apodemes or ingrowths of the cuticle, so in the insect we find homologous ingrowths known as the *forks*, or Latin, *furca*. In some insects such as the Ants, we get three well developed *furca*. In the Cockroach the anterior is rudimentary or absent. The middle and posterior are somewhat T or Y shaped, the central notch supporting the nerve cord while the long arms afford attachment to muscles. These should be isolated after the dissection is completed by boiling the skeleton in Liquor Potassae. In the pleura of each thoracic segment can be recognised two sclerites, a dorsal *epimeron*, and a ventral *episternum*.

There are three, and only three pairs of legs in all insects from which fact the class is sometimes called the Hexapoda (Greek, six legs). One pair is attached to each thoracic segment. Each leg is composed of a number of segments or podomeres united by moveable joints. The proximal is stout, muscular and flattened. It is called the *coxa* (Lat. hip). The second, very small, is called the *trochanter* (Gr. top of the thigh). The third, long and muscular, is called the *femur* (Lat. thigh).

The fourth, long, thin and covered with spines is called the *tibia* (Lat. the shin).

Lastly the foot or *tarsus* (Lat. sole) composed of six segments provided on their ventral aspect with whitish bristly pads to enable the insect to retain a foothold on slippery surfaces. The last or distal joint of the tarsus bears a pair of claws between which is a pad called the *pulvillus*.

The narrow neck connecting the head with the thorax is covered with flexible chitin strengthened by seven brown sclerites. One of these is dorsal and almost divided into two by a median groove, so that it is sometimes described as two sclerites. Two are ventral, narrow, transverse bands. On each side are two larger oblique sclerites.

THE HEAD.

While the metamerism of the abdomen and thorax is very obvious it is not so easily recognised in the head, as the exoskeleton is not divided into separate terga for each metamere of which it is composed. During the development of the embryo the segmentation is more evident so that most observers are agreed that the head is composed of at least six somites, namely,

1. One bearing the eyes, in front of the antennae.
2. The antennary somite.
3. A premandibular somite which disappears during embryonic life.
4. Mandibular somite.
5. First maxillary somite.
6. Second maxillary somite.

A large smooth sclerite, the *epicranium*, covers the nape and vertex of the head. It is marked into lateral halves by a median suture which, in front bifurcates like an inverted Y, each branch running downwards and outwards to a small white spot internal to the insertion of the antenna of its own side. The front of the head below this suture is known as the *clypeus*. To the lower margin of this is articulated a flap, the *labrum*, which forms the anterior wall of the mouth. Behind and below each eye is a sclerite known as the *gena* or cheek-piece, which passes downwards and covers the articulation of the mandible.

When the head is severed from the neck we find a large shield-shaped opening, the occipital foramen, bounded above and on each side by the epicranium which sends down processes with which the mandibles articulate. As in Palinurus we find certain *apodemes* forming an endoskeleton, by an ingrowing of the cuticle. From the lower margin of the occipital foramen one of these chitinous apodemes, the *tentorium*, grows in downwards and forwards, to form a ledge-like support for the brain.

Observe the large, black, somewhat kidney-shaped eyes one on each side of the head. They are compound eyes with numerous hexagonal facets and resemble in their essential structure the eyes of Palinurus. Owing to the hardness of the chitin in the Cockroach it is easier to make sections from the eye of some large moth to see the histological structure. Also observe the small white dots near the inner margin of the insertion of the antennae. These are called the *fenestrae* (Lat. windows). Their appearance is due to the overlying integument being transparent and allowing the white tissue below to be seen. It is doubtful what function they fulfil, but they are obviously homologous with the ocelli or simple eyes of many insects, as they are replaced by true ocelli in the jungle Cockroach, *Corydia.*

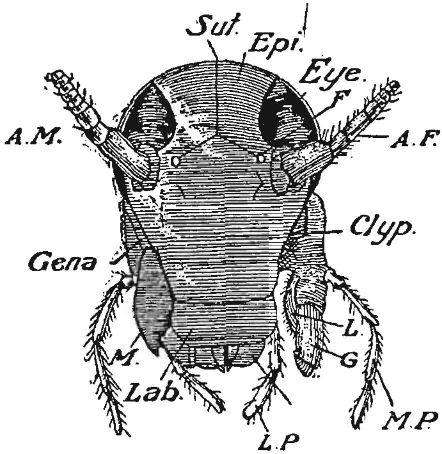


Fig. 78.

Head Seen from in front.

Sut = suture ; Epi = Epicranium ; M = Mandible ; G = galea ; L = lacinia ; Lab = labrum ; L P = labial palp ; M P = Maxillary palp ; A F = Antenna showing female characters; A M = Antenna of male type; F = fenestra.

The antennae are attached by flexible membranes to the margins of sockets bounded, externally by the eyes, above by the epicranium and below by the clypeus. They are composea of from seventy to ninety segments, their surface marked by numerous small forward-pointing bristles. They act as feelers or special organs of touch. Some observers regard them as organs of smell and hearing also.

Observe that while Palinurus and most Crustaceae pos sess two pairs of antennae, no insect as more than one pair.

In many insects the antennae show characteristic sexual differentiation. In the Cockroach this is not at first sight so obvious, yet a careful examination shows that they are usually longer in the male and that in the female the third joint from the base is about twice as long as that in the male. See *Fig. 78.*

Fix a Cockroach, back downwards, with pins passed through the sides of the pronotum; over-extend the head on the neck so that its posterior surface looks upwards; keep it in this position by crossed pins. Pass one blade of a fine pair of forceps in front of the labium and grasp the latter as close to its attachment as you can; gently pull off the entire labium with the forceps aided by a few touches of the knife; avoid injuring the lingua; if the cuticle of the ventral surface of the neck be peeled off with the labium, so much the better.

In the same manner remove the first maxillae and mandibles in successsion. They can be examined at once with a lens or may be preserved permanently in the following way.

Boil in solution of caustic potash to get rid of all muscle and other tissue except the chitin. Wash in water; mount in glycerine; ring with varnish. Or dry; or dehydrate with alcohol; pass through oil of cloves into Canada balsam. Mount the maxillae and labium under a cover-glass. Owing to their thickness and firmness the mandibles may be simply attached by balsam to the slide. The labrum, antennae, legs, gonapophyses, furca and any other sclerite may be mounted in the same way.

The mandibles are a pair of stout unjointed jaws bearing six or seven teeth on their inner opposable surfaces. They articulate with the clypeus and the lower end of the epicranium. You will note that, unlike Palinurus and most Crustacea, the mandibles of an insect never bear palps.

Both pairs of maxillæ are constructed on the biramous plan though the homology of the several parts with those of a crustacean appendage must not be taken for granted.

Each first maxilla consists of a two jointed protopodite bearing a bifid endopodite and an external palp or exopodite.

The proximal joint, the *cardo* (Lat. a hinge) is horizontal and at right angles to the distal *stipes* (Lat. stalk). The inner division of the endopodite is a sharp-pointed blade the *lacinia*, (Lat. a flap) bearing a number of stiff setæ on its inner margin. The outer, the *galea*, (Lat. helmet) is so called because it is hollowed at its distal end to form a cap which protects the point of the lacinia.

The exopodite is the five jointed maxillary palp.

The second maxillæ are formed of the same elements as the first, but the protopodites are united together in the middle line in all insects so as to form a *labium* or posterior lip.

The proximal joint, homologous with the cardines, is called the *sub-mentum*, the conjoined stipes, the *mentum*.*

---

* Lat. chin.

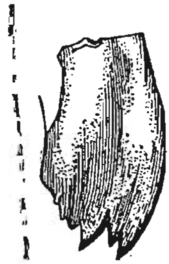


Fig. 79. Mandible.

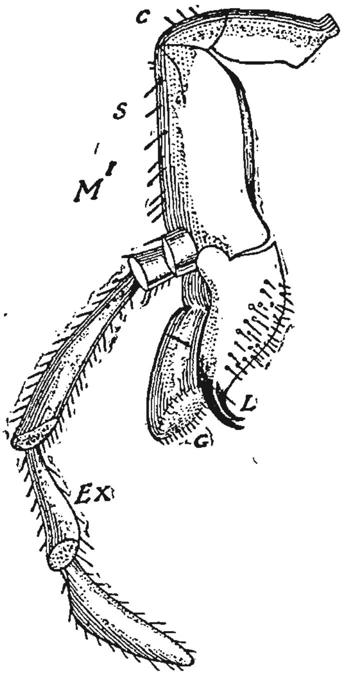


Fig. 80.

First Maxilla.

C=cardo; Ex=palp: G=galea;
L=lacinia ; S=stipes.

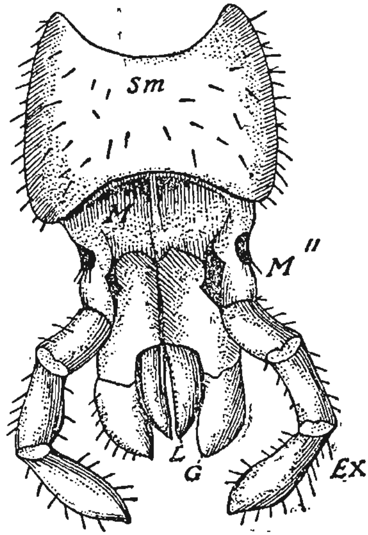


Fig. 81.
Labium.
Ex=palp ; G=paraglossa ; L.—lacinia ; M=mentum ; Sm=submentum.

The endopodite consists of an inner *lacinia*, and an outer *paraglossa* which is serially homologous with the galea.

The two endopodites taken together are sometimes called the *ligula*.† The exopodite has only three joints and is usually called the *labial palp* the projecting portion of the mentum to which it is attached is called the *palpiger*.

Before dissection of the internal organs the wings and legs should be cut off and the animal fixed, ventral surface downwards, to a cork sheet by passing pins through its lateral portions taking care to avoid injury to any important organ, or preferably by imbedding the ventral surface in melted wax or parafin. This is best done by pouring melted parafin which can be made dark by mixing some lamp black with it, into a shallow dish such as a porcelain ointment-pot. In this case the coxæ may be left attached so as to "root" the animal firmly. The central portion of the wax can then be melted by touching with a heated iron; then hold the insect in position in the melted wax till it sets. Cut the terga and nota close to each side, carefully remove the dorsal exoskeleton between your incisions, taking great care not to injure the underlying heart.

You have now exposed the body-cavity in which the viscera lie surrounded by the white *fat-body*. The insect's body-cavity like that of Palinurus and all Arthropods is not a cœlom but a hæmocoele‡ that is to say a blood-containing cavity in free communication with the open blood-vessels, so that all the internal organs are bathed in blood.

The heart can be seen pulsating in young Cockroaches, especially shortly after an ecdysis, before the cuticle has turn-

---

† Lat. a little tongue, a strap.

‡ See page 129.

ed dark and opaque. It lies close below the terga in the middle line and is exposed at once when the latter are raised. It lies in a *pericardium* the floor of which is formed by a thin perforated membrane to the sides of which are attached delicate triangular *alary* muscles arranged metamerically. The apices of these alary muscles are attached to the under surface of the terga. As the pericardial membrane is arched when at rest, the contraction of these muscles will flatten it and so increase the size of the pericardial space into which blood will therefore be drawn from the body cavity. The openings of the heart are provided with valves to prevent the return of the blood from the heart.

The heart is a long, narrow muscular tube formed of a series of thirteen funnel shaped chambers, one for each thoracic and abdominal somite. The apex of each chamber opens into the base of the one in front of it. There is a valvular opening or *ostium* on each side of the base of each chamber which allows the blood to enter from the pericardium but closes during the systole, so that the blood is driven from behind forward. The heart terminates in a narrow vessel on the dorsal surface of the œsophagus and gives off no lateral branches in any part of its course.

The fat-body is a branching mass of opaque white cells containing many small fat globules and urates or other excretory substances. It is abundantly supplied with tracheæ and fills the interstices of the body-cavity between the viscera.

Clean away with forceps, knife and scissors as much of the fat-body as you can. You will often in India find scattered in the fat-body numbers of translucent, oval, pearly bodies resembling the ova of the insect. These are parasitic worms *Echinorrhynchus moniliformis.* Draw the alimentary canal to one side and clear it of fat-body and tracheæ by teasing with sharp-edged needles. Take care not to damage the salivary glands in front, or the Malpighian tubules and the reproductive organs behind. The student need not try at his first attempt to find the testes or vasa deferentia.

The Alimentary canal of all insects is, like that of the Crustacea, remarkable for the length of both the stomodaeum and the proctodæum as compared with the mesenteron. See pages 118 and 151.

That of the Cockroach is divided into the following regions :—

Foregut or Stomodaeum	Buccal Cavity. Oesophagus. Crop. Gizzard or proventriculus.
Midgut or Mesenteron	Chylific Stomach.
Hindgut or Proctodaeum	Ileum. Colon. Rectum.

The stomodæum is lined throughout with chitin continuous with that of the external surface. We have already seen the mouth to be bounded in front by the labrum, behind by the labium and on each side by a mandible and first maxilla. The posterior wall of the buccal cavity is raised into a fold, the tongue or hypopharynx. The buccal cavity leads above into a narrow gullet or œsophagus, which passes between the anterior processes of the tentorium, through the nerve ring and occipital foramen into the neck and thorax where it gradually widens into a thin-walled capacious *crop* of an elongated pear shape. Behind this comes the thick-walled muscular gizzard of a pear-shape with its broad end toward the crop, its narrow end projecting like a funnel into the mesenteron. A transverse section of the gizzard shows its cuticle raised into six longitudinal ridges or teeth of a dark brown color. Between these main ridges are several smaller elevations. Behind these teeth are six cushions covered with bristles which act as a strainer to the food.

The mesenteron is a narrow and short tube, the only part of the canal lined by endodermic epithelium. The *hepatic caeca* are seven or eight diverticula of the anterior end of the mid-gut also lined by endodermal cells.

The proctodæum is the coiled hinder portion of the gut lined throughout by chitin. The opening into the mesenteron takes place at a very late period in the life of many insects; for instance in the larva of the Honey Bee we find the mesenteron for a long time terminates as a blind pouch. In this condition the hind-gut receives none of the food and can only act as the duct of the Malpighian tubes.

The anterior portion of the hind-gut is a short and narrow tube called the *ileum* (Lat. *gut*) into the commencement of which the Malpighian or excretory tubes open. The middle portion of the hind-gut is longer and wider and called the *colon*; a constriction at its posterior end marks it off from the *rectum*, the terminal portion of the gut which opens by the anus between the podical plates. Its wall is raised into six longitudinal ridges reminding us of the same conditions in Palinurus. Slit up the alimentary canal and note the teeth, pads and bristles of the gizzard, its projection into the mesenteron, like the neck of an unspillable ink-pot, the openings of the hepatic cæca and the chitinous ridges of the rectum.

The salivary glands of the Cockroach are very large. On each side they consist of two white lobes about 6 to 8 m.m. long, composed of numerous lobules united by ducts which join to form a main duct for each of the two lobes. These unite to form a single duct on each side which joins with its fellow below the sub-œsophageal ganglion into the common duct which opens on the floor of the mouth in the angle between the tongue and labium.

Between the lobes of the gland on each side are the salivary receptacles, two elongated sacs about 10 m.m. in length, each provided with a duct. These ducts unite first, with one another, and then with the common duct of the secretory portion of the glands. The glands and their receptacles lie along the sides of the œsophagus and crop as far as the first somite of the abdomen. They must be carefully dissected free of all fat-body from which they can be distinguished by their being more translucent than the opaque white fat-body.

The glands should be removed entire, fixed in picric acid, stained with carmine and mounted in balsam. The ducts resemble tracheae in the spiral thickening of their chitinous lining.

The Malpighian tubules are organs for the excretion of nitrogenous waste in Insects. In the Cockroach they are very numerous, about sixty to eighty, so fine as to be just visible to the naked eye. They are usually of a yellowish

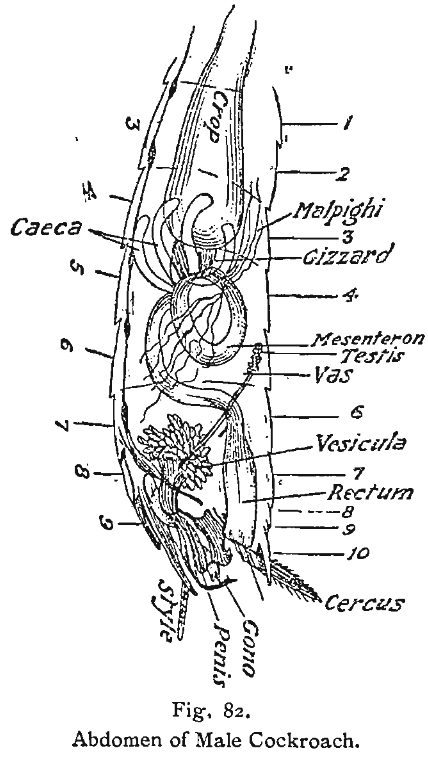


Fig. 82.
Abdomen of Male Cockroach.

green color, about an inch in length and extend throughout the whole of the fat-body of the abdomen. They originate as diverticula of the proctodæum, into the anterior end of which they open.

MALE REPRODUCTIVE ORGANS.

A young male should be selected and the testes sought for in the fat-body just below the fifth tergum of the abdomen. They are a pair of elongated glands, composed of a number of minute pearly vesicles attached to the *vas deferens.* They are difficult to find owing to their small size and their being imbedded in the fat-body from which they can however be distinguished by their greater translucence and the pearly color of the vesicles. They soon atrophy in the adult and it is then impossible to find them. The *vasa deferentia* are extremely fine tubes—finer than those of Perichaeta—which run backwards and downwards to enter the *vesiculæ seminales.* These are simple oval sacs in the nymph, but they develop a large number of caeca so that in the adult the two vesiculæ together form a large snow-white tuft of a mushroom shape. The short stalk of this mushroom is the muscular *ejaculatory duct* which opens just below the anus and does not traverse the organ commonly called the *penis* which is imperforate.

Ventral to and usually to the left of the ejaculatory duct is a gland of unknown function, called either the *accessory* or *conglobate* gland. It is composed of a number of beaded tubes lined with epithelium which branch dichotomously and are enclosed in a common capsule to form a club-shaped mass. Its duct opens on one of the gonapophyses, shaped somewhat like a hunting spur.

The gonapophyses should be isolated and cleaned by boiling with caustic potash. They are asymmetrical. A long hook terminated like a crochet needle lies to the left, next to it is the imperforate *penis*, shaped somewhat like the human organ of that name, then several weird plates and hooks of different shapes.

FEMALE REPRODUCTIVE ORGANS.

Each of the two ovaries consists of eight tapering tubules which open into an oviduct. Each tube is about ten millimeters long and beaded in appearance owing to the ova in different stages which distend it. The distal ova—those nearest to the oviduct—are the largest, those at the tapering end, the smallest. The smaller ova show a distinct nucleus and contain little or no yolk. As they enlarge and pass down the tubes yolk gradually accumulates till the egg becomes so granular that the nucleus cannot be seen. The tapering ends of the tubes unite into a slender thread which passes upward and forward to anchor the ovaries in the fat-body.

The oviducts are short and unite to open by a short *vagina* on the eighth sternum into the genital pouch.

Behind the point of union of the oviducts is the *spermatheca*, a small flask-shaped sac with a coiled diverticulum given off from its duct which opens in the median line of the ninth sternum. To find this sac trace the nerve cord backwards and you will find it close behind the last ganglion.

Two much-branched *colleterial* * or cement glands of a dead-white color open behind the spermatheca by separate ducts close to the middle line. They secrete the substance of which the egg-case is formed. The left is usually larger than the right.

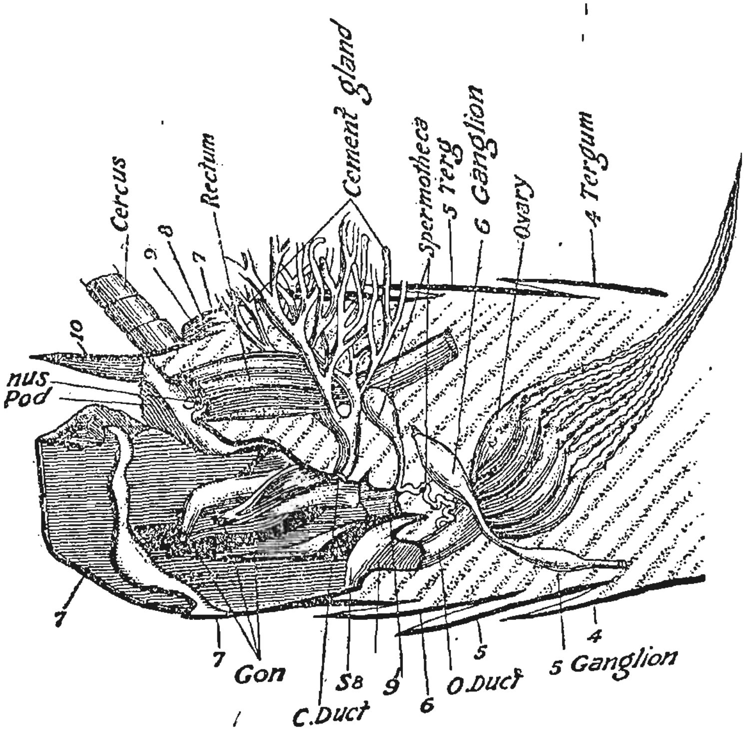


Fig. 83.
Reproductive Organs of Female Cockroach. (After Marshall and Hurst.)

* Greek, *kolle*, glue, cement.

NERVOUS SYSTEM.

The nervous system of insects is on the same metameric plan of paired ganglia for each somite united by double connectives, that we have seen in the Earthworm and Palinurus, but as in the latter, the plan is in parts obscured by coalescence of the ganglia. In the head we find the œsophagus surrounded by a thick irregular nerve-ring. To expose this, fix the head, anterior surface upwards, by passing a pin through the upper part of the epicranium and another between the mandibles. Cut away the clypeus and the front of the epicranium with the point of a knife. Afterwards turn the head on one side and remove the gena, the mandible and part of the maxillæ.

A longitudinal median section should also be made with a razor through an insect well hardened in alcohol to see the relations of the parts.

The brain or supra-œsophagal ganglia, consists of a pair of two-lobed masses. Of these the upper lobe is called the *optic* and gives off an optic nerve to the eye. The lower or *antennary* lobes give off nerves to the antennæ; from their lower portion close to the connectives a nerve is given on each side to the labrum. From this, with other evidence we conclude that the brain represents three paired ganglia from three somites, optic, antennary and the lost premandibular somite which was evident in the embryo.

The para-œsophageal connectives are two thick strands of nerve tissue which pass one on each side of the œsophagus from the brain to the sub-œsophageal ganglia and so complete the circumœsophageal nerve ring. The sub-œsophageal ganglia, as that name implies, lie between the œsophagus and the sub-mentum. They are large and give nerves to the three post-oral metameres, the mandibles and both pairs of maxillæ, representing the coalesced ganglia of three somites. Posteriorly they give off connectives to the thoracic ganglia.

After dissecting the reproductive organs and the alimentary canal, the latter should be drawn aside and the remaining fat-body and the muscles of the thorax removed to expose the ventral nerve chain which lies close above the sterna in the mid line. It is accompanied by a pair of tracheæ, one on each side, which the student must not mistake for the nerve chain itself, which is not of so silvery white a color.

The connectives lie close together touching one another. In the male the abdominal connectives are not straight, but a little wavy in their course to allow of stretching of the abdomen. There is a pair of ganglia in each thoracic segment. In the abdomen we find six pairs, recognised as dull-white spots on the more translucent connective cord. The last pair lies above the seventh sternum and supplies all the somites posterior to it.

There is also a *visceral* system of nerves. From the front of each para-œsophageal connective a nerve is given off which after giving a branch to the labrum runs forwards and inwards to meet its fellow of the opposite side in the middle line and form a *frontal ganglion* on the anterior wall of the œsophagus. From the frontal ganglion a *recurrent nerve* passes back through the nerve ring along the dorsal wall of the œsophagus and crop for about 8 m.m. beyond the ring, where it forms another ganglion from which two branches are given off to run backwards on the gut. Immediately beyond the nerve ring two pairs of ganglia are seen in connection with the recurrent nerve; to them from in front comes a nerve on each side from the posterior surface of the brain.

RESPIRATORY ORGANS.

We have seen the stigmata, openings into the tracheæ which in the course of our dissections we have found to ramify throughout all the organs and tissues of the body. In many animals such as the Vertebrates we have special organs, lungs or gills, for the taking in of oxygen and the giving out of carbonic acid from the blood; hence these animals require an elaborate system of blood vessels to carry the oxygen to distant parts of the body. In Insects as the oxygen is carried in the tracheæ directly to all the tissues a complicated circulatory system would be superfluous. The various branches of the tracheæ repeatedly anastomose with one another, so that if one or more stigmata should become blocked the tracheæ supplied by them can still carry on their functions.

The tracheæ originate as ingrowths of the epiblast, so its epithelial cells secrete a chitinous lining for the tubes.

This chitin forms a spiral thickening which is elastic and keeps the tube from collapsing.

Examine a trachea in water with the microscope and note the spiral thickening ; note the silvery white color of the trachea by reflected light when the diaphragm of the microscope is closed.

REPRODUCTION.

After copulation the semen is stored in the spermatheca. The eggs are about 5 m.m. long and each has a tough brownish shell ornamented with small hexagonal tubercles, and perforated with small holes or micropyles. As the eggs are passed out of the vagina into the genital pouch they are met by the spermatozoa from the spermatheca which enter the micropyles and fertilise the eggs. The eggs are laid sixteen at a time and are held together by the gonapophyses while the secretion of the colleterial glands forms a capsule round them. The capsule resembles a miniature cigar-case and is at first pale, but with exposure to the air soon turns to a dark mahogany color. The female usually carries the egg case protruding from the genital pouch for about a week before depositing it.

It is said that the eggs do not hatch out for about a year in Northern Europe, but in India we have seen the young leave the egg within a month of the capsule being laid. The young "nymphs" are at first white excepting their large black eyes, but they very soon become brown. They resemble the adult in external form except that in neither sex have they any wings. They moult about seven times in their life-time. European observers say the Oriental Cockroach takes about four years to reach its adult condition. Rapidity of development in most insects depends largely on temperature, being retarded by cold, accelerated by warmth.

INDEX GLOSSARY.

Abbreviations. Gr. = Greek, Lat. = Latin. pl. = Plural.

Pronounce ĕ. short, as in "—bet." œ. and ē. long, as in " teeth."

ĭ. short, as in "hit" ī. long, either as in "light," or as ee in "queen."

ŏ. short, as in "hot." ō. long, as in "hole." ŭ short, as in "hut." ū, long, as in "rude."

In Greek words, I have written "u" as "y," "gg. etc," as "ng. etc." to simplify matters for Indian students.

Abdōmen. (Lat. belly). Cockroach. 233, Mosquito. 149, 165. Palinurus. 92.

Aberrant. (Lat. *aberrans*, wandering from, deviating). Varying from the normal type.

Abīogenesis. (Gr. *a*, not ; *bios*, life ; *genesis*, origin, development). The doctrine formerly held that organisms could arise from non-living matter, "spontaneous generation." 6.

Abortive. (Lat. *abortus*, miscarriage, born prematurely). A term to indicate an organ is poorly developed. 149.

Aelosōma. A primitive species of Oligochaete. 79.

Alĕcithal. (Gr. *a*, without ; *lekithos*, yolk). Yolk-less. Applied to eggs that contain little yolk.

Alga. (Lat. Sea-weed). The phylum of plants, whose body is a permanent thallus, containing chloro pasts.

Alternation of Generations, 42, 214.

Amœba. (Gr. *amoibos*, changing). 1.

Anal spot 15.

Anabŏlism. (Gr. *anabole*, anything built up or thrown up). Constructive metabolism. 7.

Anastŏmōsis. (Gr. *anastomoo*, to open into). Inosculating or uniting and opening into one another like arteries and veins. 167.

Andrœcium. (Gr. *aner*, *andros*, man, male ; *oikos*, house : "the men's house"). The collective name for the male sporophylls in a flower. 183.

Hermaphrodite. (Gr. *hermes* and *aphrodite*, the god Mercury and goddess Venus, famed for their sexual vigor, hence organisms that possess both male and female gonads. Monoecious. 54, 58.

Histŏlogy. (Gr. *histion*, a tissue or web; *logos*, science). Minute or microscopic anatomy.

Holoblastic. (Gr. *hŏlos*, whole, complete; *blastē*, reproduction). A term applied to an egg, when segmentation affects the whole ovum. See Meroblastic. 129.

Holophytic. (Gr. *phyton*, plant). A term applied to the method of nutrition of the higher plants. Wholly vegetal nutrition. 27.

Holozŏic. (Gr. *zŏŏn*, animal). "Wholly animal;" a term applied to the method of nutrition of animals, requiring ready-made proteid as food.

Hōmōlĕcīthăl. (Gr. *hŏmos*, same, common; *lĕkithon*, yolk). A term applied to ova in which the yolk is evenly distributed.

Hōmŏlŏgous. (Gr. *homologos*, agreeing with). Arising from the same embryonic structure, of common origin, constructed on the same plan, though not necessarily performing the same function, *e.g.*, the wing of a bird, the arm of man and fore limb of a horse are all homologous.

Host. An organism upon which another is parasitic.

Hyaline. (Gr. *hyalinos*, transparent, glassy). Clear, free from granules.

Hydra. (Gr. A mythical serpent with many heads). 44.

Hypertrŏphy. (Gr. *hyper*, above-indicating excess; *trŏphe*, nourishment). An excessive increase in size.

Hypha. (Gr. *hyphaino*, to weave). A fungus filament. 38.

Hypoblast. (Gr. *hypo*, under, lower; *blaste*, developing tissue). The inner layer of the gastrula. 69, 117, 130.

Hypoderma. Hypŏdermis. (Gr. *hypo*, below; *derma*, the skin). In plants the layer of cells below the epidermis. 179. This term is uselessly and stupidly applied by Entomologists to the epidermis of Insects. Formerly the cuticle was mistaken for the epidermis.

Hypopharynx. The tongue in insects. 143.

Hypostōme. (Gr. *stoma*, mouth). That portion of a Hydra-like animal above the insertion of the tentacles and below the mouth. 45.

Imăgo. The winged adult stage of Insects. 171.

Indūsium. (Lat. a lady's under-garment). The membrane covering, a sorus, 210.

Printed by E. G. Pearson at the Times Press, Bombay, and published by Bennett, Coleman & Co., Ld., Bombay—5381'13.