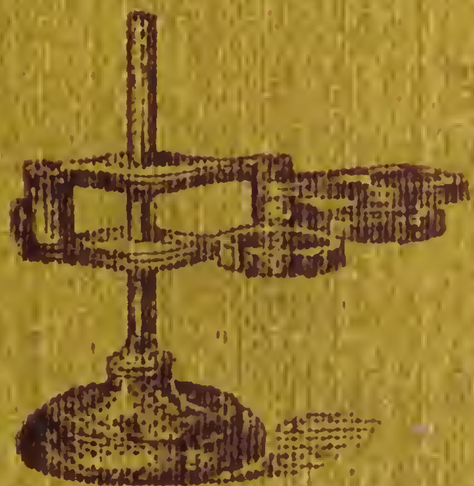
Through a Pocket Lens



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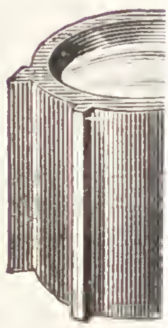

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LIMNOBIA REPLICATA

From enlarged photographs, made at the Yorkshire College, Leeds, from specimens bred by the Author, and mounted by Messrs. Watson & Son, High Holborn, London

THROUGH
A POCKET LENS

BY

HENRY SCHERREN, F.Z.S.

AUTHOR OF

'PONDS AND ROCK POOLS,' 'A POPULAR HISTORY OF ANIMALS,' ETC.

WITH NINETY ILLUSTRATIONS

THE RELIGIOUS TRACT SOCIETY

56 PATERNOSTER ROW AND 65 ST. PAUL'S CHURCHYARD

1897

Oxford
HORACE HART, PRINTER TO THE UNIVERSITY

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THROUGH A POCKET LENS

CHAPTER I

THE POCKET LENS, THE DISSECTING MICROSCOPE, AND SOME SIMPLE APPLIANCES

THE object of this little book is to show how much may be seen with an ordinary pocket lens, and with a simple microscope; and, as far as possible, to dispel the idea, far too common, especially among beginners, that no real work can be done unless one has a compound microscope, with a large battery of lenses and an array of 'accessories.'

It would be easy to multiply quotations, from high authorities, in support of the proposition implied in the foregoing paragraph. Two only must suffice.

In a recent review of a very good book dealing with Butterflies and Moths (*Natural Science*, vol. vi. p. 293), the following passage occurs: 'The only suggestion we should like to make is that a compound microscope is unnecessary for any of the details that the author mentions. A first-rate platyscopic hand lens is much more convenient and the young naturalist should train himself thoroughly in the use of it. There is no more common error than the undue use of the higher powers of a microscope. Except for the intimate details of histology, a low power or a hand lens is much more easy to use, and its employment gives a much better idea of the structure.'

The next quotation is of greater interest, as it gives some insight into the way in which Darwin carried on his investigations. In the *Life and Letters of Charles Darwin* (vol. i. pp. 145, 146) we are told: 'His natural tendency was to use simple methods and few instruments. The use of the compound microscope has much increased since his youth, and this at the expense of the simple one. It strikes us nowadays as extraordinary that he should have had no compound microscope when he went his Beagle voyage; but in this he followed the advice of Robert Brown, who was an authority in such matters. He always had a great liking for the simple microscope, and maintained that nowadays it was too much neglected, and that one ought always to see as much as possible with the simple before taking to the compound microscope. In one of his letters he speaks on this point, and remarks that he always suspects the work of a man who never uses the simple microscope.'

It may be well here to verify the quotations, and also to consult Darwin's *Naturalist's Voyage*, to ascertain what kind of objects he examined with the simple appliances at his command. In the first chapter there is an interesting account of a curious limy deposit on the rocks of the island of St. Paul's, and of the discoloration by confervae of the water, which, 'under a weak lens, seemed as if covered by chopped bits of hay, with their ends jagged.'

Then we have an account of the confervae in the Indian Ocean, and of infusoria so numerous as to tinge the water off the coast of Chile. In the second chapter we have observations and experiments on planarian worms. 'Having cut one of them transversely into two nearly equal parts, in the course of a fortnight both had the shape of perfect animals.' In the next chapter he records some observations on the structure of vitrified tubes formed by lightning striking loose sand. In the fifth chapter is an elaborate description of a kind of sea-pen; and in the ninth chapter there are some remarks on the vast number of eggs in the egg-ribbon of a sea-slug, and on the 'bird's-head' organs in certain Polyzoa. These remarks were, of course, founded on actual inspection with the simple microscope.

To this instrument, also, we owe the discovery of the tadpole-like larvae of Ascidians, or Tunicates, as they are now generally called. 'At the Falkland Islands I had the satisfaction of seeing, in April, 1833, and therefore some years before any other naturalist, the locomotive larvae of a compound ascidian. . . . The tail was about five times as long as the oblong head, and terminated in a very fine filament. It was, as sketched by me under a simple microscope, plainly divided by transverse opaque partitions, which I presume represent the great cells figured by Kovalevsky. At an early stage of development the tail was closely coiled round the head of the larva [1].'

We come now to our pocket lens, which may be purchased for a few shillings of any optician.

[1] Darwin, *Descent of Man* (2nd ed.), p. 159, note 23.

One can buy a serviceable single lens, in an ebonite handle, for a shilling; and this cheap instrument is sufficiently powerful not only to give the worker a good general idea of the form and structure of objects, but to enable him to do real work. With it the habits of many of the inmates of his aquaria may conveniently be watched; he may see their development from stage to stage of their life-history; and with it, when they are broken up, he may make out a good deal of their external and internal anatomy.

A very good form is shown at Fig. 1, which represents a hand magnifier, fitted with three lenses of different focus, generally 2 in., 1½ in., and 1 in. Examination of the catalogues of the principal London opticians shows that such a set of lenses may be bought for about 3*s*. In shape and construction there is sometimes a little variation; but the form figured is that most generally adopted, and is, on the whole, fairly convenient. It would, however, be an advantage if the hole by which the magnifier is mounted on the stand were drilled in the solid part of the handle. This would not only do away with the objection that the hole in the case permits dust to penetrate to the glasses, when carried in the pocket, but would give a longer reach, and thus obviate the necessity for moving the stand if the observer were examining a large object. The price of the stand figured is 2*s*. 6*d*.;

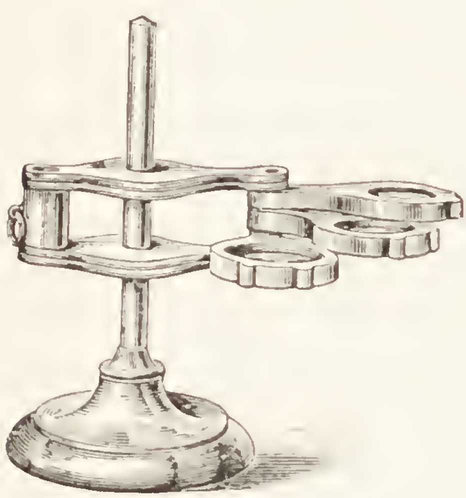


FIG. 1.—Hand Magnifier and Stand.

and one with a short adjusting arm ought not to cost much more.

Any one with a mechanical turn may make a stand for himself, though it may be doubted whether this is quite worth while when these articles may be bought so cheaply. Nevertheless, there is great pleasure in making things for oneself; and a home-made stand will enable the observer to do quite as good work as one that came from the optician's shop.

A bill-file weighted at the foot may be bought for a few pence, and adapted to the purpose. For the slider a large cork cleanly pierced will answer admirably. This should carry a piece of stout wire, bent at the end thus ⌴, to serve as a holder for the magnifier, which should have a hole in the handle, for the reasons stated above. The only difficulty will be the attachment of the wire to the cork. The Rev. J. G. Wood advocated winding the wire round the cork in a spiral; and this is a very good plan. An increase of steadiness is secured, if a larger cork, or small bung, be used, and the wire inserted in the side.

There are, of course, more expensive lenses, with which better definition can be obtained. Zeiss has an excellent magnifier consisting of two lenses, for use in the dissecting microscope (Fig. 2), and also as a hand lens, at the price of 6*s.*; one of the same construction, for use in the dissecting microscope alone, may be had for 4*s.* The Steinheil achromatic lenses are probably the best of all. These are made in powers ranging from 2 in. to ½ in. focus[1]; and the price varies from 10*s.* up to £1, according to the maker. Those made by

[1] The power of magnification of a lens is the ratio of its focal

Leitz of Wetzlar cannot be surpassed; and they are sold in London at 10*s*. each, either mounted in a handle, for use as hand magnifiers, or with a collar for use in Leitz's dissecting microscope (Fig. 3). Mr. Lewis Wright says that 'the best plan is to combine both uses, and have two or three powers in collars, with a spring ring folding into a handle, which will carry any one of them in that manner. A Steinheil lens at this low price costs little more than a Coddington, while its performance is infinitely superior[1].' It is a difficult thing to get makers to deviate from the beaten track, and so far as I have been able to learn, Mr. Wright's wishes have not been fulfilled.

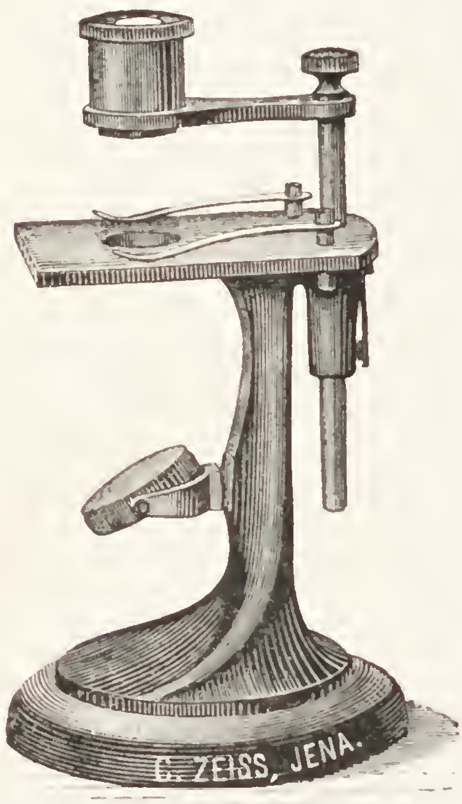


FIG. 2.—Zeiss's Dissecting Microscope.

The lenses and stand (Fig. 1) constitute a simple form of dissecting microscope. If the worker wishes for something more elaborate, he need only consult the catalogues of the principal makers to find something that will meet his requirements. Zeiss's brass stand, with stage, above which a lens slides

distance to 10 inches. Thus a lens of 1 inch focus (or focal distance) magnifies 10 times (written ×10, or ten diameters); one of ½ in. focal distance, 20 times, and so on.

[1] *A Popular Handbook to the Microscope*, p. 39.

up and down in a holder (Fig. 2), is sold for 9*s.*; with blocks for supporting the hands, at 10*s.* It is a useful instrument for small objects.

My favourite instrument is shown at Fig. 3. Here the focussing of the lens is effected by rack and pinion work, by means of the screws on each side the upright pillar. The lens is shown fitted in the collar which carries it. The stage is of glass—roughly, 2½ in. long by 2 in. wide, and the arm at the top of the pillar can be moved from side to side, so as to bring a fairly large object within

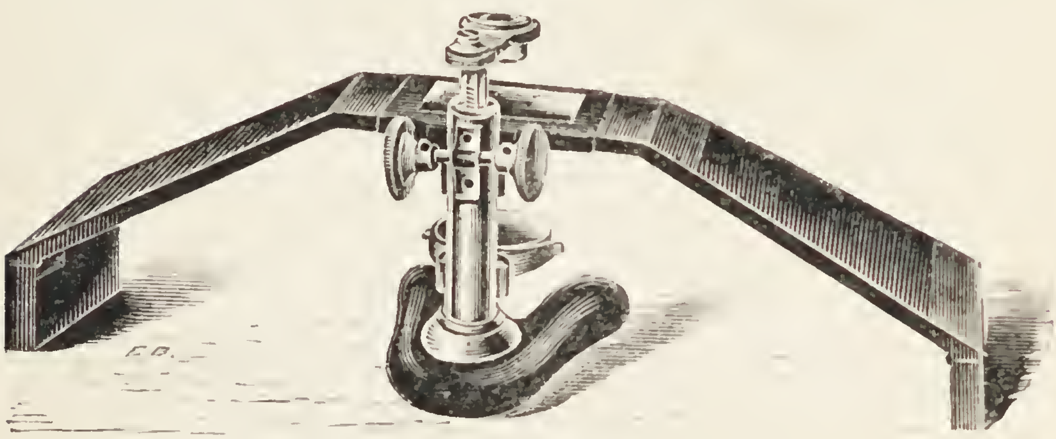


FIG. 3.—Leitz's Dissecting Microscope.

range. The metal framework of the stage is furnished with nickelled clips (not shown), which serve to hold an excavated slip. The arm-rests are detachable, and the uprights are hinged for convenience of packing. The instrument (with the exception of these rests) packs into a neat, strong mahogany box, 7½ in. in length, and about 5 in. in height and width. With two powers—1 in. and ½ in. are very serviceable ones—the cost is 38*s.*

It is to be wished that the maker would devise some plan by which the admirable lenses sold with this instrument could be utilized for the pocket. Mr. C. Curties, of Baker & Co., High Holborn, has kindly done something in the matter, and has made for me a metal holder. I have found this convenient, but should be glad to see something further done in the same direction, so that instrument, lenses, and holder could be sold for £2. This ought to be within the range of practical optics. The spring collar advocated by my friend Mr. Wright seems better, and would certainly be cheaper. The lenses would only need to be dropped in. To use my pocket holder one must unscrew the metal collar from the lenses before screwing them into the metal plates which carry them (Fig. 4). It is, however, something to

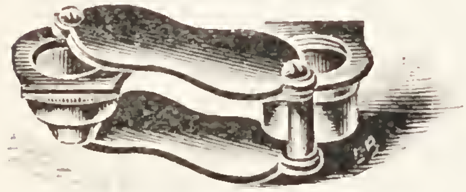


FIG. 4.—Two Leitz Lenses in holder (open).

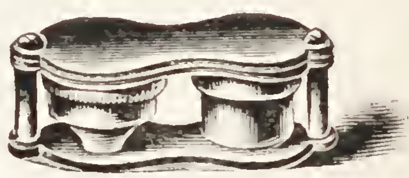


FIG. 5.—Two Leitz Lenses in holder (closed).

have made a beginning: it is a step in the right direction.

A serviceable dissecting microscope—not a toy, but an instrument with which real work may be done—can be made at a cost of a few shillings. Such a one has been made for me by a friend with a positive genius for such work. The body is fashioned out of a parcel-post box 7 in. long, 3½ in. in height, and the same in width. From the centre of the sliding top a piece is cut away, leaving ledges to take a 3 in. by 1 in. excavated slip for small dissections, or a mounted slide of a large object, such as a whole insect, for examination. A further portion is cut away on each side to take a small dissecting dish (Fig. 6). To admit the light, a hole is cut in the side of the box; and the mirror consists of a piece of silvered glass which was bought of a hawker in the street. This is placed in the box opposite the square hole, and sloped at an angle of 45°. The aid of a skilled mechanic was sought for a small rod carrying a thread, which works in a piece of brass bent at a right angle. This piece of brass is screwed on the box, just above the aperture by which light is admitted, and carries a pocket magnifier, similar to that shown at Fig. 1.

This modest little instrument generally stands

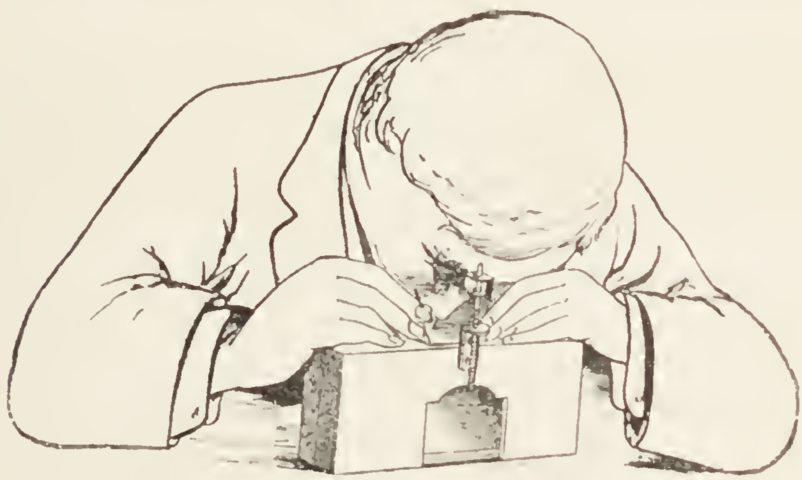


FIG. 6.—Home-made Dissecting Microscope.

on my work-table, and has provoked some remark and a little good-natured banter from friends who have seen it. Nevertheless, I should be sorry to part with it, for I have found it extremely serviceable in many ways. And more than one critic has had to confess that better results were obtained than one would expect from its appearance. The total cost out of pocket was, *3d.* for the box, *3s.* for the lens, and *1d.* for the plate-glass, while the man who made the pillar and ear-piece would take no more than *6d.* for his work. This brings the total to 3*s.* 10*d.* With a little ingenuity the pillar might be made to carry a collar, and so take a Steinheil lens. This would swell the total cost to about 11*s.*

Other apparatus need not be costly. An incident occurred at the meeting of the Quekett Microscopical Club on November 22, 1878, which shows how readily common objects may be utilized for our purpose. The late Right Hon. T. H. Huxley, who was at that time President, exhibited, and made some remarks on, the dissecting microscope which now bears his name. During the discussion which followed, Professor Charles Stewart exhibited some little saucers, which were admirably adapted for dissecting purposes. The President said that he should 'be glad to know where these convenient little saucers could be obtained.' The next paragraph of the minutes is interesting and instructive. 'Mr. Stewart said they were to be found at the corners of the streets, containing three whelks or three mussels for a penny. He bought those he had brought to the meeting at a shop in the New Cut, where they were supplied to costermongers[1].'

As very many of the objects with which we are concerned are aquatic, we shall want vessels of some sort to serve as aquaria. Any glass vessel will answer our purpose, provided it is clear, to allow of the examination of our captives ; or shallow pie-dishes may be utilized. The glass pots in which preserves are sold will do admirably, and any glazier will cut us covers for a few pence. Within reasonable limits, the smaller the aquaria are the better. The inmates can be seen more

[1] *Journal of the Quekett Microscopical Club*, v. 148.

easily, and picked out with less trouble when one wishes to examine them.

The principles on which aquaria should be kept are now pretty generally understood. There should always be a small quantity of growing aquatic vegetation, and a supply of minute life to furnish food for the larger forms. Excess of light should be avoided, and the temperature should not be allowed to rise much above 50° F. Carnivorous beetles and their larvae may be fed with small pieces of meat, small garden worms, or tadpoles. Most of the smaller larvae treated of will be satis-

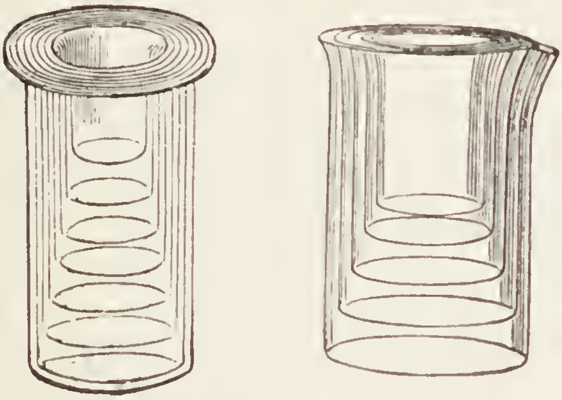


FIG. 7.—Beakers.

FIG. 8.—Glass Capsule.

fied with vegetarian diet, varied with an occasional meal of water-fleas.

If one cannot lay the household stores under contribution for jam-pots, tumblers, and bottles, beakers (Fig. 7) make capital small aquaria. They are sold in nests, and may be had either rimmed or lipped—rimmed for choice. There is no difficulty in obtaining them of any optician or glass-merchant. Mine have been bought from Messrs. Beck, of Cornhill, as have the capsules, &c., figured here.

Glass capsules (Fig. 8) are made in different sizes, ranging from $1\frac{1}{2}$ in. to 3 in. in diameter, with a height of 1 in. or 2 in. The largest size, 3 in. by 2 in., costs 5*d.*, and a glass circle to cover it, 1*d.* These capsules will be found useful for small aquaria, and for isolating aquatic larvae in order to keep them under observation during their change to perfect insects. It was in a capsule of this kind that some of my Ptychoptera larvae (p. 184) were kept, and changed into the pupal condition.

The glass block, with cover (Fig. 9), is convenient for a number of purposes. In it small creatures may be examined in air or in water, and it makes an exceedingly convenient little dissecting dish for use with the mounted hand magnifier (Fig. 1), or with Leitz's stand (Fig. 3), or the home-made

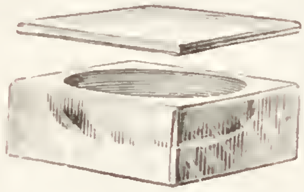


FIG. 9.—Glass Block, with cover.

FIG. 10.—Glass Box, with cover.

stand (Fig. 6). The glass box, with cover (Fig. 10), is extremely good for keeping small creatures under observation.

Excavated glass slips, 3 in. by 1 in., may be bought from any optician. They serve for the examination of objects in water, and also for dissection. The best I have been able to get have been supplied by Mr. J. Hornell, of the Biological Laboratory, Jersey, and they are very cheap.

We shall need some forceps to pick up specimens from the vessels in which they are kept, and the same little instruments will be found convenient in collecting. Both forms have advantages of their own; if we are limited to one pair, they should be curved, and of brass. Forceps with ivory tips are very useful for handling aquatic vegetation. These articles are not usually sold by opticians, but are kept by the tradesmen in Clerkenwell who sell jewellers' and watchmakers' tools, and cost from 1*s.* to 1*s.* 6*d.* a pair.

Dipping-tubes are used to take up small aquatic animals from the vessels in which they are kept. Very little practice will render the use of this instrument easy. The tube is held firmly between the thumb and the third and fourth fingers of either hand, while the index finger is pressed firmly on the top. Most people naturally prefer the right hand, but it is well to accustom oneself to use the right or left indifferently. The open end is then put into the water, just over the object to be secured, and the index finger lifted. The rush of water into the tube will carry the object into it, and if the finger be again applied to the top, the pressureof the atmosphere will prevent the water from escaping when the tube is lifted out [1].

FIG. 11.—Forceps.

Small brushes are useful for taking up specimens from the water or from pickle; common ones will do very well for large objects, but for small objects and parts it is advisable to have one or two sable brushes, as these form a better point.

Some needles fixed in handles will also be necessary. These may be bought, or made by fixing ordinary needles of requisite sizes into the handles sold for small brushes. The needles must be kept free from rust, and should always be carefully wiped after use. A good plan to keep

[1] *Ponds and Rock Pools*, p. 17.

them clean is to stick them in a gallipot in which has been melted a mixture of lard and paraffin in equal proportions.

Small dissecting-knives are useful, but all the work described here may be done with an ordinary pocket-knife in good trim.

The best preservative for our purpose is formalin,

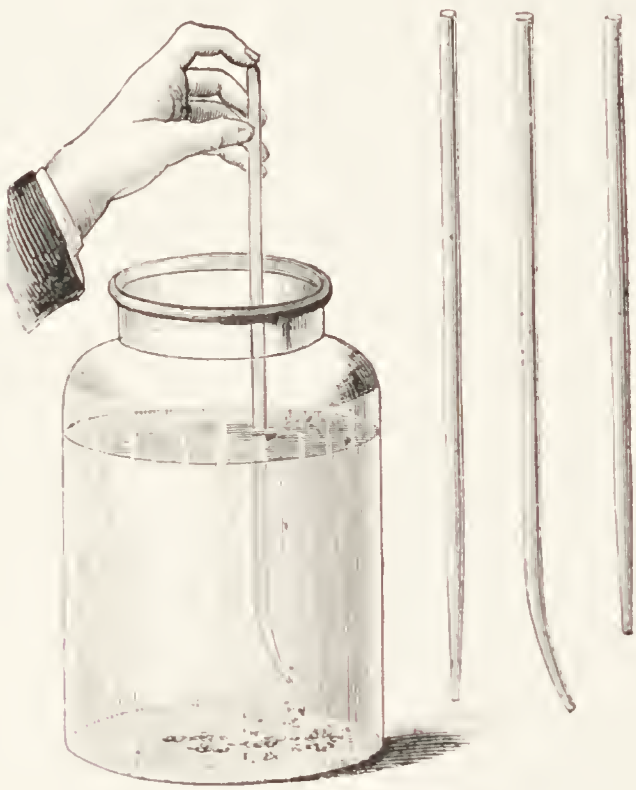


FIG. 12.—Three forms of Dipping-tube. Method of using it.

which is sold in a forty per cent. solution. This should be treated as absolute, and a five per cent. solution made. This will really be a two per cent. solution, and is sufficiently strong for general use.

The most profitable use we can make of specimens is to watch their habits while living, and to break them up and learn as much as we can about their structure when they are dead. For us to make a collection of specimens in tubes would be a waste of material.

Little need be said about collecting. The objects treated of are so plentiful that no great skill, nor any wealth of appliances, is needed to secure an ample supply. The following remarks on the methods employed at the Illinois State Laboratory for the capture of aquatic insects and larvae are, however, worth quoting :—

Fig. 13.—Mounted Needles.

'Insects in vegetation, and on or in the bottom, were taken by means of a dip-net—a net of about equal depth and width attached to a strong semicircular ring, firmly fixed to a long handle, the straight side of the ring being opposite the point of attachment. For the larger and more active forms, a coarser net was used, and for smaller forms one made of finer net proved most durable and satisfactory. To collect from the mud of the bottom, the water immediately over it was violently stirred and then swept with the net. The surface layer of mud was also scooped up in the fine dip-net, and then allowed to wash through, leaving the coarser contents in the net. Insects on the bottom in deep water were secured by using a dredge, and washing its contents through net sieves. The aquatic vegetation, when free from mud, was violently washed in a large pan, many smaller forms being thus dislodged and coming to the surface. Insects occurring in open water were taken in drawing an ordinary towing-net[1].'

[1] *Bulletin of the Illinois State Laboratory of Natural History*, iv. 158.

Here we have, so to speak, the general principles of collecting. It will be easy to adapt them to particular cases.

In choosing the subjects to be treated of in this little book, some difficulty has been experienced in deciding what to select from the multitude that lay ready to hand. It was felt necessary that the subjects should be connected, since choosing them at random would lead to purposeless work, and so to waste of time and opportunity. After some consideration, the author has decided to take all the examples from the Arthrop′oda—that great sub-kingdom of backboneless animals which includes the Lobster, the Crab, the Sand-hopper and the Woodlouse, the Spider and the Mite, the whole world of Insects and the Centipedes. One cogent reason that influenced this decision was the fact that these objects are exceedingly common, so that there can be no difficulty in procuring material on which to work. There is, perhaps, no other sub-kingdom so full of interest, on account of the many widely different forms, which may be referred to one common plan.

It may possibly appear to some readers that the powers of the pocket lens have been exaggerated. As a matter of fact the material for the book has been gathered by actual observation. The author has seen, with an ordinary pocket lens, the objects here described. If some are shown as they would appear under greater magnification than such a lens would give, this is chiefly for the sake of emphasizing points of interest which might otherwise be overlooked, but which can readily be made out with a hand magnifier, when attention has been drawn to them, and the observer knows what to look for.

CHAPTER II

ARTHROPODS AND THEIR CLASSES.—THE MARGINED WATER BEETLE; THE GREAT WATER BEETLE; THE COCKTAIL BEETLE

HAVING got together our apparatus, which, as we have seen, need be neither costly nor complicated, the next step will be to acquire some knowledge of the group from which the examples here treated of will be taken—the Ar′thropods, or animals with hollow-jointed limbs. These are the 'Insects' of the Linnaean classification, and, for the matter of that, of popular phraseology; for though few people would now venture to call a Lobster an 'insect,' we still style some of its near relatives Water 'Fleas,' as Swammerdam did two hundred years ago.

The Arthropods form a phylum, or main division of the Animal Kingdom. Above this phylum comes that of the Molluscs, or soft-bodied animals, such as the Oyster, the Snail, and the Cuttlefish. Still higher are the Lancelet, the Sea-squirts, and some few others, that bridge the chasm between the phyla without, and that phylum with, a backbone. And to this last Man himself belongs.

Two reasons contributed to the selection of the Arthropods as a subject for work with the pocket lens: (1) the great interest which surrounds many of the group; and (2) the ease with which specimens may be procured and kept under observation.

Every one has pretty clear notions as to the general 'make' of a Vertebrate or backboned animal. An Invertebrate animal has, of course, no backbone or the semblance of one; the nerve-cord, where present, lies on the under surface, and forms a ring round the gullet, and the heart lies on the upper surface or back. We may verify this by pulling to pieces a dead insect.

But a phylum, or main division, is much too large to be considered as a whole. It must, therefore, be broken up into smaller groups, which are called Classes, generally reckoned as five in number. These, again, may be grouped into two divisions, according as their members breathe by means of air-tubes (*tracheae*) or by gills. Our scheme then will stand thus:—

ARTHROPODS	Breathing by air-tubes	Peripatus.
		Centipedes and Millipedes.
		Insects.
		Spiders and their kin.
	Breathing by gills	Lobsters, Crabs, Sand-hoppers, and Woodlice.

This scheme looks well on paper; and on the whole is workable. But among our examples chosen from the Class of Insects, we shall find some that breathe by gills in their larval stage, and by air-tubes when adult. And among the Crabs are some, the gills of which have ceased to perform their normal function, so that these animals cannot live in water for a single day. And then there are the Sand-hoppers and Woodlice.

The body of an Arthropod may be represented by a series of similar rings, thus:

This similarity is clearly apparent in the Centipede, but is concealed in the Beetle, the Shrimp, and the Spider. It seems, at first sight, to be altogether lost in the Crab, and does really vanish in the adult stage of some parasitic Crustaceans.

It may be plausibly objected that our ideal Arthropod resembles nothing so much as a worm. In many respects this is true. A primitive Arthropod was worm-like, as is a Centipede. And Arthropods and Worms were formerly classed together in one group, as Annulo′sa or ringed animals. The chief external difference lies in the nature of the appendages borne by the various rings or segments.

We may represent those of the Worms thus , for they are bristles, or groups, or modifications of bristles. Those of the Arthropods may be represented thus , for the appendages are really jointed, though, of course, in a fashion different from those of a backboned animal.

The jointed appendages of Arthropods may be modified to fulfil very different functions. They may serve as legs for walking, hands for climbing or seizing prey, jaws for masticating food, feelers or organs of touch and sense, and, strange as it may seem, in one group, as eyes.

It is well to get some notion of how these joints are formed. To take the body first: the skin connecting the segments is much thinner than that of the segments themselves, which is thickened by the deposition of chitine, and, in some cases, also of carbonate and phosphate of lime. A portion of the body, then, may be represented thus , where the heavy lines denote the segments, and the thin ones the spaces between the segments. It will be seen that this arrangement allows of considerable play, and also of a telescopic movement by which the segments can be brought close together.

It is easy to construct a kind of model that shall exemplify these movements. Make a tube of calico, some six inches long, and having stuffed it with cotton-wool, paste on it strips of brown paper one inch in width, leaving an interval between each, as in the last diagram. Then we shall be able to understand how Arthropods can bend the body or move it from side to side. And the limb joints are made on a similar plan.

The most archaic Arthropod—Perip′atus—must be mentioned. It is not found in Britain, nor even

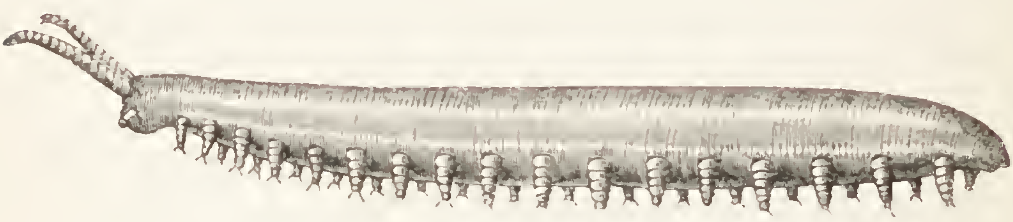


FIG. 14.—Cape Peripatus (natural size).

in Europe; so that, unless we travel, we shall only know it from books, or from museum specimens. But it is an extremely interesting creature, for it is of worm-like aspect, and breathes by air-tubes, opening all over the body, which has no external segments. The limbs are imperfectly jointed, and each of them bears two claws. Most naturalists make this genus a Class by itself, while some put it with the Centipedes. There are about a dozen species, four of which are African, two Australian, and the rest are found in South America and the West Indies. Besides these there are some doubtful species.

In habit they resemble the Centipedes, and they ensnare the insects on which they feed by ejecting sticky slime from the small processes near the mouth. The left process is shown in the illustration, just below the antenna of that side.

Professor Sedgwick, who described these animals in the *Quarterly Journal of Microscopical Science* (1888), and, more popularly, in the *Cambridge Natural History*, says, that 'the exquisite sensitiveness and changing form of the antennae, the well-rounded plump body, the eyes set like small diamonds on the side of the head, the delicate feet, and, above all, the rich colouring and velvety texture of the skin, all combine to give these animals an aspect of quite exceptional beauty.'

Unfortunately, an illustration in black-and-white can only render form. We must take the beauty of the colouring for granted. One thing, however, cannot escape the most cursory examination of the picture—the resemblance of the creature, in some respects, to a worm, and, in others, to a caterpillar, which, as everybody knows, is the larval stage of a butterfly. If this resemblance sets us thinking how it came about, and what it means, Peripatus will, for the present, have done its work for us.

With these general notions of Arthropods, we may pass on to put our pocket lens to some practical use. Our first subject shall be the Margined Water Beetle (*Dytis'cus margina'lis*), which can be taken in almost any open pond in the country. Water covered with duckweed should be avoided in hunting for these beetles, which prefer ponds with a clear surface, so that they may easily come to the top to breathe.

Every one has a good general notion of the principal Insect-groups, technically called Orders

—Beetles, Cockroaches and Grasshoppers, Butterflies, Bees and Wasps, and Flies. Insects may be defined as animals with hollow-jointed limbs, and divided into three regions—head, thorax, and abdomen. The head bears a pair of antennae; the thorax carries three pairs of legs, and (generally) two pairs of wings; the abdomen is without appendages. Insects when adult breathe by tubes that open to admit air. In Chapter VI we shall see that many larvae obtain an air supply in different ways.

Beetles may be taken as very good types of true Insects. They constitute the Order Coleop′tera, or Insects with sheathed wings, only the hinder pair being used for flight (Fig. 18), and at other times they are folded under the wing-cases, or el′ytra, as in Fig. 15.

FIG. 15.—Margined Water Beetle (male).

We may advantageously compare our Beetle with Peripatus, and note the points of agreement and of difference.

Now, if our captive Beetles are to yield us the greatest possible amount of profit, we shall keep them under observation for some time, so as to watch their habits.

In keeping these Beetles we shall not require a large aquarium. A small gathering of aquatic weed will be necessary to keep the water in good condition and the aquarium ready for its tenants.

My interest in these Beetles was quickened by a letter in the *Field* (Oct. 28, 1893), in which a correspondent at Weybridge asked 'for information as to what animal or bird bisects so neatly the shells of the Water Snail (*Planorbis*).' I thought then, and know now, that the shells were 'bisected,' if that is the proper word, by Water Beetles. From that time I have had, and still have, several

FIG. 16.—Shells of Molluscs broken up by Dytiscus. (From a photograph by Cherry Kearton.)

living in small aquaria, but for a long time was unable to get direct evidence on the subject.

Many experiments were tried, and at last these proved successful. Several specimens of Dytiscus [1]

[1] 'Dytiscus' is written of set purpose. It is not, as some people tell us, a miswriting for Dyticus; but a properly formed diminutive, from the Greek *dutēs* = a diver; like *paidiskos* = a little boy. Linnaeus consistently calls the genus Dytiscus from 1735 onwards. Dyticus only dates from Geoffroy's *Histoire Abrégée des Insectes*, first published anonymously in 1762. On this question of nomenclature I am glad to have the support of the Rev. T. R. R. Stebbing, F.R.S., who, in answer to my inquiries, kindly wrote, 'Darwin uses "Dytiscus" in the *Origin of Species*, and I should decidedly recommend its being upheld.'

were obtained, and put into a small aquarium in which was no other food for them than some snails and other molluscs. The Beetles were carefully watched, and were several times seen trying the snails. In crawling along the inner surface of the glass, Planorbis and Limnaea both protrude the foot to a considerable extent, and pieces were ripped out by the strong mandibles of the Beetles before the shells were actually broken up.

All the shells represented in Fig. 16 were taken from this aquarium, so that there is good evidence as to what creatures broke them up and devoured their inmates. In these, as in the specimen kindly sent me by Mr. Tegetmeier, the Natural History Editor of the *Field*, the bisection is not complete, though in all cases it is carried far enough to allow of the extraction of the mollusc. The large Limnaea shell in the centre has been attacked, but it seems to have been left when the beetles discovered it was empty. (The empty shell was noted before the Beetles were put into the tank.) Another Limnaea shell is figured, from which the snail has been picked out, and that of a fresh-water mollusc.

After these observations had been recorded in the *Field*[1], I found that I had been anticipated by about forty years. I picked up, at a bookstall, a copy of G. B. Sowerby's *Popular History of the Aquarium*, and there I found that the author had distinctly seen Dytiscus at this kind of work. He says[2]: 'I have only once witnessed him in the act of seizing an unfortunate Planorbis or Flat-coiled Water Snail. At first, the Dytiscus seemed to be roaming about in quest of something, first under,

[1] April 4, 1896. [2] *Popular History of the Aquarium*, p. 258.

then over, the leaves of a water-lily. At last, in a rather dark corner, he seemed to perceive suddenly a Planorbis which was browsing upon the stem of a plant just under the shade of a broad leaf. He darted at this, seized it, and then, putting his tail out of water, for the purpose of taking in a fresh supply of air, moved slowly down, bearing the snail with him. He held it by his fore-feet, turning round the coil until the aperture of the shell was opposite his mandibles, then he began nibbling away at the animal. In vain did the poor mollusc try to withdraw within its shelly fortress, for the beetle picked off the edges of the shell bit by bit, so as to expose the body as fast as it was withdrawn. All the way down to the bottom of the tank was this process continued, air-bubbles rising to the top, and bits of broken shell falling, till the beetle with his burden reached a stone near the bottom, where I left him still busy at his work.'

This puts the matter beyond doubt, if any before existed. I at once wrote to Mr. Tegetmeier to let him know that my experiments had, unknown to me, been anticipated, long ago, by Mr. Sowerby. Had he rescued his Planorbis shell, it would have compared very well with those forwarded to the *Field* office in 1893. They had been exhibited at the Malacological Society, and no one was able to solve the mystery of their mutilation. This shows, to quote the *Field*[1] on the subject, 'how easily statements that have been recorded may subsequently be overlooked and entirely forgotten.'

To return to our Beetle. The male is a handsome creature, from an inch to an inch and a

[1] May 2, 1896.

quarter long, clad in olive-green, bordered with yellow, and exceedingly active. His mate is smaller, more soberly clad in brown, without the yellow markings, and the wing-cases are more or less furrowed.

The first thing to notice is the shape of the body, oval and smooth, offering no resistance to the water. The hind pair of legs are flattened and fringed with hairs, so as to make capital paddles. In swimming the right and left legs are moved together.

Now, though this Beetle lives in the water, it is made, so far as concerns its breathing apparatus, after the fashion of a Land Beetle, and consequently is compelled to come to the surface pretty frequently for a supply of air, which it obtains in this wise. Directly it ceases paddling it floats to the top of the water; and as the head is heavier than the tail the latter projects a little above the surface. Then the wing-cases are raised, and air flows in under them to the breathing holes on each side. The operation is not a long one, and as soon as it is over the Beetle is ready for another ramble round his dwelling-house.

But if we do not supply our captive with food that he may take for himself, it is only right that we should feed him, which may be done at intervals—say, every other day. 'Little, and often,' is an excellent motto to guide us in our feeding; and though its adoption may entail some trouble, it will be more than compensated by the success that will attend our endeavours to keep the inmates of our aquarium in good condition. And the operation of feeding our Beetle will show us that he has some capital sense-organs, which are of as much, if not of more, use to him than his eyes.

He is a flesh-eater. Let us take a small piece of meat or fish in a pair of forceps, or stuck on a pointed stick, and hold it at a little distance from his great eyes. The chances are that he will not see it. Even if we put it in front of him, he is quite likely to disregard it, for he has nothing corresponding to a nose, with which he may smell. From his head there spring a pair of long feelers—the antennae—and by means of these we will let him know that his dinner is ready. That is effected by drawing the food along the side of one of the antennae. The creature undergoes a sudden change. Till the antenna was touched with the food he was resting on his swimming legs. But in a moment down goes his tail and up goes his head, he stretches out his raptorial legs, and clutches wildly at the forceps or stick, as the case may be, holding so tight that he may be dragged round and round the glass vessel. Let go he will not, of his own accord ; and it would be a difficult matter to shake him off. Similar experiments may be tried with other Beetles, and the result will be to impress on the mind the fact that the feelers are capital sense-organs.

If we are to turn our Beetle to the best account, we shall need to handle him. It may be inconvenient to wait till he dies, so we will kill him quickly and painlessly by plunging him into boiling water, and he may be preserved by putting him into a tube containing about equal parts of water and spirit, or a five per cent. solution of formalin.

Dissections should properly be made under water. The Beetle should be fastened, back upwards, to a piece of cork weighted with lead, and placed in a deep saucer, or dissecting dish, and covered with water. But a good deal of rough dissection, as is ours, may be done in air, and the Beetle may be fastened to any convenient piece of board, or even held in the palm of the left hand. Very little practice is needed to run over the external parts of a large Beetle in this manner.

First, let us look over our Beetle, and get some general notions of its make. As it lies, back

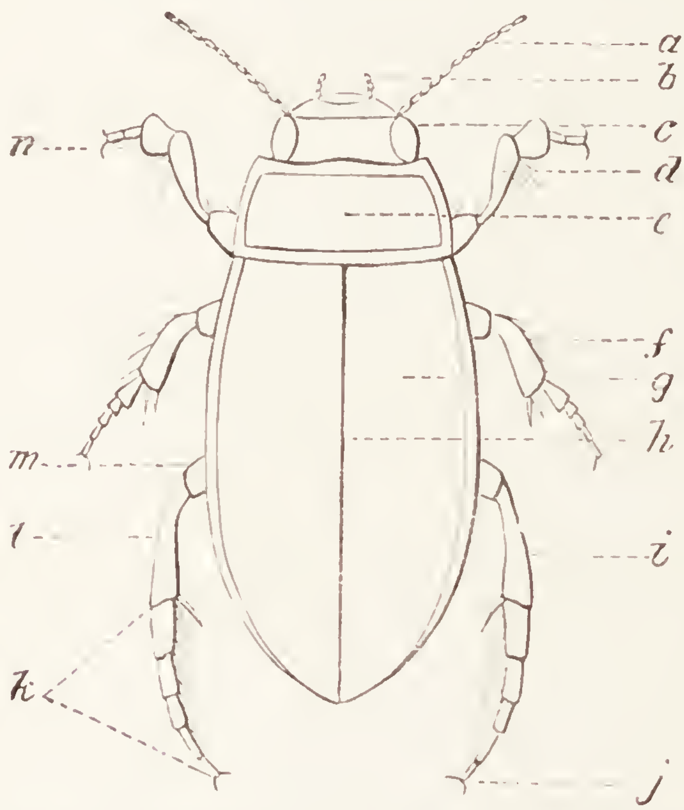


FIG. 17.—Outline of Dytiscus (male). *a*, antenna; *b*, maxillary palp; *c*, eye; *d*, fore-leg; *e*, thorax; *f*, middle leg; *g*, elytron; *h*, suture; *i*, hind leg; *j*, claw; *k*, tarsus or foot; *l*, tibia or shank; *m*, femur or thigh; *n*, first three joints of foot, widened into a plate with suckers beneath.

upwards, it is clear that it consists of three parts or regions — —— ———, the first of which is the head, the second the thorax, and the third the abdomen. Not only in our Beetle, but in Insects generally, these parts correspond to the words that denote them, in that the thorax is longer than the head, and the abdomen longer than the thorax, as shown by the three dashes, a few lines above.

These divisions are well shown in Fig. 17, where other parts are also marked. It will pay to go over our own specimen with this figure before us, and so make acquaintance with the several parts, to some of which we shall return in greater detail.

At this point, if we have not done so before, it will be convenient to fasten our Beetle, in the

FIG. 18.—Male Dytiscus in flight.

position figured, by a stout pin driven between the thorax and the abdomen, just above the suture (*h*). We want to raise one of the wing-cases.

If a needle be taken in each hand, between the thumb and first two fingers, and that in the left hand be used to steady the creature, the wing-case on the right may be raised with the needle in the right hand, and then cut off. The small filmy membrane, of somewhat triangular shape, which comes off with the wing-case, is the winglet. There is one on each side; and their vibration causes the humming noise made by these insects in flight. When the water dries up in one pond, or food becomes scarce, they will leave and fly off to another.

The wing lies folded upon the abdomen. A good deal of very interesting matter has been written on the way in which Insects fold their wings, but we can see for ourselves how this Beetle folds them. All we have to do is to take the wing, and draw it gently away from us, and so unfold it. We may use finger and thumb, or a small pair of forceps. When let go, it will spring back to its old position. Reference to the expanded wing in Fig. 18, and to the diagrams Figs. 19 and 20, will show how the wing is folded.

The cross-mark in the diagram represents a joint in the chitinous rod that forms the wings. This lies just above the cell (which is left white in

FIG. 19.—To show fold of (right) wing of Dytiscus.

FIG. 20.—To show fold of (right) wing of Dytiscus.

Fig. 18). The shorter part of the rod is bent down, forming an acute angle (Fig. 20); of course, carrying with it the membranous part of the wing.

This may seem a little difficult. But if it be tried on a specimen, no real difficulty will be experienced. When the wing has been unfolded, it will, if let go, spring back to its old position, the shorter part lying underneath, and the chitinous rod fitting into a groove formed by the projecting sides of the segments of the abdomen.

To this point the sum of our knowledge about

Dytiscus amounts to this: It is aquatic in habits; its body is divided into three regions; and it has a pair of membranous wings, covered by chitinous wing-cases, or sheaths, technically called *el'ytra* (each being an *el'ytron*). Wing-cases of this kind are the distinguishing mark of the Beetles, or *Coleop'tera*, though they are not always so well developed as in the specimen with which we are dealing. This we can discover for ourselves by examining all the Land Beetles met with in a country ramble or in a stroll round the garden.

Now let us unpin our Beetle, turn it on its back, and examine it from the under side. Head, thorax, and abdomen may be made out more clearly than before, and we can see that the last two regions are divided into segments.

Let us deal with the head first. This may be easily separated from the thorax with a dissecting needle, or with a pocket-knife—an exceedingly handy tool. The huge goggle-eyes cannot escape observation; and, even without a magnifier, they may be seen to be compound—that is, made up of a number of facets, which show like a fine network.

Just in front of the eyes are the antennae, which serve as organs of touch and perhaps also of other senses.

Kirby has recorded facts which seem to show that the antennae (in some cases) are also organs of hearing. Other authorities, after many observations, have come to the same conclusion. The matter, however, is beset with difficulty. It is certain that some Insects have their ears in their legs; and for the present, at any rate, we may be satisfied to know that the antennae are sense-organs, certainly of touch, probably of smell, and, in some cases, of hearing. An excellent authority on the subject is Sir John Lubbock's book, *The Senses of Animals*[1], which contains references to very many original papers.

Now we may pass to the mouth parts. It will be good practice to dissect these out, either in air or in water. We may hold a Beetle between the

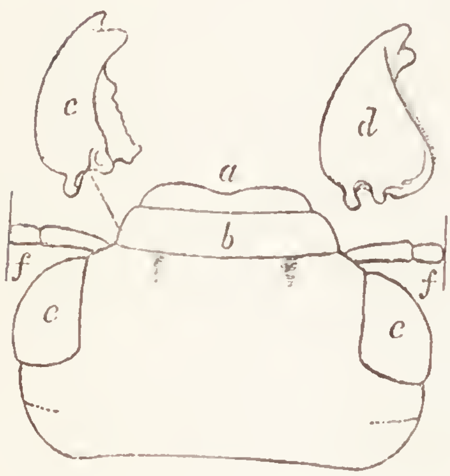


FIG. 21.

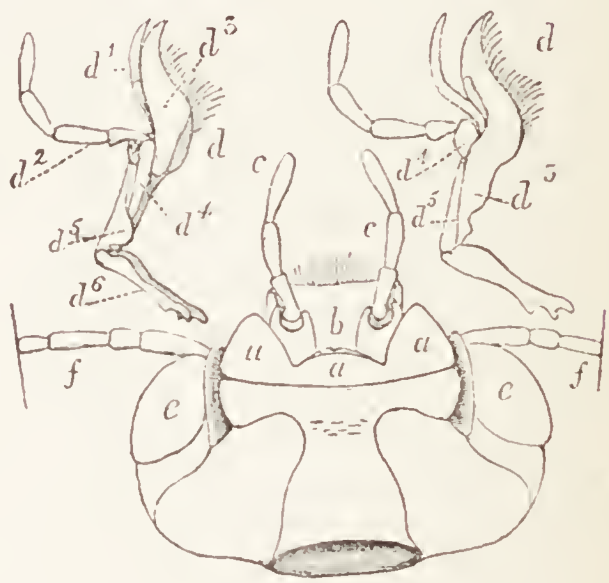


FIG. 21 A.

FIG. 21.—Upper surface of head of Dytiscus. *a*, labrum, or upper lip; *b*, clypeus or shield; *c*, mandible dissected out, and (*d*) reversed; *e*, eye; *f*, antennae.

FIG. 21 A.—Under surface. *a*, mentum or chin; *b*, ligula or tongue; *c*, labial palp; these three together forming the labium, or lower lip; *e*, eye; *f*, antennae. Above the maxillae, or lower jaws (*d d*), are shown dissected out: d^1, inner or palpiform lobe; d^2, maxillary palp; d^3, lacinia or blade; d^4, the palpifer or piece that bears the palp (d^2); d^5, stipes or stalk; d^6, the cardo or hinge.

finger and thumb of the left hand, and separate all the parts with a needle held in the right. It is a good plan to gum these parts on a card, for comparison with the figures in our favourite book —whatever that may be—on Natural History, and also with the mouth parts of insects of other Orders. For however much these may differ in form, and

[1] International Science Series, No. lxv.

in the uses to which they are put, they are really modifications of the same parts.

In Fig. 21 we have the upper side and in Fig. 21A the under side of the head represented, so that we may easily get acquainted with the different parts, and the names given to them. The cut should be gone over several times, and the parts in the picture compared with those in the specimen under consideration. It is good practice to endeavour to draw what is seen from the specimen itself, and then to compare the result with the work of the trained artist. And the mouth parts of Dytiscus may be compared with the mouth parts of the Cockroach (Fig. 33).

Returning to practical work, the first thing is to separate the *labrum*, or upper lip, from the head. Then the large *mandibles* should be dissected out, and cleaned (by soaking in caustic potash) from the muscles which will come away with them.

FIG. 22.—Disposition of mouth parts.

Behind these are a smaller pair of jaws, the *maxillae*, furnished with a pair of palps, called maxillary palps from their position. These are to be dissected out; and then the lower lip, or *labium*, may be separated by passing a sharpened needle along the line where it joins the chin. The palps on the lower lip are called labial palps.

When these parts are cleaned and dried, they should be gummed on card, as shown in Fig. 22, where the long lines represent the upper and lower lips respectively, and the shorter ones the mandible and maxilla of each side.

So much for the head. Now we discover that what appeared to be the thorax, when we were looking at the upper surface of the Beetle, and what is called the thorax in descriptions of Beetles, is really but a portion of that region, which is seen to be divided into segments. The covering on the upper surface protects only the first segment, the middle and hinder ones being covered by the wing-cases and the *scutellum* (a triangular piece jutting backward from the second segment, and meeting the suture). This is not represented in Fig. 17; but we may put in with our pen a tiny triangle, with its base towards the head, and its apex towards the tail—this will meet the case.

The first segment bears no appendage above, but to the under side is attached the first pair of legs. The middle segment also carries a pair of legs, and on its upper surface are the wing-cases, to the under side of which, and to the body, the winglets are joined. The last segment bears the wings above, and the last pair of legs below, these being placed very far back, so as to give them greater power in propelling the animal through the water.

It will be convenient to examine the legs next. First, however, it will be well to look at a normal leg of an Insect (the Cockroach), and learn the names of the different parts. First comes the *coxa* (*a*) or haunch, next the *trochanter* (*b*), then the *femur* (*c*) or thigh, the *tibia* (*d*) or shank, and the *tarsus* (*e*) or foot, ending in a pair of claws. There are three pairs of legs in perfect Insects, and usually the same number in larval forms, though in some of these legs are entirely wanting.

FIG. 23.—Leg of Cockroach.

In the males of the Margined Water Beetle and many of its near relations the first pair of legs deserve special attention. The first three joints of the tarsus have coalesced to form a disk or cup, which in our specimen bears two smaller ones on its inner surface. A power of 20 will show the disk nearly as well as it appears in Fig. 24. The purpose of this disk, or clasper, which is absent in females, is obvious. It was formerly supposed to act as a sucker, but Professor Lowne and Professor Miall[1] have shown that it does not act by atmospheric pressure, but by a viscid secretion discharged from the cup-like hairs with which the inner surface is set.

FIG. 24.—Tarsus of Dytiscus (magnified).

The middle pair of legs in the male also bear cup-like hairs on the corresponding joints of the tarsus, and in very much greater number. Professor Miall quotes Simmermacher to the effect that while the large disk on the fore-leg has 170 sucking-hairs, the enlarged joints of the tarsus of the middle leg bear no less than 1590. These hairs are plainly discernible with the half-inch Steinheil, and I have made them out with the inch, and think that I could show them to anybody else with that power. I have not looked for these sucking-hairs on the middle leg of other Beetles of the same family which have disks on

[1] *Aquatic Insects*, pp. 55, 56.

their fore-legs, but they do exist in some other genera.

If we watch a male Dytiscus in life, in a small aquarium, we shall soon be convinced that Lowne and Miall are correct in their statement that the cup-hairs discharge an adhesive substance. We shall see this all the more plainly if there is much floating vegetation. For, in swimming about, the Beetle will often come in contact with some of this, and it will adhere to the cup-hairs. His struggles to free himself from the encumbrance will show

FIG. 25.—Female Dytiscus swimming.

that the attachment is not altogether under his control. The offending weed is rubbed against the spines of one of the other legs till it is removed.

The spines with which the legs are set are worthy of a good deal of attention, and, like the adhesive cup-like hairs, though in different fashion, they doubtless assist the animal in holding its prey. The first and middle legs end in strong claws; those of the last pair are not so well developed.

The last pair of legs are the swimming organs. The tibia and tarsus are fringed with long stiff hair behind, so as to hold the water when the Beetle swims. A peculiar arrangement of the first joint of the tarsus allows the edge to be presented to the water when the limb is carried forward for the return stroke, thus offering the least possible resistance. This Dr. Sharp has compared to the action of a rower in feathering his oar. There is, however, this difference, which it is well to note. The oar is feathered after the stroke; the Beetle feathers its legs before the stroke. It is the first motion when it begins to swim, and the action is not peculiar to the male.

We now come to the third region, the abdomen. Like the thorax it is visibly divided into segments, though the division between them is not so great. Much difference of opinion exists as to the number of segments in the abdomen of a typical insect. Some authorities maintain there are eleven, while others put the number as low as five. This, however, is theoretical rather than practical. It is enough for us to know that the number apparently varies greatly, owing to the coalescence of two or more of the segments.

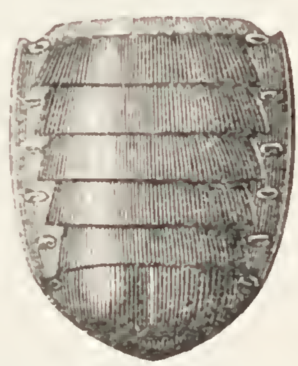


FIG. 26.—Upper surface of abdomen of typical Beetle.

The head in Insects, we have seen, carries the eyes, antennae, and feeding organs. The thorax bears the legs and wings. The abdomen bears no appendages, except in some cases, on the last segment; these are called *cerci*. It may be, however, that the stings of bees and the ovipositors of saw-flies and other insects are modified appendages.

On examining the abdomen of Dytiscus we shall probably be struck with the difference in appearance between the upper and the under surfaces. The latter is hard, smooth, and shiny; the former, when the wings are removed, is seen to be covered with felt-like hair.

Our interest is with the upper surface. Along the abdomen on each side lie spiracles, stigmata, or openings to the breathing tubes. The first and last are larger than the rest, and their general form can be readily made out with an inch magnifier, and with the half-inch we may get some idea of the detail shown in Fig. 27.

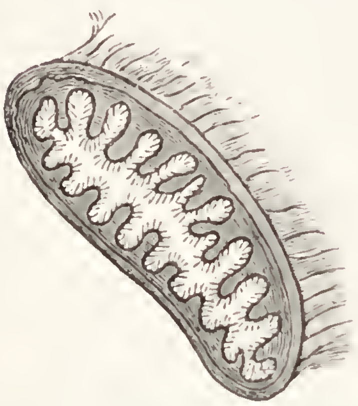


FIG. 27.—Spiracle of Dytiscus (magnified).

Dytiscus breathes in this way. Floating up to the top of the water, the end of the abdomen projects above the surface. If one watches the Beetle the wing-cases will be seen to rise a little. The air retained by the felted hairs is given off, and a further supply taken in. Then the wing-cases are lowered again; the Beetle gives two or three strokes with its swimming legs, and descends below the surface to ramble round the tank in search of food.

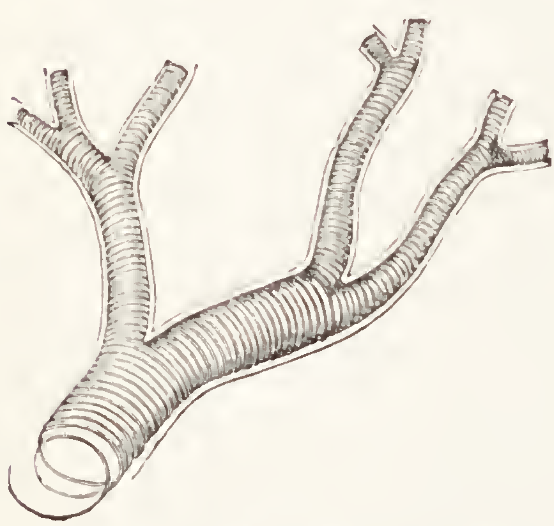


FIG. 28.—Tracheal tubes (magnified).

This air-supply between the wing-cases and the abdomen is taken in at the spiracles and distributed through the tracheal tubes throughout the body. These tubes branch and subdivide till they end in small twig-like vessels comparable to the capillaries of the human body. They consist of two layers—the inner strengthened by what probably is a spiral fibre, though Packard believes that, in some cases at least, it consists of similar rings. But we must not pursue this subject. It would lead us beyond our appointed limits.

Another Beetle fairly common in stagnant waters round London and in the southern counties is that to which the name Great Water Beetle (*Hydroph'ilus pic'eus*) of right belongs. This name is sometimes wrongly applied to Dytiscus, with which its rightful owner has little in common, except its aquatic habitat. Its scientific name is *Hydrophilus piceus*; but we shall speak of it as Hydrophilus.

It is not a very easy matter to take this Beetle with a net, by sweeping in the ordinary way, for it likes to get into the middle of a mass of vegetation, where it is sure of a good food supply, and is probably safe from the attacks of Dytiscus, who not unfrequently makes a meal of his larger relation. A good plan is to pass the net under a mass of weed and then shake it to and fro in the water. By this means any Beetles in the weed will be dislodged from their hiding-places, and fall down into the bottle.

They have, in confinement, the same habit of making a snug place for themselves; and more than once I have fancied that a Beetle of this species had escaped from the aquarium, when all the time it was hidden in a thick patch of water-moss. They are practically vegetable feeders, though Dallas says that they are not such strict vegetarians as to deny themselves a meal of animal food when they meet with a dead mollusc or larva in the course of their wanderings. I have never known them to indulge in animal food, dead or living, but I have known them refuse it.

Hydrophilus is the largest British Water Beetle, and, with the sole exception of the Stag-Beetle, the largest British member of the Order. Its total length is very little less than two inches, and across the middle of the back it measures about half as much. It is more slenderly built than Dytiscus, and the contrast in the size and armature of the legs is very striking (Fig. 29). There is also a great difference in their method of progression through the water. Dytiscus moves both legs simultaneously, while Hydrophilus walks rather than swims, moving one leg after the other.

If we cannot collect this Beetle for ourselves—which we should endeavour to do, if possible—it may be bought of almost any dealer in what are called 'aquarium requisites.' But prices rule higher for Hydrophilus than for Dytiscus. Bateman says that this species is rarer than formerly, and that specimens cost from 1*s.* to 2*s.* 6*d.* a pair, 'according to the dealer and the season.' From this I gather that I must have gone to a shop where the prices were reasonable, for I have never paid more than 6*d.* for a Hydrophilus, and then have been allowed to pick out a male. At the same shop I have paid 2*d.* for Dytiscus.

In keeping this Beetle we shall need a larger vessel than was required for Dytiscus. (In both cases the aquarium should be covered, for if food be scarce, and sometimes for other reasons, both these

FIG. 29.—Great Water Beetle. *a*, male; *b*, female; *c*, larva; *d*, pupa.

Beetles may take to flight.) The aquarium should be well supplied with growing water-weed, but none that is choice or valuable should be put in, for in moving about over the weed the animal will damage almost if not quite as much as it eats. This difficulty can be easily got over by supplying it with anacharis, water-crowfoot, milfoil, or any other common plant that grows rapidly and is easily procurable.

The only specimen that I have taken myself was captured a few miles north of London. It exhibited a strange instance of depraved appetite. In the large tank into which it was put were growing vallisneria, frog-bit, and water-crowfoot in plenty. These it was never seen to touch. The tank, at one time, had been used for newts, and floating on the surface was a piece of virgin cork. It had served the former inmates as a kind of island continent, and had never been removed. To the under side of this the Beetle would moor himself, head downwards, and nibble away, as if cork were the natural diet of a British Water Beetle.

In a few days the Beetle died. It was put into spirit, and soon after became the subject of a post-mortem. But its strange diet was not the cause of its death, which was sufficiently accounted for by injuries inflicted before its capture, probably by a larval or an adult Dytiscus.

It would be mere waste of time to go over this Beetle and describe it point by point, as was done with Dytiscus. If what was there written was of any value, readers will be able to apply for themselves the method laid down. There are, however, some points of difference to which it will be well to invite attention.

It is a good plan to lay specimens of these Beetles side by side for comparison. Hydrophilus is the larger of the two; and differs in colour as well as in size. Its hue is black with an olive tinge; and in certain lights a blue-black metallic gloss may be seen on the outer margins of the wing-cases. These are marked with faint longitudinal lines, and each bears three rows of dots running in the same direction.

The greater length and more slender build of the legs of Hydrophilus are at once apparent. There is also a marked difference in the tarsal joints of the fore-legs of the male. The disks and cup-like hairs of Dytiscus are absent in Hydrophilus, but in their stead the last joint bears a sub-triangular plate, studded on the inner surface with spines, which probably serve a similar purpose. A great deal of valuable information about organs of this kind and their functions will be found in chapter X of Darwin's *Descent of Man*. Simmermacher's paper [1] should be consulted by all who have the opportunity. Our inch magnifier will show us these spines quite clearly; and also a curious little bunch of bristles, which Simmermacher says are probably organs of touch.

It is a good plan to take Hydrophilus out of the water, and lay it upon its back, so that the difference between it and Dytiscus may be clearly seen. The Beetle should be handled carefully, for on the thorax is a kind of keel, ending in a sharp spine, which extends over part of the abdomen. This spine is free, and may easily wound the hands of those who do not watch the motions of the creature pretty carefully. The fore part of the abdomen and the thorax are covered with short

[1] *Zeitschrift f. wiss. Zoologie*, Bd. xl. S. 481.

close hairs, and when the Beetle is in the water these parts entangle a layer of air, which gives it the appearance of being covered with quicksilver.

The two Beetles differ also in their method of exchanging impure for pure air. Dytiscus, as we have seen, takes in a fresh supply under its wing-covers behind; Hydrophilus takes in a fresh supply in front, employing for this purpose the antennae, which apparently do not function as feelers, as is generally the case.

When Hydrophilus wants to take in a supply of pure air, it rises to the top of the water, slowly and deliberately. Unlike Dytiscus, it is never in a hurry. Then one of the antennae is pushed through the surface film, thus communicating with the air, which descends to the hair-covered thorax, whence it reaches the spiracles on the upper surface of the abdomen. To allow of this the wing-cases are slightly raised in front. The spiracles in Dytiscus are larger at the posterior end of the abdomen: in Hydrophilus the largest spiracles are in front. This is what might be expected, from the method adopted in each case for procuring a fresh supply of air.

These Beetles have frequently bred in confinement; but no better account than that of Lyonnet has ever been given of the operation of the female in making her cocoon and depositing her eggs. As his account is not generally available, a condensed translation of it is inserted with his illustration.

Lyonnet[1] wanted to find out how the female made the cocoons (Fig. 30), and this is how he set to work. He put some of these Beetles into a

[1] *Mémoires du Muséum d'histoire naturelle*, xviii. 454 sqq.

large aquarium, with a good quantity of water and some duckweed. On May 31 and the following

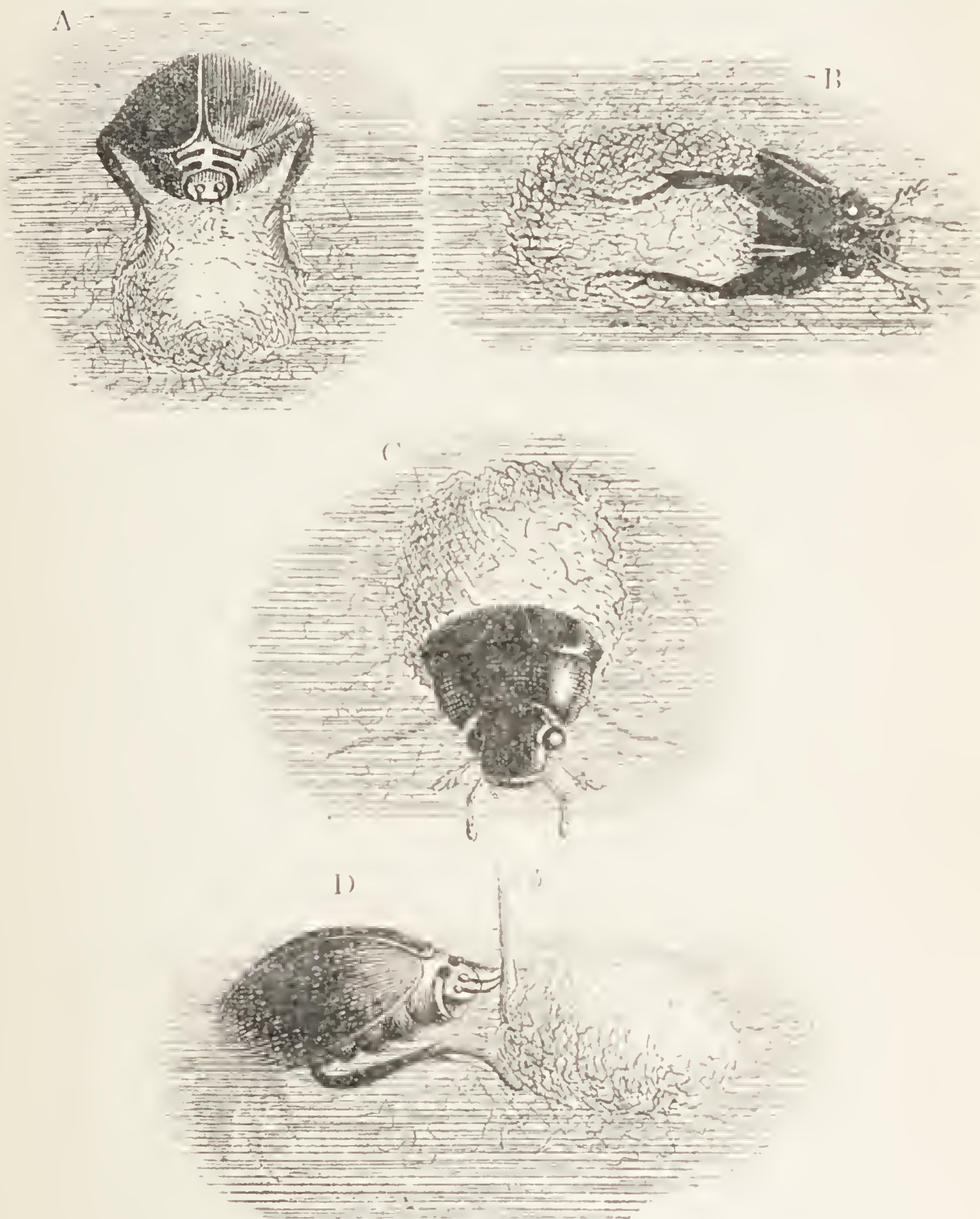


FIG. 30.—Female Hydrophilus constructing a cocoon. (After Lyonnet.)

day he noticed that one of the females was swimming about in every direction, as if in search of something. Thinking that this was because she had not the proper materials for her work, he then put into the aquarium some thread-like alga of a kind which he had seen attached to some cocoons, and on June 3 the Beetle began to make a cocoon, but soon gave up the task, apparently because she was troubled by other aquatic insects which had made a home in this weed. These intruders were removed, and the Beetle set to work once more. Lyonnet then noticed that, like a spider, she had her spinning apparatus at the posterior end of the body. She extended the last segments slightly, and opened the hindmost one, when he saw a nearly circular opening, in which was a whitish disk (Fig. 30 A, *a*). On this disk were two little brown tubercles side by side, nearly at right angles to the longitudinal axis of the body. From each there projected a blackish-brown conical tube, about a line long, stiff towards the base, but flexible and elastic towards the tip. These tubes were the spinnerets, which acted together with a parallel movement, and from each proceeded a separate thread.

And this is how she made her cocoon. She lay near the surface of the water back downwards, the under part of the body and the second and third pair of legs buried in the thread-like weed. The front legs were free, and with these she shaped the weed over her abdomen. Then she spun a covering of white silk against the under side of the weed. While she was spinning, from time to time she used her front legs to press and flatten the work against her body (Fig. 30 B), giving it the shape of a flattened arch, to which her body gave the requisite curve. This, forming the top of the cocoon, was finished in about half an hour. Then she turned (Fig. 30 C), and spun the bottom of the cocoon, moulding this, like the top, on the curve of her abdomen, and uniting the top and bottom with silk which she spun. The work occupied about an hour and a quarter.

The Beetle then remained nearly in that position for some two hours. At first she was hidden in the cocoon quite up to the thorax. The body, however, was withdrawn almost imperceptibly. During this time she was busy laying her eggs in regular order, with the pointed ends upwards.

After this she came out of the cocoon, and closed the mouth (Fig. 30 D), making the opening smaller by degrees. Then she made a little mast (Fig. 30 D, *b*), of the use of which Lyonnet admits his ignorance, suggesting, however, that its construction may serve to use up the silky matter remaining after the work is finished, lest it should acquire harmful qualities in the body of the Beetle. The true explanation seems to be that it serves to convey air to the eggs inside the cocoon.

On July 17 Lyonnet was rewarded for his patient watching by seeing a larva come out of the cocoon, and the next day some fifty more appeared. What he saw and recorded it is in the power of others to see, if they will imitate his patient observation.

The Cocktail Beetle, or Devil's Coach Horse (*Ocypus olens*), is an excellent specimen of a Land Beetle to examine, for it is of fairly large size and extremely common. Moreover it does well in captivity, so that there will be no difficulty in watching its habits in life, and pickling it for closer examination when dead.

During the day these animals usually lie concealed under stones or pieces of earth, coming forth at dusk and during the night in search of food. Occasionally, however, they may be met with in daylight, leisurely stalking a smaller beetle or a fly; then with a dash seizing the victim in their powerful mandibles, which are quite capable of making an impression on the human skin, as

Fig. 31.—Cocktail Beetle. *a*, larva; *b*, pupa.

those who handle these Beetles unwarily will discover for themselves.

Nothing of an animal nature comes amiss to them, and if they cannot capture living prey, they will make a hearty meal off carrion. This is an advantage to us, for we may feed our captives with dead insects or with small pieces of meat.

This Beetle is about an inch long, and of a deep dull black colour. The head is joined to the thorax by a distinct neck, and the abdomen is naked, owing to the fact that the wing-cases are very short. Its wing-cases bear about the same proportion to those of the Margined Water Beetle that a man's frock-coat bears to a boy's Eton jacket. And this Beetle may be taken as a good type of a group—the Beetles with short wing-cases (*Brachel'ytra*).

The attitude of this animal when irritated or alarmed is well depicted in Fig. 31. It raises its head menacingly and opens its strong mandibles to their full extent, at the same time turning up the end of the abdomen, like a scorpion about to sting. From the last segment it will often put forth a pair of white vesicles, from which is discharged a volatile liquid of disagreeable odour, that probably acts as a defence against insect-eating creatures.

The best way to capture one of these Beetles is to pick it up with what Kirby calls the 'natural forceps'—the finger and thumb. It may be dropped into any convenient receptacle; the small metal boxes in which vestas are sold will answer the purpose very well.

My specimen was given me by a friend, who kept it with another in a round tin box. It lived with me for about three months in a four-ounce bottle, that measured three inches in height, to the neck, and two inches in diameter. The bottom was covered to the depth of about an inch with garden soil, and the top tightly corked, to prevent the prisoner's escape. This precaution was necessary; for the inside of the bottle, though cleaned from time to time, soon became covered with a coating of earthy particles, which afforded the Beetle a pretty firm foothold.

It was an extremely interesting pet, and its struggles to escape by climbing up the sides of the bottle often afforded me much entertainment. It seemed to have a glimmering notion that the only way out was by the top, and knowing nothing of the cork it would rear itself up against the side, and try to climb up by vigorous movements of its fore-legs. It would also take advantage of any little lump of earth projecting about the rest. It had not intelligence enough to make anything like a mound for itself, though the inequalities were probably the result of its burrowing under the surface. Its temper was none of the best, for if it was disturbed with the forceps it would resent it fiercely. The mandibles would be opened, the abdomen curled up, and out would come the two vesicles as a means of defence. If the forceps were put near the mandibles, they would be seized, and the Beetle would hold on so tenaciously that it has often been lifted out of its bottle in this fashion.

It was exceedingly voracious, and was generally fed on garden worms. After a full meal its increase in size was very evident. This is not to be taken to mean that insects grow after they have attained the perfect or imago state, for this is not the case. But when they have had a long fast, the segments approach each other, and are forced apart when the creature is gorged with food. If a Beetle of this species were kept fasting for some days, and then carefully measured, and measured again after being plentifully supplied with worms or flies, there would be a difference of some millimetres between the results.

Dallas has an interesting passage in his *Elements of Entomology* respecting the boldness of the larval form, which is worth quoting. 'I have seen one engaged in a struggle, which lasted about twenty minutes, with a worm of some five inches in length, the larva being scarcely more than an inch long. During this contest the little savage crept under the worm, fixing his mandibles into the creature's body in various places, each bite apparently producing a considerable swelling. Sometimes he would fasten upon the head of the worm, and retain his hold with the pertinacity of a thoroughbred bulldog, although twisted about in every direction by the struggles of his intended victim. At last, however, he seemed to come to the conclusion that he had been too ambitious in his desires, and went quietly off amongst the grass, rather prematurely, as it seemed to me, for when the worm began slowly to leave the field of battle, about an inch of his tail was attached to the rest of his body solely by the intestine, a union which the jaws of the larva would easily have dissolved.'

I have never seen a fight between a larva and a worm, for the few larva I have kept have been fed on flies. But the adult Beetle which has once fastened on a worm cannot be shaken off. It will grip its prey with the first pair of legs, fixing the claws in the skin, and will finish a worm three inches long at a meal.

A dead specimen should be looked over in the way recommended for Dytiscus, raising the small wing-covers and unfolding the wings. The spiracles are to be looked for at the sides of the abdomen, in the groove formed by the meeting of the upper and under plates of each segment. The short downy hair with which the body is covered should be noticed, and the front legs are well worth examination. The tibia or shank is armed with a strong spine, and between this part of the leg and that which follows it is a notch, through which the Beetle passes its antennae to clean them from dirt. The peculiar shape of the joints of the tarsus or foot is very plainly discernible with the appliances at our command, and by a careful management we may make out the different kinds of hairs with which four out of the five of these joints are furnished; some stout and spine-like, others finer, ending in a pear-shaped bulb. These last probably serve the same purpose as the sucking-disks of Dytiscus and the tarsal plates of Hydrophilus.

CHAPTER III

COCKROACHES; EARWIGS; THE GREAT GREEN GRASSHOPPER; THE WATER SCORPION; THE WATER BOATMAN; CORIXA.

THE next insect to come within range of our pocket lens is the Common Cockroach (*Blatta orienta′lis*[1]), popularly misnamed the Black Beetle. We shall have no difficulty in procuring material for examination. Housekeepers will tell us that these creatures are only too plentiful.

In the last chapter we dealt with Sheath-winged Insects—the Coleop′tera. Cockroaches belong to the Orthop′tera, or Insects with Straight Wings. The mouth-parts resemble those of Beetles. The chief differences that mark off the Cockroaches and their kin from the Beetles are the incomplete metamorphosis which the former undergo, and the character of the wings. Straight-winged Insects, when they leave the egg, differ little in shape from the adult, except in the fact that they have no wings; and these appendages are absent, or so small as to be useless for flight in many species. When wings are present the first pair are of little or no use for flight. They are not, however, hard

[1] I have purposely given *Blatta* as the generic name, rather than *Stilopyga,* which should properly be used, as the former is only employed in very recent literature.

chitinous sheaths, meeting in the middle line—that is, straight down the centre of the back—but of a flexible leathery or membranous substance, and they usually overlap each other at the tips. The hinder wings are large and nearly semicircular. The principal veins radiate from the centre to the circumference, like the sticks of a fan, and when the wings are folded up they lie straight along the upper surface of the abdomen. It is from this fact that the Order derives its name.

There are two great groups, or sections, of Straight-winged Insects—those that run, like the Cockroaches, and those that leap, like the Grasshoppers. No Straight-winged Insect is aquatic.

The Common Cockroach, now so abundant, is not a native, but an importation from Asia; though how it reached this country is not quite certain, probably by way of Holland. It seems to have established itself in London by the end of the sixteenth century, and some two hundred years later we find Gilbert White recording (in or before 1790) that 'a neighbour complained that her house was overrun with a kind of black beetle, or, as she expressed herself, with a kind of black-bob, when they got up in the morning before daybreak. Soon after this account I observed an unusual insect in one of my dark chimney closets, and find since, that in the night they swarm also in my kitchen. . . . The male is winged, the female is not, but shows something like the rudiments of wings, as if in the pupa state. . . . They are altogether night insects, *lucifugae*, never coming forth till the rooms are dark and still, and escaping away nimbly at the approach of a candle.'

This description leaves no doubt as to what the 'black-bobs' really were. This name seems to have dropped out of use, and it would be well if 'black beetle,' in the sense of Cockroach, were also allowed to drop, for the term contains just as many errors as words.

We may make our first acquaintance with these insects by keeping some specimens in confinement. A tin box, with a glass lid, will make a capital dwelling for them. Some paper should be put in, for them to hide in away from the light, and there can be no difficulty in providing them with food. 'Bark, leaves, the pith of living cycads, paper, woollen clothes, sugar, cheese, bread, blacking, oil, lemons, ink, flesh, fish, leather, the dead bodies of other cockroaches, their own cast skins and empty egg-capsules, all are greedily consumed. Cucumbers, too, they will eat, though it disagrees with them horribly [1].'

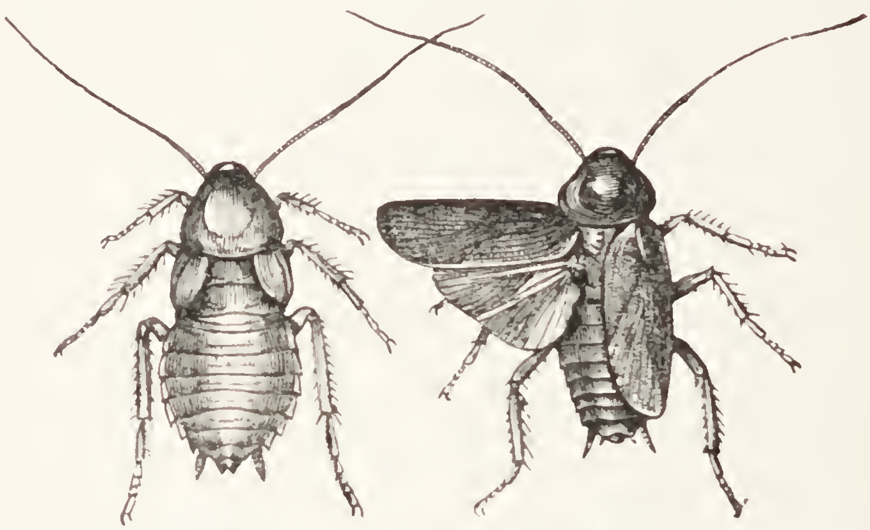
We have Dr. Sharp's authority for the statement that in confinement these insects are rather amusing pets, as they 'occasionally assume most comical attitudes, especially when cleaning their limbs. This they do somewhat after the fashion of cats, extending the head as far as they can in the desired direction, and then passing a leg or an antenna through the mouth; or they comb other parts of the body with the spines on the legs, sometimes twisting and distorting themselves considerably in order to reach some not very accessible part of the body [2].'

The prejudice against these insects is, however, so strong, that most people will prefer to examine dead rather than living specimens, on account of the disagreeable odour of the latter. This odour is due to a fetid excretion from the mouth, and if

[1] Miall and Denny, *The Cockroach*, p. 20.
[2] *Cambridge Natural History*, v. 231.

the specimens are killed by dropping them into boiling water, this will be discharged, and after a little while they may be taken out with a pair of forceps, and put into spirit for preservation. If they are dropped alive into spirit, the excretion will communicate its strong scent to the preserving medium, and this should be changed before the insects are examined.

From Fig. 32 we may get a general idea of the



Female. *Male.*

FIG. 32.—Cockroaches.

appearance presented by a male or female, lying back upwards in a small glass dish, ready for examination with the pocket lens. The female may be distinguished at a glance by her wingless condition—only rudiments of wing-cases being present, and no wings—and her broader abdomen. In life she does not stand so high upon her legs as does the male, and her abdomen trails along the ground. The male does not acquire his wings till the last moult.

As the Cockroach lies back uppermost in a glass dish, the head is almost concealed. This is especially the case, unless the insect is flattened out in some way, or pinned down to a piece of weighted cork. There will thus be, apparently, two, instead of three main divisions. This arises partly from the fact that the head is deflexed, or bent down so that the mouth is turned towards the rear, and partly because the first segment of the thorax bears a chitinous shield, roughly semicircular, which covers so much of the head as would otherwise be visible.

The difficulty, however, may be easily got over, by reversing the position of the insect, and raising the head with a needle. The antennae will attract attention by their great length. In the male insect they exceed, while in the female they fall a little short of, the total length of the body. They are well worth examination. Even a low power will show that they consist of a number of joints—usually from seventy-five to ninety. The three basal joints are much larger than the rest, and in the female the third basal is nearly as long as the first. All these joints are thickly set with stiff hairs directed forwards. At the outer side of each antenna is a compound eye, and on the inner side is a pale spot, the *fenestra*, which in the males of some foreign Cockroaches is replaced by a simple eye.

If Cockroaches are kept in confinement, and forced out into the light, the constant motion of the antennae will satisfy the observer that they are of great use to their owners. By means of these organs they not only discover their food, but become by some means, probably by the motion of air-waves, aware of danger that threatens them. Belt, in his *Naturalist in Nicaragua* (p. 110), speaking of the Cockroaches that infest houses in the tropics, says, 'They are very wary, as they have numerous enemies—birds, rats, scorpions, and spiders; their long, trembling antennae are ever stretched out, vibrating as if feeling the very texture of the air around them; and their long legs quickly take them out of danger.' It is not given to every one to visit the tropics, but we may all use our eyes in observing the common insects that abound in our country, and in doing this we shall strengthen the habit of observation, and very often find confirmation of what we read of the habits of insects in distant lands.

Sir John Lubbock [1], in treating of the sense of smell in Insects, says that 'Plateau put some food of which cockroaches are fond on a table, and surrounded it with a low circular wall of cardboard. He then put some cockroaches on the table: they evidently scented the food, and made straight for it. He then removed their antennae, after which, as long as they could not see the food, they failed to find it, even though they wandered about quite close to it.'

The large kidney-shaped compound eyes are sure to attract attention. It is worth while to take out and break up an eye, gently washing out the pigment. If we do this, and then examine it with the pocket lens, we shall have some idea of the multiplicity of lenses in the eye of a Cockroach, each of the six-sided facets being a lens.

Next come the mouth parts, which may be run over very quickly, for those of Beetles are formed upon the same plan, and from this primitive plan are derived the mouth parts of all other Insects, of whatever character they may be. To examine the

[1] *The Senses of Animals*, p. 44.

mouth organs the insect must be turned on its back, and the *labrum* (*a*), or upper lip, raised with a needle, so as to allow of a general view of the rest. Then the jaws or mandibles (*b*) may be picked out with a needle. These jaws are strongly toothed, and work from side to side, and it is easy to see that they are very efficient organs. The lower jaws (*c*), or *maxillae*, lie below, and are compound organs, each being made up of several parts--the base, called the *cardo* or hinge (not shown in the illustration, but connected at right angles by a joint with the lower part, the *stipes*). From the stipes rise the *galea*, or helmet, on the outer side; and, on the inner side, the *lacinia*, to which the name maxilla is often applied, though it properly belongs to the whole. At the base of the *galea* is inserted the five-jointed maxillary palp, thickly set with hairs, and probably an organ of touch.

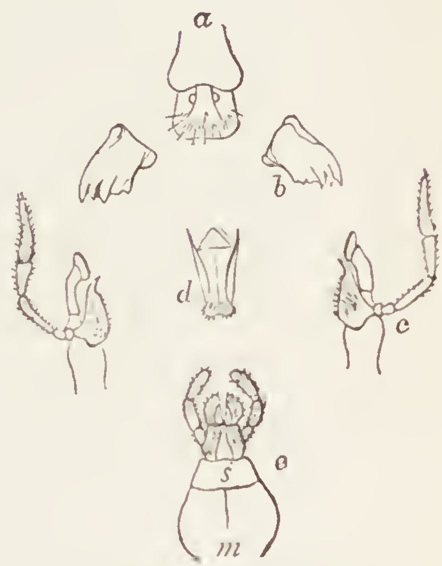


FIG. 33.—Mouth parts of a Cockroach.

By examining the maxillae (*c*) before they are separated, and comparing them with the *labium* (*e*) or under lip, which closes the mouth from below, it will be evident that there is no slight similarity between them. Nor is this strange: for the under lip consists of the second maxillae joined at their bases, which form the *submentum* (*s*) and *mentum* (*m*). (The former is the small, the latter the large white basal portion; the vertical line in the illustration shows the mental suture, and should be traced in the dead insect.) The organs in the centre constitute the *ligula*; and on each side of the labium is a three-jointed palp (*labial*), like that on the maxillae, thickly set with hairs, and with a similar function. It is well to work over the mouth parts a few times till the relation between the maxillae and the labium is seen and understood. The internal tongue (*d*) is attached to the inner side of the labium.

Now, still working on the under side of the insect, the three segments of the thorax are to be made out, and one cannot fail to notice the great size of the first joint (the *coxa*) in all the legs, and that these joints seem to serve as shields to protect the under side of the thorax. Then the different parts of the legs should be traced, and compared with Fig. 23 on p. 44. The spiny armature of the tibiae is to be noticed, as are the claws, between which is a projecting lobe, though this is absent in immature specimens. We shall find that the appendages of the thorax are the same as in the Margined Water Beetle. It is well to take as little as possible on trust, and to verify everything that we possibly can.

Now we may reverse the position of our subject, and having cut off the wing-cases, which are technically called *teg'mina*, examine the wings. These may be gently unfolded with a needle or a camel's hair brush, when the longitudinal method of folding will be clearly seen, and the difference of the veining from that of the wings of the Margined Water Beetle will be apparent. A female should also be examined, and the small tegmina cut off, so as to see that not even the rudiments of wings are present.

The Cockroach breathes like other adult Insects, and the spiracles are ten in number—two on the thorax and eight on the abdomen. The thoracic spiracles may be pretty readily seen, but those on the abdomen are not so easy to make out. But by cutting away, with a fine pair of scissors, the edges of the plates that cover the upper and under surfaces of the abdomen and the membrane that unites them (Fig. 34), we may discover them as the open ends of small tubes. While dealing with the insect in this fashion, it will be easy to take out a piece of the tracheal tube, which may be compared with Fig. 28.

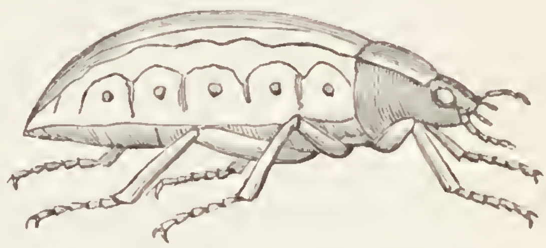


FIG. 34.—Cockroach, showing Spiracles.

The abdomen consists of a series of rings or segments, the exact number of which is rather difficult to decide, from the fact that some are concealed and others altered in form. Dr. Sharp[1] says that 'it is considered that ten dorsal and ten ventral plates exist, though the latter are not so easily demonstrated as the former.' In the male, ten above (dorsal) and nine below (ventral), and in the female two less in each case, may be made out without dissection.

From the sides of the tenth segment two organs, the *cerci* (Fig. 35, *a*), are given off, one on each side. These may be distinguished from the styles of the males by their presence in both sexes. Our inch lens will show that each cercus consists of sixteen rings. If we use the half-inch, we shall see that each ring is set with hairs of different lengths.

When we have got so far it may be well to compare the structure of a *cercus* with that of an

[1] *Cambridge Nat. Hist.* v. 223.

antenna (p. 67). In each we have a succession of jointed rings giving flexibility to the organ, and the rings in each case are studded with hairs. It has been shown pretty conclusively—and we may verify the experiments—that the antennae are sense-organs. Are we not justified in coming to the conclusion that, since the antennae and the cerci resemble each other in structure, they also resemble each other in function? If the Cockroach receives sensations by means of the antennae, is it not probable that it also receives sensations by means of the cerci?

Having worked over the Cockroach from the outside, it will be advantageous to get some acquaintance with its internal anatomy. This is not a difficult matter. The specimen is to be pinned down, under water, with its back uppermost. The wings having been removed, a longitudinal cut is to be made down the centre from the posterior part of the abdomen to the back of the head, and the two sides of the integument turned back. Or the junction between the upper and lower plates on each side may be cut through with a cutting needle, and the whole integument removed.

The first task is to clear away the fat-body, a whitish substance which overlies the chief organs of the body. When this is picked to pieces and floated off the digestive system will be exposed. After this has been worked over a few times there should be no difficulty in dealing with similar parts in other Insects. At the back of the head lies the gullet or oesophagus leading into the crop (*c*), at the base of which lies the gizzard (*g*). The interior of this organ is furnished with six strong chitinous teeth, with small ridges of the same substance between them. Towards the posterior end are six cushions, all set with fine bristles. Behind this comes the stomach (*v*), into which open seven or eight tubes, closed at one end, and between it are the Malpighian tubes, which are concerned in the process of excretion. The small intestine (*co*) succeeds, and behind this is the rectum (*r*).

It will be interesting to separate the gizzard from the crop (*c*) and stomach (*v*) and break it open with a couple of needles, so as to examine the teeth, which will be more easily made out if the opened organ be allowed to soak for a time in a solution of caustic potash.

Similar teeth-

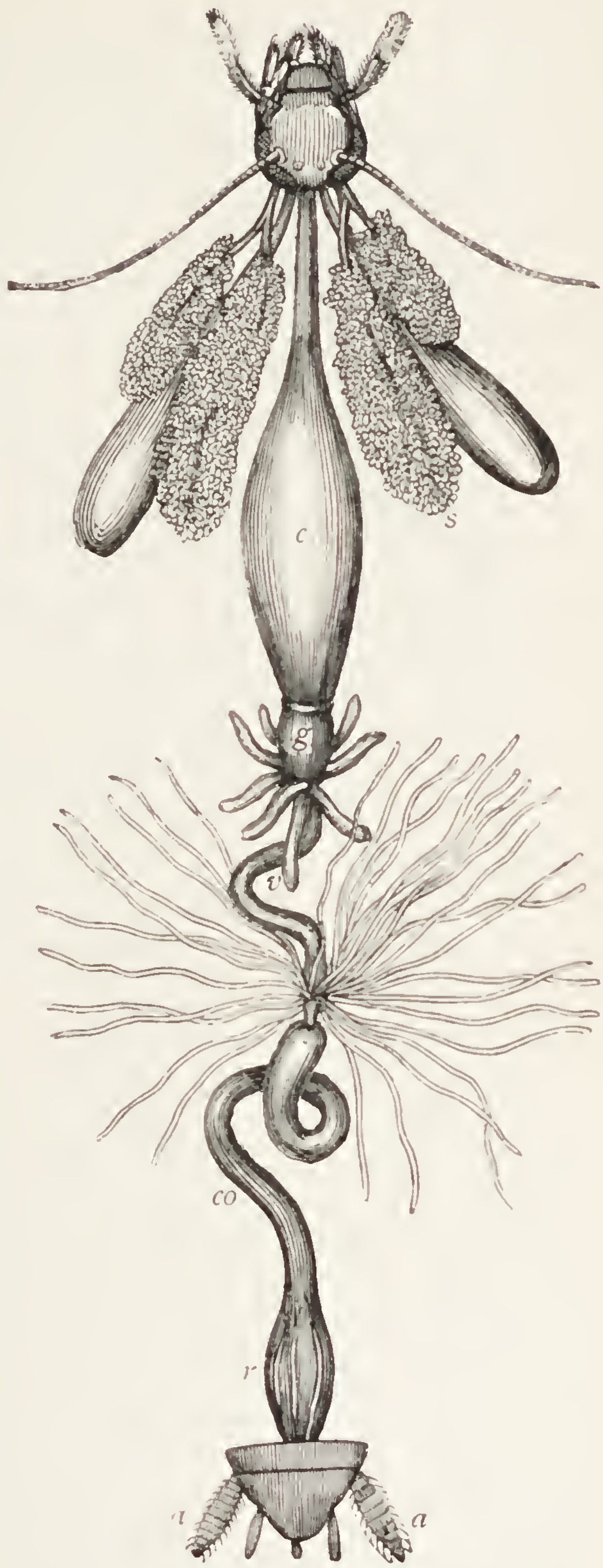


FIG. 35.—Alimentary Canal of Cockroach.

like processes are found in the gizzards of many other Insects, and their presence has given rise to some strange ideas. Swammerdam[1] says, 'I preserve also the threefold stomach of a locust, which is very like the stomach of animals that chew the cud, and particularly has that part of the stomach called Echinus[2] very distinctly visible. I do not, therefore, doubt but locusts chew the cud, as well as the animals just mentioned. Indeed, I persuade myself that I have seen this.'

Somewhat similar teeth-like processes exist in the Lobster, the Crab, and the Crayfish. 'Professor Plateau has expressed a strong opinion that neither in the stomach of Crustacea nor in the gizzard of Insects have the so-called teeth any masticatory character.' He adopts Swammerdam's comparison, but considers them strainers, not dividers of the food[3].

We may be fortunate enough to meet with some specimens of the American Cockroach (*Periplané'ta americá'na*, Fig. 36), a much larger species, which has established itself in some few places in this country. At the Zoological Gardens, Regent's Park, it is abundant, and has almost, if not entirely, driven out the common form. Mr. Bartlett believes that it was introduced in cases in which animals have been sent over from America. Both sexes are winged. They not only possess organs of flight, but use them. If one visits the Gardens, there will be no difficulty in getting specimens; and it is interesting to compare the points of

[1] *Book of Nature*, p. 94.

[2] This refers to the gizzard. *Echinus* was used to denote the third stomach of Ruminants (now called the manyplies), because it was thought to resemble a hedgehog rolled up.

[3] Miall and Denny, *The Cockroach*, p. 118 (note).

agreement in and of difference between this animal and our common form.

FIG. 36.—American Cockroach (male).

The Earwig (*Forfic'ula auricula'ria*) is common enough to furnish us with plenty of specimens on which we may employ our pocket lens. Any garden in the summer months will yield an ample supply. Earwigs, like Cockroaches, are light-shunning insects, and love to hide themselves in the corollas of flowers ; and it is probably from their habit of seeking to conceal themselves that they have acquired their bad reputation—by no means confined to our own country—of creeping into the ears of persons lying asleep, and causing death by getting into the brain. Such an occurrence is beyond the bounds of possibility. No insect of this size could pass the drum of the ear.

We may easily keep these insects and observe their movements, if we put them into a wide-mouthed glass bottle and supply them with food. They are extremely fond of the flowers of the dahlia; but a dahlia would offer too many hiding-places, so we will put into the bottle some nasturtium flowers, or any others with a bell-shaped corolla.

If we get a colony in spring we may watch the care of the female for her eggs. According to Kirby and Spence[1], 'she absolutely sits upon her eggs, as if to hatch them—a fact which Frisch appears first to have noticed—and guards them with the greatest care. De Geer (*Mémoires*, iii. 548) having found an earwig thus occupied, removed her into a box where was some earth, and scattered the eggs in all directions. She soon, however, collected them one by one, with her jaws, into a heap, and assiduously sat upon them as before. The young ones, which resemble the parents, except in wanting elytra and wings. . . . immediately upon being hatched creep like a brood of chickens under the belly of the mother, who very quietly suffers them to push between her feet, and will often, as De Geer found, sit over them in this posture for some hours.' Mr. Kirby adds: 'This remarkable fact I have myself witnessed, having found an earwig under a stone which I accidentally turned over, sitting upon a cluster of young ones, just as this celebrated naturalist has described.'

Like the Cockroaches, Earwigs undergo an incomplete metamorphosis. When the young leave the egg they resemble their parents, as may be seen from the immature forms represented in

[1] *Introduction to Entomology*, letter xi.

Fig. 37. The resemblance becomes greater at each successive moult.

In working over these insects, the forceps, or pincers, at the end of the abdomen will attract attention. They are found throughout the family, but little is known of their function. It is said that they are used to aid in folding the wings, and tucking them under the wing-covers. This can scarcely be their only function, for they are found in species that have no wings. Probably they serve as organs of defence and, to some slight extent, of offence. When the abdomen is curled up, these forceps certainly give the insect a threatening appearance. They cannot, however, do much harm.

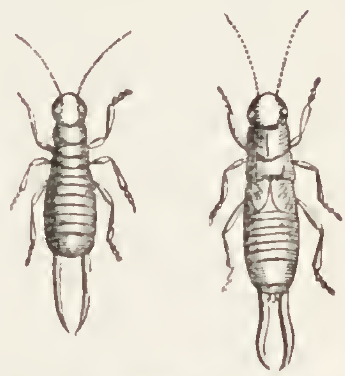


FIG. 37.—Larva and Pupa of Earwig.

These forceps differ in shape in the male (Fig. 38) and female, the blades being almost close together in the latter. In the males they differ considerably in size. Of 583 mature males taken in one day in the Farne Islands, and examined by Messrs. Bateson and Brindley, the forceps varied in length from 2·5 mm. to 9 mm.[1] These are called respectively 'low' males and 'high' males. The latter are in all points larger than the former, and have been described as a separate species, 'but it was impossible to get reliable measurements of the total length, owing to the fact that the abdominal segments telescope into each other' (cf. p. 30).

After examining the antennae and dissecting out the mouth organs, the peculiar overlapping or im-

[1] *Proceedings of the Zoological Society*, 1892, p. 586.

brication of the plates of the abdomen should be looked for; and on the membrane that connects them the spiracles may be detected.

The wings and the complex method of folding have led some systematists to rank the Earwigs as an Order, while some others rank them as a Sub-order. For the present, at any rate, we need not concern ourselves about this. It is enough for us to know that they are closely related to the Orthop′tera.

As we look at the Earwig from above, the wing-cases recall to our mind those of the Devil's Coach Horse (Fig. 31), though there is one great difference. From beneath those of the Earwig project two small leathery pieces which are absent in the Beetle. These pieces are not, as one might imagine, at the tips of the wings, but on the front margin, about halfway down, and is indicated in the illustration by the shading between the extremity of the wing-case and the crease-mark at *a*.

FIG. 38.—Earwig (male)

From the illustration we may understand how the Earwig opens and closes its wings. From the point *a* veins, which are thickened about halfway down, radiate to the hinder edge of the wing, and a little beyond the thickening they are connected by a vein which runs parallel with the hinder edge. These radiating veins are brought together, so that there is a fan-like closing, like that of the Cockroach, but from a different centre. The wing is then folded back at the place where the veins are thickened, and then there is a second transverse fold at the point *a*, so that the only part of the wing now visible is the leathery patch, which projects beyond the wing-case when the wing is tucked away.

It is not difficult to unfold the wing of a dead specimen, under water, using a needle and fine brush. Mr. E. A. Butler [1] recommends a simple but excellent plan for unfolding and preserving the wing, by gumming it, with the upper surface downwards, to a piece of card, and gradually unfolding it and fastening it down. This is not so easy as it may seem, but with patience and perseverance success will be obtained; and a similar method may be adopted with the wings of other Insects, which may be mounted in this way without any trouble. Thus they may be easily preserved for examination at a future time, or for comparison with the wings of other Insects.

It is rather remarkable that an insect like the Common Earwig, which very rarely takes to flight, should have such a complex method of folding its wings. Dr. Sharp says that though the Earwig 'is scarcely surpassed in numbers by any British insect, yet it is rarely seen on the wing. It is probable that the majority of individuals of this species may never make use of their organs of flight, or go through the complex process of folding and unfolding them.'

Let us choose our next example from the Leaping Orthop′tera. They may be distinguished at a glance from their relatives that run, but do not

[1] *Our Household Insects*, pp. 159–163.

leap, by the peculiar structure of the third pair of legs. These are much longer and stouter than the other two pairs, and the thigh is very muscular. This insect is a very good type of the family Locus′tidae, to which, however, none of the insects popularly called 'locusts' belong. They are included in another family (Acridi′idae), where the common British Grasshoppers are also placed. The Locustids and the true locusts may be distinguished by the difference in their antennae: in the latter these organs are short, in the former they are very long and delicate.

The Great Green Grasshopper (*Locus′ta viridis′-sima*) (Fig. 39) is fairly common all over the country, but often escapes observation from the fact that its hue corresponds so nearly to that of the foliage on or among which it lives. One specimen taken in a Devonshire lane gave me a great deal of trouble before it was secured and transferred to a small tube. It was perched on a leaf when I first saw it, and as I approached it leaped away. Though I was certain it had not gone far, it was some little time before I discovered it. and got near enough to grasp leaf and insect, in time to prevent the latter from taking another jump.

This insect may be kept alive in confinement for a considerable time, and will do fairly well on a diet of leaves and fruit, though it will not refuse an occasional meal of flesh. Dr. Sharp says that a specimen in confinement 'mastered a humble-bee, extracted with its mandibles the honey-bag, and ate this dainty, leaving the other parts of the bee untouched.' It is said that if two be placed together in a box they will fight most desperately, and that the victor will make a meal off the body of its victim. De Geer witnessed a case of this kind in a closely allied species that is found in Sweden. Its specific name signifies 'wart-eater,' and commemorates the fact that the peasants incite these insects to bite their warts, firmly believing that warts once bitten speedily disappear, and do not grow again. Westwood says that one of these insects actually devoured part of its own leg that had been broken off accidentally. When the

FIG. 39.—Great Green Grasshopper (female).

creature was seen at night the detached leg was whole; in the morning about half of it had been eaten.

It is well to get specimens of male and female insects. We shall require the former in order to examine the sound-producing apparatus, which the females do not possess; and the latter for the sake of the ovipositor—a long scimetar-like organ by means of which the eggs are deposited. Let us take the female first. The length, including the ovipositor, is a little under two inches, and the antennae will measure about as much more. The wing-cases do not lie flat upon the back, as do those of the Cockroach, but in a slanting position, like the sides of a roof, forming a ridge in the centre. The head is not bent back, as in the Cockroach, nor does it project in front, as in the Beetles, but the front is almost vertical. The armature of the mouth is strong, and of the same pattern as that of the Cockroach. The hood—so the upper covering of the thorax is called—is of a peculiar shape, somewhat like that of a saddle. The wing-cases and wings, with their folding, will offer little difficulty. Next we may examine the cerci, and contrast them with those of the Cockroach and with the forceps of the Earwig. Last of all, the ovipositor must be examined, and its structure made out, so far as the means at our command will allow.

Apparatus of this kind for placing eggs in positions favourable to their development is by no means confined to these insects, for examples may be found in other Orders. Sirex, the so-called Tailed Wasp, has a long straight one, which is often supposed to be a sting, and the insect itself is not unfrequently taken for a gigantic wasp or hornet.

When the ovipositor of our subject is looked at with the unassisted eye, it appears to consist of two curved blades placed side by side, with an internal groove on each. The apparatus, however, is not quite so simple : it is made up of six chitinous rods, of which four—the two above, and the two central ones—are developed from the ninth segment of the abdomen, while the two lower ones spring from the eighth. It is not difficult to test these statements. Specimens are plentiful ; and as the ovipositor in this insect is large, and easily broken up into its component parts, it may well serve as an introduction to the study of these organs in other Insects—the Saw-flies, for example.

When the insect is about to deposit her eggs, she selects a spot where the soil is light, and bending the ovipositor nearly at a right angle to her body, thrusts it into the ground as far as possible. Then, by a muscular effort, the plates of the ovipositor are separated, and several eggs travel down the passage formed by the central pair of rods into the hole. This is repeated time after time, till the operation of egg-laying is completed. This takes place in the autumn, and the young emerge from the eggs in the spring. When they come out they are tiny copies of the adults ; but they do not acquire wings till after several months. The ovipositor of the female appears after the second moult, and till this organ is developed no difference is apparent between the young insects.

The chief interest of the male insect lies in its wings, for the first pair (the *teg'mina*) are the organs with which it produces its 'love-songs.' Kirby comments on the fact that Lichtenstein, in the *Linnaean Transactions* (iv. 51), 'draws attention to the eye-like area in the right wing-case of the males of this genus,' adding that that author seemed 'not to be aware that De Geer had noticed it before him, as a sexual character ; and also, with good reason, supposed that it assists these animals in the sounds they produce.'

This is how De Geer (*Mémoires*, iii. 429) describes the sound-producing apparatus of the Great Green Grasshopper: 'In our male grasshoppers, in that part of the right elytron which is folded horizontally over the trunk, there is a round plate of very fine transparent membrane, resembling a little mirror or piece of talc, of the tension of a drum. This membrane is surrounded by a strong and prominent nervure, and is concealed under the fold of the left elytron, which has also several prominent nervures answering to the margin of the membrane or ocellus. There is every reason to believe that the brisk movement with which the grasshopper rubs these nervures against each other produces a vibration in the membrane, augmenting the sound. The males in question sing continually in the hedges in the months of July and August, especially towards sunset, and part of the night. When any one approaches they immediately cease their "song."'

It is probably unnecessary to do more than remark that the noises made by Insects do not correspond to the voices of the higher animals. 'For no insect, like the larger animals, uses its mouth for utterance of any kind: in this respect they are all perfectly mute; and, though incessantly noisy, are everlastingly silent [1].'

Our plan with these wings is to first verify the fact of their bearing these talc-like spots, the serrated nervures on the right and the rudimentary file on the left elytron. The sound is produced by rubbing the base of the left elytron against that of the right. A recent author compares this insect to a fiddler, and says that the left tegmen is the bow and the right the fiddle.

[1] Kirby and Spence, *Introd. to Entomology*, ed. 1870, p. 484.

The last point to examine is the ear. It seems strange to say that these insects have ears in their legs ; but though some of the older entomologists regarded these structures in the tibiae of the first pair of legs as nothing more than resonators or sound-boards to intensify their chirping, there is no doubt that they are really organs of hearing. Much interesting information on this subject will be found in Sir John Lubbock's *Senses of Animals*.

FIG. 40.—Tibial ear of Great Green Grasshopper.

These oval patches are plainly distinguishable by the unassisted eye, and correspond in function to the tympanum or drum of the human ear. The air-supply to the tibiae is distinct from that of the rest of the body, and is derived from a large orifice on each side of the first segment of the thorax. These orifices may be seen by removing the 'hood.' Indeed, they cannot escape observation. From these orifices an air-tube passes to each leg, dividing into two branches in the tibia and reuniting below the drums.

Dr. Sharp[1] says that 'although the tibial ears of the Locus'tidae are very perfect organs, there is great difficulty in deciding on the exact nature of their functions. They would appear to be admirably adapted to determine the precise locality from which a sound proceeds . . . for the legs can be moved in the freest manner in every direction, so as to bring the drum into the most direct line of the vibrations. But as to what kinds of vibrations may be perceived, and the manner in which they

[1] *Cambridge Natural History*, v. 318.

may be transmitted to the nerves, there is but little evidence.'

The next Order from which we shall choose examples will be the Hemip'tera, containing the Land and Water Bugs and some other forms. Our chief concern, however, is with the Water Bugs. In this Order the metamorphosis is incomplete; the mouth is adapted for sucking the juices of plants and animals ; and there are usually four wings. In the Land and Water Bugs, part of the fore wings is harder than the hind wings ; in the other winged members of the Order both pairs of wings are membranous. The front wings are called hemel'ytra or half-el'ytra, to distinguish them from the el'ytra or wing-cases of Beetles, which are chitinous throughout. Fig. 41 shows the hemel'ytron and hind wing of a Land Bug, and the names given to the different parts of the front wing.

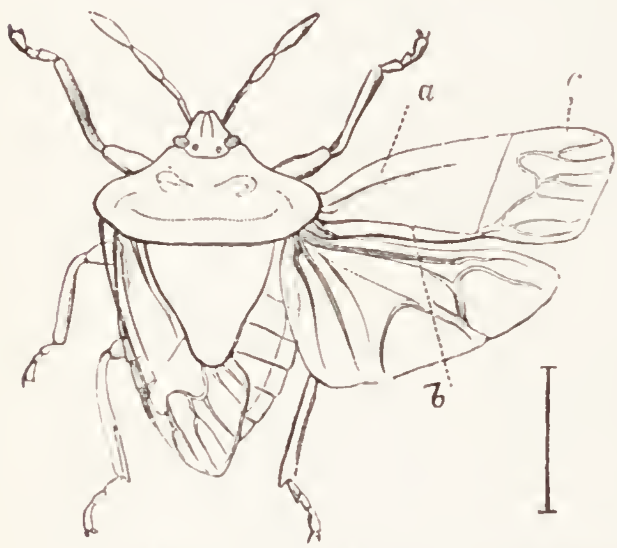


FIG. 41.—A Land Bug (magnified). *a*, corium ; *b*, clavus ; *c*, membrane.

The Water Scorpion (*Nepa cine'rea*) is not difficult to procure, or to keep in confinement when it is caught. It would be straining language to call it a handsome creature, yet it well deserves careful study, on account of the wonderful modification of the first pair of legs, and it is from the resemblance of these to the pedipalps of the scorpion that the insect derives its popular name. Its length is about an inch and a quarter, from the tip of the beak, or rostrum, to the end of the breathing-tube. Its greatest width is a little over a quarter of an inch (Fig. 42). The general hue harmonizes well with the mud, but the upper surface of the abdomen is a warm red, 'and is thick set with hair, so as to afford a very agreeable sight.'

FIG. 42.—Water Scorpion.

It is extremely common in shallow pools, and its favourite haunt is near the shore, where it will lie, almost buried in the mud, with its raptorial legs elevated, ready to seize on any passing insect, and its breathing-tube just pushed through the surface-film. I learnt this habit of the insect on the first occasion on which I tried to collect specimens of it. I had been told that a certain piece of water swarmed with Water Scorpions. This, I afterwards found, was quite correct; but though I worked the pond from end to end, a single specimen was all that rewarded my labour. Whilst transferring the insect from the net-tube to the bottle for transport, a stranger joined me, and kindly volunteered his assistance. He had no collecting tackle, but in about a quarter of an hour he brought at least a dozen good specimens in the bottle he had borrowed.

It was natural to inquire to what his success was due. He told me that it was his first attempt at collecting, but that just before joining me he had noticed the ends of the breathing-tubes sticking out of the water. This excited his curiosity, and on moving the mud with his walking-stick, the insects were seen to crawl away slowly. When he saw me transfer the Water Scorpion from the net-tube to the bottle, he immediately recognized it. Then he courteously offered his help, for which, of course, I was grateful.

We may keep the Water Scorpion alive for a considerable time in a small bottle of water, in which is some growing weed. If we watch it moving about, we shall see that the front legs are used for locomotion as well as for seizing prey. Some authors doubt this. Any one may settle the question for himself, if he will put one of these insects into a small bottle with plenty of weed. Generally, however, the insect uses only the second and third pairs for walking, the first pair being raised and directed forward, with the tarsus bent at an angle (Fig. 42). Even when it does use its front legs for locomotion, the action is not that of walking; the insect employs these limbs to pull itself along in a sort of 'hand-over-hand' fashion, but on a level surface it uses the first pair in the same way as it does the other two pairs.

Its habit of burying itself in the mud may also be watched with very little trouble. A common pudding-basin will make an excellent aquarium for this purpose. The bottom is to be covered with garden mould and vegetable *débris*, mixed with a few stones. The whole mass should be arranged unevenly, so that when water is added it may not form one sheet, but a series of small shallow pools. Very little duckweed will serve to keep it sweet. It only remains to drop in the Water Scorpion. Before long it will accommodate itself to its new surroundings, and so bury itself that it will be no easy task to discover it.

An aquarium of the kind described stands at present on my writing-table. Many have been the inquiries as to what kind of creature lived therein; and more than one old hand at collecting has failed to find the insect. It is always safe to look round the sides of the basin for the breathing-tube; if it is not detected in this situation, a glance along the surface of the tiny pools will probably show a break in the film. The Water Scorpion will not be far off.

That the insect really does cover itself with mud may be demonstrated by transferring it from the aquarium described to any shallow vessel, and allowing a fine stream of water—say, from a dipping-tube—to fall gently on it. The mud will be washed away, and in a few seconds will settle at the bottom.

It is well to keep such an aquarium covered, for the Water Scorpion has no mean power of flight. A circular plate of glass, which may be bought for a few pence, makes the best cover, but a piece of fine muslin fastened round the rim of the basin will do. Swammerdam says, 'These Water Scorpions live all the day in the water, out of which they rise about the dusk of evening into the air, and so flying from place to place, often betake themselves in quest of food to other waters.' Then follows a deduction which shows how far he was in advance of his time: 'This affords us a satisfactory reason for the great number of insects that immediately appear in the smallest collections of water, since they may very well get thither when it is dark, so that the opinion which ascribes to putrefaction the power of forming insects, &c., must, by this instance of the Water Scorpion's nocturnal transmigrations, appear more and more frivolous and unnecessary.'

No larva or other animal that is of any value should be kept in the same aquarium with the Water Scorpion. Dr. Hill, who annotated the English edition of Swammerdam, says, 'There is

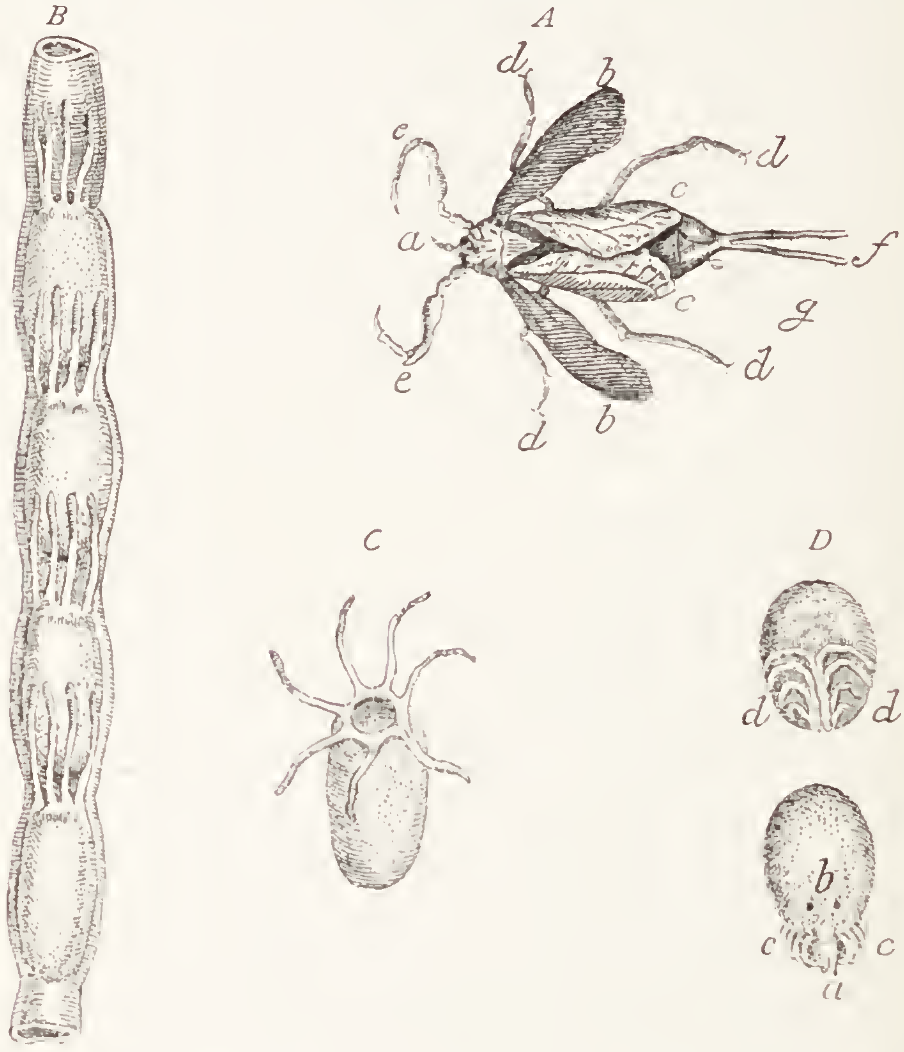


FIG. 43.—*A*. Water Scorpion. *a*, rostrum; *b*, wing-cases; *c*, wings; *dd*, second and third pairs of legs; *e*, raptorial legs (the first pair); *f*, spine forming breathing-tube; *g*, parasitic mite. *B*. Portion of an oviduct containing eggs (magnified). *C*. An egg (magnified). *D*. Parasitic mite. *a*, head; *b*, eyes; *c*, legs; *d d*, legs (seen from under surface). (After Swammerdam.)

not perhaps in all the animal creation so outrageous or fierce a creature against those weaker than itself as the Water Scorpion. It destroys, like the wolf among sheep, twenty times as many as its hunger requires.' The Rev. G. C. Bateman placed one in a saucer with a tiny minnow; 'but no sooner did the little fish swim within reach of the fore-legs of the scorpion than it was seized by them, and pressed against the hungry creature's rostrum.' It seems to be particularly fond of Asellus, the water woodlouse. I have often taken dead specimens of this crustacean, sucked completely dry, from between the raptorial legs of the insect. One specimen was so thoroughly cleaned out that it was mounted just as it was, the only preparation being a brief soaking in spirit.

In examining the head the eyes may be readily distinguished, and on pressing the rostrum or beak with a needle, the proboscis will be forced out, just as one may force out the sting by pressing the abdomen of a bee or a wasp. In this group the antennae are three-jointed and concealed. When one begins to look for these organs he will probably come to the conclusion that the concealment is highly effectual.

A very simple method of finding them in a spirit specimen is to take the insect between the thumb and index finger of the left hand, holding it up to the light in such fashion as to keep the first pair of legs well clear of the head. Then, with a needle held in the right hand, raise the thorax till it lies in the same plane as the body. Each antenna lies in a groove beneath the eye. Gentle manipulation with the needle will lift them out, so that they may be clearly seen, not only with the hand magnifier, but with the unassisted eye. Or the insect may be pinned down under water instead of being held in the hand, and the antennae lifted or brushed out of the groove.

It will greatly simplify matters if, before attempting to raise the wings, the fact is borne in mind that the tip of the right wing-case lies over that of the left. It is perhaps as well to remove the wing-case altogether by inserting a needle under it, and gently raising it, using a little pressure in an outward direction. It will then be quite time to raise the wing and to see the method of folding and unfolding.

In Fig. 44 we have a representation of the raptorial (front) leg of this insect. This leg should be compared with the legs of other Insects—not in pictures only, but in actual specimens—that we may see how, while the general plan is preserved, different joints are modified to suit the special function of this limb—that of taking prey. (See also Fig. 43.)

FIG. 44.—Raptorial leg of Water Scorpion.

The thigh (*f*) is the largest joint, for the obvious reason that it contains the muscles that work the tibia and tarsus, which together form a kind of knife-blade, shutting down into a groove in the thigh, which may very well be compared to the handle of a pocket-knife. This description, however, is not to be taken on trust. It is not enough to read about the groove: we must see it for ourselves, raise the 'knife-blade' from the groove, and press it down again, and pass the needle along the groove. If we examine the interior of the groove, we shall find that there is a projection along the bottom, so that a cross section would appear like this—W. The inner portion of the tibia is also grooved; so that when once the prey is seized by this powerful limb, it has no chance of escape. The tarsus (*tar*) is not clearly distinguished from the tibia (*tib*) in the engraving, but it may be distinctly seen as a claw-like appendage in a living or dead specimen.

The breathing-tube remains to be examined. It may be detached from the body for more convenient manipulation. When this is done, the tube will be seen to consist of two pieces, each grooved on the inner side and set with hairs, which, as they interlock, prevent the entrance of water.

A somewhat similar arrangement occurs in the proboscis or tongue of butterflies. There is perhaps a closer parallel in the antennae of the masked crab, which, under certain conditions, form a kind of breathing-tube, each antenna being joined to its fellow by the hairs with which it is set.

There are two other Water Bugs which lend themselves to our purpose very well. Each is popularly called Water Boatman, though that name is better confined to Notonecta, because the insects of this genus 'row themselves about on their backs with their long feathered legs.' In the United States they are called Water Cicadae, from the shrill noise they make, probably by rubbing the fore-legs together.

FIG. 45.—Water Boatman.

In Fig. 45 the Water Boatman (*Notonec'ta glauca*) is represented as seen from above—a position in which we shall rarely discover it, if we keep it in a small aquarium. In Fig. 46 the same insect is shown swimming on its back, or in the position it assumes when taking in a supply of air. The end of the abdomen and the tips of the feet rest against the surface-film ; and at the slightest alarm a vigorous stroke of the last pair of legs sends the insect to a place of safety. From the way in which these insects habitually swim, Mouffet came to the conclusion that it was probable men learned the art of swimming on their backs from them.

FIG. 46.—Water Boatman swimming.

Active as the Water Boatman is, it often falls a victim to the Water Scorpion, if both are kept in the same aquarium. I learnt this fact by experience, for having put two Water Boatmen into a small tank in which was a Water Scorpion, I found both the former dead in the morning. It was evident that their destroyer had had a good meal.

The only point to which attention need be called in examining the Water Boatman is its method of taking in a supply of air. In looking at a dead specimen we shall see a ridge or keel running down the middle of the under side of the abdomen, and fringed with hair on each side. A similar fringe runs along each side of the abdomen, thus forming two passages along which the air taken in at the end of the body is conveyed to the spiracles, the largest of which are on the thorax.

Corixa (Fig. 47) swims with its back uppermost, and when kept in the aquarium may generally be seen foraging for small creatures—larvae or worms—among the sediment at the bottom. Bateman, who kept a number of these insects, says that he fed his specimens on garden worms and pieces of raw meat. Mine have always foraged for themselves, and done very well without feeding. They may often be seen to rub the short fore-legs alternately across the front of the head, probably for the purpose of producing a call-note. I have often watched them at this practice, but have never been able to detect any sound. The defect is evidently in my sense of hearing, for the sounds rest on undoubted authority, and are coincident with the rubbing of the fore-legs across the head.

FIG. 47.—Corixa, with wings expanded.

Where sound-producing organs exist it is more than probable the capacity for receiving sound-impressions also exists. Graber made some interesting experiments to test the sense of hearing in Corixa. His results are thus summarized by Sir John Lubbock[1]: 'He placed some Water Boatmen (Corixa) in a deep jar full of water, at the bottom of which was a layer of mud. He dropped a stone on the mud, but the insects, which were reposing quietly on some weeds, took no notice. He then put a piece of glass on the mud, and dropped the stone on to it, thus making a noise, though the disturbance of the water was the same. The Water Boatmen, however, at once took to flight.'

[1] *The Senses of Animals*, p. 75.

CHAPTER IV

SPIDERS, MITES, AND MYRIAPODS

IN this chapter we shall take examples from two Classes—the Arachnoi′dea and the Myriap′oda. To the first-named Class belong also the Scorpions, which, with the Book Scorpions, the Harvestmen, and some others, may be neglected here. This will leave us only the Spiders and Mites to deal with.

Every one knows a Spider when he sees one, though not every one can give offhand a definition that shall include the whole Order. Let us endeavour to express their characters in simple terms, keeping in mind the definition of head, thorax, and abdomen in Chapter II. In Spiders the head and thorax are joined together in one unsegmented portion, called the cephalothorax, and this is connected with the abdomen, which is also unsegmented, by a more or less slender stalk or peduncle. So that while Insects have three regions, Spiders have but two. We may express the difference thus:

Insects	head, thorax	abdomen.
Spider	cephalothorax	abdomen.

The cephalothorax bears six pairs of appendages (Fig. 48 A). Taking these in order, there are—

1. A pair of falces (*an*), representing the antennae of insects. These have a movable claw-like joint at the extremity, perforated so as to convey into a wound the secretion from the poison-glands.

2. A pair of five-jointed pedipalps (*p*), sometimes called maxillary palpi, from the fact that the parts whence they spring correspond to the maxillae of insects (Fig. 21 A, *d*). In the female the last joint terminates in a claw; in the male this joint is specially modified for sexual purposes (Fig. 48 B).

3. Four pairs of walking legs, of which only the coxae (*c*) are shown in the diagram. The two front legs are often used as organs of touch.

Breathing is carried on by chambered air-tubes or lung-sacs, and in all our British Spiders (with the single exception of the native Trap-door Spider, which, by the way, does not make a trap-door) there are also air-tubes resembling those of Insects. The lung-sacs open to the external air by stigmata (*st*) on the abdomen, while the ordinary air-tubes open near the spinnerets (*sp*), the organs employed in the production of the silky threads from which are formed webs, nests, egg-bags, and ropes. By means of these threads, spiders drop from their webs to the ground, construct flying bridges from one point to another, and even in some sort travel through the air.

Spiders live upon the juices of their prey, which are drawn up into the stomach by means of a suctorial apparatus at the end of the gullet.

The young, when they leave the egg, resemble their parents in all respects but size—that is, they undergo no metamorphosis.

The eyes of spiders are simple, and six or eight in number. These vary much in size and relative position, and furnish characters of great importance in classifying species. Those of the Hunting Spiders, which make no web, but pursue or spring upon their prey, are usually arranged in three rows; while those which make webs for the capture of prey have the eyes in a double row. In all cases they are on the front part of the upper surface of the cephalothorax.

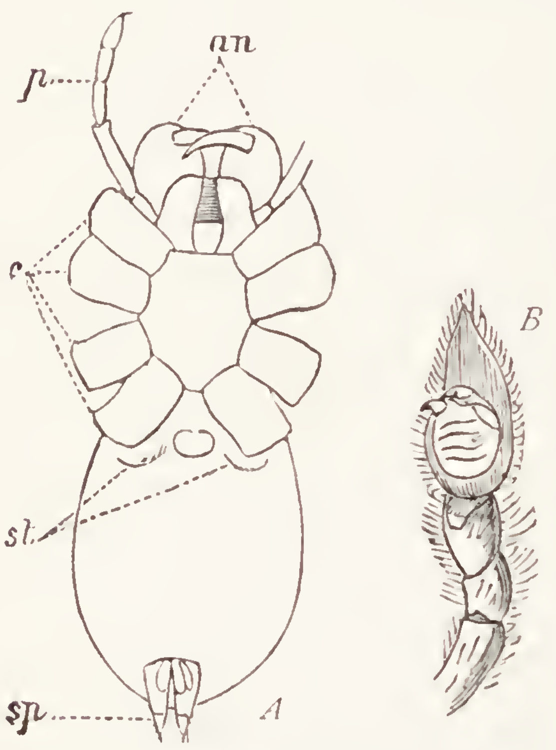


FIG. 48.—*A*. Scheme of under surface of Wolf Spider (female). *B*. Pedipalp of male (enlarged). For other references, see text.

The Common Garden Spider (*Epei'ra diade'ma*) is a very good subject, and there can be no difficulty in procuring any number of specimens. The smallest garden will be sure to yield a plentiful supply; and even if we have no garden, a very superficial search among the hedgerows will give us as many as we can possibly want. Every one knows this spider, and the beautifully regular web which it makes. First of all, what one may call the outline of the web is spun—strong threads stretching from point to point, to which are attached lines radiating from a common centre. This may be represented diagrammatically by drawing a circle and producing radii from the centre to the circumference in all directions, or by making a rectangular figure and drawing lines to the boundaries from the point where the diagonals intersect. It must not, however, be supposed that the outline of the web is of a regular form. In this respect the spider adapts itself to circumstances, and spins a greater or less number of supporting threads, as may be necessary.

FIG. 49.—Garden Spider and Web.

Then the spiral is made (Fig. 49) from the centre to the circumference. The first few turns are of the same character as the radial lines; but all the rest of the short lines forming the spiral, and connecting the radial lines, are coated with a viscid secretion, which is the essential part of the snare; for the victims are really limed like birds on a twig, not entangled in the threads. It is well to test the character of the different parts of the spiral, not only by touch, which is convincing enough, but with pocket lens. Our low powers will not give such results as are shown in Fig. 50, but we shall have no difficulty in distinguishing the sticky parts from those not coated with the secretion.

It may be doubted whether all the Spiders of this genus make the spiral in the same way, for observers differ in their description of what they have seen. Some say that a non-adhesive spiral from centre to circumference is first made, and that the spider then moves 'in a closer spiral from the circumference inwards, biting away the former spiral, replacing it by another, which is viscid and adhesive[1].' Dr. Butler, on the other hand, who 'watched spiders for months together, petting, feeding, and trying experiments with them every morning,' after describing the making of the first and non-adhesive part of the spiral, says, 'This line is not carried to the boundary, but at some

FIG. 50.—*A* Adhesive Threads of Spiral. *B*. Non-adhesive Radial Threads.

distance from the centre a second is commenced, formed of extremely viscid silk, upon which the gummy secretion is distinctly visible, with the aid of a lens, in the form of closely approximated globules of amber-coloured glue. It is said that when the viscid lines are completed the spider cuts away the unadhesive lines, but this I have never observed[2].' My own observations lead me to believe that Dr. Butler is correct in his description. Though I have often watched, I have never

[1] J. Arthur Thomson, *Outlines of Zoology*, p. 288.
[2] *Science for All*, ii. 178.

seen a spider 'biting' away any part of its web, nor would the falces appear to be adapted for such an operation. They are piercing, not cutting, weapons.

The spider may be watched at leisure, if put into a bottle of moderate size, the top of which should be covered with muslin or calico to prevent escape. Here it is fairly easy to bring the pocket lens into play, and to distinguish the different parts of the animal. The eyes, and their arrangement, should be particularly noticed.

FIG. 51.—Anchorage of Web.

Blackwall, in support of the position that in making their webs spiders are guided by touch rather than sight, says, 'Various species, when confined in spacious glass jars placed in situations absolutely impervious to light, construct nets which do not exhibit the slightest irregularity of plan or defect of structure[1].' My specimens have always been kept in the light, and in small bottles rather than spacious jars, but I have never seen spiders attempt to make a geometrical web under such conditions.

A bottle which for some months served as a prison-house for a Garden Spider now stands on my writing-table. Its sides are marked by hundreds of 'anchorages'—but the threads cross and recross, forming in some parts a kind of sheet, and in others a tangled mass. Some of these

[1] *British Spiders*, p. 10.

threads must have been covered with viscid secretion, for flies were limed, and so fell a prey to the spider. Their dried skins are dotted about among the threads, and the spider itself perished long ago from cold. But I keep the bottle as a curiosity, to show that these spiders do not always make geometrical webs.

When one has a Garden Spider in a bottle, it may be observed to practise a curious and very effective method of disabling its prey. If a bluebottle or any other large fly be dropped and entangled among the threads, the spider will envelop it in a sheet of web. This is how Blackwall describes the operation: 'Causing the victim to rotate by the action of the third pair of legs and the palps, the first pair of legs also being frequently employed in a similar manner, they extend the spinners laterally, and applying to them alternately the *sustentaculum* of each posterior leg, they seize and draw out numerous fine lines in the form of a fillet, which they attach to their revolving prey, and thus involve it in a dense covering of silk from one extremity to the other. By means of this stratagem they are capable of overcoming formidable and powerful insects, such as wasps, bees, and even large beetles[1].'

The operation does not occupy much time; in a very few minutes the fly is swathed in a silky covering as completely as an Egyptian mummy in its linen folds. Of course resistance, much less attack, is out of the question, and when it is thus rendered powerless for harm the spider proceeds with its meal.

The *sustentac'ulum* — or support — is a strong

[1] *British Spiders*, p. 359.

movable spine near the end of the tarsus, on the under side of each of the last pair of legs. These spines act in opposition to the claws, and thus these animals are enabled to hold with a firm grasp such lines as they have occasion to draw from their spinners with the feet of the hind legs, and such also as they design to attach themselves to.

With regard to this method of swathing prey, Hudson[1] says of an Argentine spider, 'that its intelligence has supplemented this instinctive procedure with a very curious and unique habit. The Pholcus, in spite of its size, is a weak creature, possessing little venom to dispatch its prey with, so that it makes a long and laborious task of killing a fly. A fly, when caught in a web, is a noisy creature, and it thus happens that when the Daddy longlegs—as Anglo-Argentines have dubbed this species—succeeds in snaring a captive, the shrill outrageous cries of the victim are heard for a long time—often for ten or twelve minutes. This noise greatly excites other spiders in the vicinity, and presently they are seen quitting their webs and hurrying to the scene of conflict. Sometimes the captor is driven off, and then the strongest or most daring spider carries away the fly. But where a large colony are allowed to continue for a long time in undisturbed possession of a ceiling, when one has caught a fly he proceeds rapidly to throw a covering of web over it, then, cutting it away, drops it down and lets it hang suspended by a line at a distance of two or three feet from the ceiling. The other spiders arrive on the scene, and after a short investigation retreat to their own

[1] *Naturalist in La Plata*, p. 188.

webs, and when the coast is clear our spider proceeds to draw up the captive fly, which is by this time exhausted with its struggles.'

In this connexion Hudson notes that spiders are attracted by the sound of the vibration of a string or wire, thinking it made by an insect that has been caught; and he says that the stories of tame spiders are founded on a misunderstanding of the motive that brings the animal down. We may well doubt if spiders are attracted by music, but that some spiders possess a sense of hearing, or something analogous thereto, seems to be proved

FIG. 52.—Foot of Garden Spider.

FIG. 53.—Spinnerets of Garden Spider.

by the existence of stridulating organs in certain members of the group.

Two other points remain to be noted. The feet should be examined, for their structure throws some light on the way in which the Garden Spider runs so securely to and fro on the radial lines. One of the legs of a dead specimen should be detached, and its armature of spines and hairs noted. The foot is armed with three stout claws, which are pectinated — that is, toothed like a comb, and beneath them are smaller ones, sometimes described as toothed hairs. It will be easy to understand what a secure foothold these claws give the animal as it runs backwards and forwards over the radial lines; for if the web be shaken by the wind or designedly its owner can take a firm hold with each foot, and thus have eight separate points of attachment. An inch hand lens is quite sufficient to give a general idea of the hairy and spinous clothing of the legs and the position of the claws; but to see the teeth a higher power—a half-inch—will be necessary.

It is a good plan to choose a freshly killed specimen for the examination of its spinnerets. If the spider is laid on its back in a glass dish, gentle pressure on the abdomen away from the cephalothorax will cause the material secreted by the spinning-glands to ooze out. This, however, cannot be done if the specimen has been for some time in spirit. We shall be able to make out six tubes (four of them larger than the other two) grouped round the anal aperture; but, for the present, we must take for granted the fact that these are made up of a number of smaller tubes, so that the end of each spinneret is not unlike the rose of a watering-can. A good half-inch will give some indications of this rose-like appearance.

The Jumping Spider (*Sal'ticus scé'nicus*) belongs to a family the members of which make no web or snare for the capture of prey, but trust for their food-supply to their skill in stalking flies and other insects, which they capture by a sudden spring. It is from this habit that the type-genus and the family have received their scientific and popular names.

The common British species is extremely abundant, and wherever flies are plentiful these spiders will not be very far off. This is the case not only in the country, but also in London and other large towns. It is a noticeable spider from its coloration—black marked with white. The eyes are eight in number; though the artist in our illustration has only represented four. The centre two of the front are the largest of all, and have been compared not inaptly to bull's eyes. Two others are placed on each side of the cephalothorax, so that the eyes form, roughly, three sides of a square, and the central eyes in the lateral lines

FIG. 54.—Jumping Spider. (Line shows natural size.)

FIG. 55.—Falces of Male Jumping Spider.

are the smallest. We may represent them thus ⁚ ·· ⁚, while the eyes of the Garden Spider are disposed in this fashion ˙·⁚·˙

It requires some little practice to detect the eyes of spiders and to remember their position in the different genera, but by examining every spider met with, and consulting some handbook to the group, one will soon be able to determine the commoner British species.

With a couple of needles we may remove the falces (Fig. 55) for examination; and there is no difficulty in mounting them, as shown in the cut, on a piece of card, so that they may be compared with the same weapons in other species. For example, the falces of the Garden Spider differ from those of the Jumping Spider in that they are short and stout, and the teeth on the basal joint are more in number.

The following account of the habit of this spider in capturing prey is from Kirby and Spence's *Introduction to Entomology* (ed. 1870, p. 453):—'When these insects spy a small gnat or fly upon a wall, they creep very gently towards it with short steps, till they come within a convenient distance, when they spring upon it suddenly like a tiger. Bartram observed one of these spiders that jumped two feet upon a humble-bee. The most amusing account, however, of the motions of these animals is given by the celebrated Evelyn in his *Travels*. When at Rome, he often observed a spider of this kind hunting the flies which alighted upon a rail on which was its station. It kept crawling under the rail till it arrived at the part opposite to the fly, when stealing up it would attempt to leap upon it. If it discovered that it was not perfectly opposite, it would immediately slide down again unobserved, and at the next attempt would come directly upon the fly's back. Did the fly happen not to be within a leap, it would move towards it so softly, that its motion seemed not more perceptible than that of the shadow of the gnomon of a dial. If the intended prey moved, the spider would keep pace with it as exactly as if they were actuated by one spirit, moving backwards, forwards, or on each side without turning. When the fly took wing, and pitched itself behind the huntress, she turned round with the swiftness of thought, and always kept her head towards it, though to all appearance as immovable as one of the nails driven into the wood on which was her station: till at last, being arrived within due distance, swift as lightning she made the fatal leap and secured her prey.'

This spider employs a clever precaution against falling, when about to spring upon its prey. It applies the end of the abdomen to the surface on which it stands, and opening its spinnerets, makes an 'anchorage' (Fig. 56). Then, by the act of springing, it draws from the spinnerets a line attached to the spot from which it started. This line is strong enough to support the spider in case it misses its prey.

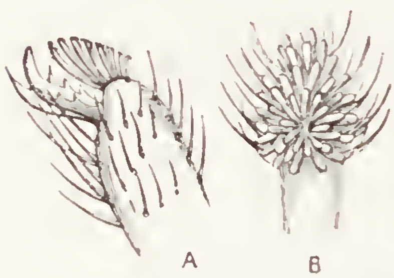


FIG. 56.—*A*. Foot of Jumping Spider. *B*. Scopula. (Much enlarged.)

The foot of the Jumping Spider is extremely interesting, and shows a very ingenious arrangement, by means of which the animal can run with difficulty on smooth polished upright surfaces, or retain its footing when it alights on such surfaces after a spring. We can see this arrangement in Fig. 56. Just behind the claws is a bundle of coarse hairs, technically called a *scop'ula*, or little brush. From these hairs adhesive matter flows, and in this fashion the spider literally sticks on. With this brush of hairs may be compared the tarsal cushions of many flies, and the adhesive hairs of Dytiscus and other beetles (see Chap. II)—though these last have a different function.

Diving Spiders (*Argyrone'ta aquat'ica*) are especially suitable for our purpose. They are very common in most ponds, and in some places are so abundant as to be almost a nuisance to the collector who is in search of other things. Three of them are represented in Fig. 57. One is swimming; another is just entering the bell-shaped web

FIG. 57.—Diving Spiders.

under water; and the third is just climbing out of the water on to the broad floating leaves of the water crowfoot.

De Geer's account of these spiders is extremely interesting[1], and we may verify it for ourselves, for these creatures may be kept without any trouble. They certainly agree, when a number are kept in captivity, much better than do other spiders. De Geer kept several in the same aquarium, and says that when they met they felt each other with their palps, and opened their falces, but he never saw them do any harm to each other. I have kept them under similar conditions with the same result.

He tells us that these spiders spin under water a cell of strong, close, white silk, the shape of which he compares to a skull-cap, the half of a pigeon's egg, or a diving-bell. In September, 1736, he first became acquainted with these creatures, and kept one in an aquarium for four months. It made its cell against the side of the aquarium, and the top of it rose above the surface of the water. (This was due to its being inflated. The web was not spun above the surface.) The walls of the cell were very thin, but it was filled with air, and the spider was resting inside, head uppermost, with its legs pressed against the body.

About three months later he found that the mouth of the cell was closed, and the spider was comfortably settled in its winter quarters. When pressure was applied the cell burst and the air escaped, mounting up to the top in bubbles. The spider made its way out, and took an Asellus that was offered, and made a meal of it.

De Geer then came to the conclusion that these cells under water were constructed for the purpose of affording the spider a retreat when the water was frozen over, so that they could not come to

[1] *Mémoires*, vii. p. 304 sqq.

the surface for a supply of air. He found, however, by observation, that they were also made in summer by both sexes. In a cell of this kind the female deposits her eggs—from eighty to a hundred in number, enclosed in a cocoon of white silk—and keeps guard over them, with her head defending the entrance to the cell.

He succeeded in finding out the method by which the Diving Spider fills its cell with air. He noticed that when the creature was moving about in the water, its body was covered with a layer of air, and that this air was renewed from time to time when the animal came to the surface and raised its abdomen above the water. Loaded, so to speak, with air in this fashion, the spider descended, and entered the cell backwards, leaving an air-bubble. Having repeated this several times, at last she removed all the water from the cell. introducing in its place an equal quantity of air.

It is very easy to watch the Diving Spider making its dwelling under water, and filling it with air. First of all the web is woven in a bell or thimble shape between the sprays of water-weed, or against the bottom or side of the aquarium. It is curious to notice how practices that must be necessary when the creature is at liberty are continued in captivity where they are useless. A web constructed in running water, or even in a pond or ditch, is liable to be swept away or to be emptied of air by a very slight current, so its owner has recourse to a system of guys and supporting threads, which are not required when the spider is safely housed in a small aquarium. Nevertheless, the guys are made. In an eight-ounce bottle I have now a male Diving Spider, which has lived there for about seven months. Its cell is made between the whorls of a spray of milfoil, and guy threads have been carried to no less than five whorls—two above and three below the opening. Now that it is filled with air, the cell gleams in the water like a great bubble of quicksilver. The air may be expelled by shaking or tilting the bottle, and if the web be not damaged the spider will generally refill it with air, though sometimes it prefers to make a new dwelling. Fig. 58 shows the cell of a Diving Spider; the white lines represent supporting threads attached to the water plants.

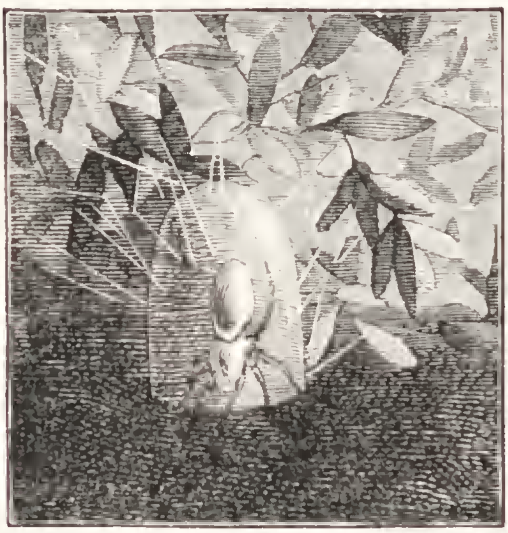


FIG. 58.—Cell of Diving Spider.

In examining dead specimens we shall find that, contrary to what is usual, the male exceeds the female in size. I have a slide of a male, with the legs spread out before and behind, and the measurement from the claws of the first pair of legs to those of the fourth pair is 1¾ inches. The body is ¾ inch long. The whole surface is more thickly clothed with hair than is the case with other spiders, and the reason for this is obvious. This hairy body-covering serves to carry down into the water a layer of air, and the fringe of hair on the legs makes them efficient swimming organs.

The Order of Mites will yield us subjects for our pocket lens. Mites are related to Spiders, but form a distinct Order. Like the Spiders, some are aquatic, though the most of them live on land. Many are parasitic, during the whole or part of their lives subsisting on the juices of their hosts: the food of others consists of organic *débris*, and these seem to be of benefit to man, since they act as scavengers. If we turn to page 96 we shall there find noted the points of difference in the arrangement of the main divisions of the body in Insects and in Spiders. In Mites the distinction between the cephalothorax and abdomen is lost, and the body is more or less oval or globular. In the perfect forms there are eight legs; but some, in their earlier stages, have only six. The mouth may be adapted for biting, though it is usually suctorial. In the Cheese Mites and some others breathing seems to be carried on through the skin, for there are no air-tubes; but in most Mites air-tubes, with two stigmata, are present.

If we take a dip with the collecting-net in almost any pond we shall be pretty sure to capture some specimens of Water Mites of the genus Hydrach′na, easily recognizable by their bright coloration, their eight swimming legs thickly fringed with hair, and their unceasing activity. They may be kept in a bottle, or other small vessel, with some water-weed, and will forage for themselves. In Fig. 59 we shall see the points we have to look for in examining a Water Mite with a pocket lens. There should be no difficulty in making out in the specimen all the details shown in the cut.

It may be that they will breed: if so we should avail ourselves of the opportunity of watching their development. Their life-history is somewhat curious, and is specially interesting from the fact that while Swammerdam had some faint perception of the true meaning of what he saw, De Geer, writing a hundred years later, drew entirely wrong conclusions from similar observations. It was left for Dugès to clear up the matter in the *Annales des Sciences Naturelles*, 1834. Before summarizing the account of the French naturalist it may be well to quote what Swammerdam and De Geer have said on the subject:—

'There is nothing more remarkable in this insect [the Water Scorpion] than that it constantly appears covered with a prodigious number of nits of different sorts and sizes, though perhaps we may with more reason consider them as so many little creatures, which live and grow by sucking the Scorpion's blood. These are somewhat of an oblong figure, approaching to round, and have a shining, and as it were bloated, surface, without any of the rings observable in most insects. The neck is oblong and shaped like a pear, with the small end sticking in the Scorpion's body. The colour of this insect is a mean between that of vermilion and purple; and when it is pretty well grown there appears within it an elegant transparent spot or particle (Fig. 59).

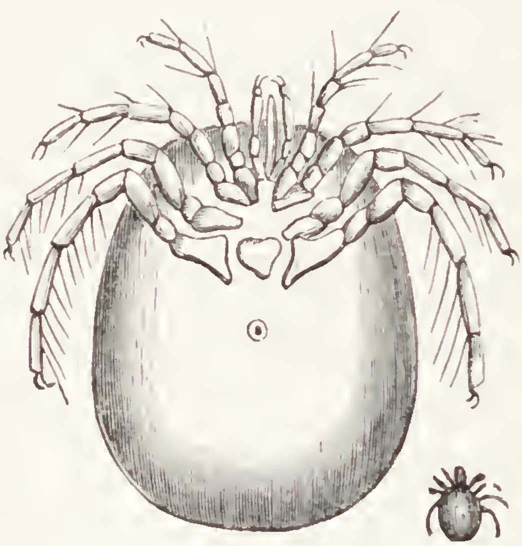


FIG. 59.—Red Water Mite (nat. size, and under surface magnified).

'This spot or particle induced me to consider with more attention this minute and hitherto unregarded insect, and even to undertake the dissection of it. But who would imagine that on this examination it should prove a perfect and surprising insect? This is, however, a certain fact; and thus in that infinite variety of works, by means of which God is pleased to make Himself known to us, we ever meet with new matter of admiration and astonishment.

'This little creature being extracted from the shell that covered it, looks like a young spider before it has left its egg. On the fore part is the head (Fig. 43 D, *a*) and on its head are the eyes, *b*: under the eyes are placed its little legs elegantly coiled and folded, *c c*; but they appear much more distinctly on turning the insect on its back, *d d*; and in this situation also it best appears with what art these legs are laid up in the shell, and all are covered with hair. The colour of this little creature is, as I have already observed, a mean between that of vermilion and purple; and this colour shows itself through the coat or shell, which is transparent. I cannot determine to what species of insects this is to be referred; nor can I say to what size it grows, or by what kind of creature it is thus deposited on the Water Scorpion in the form of an egg, there to receive life and growth. Nevertheless, I cannot but look on the discovery I have made as very interesting, since it proves that there are in the nature of things eggs which acquire a sensible growth by an entraneous nourishment, unless perhaps some naturalist should choose to consider this as a complete insect, rather than as an egg; nor shall I strenuously oppose his opinion, seeing that, in all cases, the egg is in reality no other than the insect itself, which remains in that state till it has acquired sufficient strength to break its prison, and live without such a covering[1].'

[1] *Book of Nature*, pp. 101, 102.

Having quoted Swammerdam, let us see what De Geer has to say on the subject :—

'On the body and legs of many aquatic insects, such as Dytiscus and Water Scorpions, may be frequently seen little oval, seed-like bodies, of a bright red colour, firmly attached, and, as it were, implanted in the skin, by a little stalk. I have had Water Scorpions with the upper surface so covered with these red bodies that there was scarcely a vacant space on the skin. They are most frequently to be seen in the spring; but the insects on which there was such a great number did not live long with me. Having crushed some of these seed-like bodies, I found them filled with red liquid matter. I am convinced, by experiment, that they are the eggs of Water Mites, since there came out of them little red Mites with round bodies and long legs, which swam about with great swiftness.

'These red Water Mites, then, attach their eggs to the bodies and legs of larger aquatic insects, and there they remain till the young are hatched. And since we find eggs of many different sizes, we may be sure that they grow and increase in size, doubtless owing to a certain nutritive juice which passes from the body of the insect into the egg. Hence it is, as I have seen myself, that Water Scorpions loaded with these eggs become weak and feeble, because they are obliged to furnish their hangers-on with nourishment from their own bodies. Moreover, these eggs appear to cause the Water Scorpions some irritation or uneasiness, since I have often seen them rub with their feet those parts of the body where the eggs were; and perhaps they did this with the view of rubbing them off, but they were too securely fastened [1].'

[1] *Mémoires*, vii. 144, 145.

Dugès watched the development of the common Red Water Mite (Fig. 59), and tells us that towards the end of May the females deposit their eggs in the leaves of pond-weed, which they puncture with their beaks. The larva (Fig. 60), red in colour, with six legs, is free-swimming, and has a large beak, which looks like a great head, and terminates in a narrow mouth. It is not known how long this larval stage continues; but in the next stage (Fig. 61) the Mite becomes parasitic on aquatic beetles and bugs, fastening its beak into the body of its host, from which it derives its nourishment.

FIG. 60. - Larva of Water Mite.

The legs and palps are often retracted or absorbed, so that it is not difficult to understand how it was Swammerdam and De Geer took these parasitic nymphs to be the eggs of the Mite. During their parasitic condition they increase considerably in size, at last emerging as adult eight-legged free-swimming Mites. It was just before the emergence of the Mite that Swammerdam examined the parasitic nymph, for he figures the 'insect,' which he extracted from the egg, as having eight legs (Fig. 43 D).

FIG. 61.—Nymph of Water Mite.

I once found a Water Mite in the body of a

Dytiscus[1]. I was breaking up the beetle, and had removed the elytra and the wings. I only wanted the external skeleton ; so a slit was made between the plates of the dorsal and ventral surface, and the intestines removed. The Mite was embedded in the fat-body. I could find no mention in the literature of Beetles or Mites of any similar occurrence ; and should scarcely have mentioned it here, had I not been unexpectedly confirmed by my friend Mr. G. E. Mainland, F.R.M.S., who once had a similar experience, and who kindly allows me to quote from a letter he sent me on the subject :—

'I am sorry to say I can find no documentary evidence as to the Arachnid I found embedded in the tissues of Dytiscus, but a good deal has come back to my recollection. On removing the right elytron and slitting up the dorsal surface, I found it in the tissue close up to the thorax. I cannot recollect what ultimately became of it, after I had shown it to friends at the Hackney Microscopical Society. . . . I know that I carefully measured the Hydrachna (which was abnormally large) and its relative size to that of its host, and made a comparison in a lecture (to the Senior Band of Hope at St. Michael's. Hackney) of a man with a creature as large as a guinea-pig under his shoulder-blade.'

The occurrence of the Mite *inside* the Beetle was, of course, quite exceptional. It probably found its way in through one of the abdominal spiracles.

[1] The specimen was kindly identified for me, by Dr. Trouessart of Paris, as a nymph of *Hydrachna globula* (Dugès), and has been deposited in the British Museum (Natural History).

The Beetle Mite (*Gam'asus coleoptrato'rum*) (Fig. 62) is extremely common, and is parasitic on the Dung Beetle and on the Humble Bee, so that in order to examine the parasite we must capture the host. There can be no difficulty about this, for Dung Beetles and Humble Bees are plentiful enough. This Beetle Mite, apparently, does not infest other species of beetles. I have kept the Devil's Coach Horse in a bottle with the common Dung Beetle for some months, and though the latter swarmed with these parasites, they never left their host for the other beetle. Even when removed by means of a small brush from one beetle to the other, they left the Devil's Coach Horse of their own accord, and soon made their way back to the Dung Beetle.

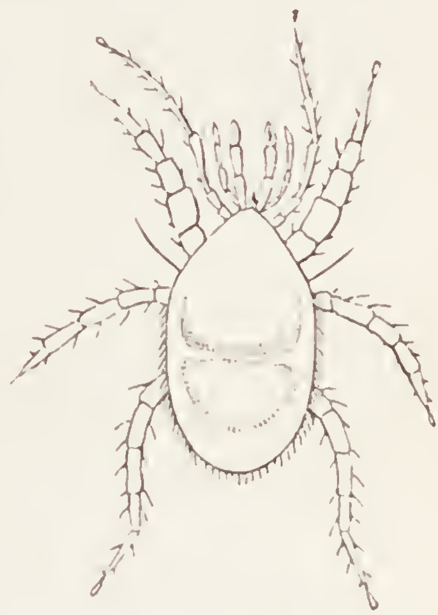


FIG. 62.—Beetle Mite.

These parasites, with their host, came into my possession in a strange way. A friend, who knew my hobbies, told me that he had managed to procure for me some young beetles just born. I ventured to suggest that beetles were not born as beetles, but in quite a different shape. My suggestion was received unsympathetically, and I was told that I should alter my opinion when the creatures were sent me. But I did not. The box contained a Dung Beetle, over which were swarming scores of these little Mites, and I had some difficulty in convincing the gentleman who sent them to me that these Mites were not the young of the beetle.

We should compare this Beetle Mite with the Water Mite, and notice the difference in the mouth parts and the legs, which have a large pad between the claws.

We may find another Beetle Mite, closely allied to this species, on the Devil's Coach Horse, and some of its near relations. This Mite was also known to De Geer[1], whose remarks upon it are worth quoting, in a condensed form.

He found a beetle covered with these Mites, and on examining them with a hand lens saw that they were attached to their host by a long thread or stalk, which came from the posterior end of the body. Several Mites, he tells us, were joined together by one thread which fastened them all to the beetle; and he came to the conclusion that the parasites were nourished at the expense of the beetle, the thread serving to convey the juices of its body to them.

'It is very singular,' he says, 'to see living insects planted on the body of larger insects, from which they draw their subsistence by means of a thread or stalk.' And then he goes on to compare these 'vegetative Mites,' as he calls them, with the 'eggs' of the Water Mites, which he found on Dytiscus and the Water Scorpion. The thread exists, and the Mites are attached by it to their host, but they do not draw nourishment through it from the beetle, for it is composed of their excrements.

The Myriapods are worm-shaped creatures, breathing by means of air-tubes, and furnished with a number of limbs closely resembling each

[1] *Mémoires*, vii. 123–128.

other. There are two groups: the Centipedes and the Millepedes. The former have the body flattened, with one pair of appendages to each segment, the first pair being modified into piercing poison-organs, and they feed on living prey. The body of the Millepedes is round, with two pairs of appendages to each segment; they have no poison-organs, and their food consists chiefly, if not entirely, of vegetable matter.

There seems to be some doubt, however, as to whether *Julus*, one of the commonest Millepedes, does not occasionally indulge in animal food. In *Nature Notes* (Jan. 1896) there was a review of the *Cambridge Natural History* (vol. v). The reviewer, in a brief summary of Mr. Sinclair's part of the book (the Myriapods), said, after describing the Centipedes: 'The millepedes, on the contrary, are sluggish vegetarians, with hard, cylindrical bodies, &c.' On this a correspondent wrote in the March number: 'Some time ago my attention was attracted to a large earthworm, writhing and twisting about on the garden path, as though in pain, or through having received some injury. On examining it more closely to ascertain the cause of its unusual movements, I found that a millepede had fastened itself to the side of the worm, and appeared to be boring or eating its way into the body, whilst the most violent efforts on the part of the worm were ineffectual in shaking off its antagonist. If the millepede is a vegetarian, what could be its object in attacking so harmless and defenceless a creature as the earthworm? The above, which I take to be a millepede, is the black or dark-coloured creature "with hard, cylindrical body" ordinarily found coiled up in a spiral under stones or rubbish.'

The editor, as a matter of course, referred the matter to the writer of the review. His reply was as follows: 'If there is no mistake about the identity of the aggressor in the account cited above, the observation is one of considerable interest; for, so far as we are aware, it is the only case on record of a millepede being guilty of such conduct. But were it not for the positive statement that the species was the dark-coloured creature with a hard, cylindrical body, which is ordinarily found coiled up in a spiral under stones or rubbish—a description which exactly applies to the millepedes of the genus *Julus*—we should have concluded without hesitation that the struggle in question was merely one of those that habitually takes place between the centipedes of the genera *Litho'bius* or *Geoph'ilus* and the earthworms upon which they feed.'

Both the Centipedes and Millepedes are shy, light-shunning animals, and if we turn over some stones in the garden or in a walk through the fields we shall probably find specimens enough to serve us in getting some idea of both groups.

The Centipedes are sometimes called 'Hundred-legs,' but this implies the possession of many more legs than the creatures really have. In Norfolk and Suffolk the people call them 'Forty-legs,' and this is much nearer the mark.

Litho'bius forfica'tus, about an inch long and rufous brown in colour, is extremely abundant under stones and the bark of trees, and in cellars and outhouses. These animals run with great rapidity when disturbed, so that one needs to be on the alert to seize them when they are driven from the places in which they lurk. The body has nine principal and six subsidiary or smaller rings, and there are fifteen pairs of walking legs, besides the first pair, which are modified to serve as poison-organs. De Geer says that he never dared to pick up these Centipedes with ungloved hands, because he had seen a fly, which had been bitten by one, die on the spot, 'which seems to be a sign that their bite is venomous.' He examined their modified legs with a good microscope, but could not distinguish any opening. There is, however, an opening, as De Geer suspected, though he could not distinguish it; it lies near the point, and we may also trace the canal through the claw down to the poison-glands which lie, one on each side, at the base of the claws. The mouth parts resemble those of insects, and may be dissected out in the same way. When this Centipede walks, says De Geer, it does not use the last four pairs of legs, but drags them after it; but when it walks backwards, which it does as well as forwards, it then makes use of these four pairs of legs in the same way as the others. If we keep Lithobius alive we shall see that it can walk backwards, though it can scarcely be said to go as well one way as the other. From the same old writer some useful hints as to the method of keeping these animals may be gathered. Those that he kept in a vessel without any moisture soon died, and were quite dried up in twenty-four hours, which will teach us to keep them in a vessel with damp earth, shaded from light and heat.

Dr. Sharp[1] gives some interesting details about the breeding habits of Lithobius, and describes, for the first time, the uses of the two hooks on the under surface of the body of the female.

[1] *Cambridge Natural History*, vol. v. ch. ii.

He experimented with Centipedes and Millepedes. Keeping them in large shallow glass vessels, the bottom of which was covered with a layer of earth, he fed the specimens of Lithobius on insects and worms, and sometimes on raw chopped meat, but they did not thrive on this as they did on prey which they could kill for themselves.

Lithobius, he tells us, lays but few eggs compared with the number deposited by Julus. Each egg, as it leaves the oviduct, is received by the hooks mentioned above, and by means of them it is rolled on the soil till a covering of earth adheres to the viscous material with which the egg is coated.

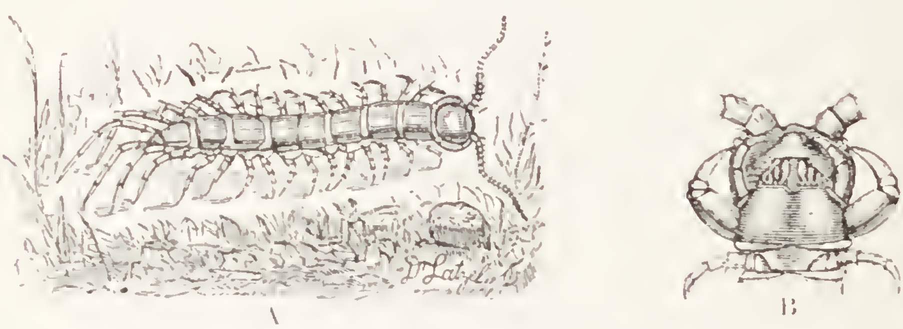


FIG. 63.—*A. Lithobius forficatus. B.* Mouth parts seen from below (After Graber.)

The male considers the eggs special delicacies, and devours them whenever he has the opportunity. It is to prevent this that the female covers them with earth, so that the male may not recognize them.

Geophilus is a much longer animal than Lithobius, for its body may consist of from 80 to 180 rings. The species have no eyes. Several of them are common, especially in the south of England, and possess, as do many genera of the same family, the property of phosphorescence, whence have arisen the stories of 'luminous earthworms' current from time to time. *Geophilus crassipes* is the form most frequently captured when displaying its light. It is from one inch to two inches long, of a reddish-orange colour, and somewhat worm-like in shape. Mr. Pocock, of the British Museum (Natural History), says: 'The property of luminosity lies in an adhesive fluid secreted by glands which open upon the lower surface of the body, and the power of discharging or retaining the fluid appears to be entirely under the centipede's control. The phenomenon is observable during the autumn months, from about the middle of September to the end of November, and although its significance is not clearly understood, it is generally believed to be connected with the pairing of the sexes [1].'

During a visit to the seaside it is well to look out for specimens of a marine Centipede, which is, apparently, not very common. It is said to occur 'under stones and sea-weeds on the shore at or near Plymouth'; and in 1895 I had the good fortune to meet with one at Bexhill. This Centipede does not live in the sea, but will survive prolonged immersion in salt water. It is far too valuable for us to pick to pieces, so that, if we should have the good fortune to meet with one, we should carefully examine it, making what notes are necessary, and then pickle the specimen and send it to the British Museum, Cromwell Road, S.W. The tube should be labelled with the place and date of capture, and it should be stated on the label whether the animal was taken above or below high-water mark.

The Common Millepede—often miscalled the

[1] *Nature*, Dec. 12, 1895.

wireworm—is readily distinguished by the absence of poison-claws, and its cylindrical worm-like appearance. De Geer, who of course adopted the Linnaean definition of 'Insects,' says of the Millepedes of the genus Julus, to which our Common Millepede (*Ju'lus terres'tris*) belongs: 'They form, as it were, the last link of the chain which unites the class of Insects to that of Worms, for the body is elongated and cylindrical; and though they have a great number of feet, these are so short, that when

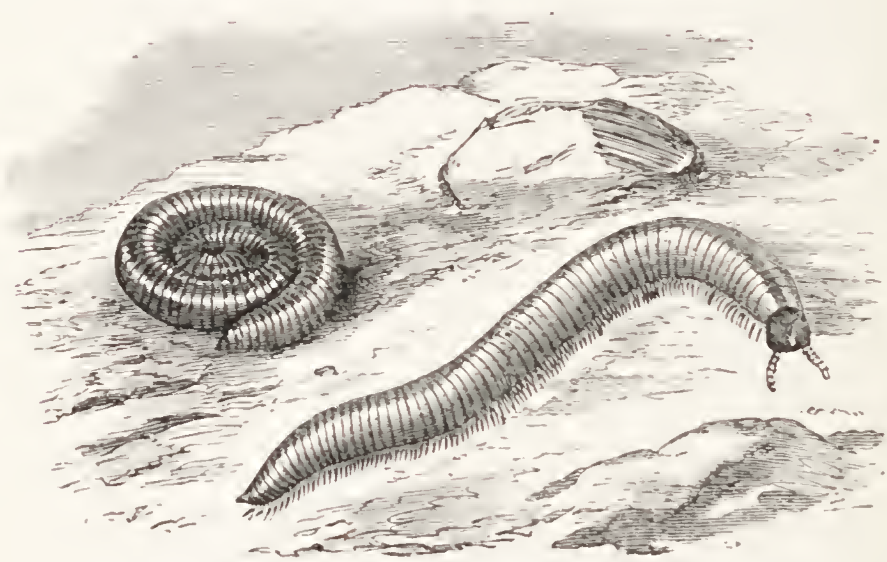


FIG. 64.—The Common Millepede.

these animals walk, they seem rather to glide along after the fashion of legless worms[1].'

Dr. Sharp says that these animals do very well in confinement, and he found that sliced apples and grass formed the best food for them. He watched the process of nest-making and egg-laying, and these creatures are so abundant, and the necessary appliances so simple, that we may follow his

[1] *Mémoires*, vii 569.

example and see it for ourselves. His arrangements were the same as for Lithobius, and he saw the female make a hollow sphere of a bit of earth, stuck together by the secretion from the salivary glands, and smooth on the inside. A small hole was left on the top, and through this she passed in from 60 to 100 eggs, closing the aperture with earth moistened with the salivary secretion. The eggs were hatched in about twelve days. The young of all the Myriapods when they leave the egg have but three pairs of legs, but the number of limbs and segments is increased at each successive moult.

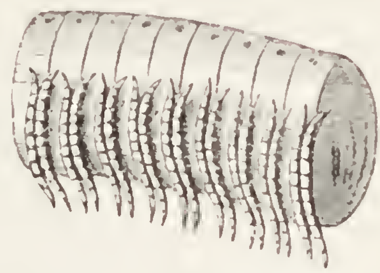


FIG. 65.—Segments of Miliepede (magnified).

Having watched our Millepedes in confinement, it will be well to take a preserved specimen and examine it carefully with the pocket lens, so as to compare it with the Centipede; then to compare both with the common earthworm, and to note the points of likeness and of difference. The dark spots on each segment in the illustration show the stigmata.

CHAPTER V

CRUSTACEANS.—PRAWN, SHRIMP, MYSIS, CRABS: AMPHIPODS; ISOPODS

THE next group of Arthropod animals with which we have to deal is that of the Crusta′cea. Some or other of the members of this class are well known to everybody, if only in the shape of toothsome food—the Prawn, the Shrimp, the Lobster, the Crayfish, and the Crab. The great characteristic of this class of the Arthropod phylum is the so-called 'shell,' which differs greatly from true shell in being composed of chitine, hardened with salts of lime. Most of the species live in the water and breathe by means of gills or through the skin. In dealing with these creatures, some long words must be employed, if our present work on them is to be a stepping-stone to something more advanced. The difficulty is more apparent than real, and if boldly faced will soon be overcome.

Our first division, or sub-class, of the Crusta′cea is that of the Malacos′traca, or animals with soft shells—a name originally adopted, as Mr. Stebbing tells us[1], 'to distinguish such creatures as crabs and crawfish and prawns from such others as oysters and clams; not because of the absolute,

[1] *Crustacea*, p. 7.

but because of the comparative softness of their shells.' Under this sub-class are grouped two Orders—the Stalked-eyed and the Sessile-eyed Crustaceans, the technical names for which are the Podophthal′ma and the Edriophthal′ma.

To the Stalked-eyed Crustaceans belong the Prawn, the Shrimp, Mysis, or the Opossum Shrimp, and the Crabs, to mention only those forms with which we are dealing here. The reason for scientific and popular names will be evident if living or spirit specimens are examined, for it will be seen that the eyes are elevated on stalks. Mr. Stebbing[1] relates an amusing story of a very intelligent student, who, on being told that the eyes (of the shrimp) were stalked, candidly confessed to having always thought that this appearance was due to their having been forced out of the head by boiling.

The general shape of a Prawn (*Palaemon serratus*) is fairly familiar to everybody. The body is divided into two principal regions—the carapace, or cephalothorax, as it used to be called (formed by the union of the head and thorax), and the pleon, or swimming part. The carapace has a projecting beak or rostrum, and is unsegmented ; the pleon is divided into segments, and the whole may be represented thus :—

——— — — — — — —)
c 1 2 3 4 5 6 *t*

where the long stroke (*c*) stands for the carapace, the shorter ones (1–6) for the segments of the pleon, and the) for the telson or tail. The carapace consists of fourteen united segments, and this

[1] *Crustacea*, p. 225.

will give twenty or twenty-one segments in all, according as we reckon the telson an appendage of the sixth segment of the abdomen, or as a distinct segment. The carapace bears the eyes, two pairs of antennae, six pairs of mouth appendages, and five pairs of walking legs or perei′opods, normally with seven joints—in all, fourteen pairs of appendages, that is, one pair for each of the fourteen segments of which the carapace is composed. The segments 1–5 of the ple′on bear swimming feet, or ple′opods, and the female uses these for retaining the eggs, which she bears about with her. In this fashion the 'hen' lobster carries her 'berries.'

The Prawn is a capital inmate of the aquarium, and as it does well in confinement, specimens should be kept in order to get a general acquaintance with their form and external anatomy, and to watch their habits. The Common Prawn will answer the purpose, but still better is *Palaemone′tes varians*, an exceedingly common species. It has this advantage, that it 'seems to be equally at home in salt water and fresh.' The only condition necessary is a good supply of food, and this may be furnished by putting into the aquarium from time to time a quantity of water-fleas. If these Prawns are well fed they will shed their skins at frequent intervals, and this operation will give us material for examination, for the cast skin will serve our purpose almost as well as a spirit specimen.

Some of these Prawns are now living in one of my aquaria. They were taken in a brackish dyke or cut near Newhaven, in Sussex, and in the mud which was brought back with them were a number of small bivalves of the genus *Sphaerium*. Most people know Mr. Kew's exceedingly interesting book, *The Dispersal of Shells*[1]. In it he relates some extraordinary instances of the way in which species of shells are carried short distances, and may be carried from one district or country to another. These Prawns offered a good illustration of this, and practically confirmed some of the statements in his book, for on several occasions they were seen with the bivalve shells attached to their walking legs. The molluscs lay half buried in the mud and vegetable *débris* at the bottom of the tank, and as the Prawns walked about they sometimes trod between the open valves, which, as they closed, fastened on to the intruding limb. On one occasion the molluscs did not relax their grasp for days; and had this incident occurred when the creatures were at liberty the molluscs might have been carried for a considerable distance. If specimens of *Sphaerium* are put into an aquarium containing Prawns of this kind, it is probable that before very long the crustaceans will have one or two attached to some of their limbs.

Prawns are exceedingly beautiful, and if we get hold of live specimens, from salt water or fresh, they should be put into an aquarium—the smaller, in reason, the better—so that their motions may be watched with the hand lens. If much weed be put in, the Prawns will use their walking legs in preference, while if there is little vegetation the powerful tail-fan will be employed for motion backwards, while the five pairs of limbs on the abdomen enable their owners to move forwards through the water.

From Fig. 66 one may get a good notion of a Prawn, and of the points in which Prawns, in

[1] International Science Series, No. lxxv.

the zoological sense of the word, differ from Shrimps. The head of the Prawn is armed in front with a long blade-like beak, studded along its upper and lower edges with a series of teeth like those of a saw, and the second leg is chelate, that is, armed with pincers, resembling, in miniature, that of a lobster or crab. In the Shrimp, on the contrary, there is scarcely a trace of the beak, and the first leg is incompletely chelate, or sub-chelate[1] (Fig. 67), its last joint folding back upon the one that supports it, just as the blade of a pocket-knife closes on its handle. These two distinctions hold good between all Prawns and all true Shrimps.

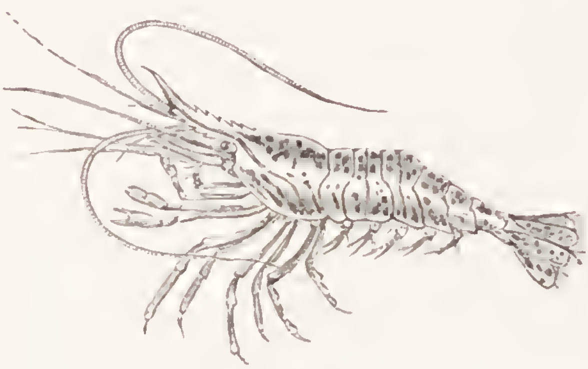


FIG. 66.—Prawn.

Now let us go over our Prawn—a spirit specimen—in detail. The antennae may be separated, and examined, and the appendages of the inner pair distinguished, for at first it may be thought that there are more than two pairs. This, however, is not the case, as should be ascertained by actual investigation. A needle inserted at the base of the outer antennae will separate the first three

[1] 'A limb is *chelate* when it has joints that will act together like a pair of tongs. Generally this character is produced by the hinging of the seventh joint a considerable way down on the side of the sixth. When the seventh joint, or finger, can be folded back upon the sixth, although the latter is not produced into any thumb-like process to oppose it, the limb is then said to be *sub-chelate*, the claw being in that case partial, though often extremely efficient.' Stebbing, *Crustacea* (International Science Series, lxxiv), p. 45.

segments, bearing respectively the eyes, and the first and second pairs of antennae. The eye should be carefully looked at to make out that it is really compound. Then the joints of the antennae, each with its circle of sense-hairs, are to be noticed. Last of all, the inner pair of antennae deserve attention, for these carry in the basal joint an organ of hearing. This joint is large and sac-like, and contains an opening through which grains of sand are introduced by the animal itself. The grains serve to transmit the vibrations of the water in the sac to the auditory hairs, to each of which a branch is sent off from the auditory nerve. If the joint is opened the sand will be found. The first antennae of a lobster or crayfish may also be examined and compared.

The mouth organs, of which there are six pairs, will offer some difficulty, and for this reason it may be well to pass them over in this case and to deal with these organs generally when treating of the Crab.

Beneath the outer foot-jaws are the first pair of walking feet, which are used as cleansing organs. Gosse describes them as 'beset with hairs which stand out at right angles to the length of the limb, radiating in all directions like the bristles of a bottle-brush.' If we watch our Prawn in life, we shall frequently see these limbs in active operation. They are brought to bear on every part of the body within reach. Sowerby says[1]: 'The prawn loves to be clean, and he takes surprising pains to keep himself so. Drawing up his tail and abdomen, he subjects their under surface to the most careful revision, scrubbing and poking between the lappets

[1] *Popular History of the Aquarium*, p. 223.

of the shell and body, diving into every crevice, and with the pincer-hand picking out every speck too large to brush away.' The next pair of legs are also chelate ; but the three following pairs are armed with claws, and it is upon the points of these that the animal walks on the bottom. The pincers of the second pair of legs are used to pick up food and bring it up to the mouth organs, where it is taken by the outer foot-jaws, and passed into the mouth. The swimming feet carry two branches, finely fringed with hairs.

Fig. 67.
First walking leg of Shrimp (enlarged).

If the carapace be removed the gills at the base of the walking feet will be exposed. These consist of thin leaf-like plates attached to a central stalk, and they are aërated by water passing in behind and out in front.

After what has been said of the Prawn, little space need be devoted to the Shrimp, for it may be gone over in precisely the same way. It will be sufficient to call attention to the difference in the antennae, to the rudimentary rostrum or beak, and to emphasize the distinction between the terminal joints of the first leg in the two creatures. The leg shown in Fig. 67 corresponds to the limb used for cleansing by the Prawn.

There is a great difference in their habits, for Shrimps burrow in the sand for concealment. In doing this the swimming feet, as well as the walking legs, are brought into action, and when the Shrimp is settling down, sand is swept over its back by the antennae, to render the concealment complete.

In many of the rock-pools round the coast, and also in brackish water, Mysis, or the Opossum Shrimp, may be met with. It is not, so far as my experience goes, a good inmate of the aquarium, but it is extremely interesting from the fact that, unlike its higher relations, the auditory apparatus is not situated in the antennae, but in the plates of the telson (Fig. 68, E).

Mysis is shrimp-like in general appearance, but

FIG. 68.—Mysis, or the Opossum Shrimp.

differs from Shrimps in the structure of the legs, in the absence of gills, and in other particulars.

The telson consists of five pieces. In each of the two inner and smaller pieces is an oval sac, like that described in the basal joints of the first antennae of the Prawn, containing a single lens-shaped otolith, consisting of chalky matter embedded in some organic substance.

'The vibration of the hairs [in this sac] is mechanical, not depending on the life of the animal. Hensen took a Mysis, and fixed it in such a position that he could watch particular hairs with a microscope. He then sounded a scale; to most of the notes the hairs remained entirely passive, but to some one it responded so violently and vibrated so rapidly as to become invisible. When the note ceased the hair became quiet; as soon as it was re-sounded, the hair at once began to vibrate again. Other hairs, in the same way, responded to other notes. The relation of the hairs to particular notes is probably determined by various conditions; for instance, by the length, thickness, &c.[1]'

We shall not be able at present to repeat Hensen's experiment, but we may break up the sac and extract the otolith, which may be seen with the lenses at our command.

Small specimens of the Shore Crab (*Car'cinus mac'nas*) are fair game for us. They will interest us while living in the aquarium, and when dead we can put them into pickle, and break them up at our leisure.

The broad shell of the Crab—the crab-cart of children — corresponds to the carapace of the Lobster, the Prawn, and the Shrimp, and bears the same number of appendages—fourteen pairs. To make out the pleon or swimming part, it is only necessary to lay the crab on its back, and, with a needle, or small knife, turn back the flap—or 'apron,' as fishermen call it—which lies in a groove on the under surface. Here we shall find the pleopods, or swimming feet, though they are not really used for that purpose. The eyes, the two pairs of antennae, and the five pairs of walking legs

[1] Lubbock, *Senses of Animals* (International Science Series, lxv), p. 93.

will offer no difficulty. It is only necessary to remark that the terminal joints of the last pair of walking legs are flattened and fringed with hair, showing some approach to the swimming crabs, which use those organs to swim with.

Now we may examine the mouth organs, of which there are six pairs. To do this, the crab may be fixed, with the back downwards, or held lightly but firmly in the left hand. The latter plan is perhaps the more convenient. The index and middle fingers should support the carapace, and the thumb should be placed on the pleon. The outer pair of mouth organs are the third maxillipedes, or jaw-feet. These close the area of the mouth, somewhat after the fashion of the double-doors of a cupboard, though the hinging, of course, is different. To open these jaw-feet, a needle should be inserted at the top, with a gentle pressure downwards and outwards. The back of the crab is turned away from us, so that the left jaw-foot should be pressed outwards to the right, and the right jaw-foot to the left.

Theoretically these limbs consist of the same number of joints as the perei′opods or walking legs; and this is to be borne in mind, even if we do not succeed—and we probably shall not—in tracing the full number of seven joints. But we may notice and count the terminal joints, and observe the fringing of the limb with hair.

A similar method of using the needle will enable us to raise the second and first pairs of maxillipedes, which are of smaller size and softer structure.

Having raised these organs, it is well to replace them—to close the doors, as it were—and then to raise them again, to observe how they work. They may then be detached and fastened to a small piece of card, for comparison with similar organs in the lobster and the crayfish, and with the mouth organs of insects.

Beneath the maxillipedes are the second and first maxillae—thin, leaf-like organs. The first-named are furnished with spoon-like scoops, which serve to carry out from the gill-chamber the water that has parted with its oxygen in aërating the gills.

Immediately below the maxillae lie the mandi-

Fig. 69.—Maxillipedes and Maxilla (*b*) of Shore Crab. (*d*) First maxillipede. (After Savigny.)

bles, with hard cutting edges, by means of which the food is broken up. Each carries a palp.

These inner three pairs should also be detached, and the whole of the mouth organs arranged on a card thus:—

Mandibles.
First Maxillae.
Second Maxillae.
First Maxillipedes.
Second Maxillipedes
Third Maxillipedes.

The first attempt will certainly be unsuccessful; and the first few attempts will probably be unsatisfactory; but we shall gain knowledge with each successive trial. And knowledge is worth the winning.

The stomach is interesting, and the gastric mill may be easily examined. When the mouth organs are removed, there will be no difficulty in taking out the stomach. This should be cut open with a needle, and then we shall see the gastric teeth (*gg*) which grind up the food against the fixed calcareous plate (*bb*). The lower end of the stomach is set with fine hairs, which prevent the passage of food into the intestines until it has been ground fine between these living millstones. A similar arrangement is found in all the higher Crustacea. The time spent in comparing the gastric mill of the Crab with the 'gizzard' of the Cockroach will not be thrown away.

FIG. 70.—Stomach of Crab laid open. *b b b*, fixed plate, against which the gastric teeth *gg* are opposed; *b′ b′*, gastric teeth enlarged.

The Broad-clawed Porcelain Crab (*Porcella′na platyche′les*) is also worth keeping, for it is a droll little creature. These crabs are generally to be found clinging to the under surface of stones or of ledges of rocks overhanging small pools. The chief interest of these crabs, for us, lies in the exceedingly beautiful arrangement for procuring food with which the outer pair of foot-jaws is furnished.

'Watching a Broad-claw beneath a stone close to the side of my tank, I noticed that his long antennae were continually flirted about; these are doubtless sensitive organs of touch, or some analogous sense, which inform the animal of the presence, and perhaps of the nature, of objects within reach. At the same time I remarked that the outer foot-jaws (pedipalps) were employed alternately in making casts, being thrown out deliberately, but without intermission, and drawn in, exactly in the manner of the fringed hand of a Barnacle, of which both the organ and the action strongly reminded me. I looked at this more closely with the aid of a lens: each foot-jaw formed a perfect spoon of hairs, which at every cast expanded and partly closed. That you may understand this better, I must say that the foot-jaw resembles a sickle in form, being composed of five joints, of which the last four are curved like the blade of that implement. Each of these joints is set along its inner edge with a row of parallel bristles, of which those of the last joint arch out in a semicircle, continuing the curve of the limb; the rest of the bristles are curved parallel or concentrical with these, but diminish in length as they recede downwards. It will be seen, therefore, that when the joints of the foot-jaw are thrown out, approaching to a straight line, the curved hairs are made to diverge; but as the cast is made they resume their parallelism, and sweep in, as with a net, the atoms of the embraced water [1].'

All this description may be verified from a spirit specimen, if the foot-jaws be carefully removed. And the examination with the lens will also show that these hairs are plumose, that is, set with smaller hair, like the barbs of a feather.

At this point we may conveniently take leave of the Stalk-eyed, and pass on to the Sessile-eyed, Crustacea. Leaving the Cuma′cea out of the

[1] *Aquarium* (ed. 1856), pp. 41, 42.

question, we have two Sub-orders from which to choose our subjects—the Amphip′oda and the Isop′oda—conveniently Englished. Am′phipods and I′sopods. We learn from Mr. Stebbing[1] that 'the Amphip′oda, which are common in fresh as well as in salt water, were so named by the French naturalist Latreille, as having feet extending in all directions, their limbs at the same time having much diversity of form, in correspondence with diversity of function. The Isop′oda, or equal-footed animals, besides being found both in fresh and salt water, have more decidedly than the Amphip′oda extended their range to the dry land. The name was invented by Latreille in ignorance of the great number of species since investigated, in which the feet are strikingly unlike and unequal. Nevertheless, the name may stand, just as a rose remains a rose even when it is not rose-coloured.' These last two sentences must be borne in mind. for they throw great light on a subject that may give us some trouble—the question of priority in nomenclature.

The majority of the Amphipods live in salt water, but a few are found in ponds and streams, and some dwell on the shore, near, but not in, the sea. The animals of this Sub-order are distinctly segmented, and three regions may be distinguished thus $\overbrace{\ldots\ldots}^{\text{Pl.}}\ \overbrace{\ldots\ldots\ldots}^{\text{Per.}}\ \overset{\text{C.}}{-}$, where C stands for the Cephalon, or head, Per. for the Perei′on, or body, and Pl. for the Ple′on (literally, the swimming part), or tail. On the head we shall find two pairs of antennae, the eyes, and the mouth appendages. Each segment of the perei′on bears

[1] *Crustacea* (International Science Series, lxxiv), pp. 8, 9.

a pair of appendages; the first two pairs are called respectively the first and second gnath′opods (or jaw-feet), and the other five pairs perei′opods, or walking feet. The pleon carries three pairs of ple′opods, or swimming feet, on the first three segments, and each of the following three has a pair of uropods or tail appendages. It is well to make out these parts in every specimen that

FIG. 71.—Gammarus. (After Sars.

comes in our way. More is learnt by breaking up one specimen than by reading the clearest description so often that one knows it by heart.

We may begin with the Fresh-water Shrimp (*Gam′marus pulex*), which may be taken abundantly in running water where there is plenty of vegetation. Willow-moss affords these Crustaceans a favourite hiding-place. It is an excellent plan to gather a quantity of weed and shake it over a newspaper or a piece of mackintosh. The 'Shrimps'—which, by the way, are not really Shrimps—will be dislodged from the weed, and we shall see them wriggling along on their sides, from which habit they and their near relatives are often called 'Scuds,' and 'Screws.' They are useful inmates of an aquarium, because they feed on decaying animal matter, and so keep the water pure and sweet. Opinions are divided as to whether these animals feed on water-plants; it is probable that when their natural food fails them, they take what comes in their way. I have kept marine and fresh-water species of Gammarus (the genus to which the Fresh-water Shrimp belongs) in tanks which contained no other animals, but plenty of vegetation, and both lived and did well for a considerable time. They are by no means unwilling to make a meal off the dead body of one of their own species; but it is exceedingly doubtful if they prey on each other, as some old writers have asserted. This notion probably arose from the fact that the male carries the female, which is much smaller, about with him, during the period of courtship, holding her tightly beneath his body by means of the fingers of its first two pairs of hands. The habit is not confined to this genus, nor even to this Sub-order; for some, if not all, the species of Idotea carry on their courtship in similar fashion, as does also the Water Woodlouse. For the verification of statements such as these, a small aquarium is necessary, but the animals will not be under observation long before the observer will be convinced of their truth.

All species of Gammarus, whether living in the sea or fresh water, may be readily distinguished by the rows of small spines on the three hinder segments of the pleon, for this is one of the characteristic marks of the genus. After we have kept specimens in the aquarium for a time, so as to become familiar with their general appearance and habits, we will put them to practical use by breaking them up.

Our first task is to work over the animal as a whole, and to make out the three regions—ceph′alon, or head; pereī′on, or body; and plē′on, or swimming part, or tail—into which it is divisible. It will not be sufficient to do this once, and then to imagine we have the whole matter fixed in our memory. It should be repeated over and over again, with every specimen that comes into our hands, till we know these regions practically, and the number and kind of appendages they carry. And then the three rows of spines are to be looked for. For all this the inch lens will be quite sufficient.

Now let us separate the head. When this is done, and if we use the lens, we shall at once be able to account for the name 'Sessile-eyed Crustacea,' for the difference between the eyes of our specimen and those of a shrimp or a crab will be evident. Nor can there be any doubt that they are compound eyes, though the outer integument is not divided into facets. The antennae are next to be considered. Of these there are two pairs, the superior, or inner, pair being the longer. These antennae consist of three basal joints and a many-jointed flagellum, or lash, and on each of the inner pair is a secondary appendage, arising from the distal (or outer) end of the third basal joint. We

may represent one of the superior antennae thus:
 The dashes represent the three basal joints, the long row of dots the many-jointed flagellum, and the slanting row of dots stands for the secondary appendage. The sensory-hairs on the joints of the flagellum should be looked for, and may be made out with the inch lens. The same power will show the denticle, or tooth-like projection at the base of the lower antennae.

Next come the mouth parts. As compared with Crabs, Amphipods seem badly off in this respect; for the second and third maxillipedes of the former become the first and second gnathopods of the latter, so that instead of six pairs of mouth organs the Amphipods have only four.

It is not an easy matter for a beginner to separate the mouth parts of an Amphipod, but the difficulty is not insuperable, and will grow 'small by degrees and beautifully less' with practice. We have to make out four pairs of organs arranged in the order given at the side of the page, the mandibles being the innermost.

MANDIBLES.
FIRST MAXILLAE.
SECOND MAXILLAE.
MAXILLIPEDES.

Of course we must begin with the maxillipedes (Fig. 72). The specimen may be held between the finger and thumb, and the parts picked out with a needle. It is, however, better and easier to make the dissection under water. Then we can remove the second and first maxillae, the latter easily recognizable by its palp or feeler. Last of all come the mandibles, also bearing a palp. We shall *feel* these under the needle, because of their hardened cutting edges. These are distinctly toothed. When practice has made the separation of these parts fairly easy, they should be compared with the mouth parts of other members of the group, so as to utilize the knowledge we have gained.

Next come the two pairs of gnathopods, and in these we have to find seven joints—which may be

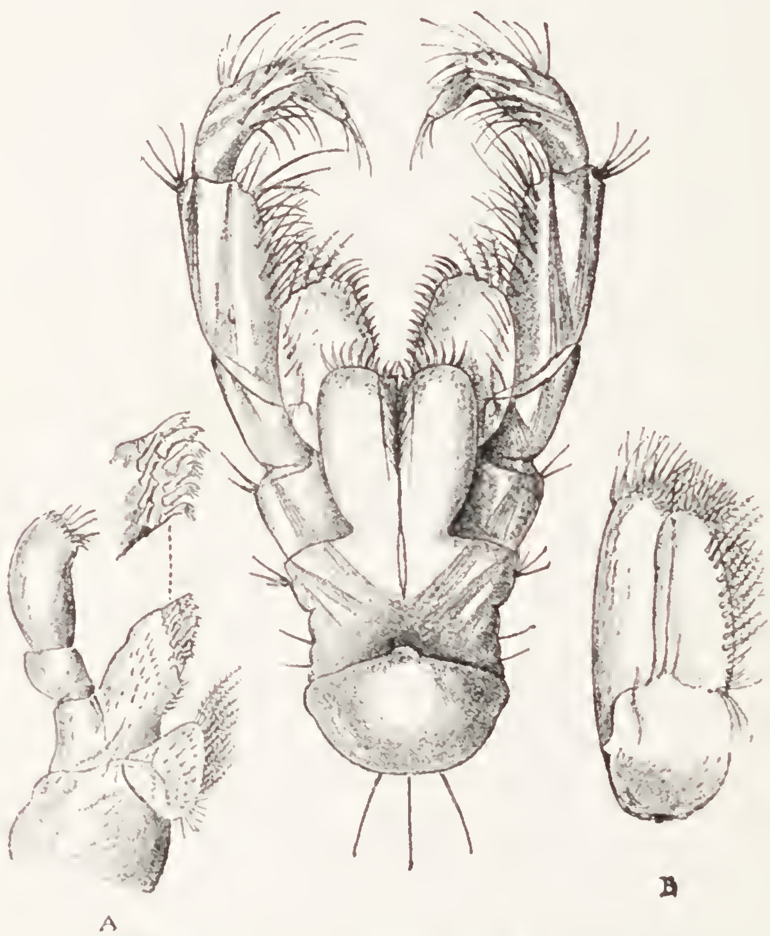


FIG. 72.—Maxillipedes of *Gammarus marinus* (in centre). *A.* First maxilla. *B.* Second maxilla (magnified).

denoted by the numbers 1, 2, 3, 4, 5, 6, 7; 1 being the basal joint, or that nearest the body. The sixth joint is often called the 'hand,' and the seventh, the 'finger.' The joints vary greatly in different genera. The walking legs are next to be examined, and we may notice that the first and second pairs are turned forwards, and the third, fourth, and fifth pairs backwards. At the bases of these legs are the breathing apparatus, and the females have leaf-like plates on the anterior four pairs, forming a pouch in which the eggs are hatched, and here she shelters her young, and carries them about with her.

The following account of this habit is taken from Bate and Westwood's *Sessile-eyed Crustaceae* (i. pp. 380, 381), and was furnished to the authors of that book by Dr. James Salter: 'On catching a female with live larvae, nothing is seen of the progeny till the parent has become at home in the aquarium, when the little creatures leave her and swim about in her immediate neighbourhood. The plan I have adopted to watch this curious habit of maternal protection, has been to place a single individual in a bottle of sea water. After a time, and that soon, the little crustacean seems at ease and swims slowly about, when the young fry leave her and swarm around her in a perfect cloud; they never leave her for more than half or three-quarters of an inch, and as she slowly moves about they accompany her. If now one taps the side of the bottle with one's finger-nail, the swarm of larvae rush under their parent, and in a second are out of sight. The parent now becomes excited, and swims about quickly, as if trying to escape; but by letting the bottle containing her rest quite still she soon gets composed, when out come the young larvae again and swim about as before. This may be repeated as often as the observer wishes, and always with the same result. I have only seen this in one species, but it is quite a common species in Poole Harbour, and I have watched the interesting habit many times.'

The swimming legs are, roughly speaking, λ-shaped—that is, they consist of a stem, carrying two many-jointed filaments, fringed with fine plumose hairs. A hair is said to be plumose when it bears smaller and finer hairs on each side. 'By folding the tail beneath the body, and suddenly striking it out again, those animals which exist in

FIG. 73.—Nest-building Amphipod. (From life.)

the water, as well as those which live on the shore, are enabled to dart or leap to a considerable distance[1].'

Our hand lens may be well employed in watching some of the nest-building Amphipods at work in the aquarium. There can be no difficulty in keeping these creatures in captivity, and under

[1] Bate and Westwood, *British Sessile-eyed Crustacea*, i. 8.

observation, as they build their tubes and rear their families. They are plentiful in every rock pool round the coast, and it would be a hard matter to dip the net into any such pool without getting a few specimens.

They need absolutely no care. The aquarium of the specimen figured was a four-ounce bottle, tightly corked; and in it was a spray of Cladophora, on which the animal fed, and the growth of which broke up the carbon dioxide and set free good store of oxygen. Here it lived for some months, and built more than one tube for itself against the side of the bottle.

It is easy enough through the pocket lens to watch the Amphipod at work. Like other builders, the first thing it does is to get its materials ready. Lying on its side, with its back against the glass, it will rake together with its antennae and jaw-feet a good store of vegetable *débris*, or if there be no supply of this, will break off branches from the growing weed.

But gathering vegetable *débris*, or even filaments of living weed, is very far from being tube-building. Something more is needed to bind the mass into a coherent structure. This the animal itself supplies. The bases of the first two pairs of walking feet are large, and contain glands which secrete a glutinous cement, that can be spread like mortar, or spun out into threads.

An American observer devoted much time to the observation of these animals. He says[1]: 'When captured and placed in a small zoophyte trough, with small branching algae, the individuals almost always proceeded at once to construct a tube, and

[1] *Trans. Connecticut Academy* (1882), iv. 274, 275, note.

could very readily be observed under the microscope. . . . The branches were not usually at once brought near enough together to serve as the framework of the tube, but were gradually brought together by pulling them in and fastening them a little at a time until they were brought into the proper position, where they were firmly held by means of a thick network of fine threads of cement spun from branch to branch. After the tube had assumed very nearly its completed form, it was still usually nothing but a transparent network of cement-threads woven among the branches of the weed.'

Then he describes the method in which the Amphipod works up bits of weed and its own droppings into the framework of the tube. In putting its foecal pellets to this use, it reminds one of a species of Melicerta (*Melicerta janus*)[1], which employs the same material to coat its gelatinous sheath.

In breaking up weed and pellets with its foot-jaws and (probably) its mandibles, the Amphipod recalls the practice of some of the Masking Crabs, which have been seen to apply to the mouth the material they were using to deck themselves. Dr. Aurivillius suggests that in the case of the Crabs there may be an adhesive secretion from the mouth, as there is possibly in the Amphipods. 'The spinning was done wholly with the first and second pereiopods, the tips of which were touched, from point to point over the inside of the skeleton tube, in a way that recalled strongly the movements of the hands in playing upon a piano. The cement adhered at once to the points touched, and

[1] *Ponds and Rock Pools*, p. 118.

spun out between them in uniform delicate threads. The threads seemed to harden very quickly after they were spun, and did not seem, even from the first, to adhere to the animal itself. In one case, in which the entire construction of the tube was watched, the work was apparently very nearly or quite completed in little more than half an hour.'

The species we are likely to meet with in rock-pools fashion their tubes in a similar way. The only difference to be noted is that they employ less cement, and a larger proportion of broken-down weed and other matters.

The Sand-hopper (*Tali'trus locus'ta*) and the Shore-hopper (*Orches'tia littorea*) are so exceedingly plentiful that it may be well to collect and preserve some during any visit to the seaside. Both are of fairly large size, and present no great difficulty to us in making out their several parts. Let us take the Sand-hopper first.

Sand-hoppers swarm on most sandy shores, where they perform the useful part of scavengers. They are always found above high-water mark, and do not enter the sea of their own accord. In hunting for them it is a good plan to turn over decaying masses of sea-weed, for under them the Sand-hoppers are sure to swarm.

Strange tales have been told of their voracity. Bate and Westwood[1] record the story of a correspondent who says that at Whitsand he 'saw "not millions, but cartloads," of this species lying piled together along the margin of the sea. They hopped and leaped about, devouring each other, as if for very wantonness. A handkerchief, which a lady let fall amongst them, was soon reduced to a piece

[1] *British Sessile-eyed Crustacea*, i. 21.

of open work by the minute jaws of these small creatures.'

This statement has been copied into a good many books, without criticism. At last Mr. David Robertson tried various experiments with a view to discover if these creatures would feed on each other, or, failing other food, put up with cambric or muslin. The specimens upon which he made his observations did neither the one nor the other. Mr. Robertson embodied the results of his experiments in a paper which he read before the Natural History Society of Glasgow[1]. And the story may be read in an abbreviated form in the Rev. T. R. R. Stebbing's *Naturalist of Cumbrae*, p. 329.

In Gammarus we have a standard with which to compare our Sand-hopper. The first thing to notice is the difference in the antennae. Here the superior pair are very short, and carry no secondary appendage, and the lower pair have no denticle or tooth-like process. There is also considerable difference in the gnathopods, or jaw-feet, the sixth joint of which, in the Sand-hopper, does not form a 'hand.' The pleopods, or swimming feet, are small, and are used for leaping. We shall also find some difference in the details of the mouth parts, especially in the toothing of the mandibles.

We now come naturally to the Isop′oda, which are distinguished by the nearly uniform size of the seven segments which constitute the trunk, and the seven pairs of limbs borne by these segments. The head is distinct, and the breathing apparatus is carried on the under side of the pleon—in these animals not the 'swimming' part—five pairs of

[1] *Proceedings Nat. Hist. Soc. Glasgow*, vol. i. pt. ii. n. s. pp. 130–132.

plates lying one over another, sometimes covered by a larger outer pair.

A normal I′sopod may be represented — · · · · · · · –, where the small dash will stand for the cephalon, or head; the seven dots for the segments of the perei′on, and the long dash for the pleon.

The Common Asellus (*Asellus aquaticus*) of ponds and ditches is an excellent subject. It lives well in confinement, and if the conditions are fairly favourable, will increase and multiply. These animals will forage for themselves, and pick up a comfortable living from the vegetable *débris* that always accumulates at the bottom of an aquarium, and they are not averse from an occasional meal of animal food.

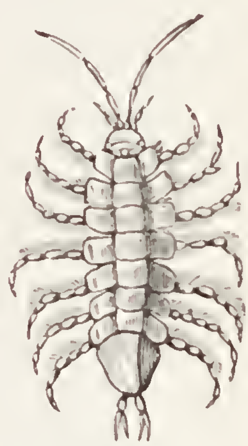


FIG. 74.
Water Woodlouse.

While our specimens of Asellus are moving about in any convenient vessel, we may verify with the hand lens what has been said about the general form. Then we may notice the antennae, the inner pair being much the smaller. There can be no difficulty in discriminating the head and the eyes; the seven segments of the perei′on, each bearing a pair of limbs; and the pleon with its two terminal appendages. These last consist of a stalk bearing two longer filaments, armed with spines, and ending in a small pencil of hairs.

It is easy to see that the segments of the pleon have coalesced, so as to form a continuous plate or shield on the upper surface.

If we now take our dissecting microscope and place an Asellus in some water in an excavated 3 in. by 1 in. slip on the stage, examination with an inch lens will show us a considerable amount of detail. With the half-inch Leitz lens (see p. 18) one may see quite clearly the beautifully annulated form of the flagella of the antennae, the sensory hairs with which these organs are set, and the circulation of the blood in the limbs and the antennae—the corpuscles moving in a continuous stream. More than this: we shall be able with the same power to distinguish tufts of Vorticellids that settle on the Asellus, and the commensal rotifers that roam about on the body of their host, generally on the limbs and under surface.

Now we may turn the Asellus on its back, to examine the breathing apparatus more closely than we were able to do when the creature was moving about in the bottle. It will be easy to make out the opercular plates—modified tail appendages—that open and shut to admit water to, or allow it to flow out from, the true breathing-plates which function as gills, and correspond to the swimming feet of the Amphipods.

In the female there is a pouch beneath the pereíon, in which the eggs are carried till they are hatched, and which serves as a nursery and refuge for the young.

If a good number of these animals be collected they will probably breed, and then there will be the opportunity of seeing for ourselves the young carried about in the incubatory pouch.

There are two other aquatic I′sopods which will make good subjects for us on account of their great abundance, and the ease with which they may be kept in any improvised aquarium, with a little weed. They may both be taken in brackish water, and will live and thrive in fresh water, without any admixture of salt. Indeed, both have lived for some months in a small bottle of New River water, in which the only weed is some willow moss. They feed on this and on the vegetable *débris* that accumulates at the bottom of the bottle, and both species have bred.

The first is Idot′ea (*I. pelag′ica*), a long, narrow creature, with very short inner antennae. The last four segments of the pleon form a plate on the upper surface; and on the under surface the opercular plates may be opened like tiny folding-doors, to show the breathing plates.

These vary greatly in colour. Of another species, Spence, Bate, and Westwood say: 'According to our experience the colour of the animal is dependent upon that of the weed on which it lives. Those that live on the black fucus are generally very dark purple, while those that we find on the green algae are brightly verdant; and it has always been our opinion that this change was due to the food[1].'

The other little creature is called Sphaero′ma—it has no English name—from the fact that it can roll itself into a ball. It is not difficult to identify, from the fact that all the segments of the pleon are joined into one plate, the hinder margin of which is entire, thus  .

The garden will afford us a hunting-ground for the last specimen of this group for which we have space—the Woodlice. Enough has been said of the method of looking over and breaking-up I′sopods generally to render detailed description unnecessary. The inner pair of antennae, however, are so small as to be readily overlooked: indeed, on first sight these creatures seem to have but

[1] *British Sessile-eyed Crustacea,* ii. 381.

a single pair. Some have, and others have not, the power of rolling themselves into a ball ; and, concerning the former, Swammerdam tells the following story :—

'One of our maidservants had at one time found a great number of Woodlice in the garden, contracted into round balls . . . , and thinking she had found a kind of coral beads, she began to put them one after another on a thread, but it soon happened that these little creatures, which roll themselves up in such a manner only for fear of harm, and appear as if they were dead, being obliged to throw off their mask, resumed their motions. On seeing which, the maidservant was so greatly astonished, that she threw away the Woodlice and the thread, and cried out, and ran away [1].'

[1] *Book of Nature*, i. 174.

CHAPTER VI

AQUATIC INSECT LARVAE

IN this chapter we shall deal with a few aquatic insect larvae. Of these, some are aquatic also in the perfect condition, while others emerge from the pupa stage as aërial insects. It requires no great amount of care to keep these creatures, and some hints on this subject and on collecting are given in the first chapter.

The larva of Dytiscus is abundant during the greater part of the year, and is almost sure to be met with by the collector, who will find it an extremely interesting object for examination and study. No other creatures should be put in the same bottle with these larvae; and if there are several of them in one bottle, it is a good plan to put in plenty of pondweed, which will often keep them from attacking each other.

When full grown, the Dytiscus larva may attain a length of two inches or rather more. Its colour is dingy brown, and its aspect forbidding enough to justify the uncomplimentary names that have been bestowed upon it—Water-devil and Water-tiger. It certainly rivals the tiger in fierceness, and its method of stealing up to its prey and attacking it from behind led Swammerdam to call it the Sicarius or Assassin Worm.

One must not imagine that Swammerdam was ignorant of its nature; 'worm' with him was a general term for any larval form. Indeed, he says, 'It is extremely probable that some peculiar species of the Water Beetle proceeds from this worm, when, having remained in the water a sufficient time, it betakes itself to the land to undergo its mutation; but this is mere conjecture.' What was conjecture for him is fact for us.

Now let us put our larva into a small tube, and examine it more closely. The head is large and joined to the first segment of the thorax by a distinct neck. There are twelve small eyes, six on each side, a pair of antennae, two pairs of palps, and a large pair of sickle-shaped mandibles, which Swammerdam calls 'teeth,' and says that 'it is perhaps to contain the muscles such teeth require that Nature has made the head so large.' Behind the head come eleven segments, of which the first and last are the longest. They gradually increase in width till the sixth, the rest again decreasing, till the eleventh ends in a blunt point, from which diverge two appendages, thus ∧, thickly fringed on both sides with hair, as are the tenth and eleventh segments.

There are six legs, one pair to each of the first three segments. These also carry fringes of hair, thus increasing their power as swimming organs; and, in addition, they bear numerous spines, and end in strong double claws, which must be of service in climbing over aquatic vegetation, and may assist in holding a struggling victim or in striking it down, so as to bring it within reach of the mandibles.

Spiracles will be found—seven on each side. These do not, however, in the larval condition, serve as breathing organs, though they fulfil their proper office in the pupa. The air-tubes of the larva open at the extremity of the last segment. When the larva wants to breathe it comes to the surface without an effort, for it is lighter than the water it displaces. The tail rises above the surface, and a fresh supply of air is taken in. When the larva wishes to descend, a stroke of the tail sends it downwards, and as it reaches the bottom of the tube it will cling with its claws to any weed we may have put in with it, or hold on with them to the glass itself.

The chief interest of this animal lies in its mandibles, and the method in which they are employed. It was formerly believed that the mouth of this larva was closed, so that it could not take solid food, and that it lived entirely on the juices of its prey, which it sucked up through its hollow mandibles.

Swammerdam says of this larva, 'When about to eat he seizes with the two teeth (mandibles) the little creatures that come in his way, and pierces their body with the sharp crooked points. The teeth being perforated from the points to the roots, he in a surprising manner sucks through them into his mouth the blood of the unfortunate captive. This may be easily seen, especially when the blood of his prey is of a red colour, as the teeth are transparent.'

He then describes how he watched one of these larvae feed, and saw the blood, mixed with air-bubbles, travel up the mandibles. After this he tells us how, if we have a Dytiscus larva, we may 'procure ourselves a very entertaining and surprising sight, by throwing to it a small earthworm; for let this last move, twine, and otherwise bestir itself ever so much, the other keeps its hold, and very calmly sucks the blood of its prisoner.'

We may, however, go to work in another fashion. We may dissect out the mandibles from a dead larva and pass a fine hair into the slit near the point, and it will come out at the orifice near the base. It is through this orifice that the nutritive juices of the prey are drawn into the true mouth. This practical proof that the mandibles are pierced is by no means so difficult as one might suppose.

De Geer[1] seems to have been the first to suggest that there must be some kind of true mouth, and in support of his suggestion tells us that he saw this larva eating up the solid parts of a Water Woodlouse (*cloporte*), after having sucked up its juices. More than this, he places the mouth in what has proved to be the true position, though he did not solve the mystery as to why it is kept so firmly closed. This was done by Mr. Burgess, an American naturalist, from whose paper[2] the following particulars are condensed:—

'Authors have described this creature as mouthless; and if we examine the slit where we should expect the mouth to be, we find that this slit ends in a perfectly closed seam. The methods of microscopical research were brought into play, and a longitudinal section of the head cut and mounted. This showed that the upper and lower lips were locked together by a peculiar joint—the upper coming over and locking into the under lip (Fig. 75).'

We may get some idea of this mouth-lock by

[1] *Mémoires*, iv. 386.
[2] *Proceedings Boston Society of Natural History*, xxi. 223–228.

placing the fingers of the right hand over those of the left, and then bending them.

Mr. Burgess concludes his paper thus: 'We find that the Water-tiger, far from being mouthless, as ordinarily assumed, has in fact a very wide mouth, though its lips are closely locked together by a dove-tailed grooved joint developed for this purpose. Whether this joint can be unlocked by the animal itself is another question, which I cannot answer, though De Geer's observation above quoted makes this probable. It is, at all events, easy to open the mouth by manipulation with a pair of forceps.'

FIG. 75.—Mouth-lock. *m*, mouth ×125. (After Burgess.)

Professor Miall[1] has verified Burgess's observations, and carried them a step further. He found by actual experiment that 'the mouth-lock acted automatically, opening when the mandibles opened, and closing when they closed.'

Both these authorities stand very high. Yet, with all respect to them, it will be well to test these statements before accepting them.

Something of this mouth-lock may be seen in any well-prepared slide of a Dytiscus larva. If we hold the slide up to the light and examine with

[1] *Natural History of Aquatic Insects*, p. 47.

a power of 10, we shall see a dark line—in some cases two nearly parallel thinner lines—running from the base of one mandible to the base of the other. The dark line is the closed mouth-lock. The two nearly parallel thinner lines are the edges of the lips drawn asunder in preparing the specimen or by the pressure of the cover-glass. If we get to see this much, we shall have advanced one step.

Next we may verify Professor Miall's experiment, though not quite in his way, for such section-

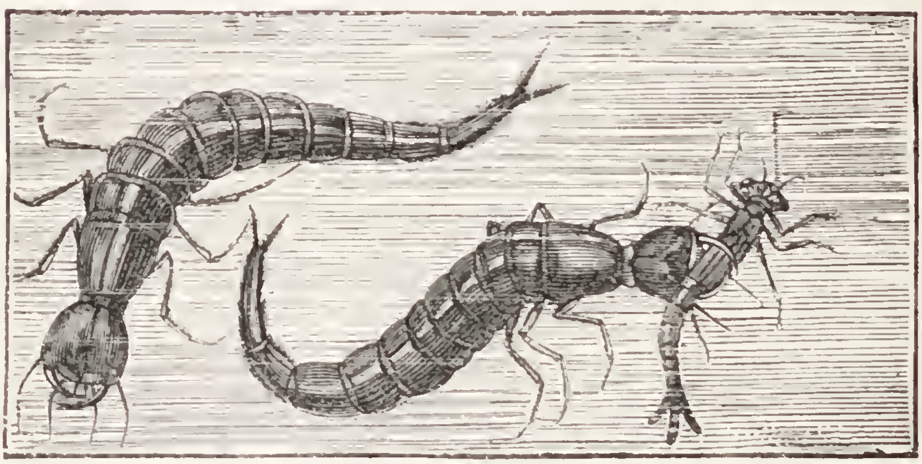


FIG. 76.—Dytiscus Larvae.

cutting as he speaks of is beyond our powers. Larvae as large as possible should be chosen, and killed by dropping them into boiling water. The mandibles of one should be allowed to remain closed, and those of the other plugged open with pith or a small piece of wood—a bit of a match will serve. By putting each in turn into an excavated slip with water, carefully covering this with a plain slip, and holding these slips together with an elastic band, we may examine the larvae as we did the slide.

The result will be practically the same. Where the mandibles are closed, we shall see the dark line; and where they are open, we shall see the two thinner ones nearly parallel.

One caution may be necessary. The mandibles bear at the base a rounded process, which fits into a chitinous cup. It is not difficult to mistake this for the mouth-lock, with which, however, it is not connected.

There is still one other method which we may adopt to see the mouth. The head of one of these larvae may be cut off, dropped into a strong solution of caustic potash, where it should remain for a day or two. After washing it well in water, cut it in half lengthways, and turning either half upon its side, so as to expose the part cut, examine with the pocket lens.

These experiments are by no means difficult. But if carried out step by step, it will be easy to understand how the larva can suck out the juices of its prey, and how it can open its mouth to swallow some of the solid parts.

The larva does not readily change into a pupa in confinement. If, however, we wish to rear a beetle, the larva must be plentifully supplied with food, and removed from a bottle to a flat dish, where earth can be placed against the side so as to rise above the water-level. Fig. 77, where a pupa is represented in a bank by the side of a pond, will give us a hint how to go to work. The time occupied in pupation will vary according to the temperature of the room—but is never less than a fortnight. In the open it is probable that the winter is passed in the pupal condition, the perfect insect emerging in the spring. Like Land Beetles, it does not assume its dark hue for some days, but its pale skin darkens by degrees.

The larva of Hydrophilus does not seem to be often taken in this country. It would make a capital subject for investigation, and the food-supply could be arranged easily enough. The repetition of the experiences of Lyonnet, who reared these larvae from the egg, would be of great interest. He says that he took about thirty larvae from the brood, and fed them with very small water-snails. These they devoured in the same

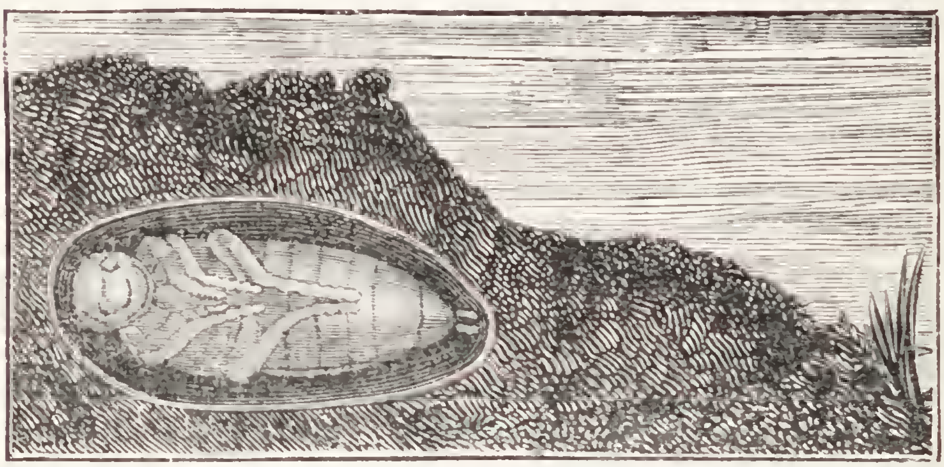


FIG. 77.—Pupa of Dytiscus.

way as the larger larvae do. Having seized the snail with their mandibles, they bent backwards, and supporting it on their back, which served them for a table, eat it there, without making any use of their legs to hold their prey. When the supply of small snails ran short, they did very well with large ones cut up into pieces, and with tadpoles. If, however, food was not supplied to them, they fed on each other. But, except when pressed by hunger, they lived together peaceably enough, and seemed to take pleasure in each other's society [1].

The larva of *Limnobia replicata*, a Crane-fly allied to, but smaller than, the well-known Daddy-longlegs, is another excellent subject for investigation. It is not very often taken; perhaps because it is not often looked for. But it is common enough, for all that.

In general appearance these larvae resemble small caterpillars covered with spines. Some of these are simple and others forked, not much unlike the letter Y, with a short stem, and the arms slightly curved. There are no feet, and the last segment carries two pairs of hooks, one large and the other small. From their position they are called anal hooks.

The dykes of the Sussex marshes are an excellent hunting-ground. Probably the channels of water-meadows, or any other shallow standing water in which aquatic moss grows, would serve the collector's purpose quite as well. And such pieces of water abound all over the country.

For taking these larvae the ordinary net and bottle are of little use, though a few may be captured by sweeping backwards and forwards among patches of aquatic moss.

There is, however, a far easier and surer method. A good handful of the moss should be gathered, and put into a shallow vessel half full of water—a developing-dish answers capitally—and then shaken to and fro or gently stirred with a small piece of stick. The larvae will curl into a ring and fall to the bottom, whence they may be picked up and dropped into a bottle or other receptacle

[1] *Mémoires du Museum*, xviii. 442, 443.

to be taken home. A fair quantity of moss should be gathered, for this is their favourite food, and all larvae are greedy feeders.

Other water-plants, however, do not come amiss to them. Just before these lines were written I was examining a bottle in which some of these larvae were kept. It contained a few sprays of willow-moss and some ivy-leaved duckweed, which floated on the surface. One larva on a spray of moss was reaching upward, and it was distinctly seen to feed on the duckweed. This must have been from choice, for there was within reach plenty of what all observers consider to be its natural food. This, too, might have been more easily obtained; for, to reach the duckweed, the larva had to hold on to the moss by the anal hooks, and extend its body in a fashion analogous to that of the caterpillar of a geometer moth, which will hold on to a branch with its forelegs and claspers and maintain the body at an angle of 45°, sometimes for hours together. I have also seen them feed on hornwort.

The larva of this small Crane-fly is not at all difficult to keep. It is exceedingly hardy, and will survive a great deal of rough treatment. In November, 1895, I sent three in a tube—securely packed, as I thought—to a friend in Yorkshire. A few days afterwards I heard, with regret, 'that the bottle was broken in transit, and that the larvae arrived dead.' Three days later I was gratified by receiving a letter, from which the following is quoted: 'The Limnobia larvae have come to life again. I put them into water as soon as they arrived, and after lying motionless for many hours they have begun to creep about and feed.'

This is excellent testimony to their powers of endurance, but it is weak in comparison to that which De Geer supplies [1].

He was Marshal of the Court of Sweden, and one November, before leaving his country house for his official duties at Stockholm, he put four of these larvae into a vessel of water, and left them to take their chance. The water froze into a solid mass. When he returned in the following May he found about half the water thawed, and two of the larvae dead. The others, though they had been enclosed in ice all the winter, were lively and in good condition. He put them into another vessel with fresh water and some aquatic moss, and at once they began to move about and commenced to feed. Both pupated by the fifteenth of the month, and the perfect fly emerged after six days in the pupal stage.

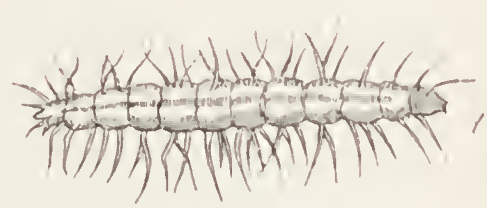


FIG. 78.—Larva of *Limnobia replicata.*

The following description of this larva is principally condensed from De Geer, whence the figures are also taken. The body is long and cylindrical, and divided into eleven segments, of which the first and largest is sub-triangular. The second and third segments are shorter than the rest.

The head (*t*) is very small and completely retractile within the first segment, the anterior margin of which completely closes the orifice, so that, in this condition, the creature appears to be headless. The body is covered with spines, some simple and

[1] *Mémoires,* vi. 352–55.

others branched. On the first three segments there are only simple spines; but from the fourth to the tenth segment inclusive there are also on each segment two forked spines—that is, fourteen in all. On the last segment the spines are simple, and here are also four chitinous hooks, one pair much larger than the other. These simple spines carry a white vessel, which extends throughout their whole length; but in the forked spines there are two such vessels placed side by side in the stem, and diverging one to each branch.

FIG. 79.—Forked spine of Limnobia, enlarged; the dark lines show air-tubes.

He comes to the conclusion that these spines are probably the breathing apparatus of the larva, for they are similar to those which he observed in an aquatic caterpillar. Walker[1] calls these spines 'long filamentous processes, which appear to be internally supplied with air-tubes,' but he does not seem to have taken the trouble to break up a specimen, or he would have been in no doubt as to their real nature. This is shown by the fact that the larva never comes to the surface to take in a supply of air, but contents itself with the oxygen dissolved in the water.

The pupa is quite as remarkable as the larva, though the breathing apparatus does not assume the form of spines, but consists of two 'trumpets,'

[1] *Diptera*, iii. 281.

one on each side of the head, as is the case with the pupae of gnats, using that term in a wide sense. The colour is a greenish-brown, dotted with black. The abdomen is capable of a good deal of motion from side to side; and by this means the pupa can raise itself to the surface of the water to take in a supply of air.

De Geer remarked that when the pupa rose for this purpose it lay with its body horizontal, having the lips of the trumpets a little above the surface. It appeared not to like being placed on its back, because in that position the trumpets cannot be raised above the surface. When he tried the

FIG. 80. Pupa case of Limnobia.
(From a photograph taken at the Yorkshire College, Leeds.)

experiment of putting the pupa back downwards, it wriggled over by bending the abdomen.

On the abdomen there are several chitinous hooks, which serve in some sort as substitutes for limbs. By their means the pupa can moor itself to the stems of aquatic plants; and this is necessary, since its specific gravity being less than that of the water it would be always at the surface, if it had no such means of anchorage. And of course, at the top of the water, it would be exposed to the danger of being snapped up by birds.

De Geer's specimen passed six days in the pupal state, and then emerged as a perfect Crane-fly.

My specimens did not emerge till after ten and eleven days of pupahood, which seems strange, as they were plentifully supplied with food in their larval stage.

The fly is a little more than half an inch long, and may be distinguished from the common Daddy-longlegs by the character of the wings, which are folded somewhat like those of a wasp, but with this difference: that the wings of this fly are folded outward, while those of the wasp are folded inwards. When the insect wishes to fly, it opens the fold so that the whole wing presents a plane surface, but the fold reappears directly the Crane-fly ceases its flight (Frontispiece).

De Geer's allusion to the wing of the wasp might

FIG. 81.—Fore-wing of Bee, showing marginal fold (× 7).

have been extended to most of the Hymenoptera, as we may see by examining the fore and hind wings of a bee or a sawfly. Dr. Sharp [1] says, 'The wings [of the Hymenoptera] are remarkable for the beautiful manner in which the hinder one is united to the anterior one, so that the two act in flight as a single organ. The hind wing is furnished with a series of hooks, and the hind margin of the front wing is curled over so that the

[1] *Cambridge Natural History*, v. 494.

hooks catch on to it. In some of the parasitic forms the wings . . . have no hooks. The powers of flight, in these cases, are probably but small.'

If we were taking our subjects in consecutive order, the larva of Ptychoptera would properly come here, as being that of a Crane-fly. But since it will be convenient to examine another larva which resemble Limnobia in its breathing apparatus, we will take next the larva of *Parap'onyx stratiota'ta*, one of the China Marks, for it is extremely interesting and by no means hard to come by.

The China Marks are small moths, with white wings bearing dark markings, which have been supposed to resemble Chinese characters. Their larvae are aquatic in varying degree—that is, some breathe air in the usual way, by means of spiracles; while others, by means of gills, breathe the oxygen dissolved in the water.

Many collectors have, no doubt, taken these larvae, and cast them away in the belief that they were caddis-worms. Such was the experience of the Rev. Gregory Bateman, the author of *Fresh-water Aquaria*, who says (p. 259): 'While hunting for fresh-water animals, one not seldom comes across an insect wrapped up in two or more green leaves, or pieces of leaves, of some aquatic plant. The leaves and the animal have somewhat the appearance of a caddis-worm in its case; in fact, for a time, before I knew what it was, I mistook it (and I daresay others have done so also) for a caddis-worm.'

The cases are usually, but not invariably, made from the food-plant of the insect. Mr. Bateman has noted that these larvae 'do not always confine themselves to the same weed, either for food or for building material.' This has also been my experience. A larva of the Brown China Mark, recently taken on the Norfolk Broads—an excellent collecting ground for aquatic larvae—was put into a tube. The case had been damaged, and the only vegetation in the tube was a spray of bladderwort. On examining the tube, after some days, I failed to find the larva. The reason was evident on removing the cork, a small part of which had been gnawed away to procure material for the repair of the larval case, which was affixed to the under side. The larva was dead and too much decayed to be put into pickle, a circumstance I much regret, as I should like to have preserved the larva in such a strange dwelling. As it is, I have only been able to keep the house without its tenant.

Pondweed is the usual home of the larva of the Brown China Mark, and from the leaves of this plant the first larval case is generally fashioned. This was the species upon which Réaumur made his interesting observations, most of which have been confirmed by succeeding observers. In well-grown larvae the contrivance by which the animal is protected from contact with the water in which it lives should be noted, as it may be easily, with the hand lens. The skin is thickly set with tiny protuberances between which the water cannot penetrate, the surface film stretching from tip to tip of these prominences, just as it does over the hairs that cover the body of a water-spider.

De Geer[1] describes an aquatic larva of one of the China Marks (*Paraponyx stratiotata*), which has its breathing apparatus fashioned on a similar plan to that of Limnobia, though there is some

[1] *Mémoires pour servir*, i. 577 sqq.

difference in the details. He found his specimens on the leaves of the Water Soldier, and his interesting account recalls the fact to memory that this remarkable plant was at one time called the Marsh Aloe—an exceedingly appropriate name.

He describes the filaments on the body of the larva, and concluded that they were probably breathing-organs, because of the dark-coloured vessels within them. These he traced, as we will presently do, to their union in the stem of the gill, and thence to the air-vessels running down each side of the body of the larva. He fed them on leaves of the Water Soldier, and kept them through

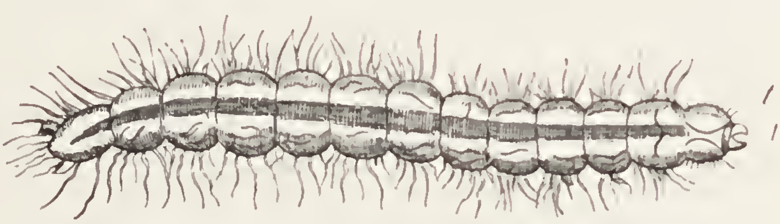


FIG. 82.—Larva of *Paraponyx stratiotata* (enlarged).

the winter. In the following June he found them preparing to undergo their transformation into the pupal stage, and at the end of the month the moths came out. He was gratified by seeing the congress of these insects. The females deposited their eggs on the floating vegetation and on the sides of his aquarium, a little below the surface of the water, and in about eight days the young larvae were seen.

These larvae must be very abundant, though they do not seem to be often taken by collectors. In describing an allied (American) species, which is found on Vallisneria and pondweed, Mr. Hart says[1], 'They feed at first exposed on the leaf, but later two or even three leaves are loosely webbed together, face to face, by each larva, between which it remains concealed while feeding. They are, therefore, hard to discover unless their hiding-places are broken up by seining, or the like, when the larvae may be seen swimming about.' This is, no doubt, the reason why these larvae are not more often taken. Anything like a seine net is of course out of the question for us; but masses of vegetation may be readily broken up by vigorously working the bottle and net backwards and forwards amongst them. Specimens I have seen were taken among duckweed; and Mr. Hart mentions one instance of part of the larval case being constructed of ivy-leaved duckweed, 'which was abundant there at that time.'

Now let us bring our lens to bear, so that we may make out the external structure, and recognize the similarity of the breathing-organs of this Moth-larva to those of the Crane-fly larva already treated of (p. 168).

In order to make out the scheme of the gills, which is somewhat complicated, one should first of all distinguish the spiracles, remembering that they are not functional. And it is best to begin with those on the middle segments of the body. They may be detected as little dark spots, sometimes enclosed in a ring. The head, the first segment of the thorax, and the last segment of the body, bear no gills; the second segment of the thorax has but two pairs on each side; and there is but a single gill on each side of the ninth

[1] *Bulletin of the Illinois State Laboratory of Natural History*, iv. 167.

segment of the body. On the other (nine) body-segments there are the full number of five gills on each side, arranged two above, and three below the spiracle. The upper pair are called supra-stigmals, or gills which lie *above* the spiracles; the lower pair are called infra-stigmals, or gills which lie *below* the spiracles; and the single one, the lowest, is known as the pedal or foot gill. These technicalities need not give us any trouble here, in our examination of the larva; nor do they present any real difficulty. But it is worth while to master the arrangement as soon as we get hold of one of these larvae, and then we shall be able to take up and understand technical descriptions of this aquatic caterpillar and its allies, in so far, at least, as they refer to the breathing apparatus.

FIG. 83.—Diagram of segment of Paraponyx, showing arrangements of tracheal gills.

The gills differ in their character: some few are simple, while most of them are more or less branched. In Limnobia the branching of the gills is into a simple fork; in Paraponyx this kind of division also occurs, and in others most of the gill branches are also given off from the main stem below one of the branches of the fork.

In Fig. 84 we have a representation of one of these branched gills. It will not be difficult for us to make out the details as there shown. But the vessels that run down into the filaments, constituting them breathing-organs, are smaller than those of Limnobia, and will consequently require a little more care and patience before we can distinguish them.

One would think that, with such an array of gills, this larva ought to be in good case for its air-supply. It may, perhaps, be doubted whether this is so. At any rate, the creature adopts the same plan as the larva of Chironomus, which has no gills at all, for driving away from its case water that has parted with its oxygen. Water charged with oxygen pours into the case, and so the air-supply is renewed. This plan is nothing more

FIG. 84.—Gill of Paraponyx larva. *a*, *b*, stem; *c*, *d*, *e*, *f*, branches; *g*, attachment of the air-vessel of the gill to the main tracheae of the body. (After De Geer.)

than keeping the fore-part of the body in undulating motion, the tail in both the larvae serving as a point of attachment. One or two that I have kept made their cases against the side of the bottle, and so afforded an excellent opportunity of seeing them in this motion. The Tanypus larva does the same thing. Against the side of one of my small aquaria a Tanypus larva and a Chironomus larva have both made tubes; and as I look up from writing these lines I can see them both hard at this work.

The larva of the Alder-fly (*Si'alis luta'rius*) is also furnished with tracheal gills, seven on each side. So little is known of the life-histories of common insects that it may be profitable to introduce the account of an observer who watched the deposition of the eggs and the emergence of the young larvae:

'On April 25 I found, on the rushes round the margin of a small pond, a great many patches of eggs, and shortly after observed many of the *Sialis lutarius* depositing them.

'They form large patches of from two to three inches in length, generally encircling the whole rush near the top, but sometimes deposited on one side only, and extended to about a line in breadth.

'I counted 100 in a square line, so that each batch may be fairly considered to contain from 2,000 to 3,000 eggs; the greater portion of which must consequently perish either in the egg or larva state; as, common as the insect is, and widely distributed throughout the country, we should be perfectly overwhelmed with the swarms of the perfect insect if such were permitted, when it is considered that round this one small pond there could not have been less than 100 patches of them.

'The eggs are of a very singular form, and placed in a slanting position.

'The females, while depositing them, appeared perfectly motionless on the rush, and varied considerably in size, being from five lines to nearly double that in length. Some parts of the patches of eggs are of a much lighter colour than the rest.

'On May 3 I found many of the eggs hatching, the little larvae tumbling about in great numbers, with their bodies erected like [the larvae of] the *Staphylinidae*.

'On putting them into water they swam about with the greatest activity, wriggling and undulating their bodies about much like a serpent or the tadpoles, and working their legs at the same time[1].'

The author draws attention to the disproportionately large head of the larvae, which, however, he did not describe, as he had 'brought some of them alive, and some eggs for exhibition.'

Sialis larvae occur in most ponds with muddy bottoms. They may be taken by scooping up some of the mud in a long-handled spoon—a most useful instrument for the collector—and washing it, or by throwing in the drag, and bringing to land a mass of water-weed, roots and all. A few may generally be detected near the roots. They may be picked up with a small pair of forceps, or with a brush, and dropped into a bottle; or, better still, into separate tubes; for they are fierce and voracious, and, failing other food, by no means indisposed to prey on each other.

Their general appearance, and especially their powerful mandibles, give them some resemblance to the larvae of a water beetle, for which a celebrated naturalist not unnaturally took them, when he began to study them. And this would seem to be the opinion of some mounters, for I have a slide of the mouth parts of this larvae, labelled 'Mouth parts of the larvae of a water beetle.' It was not till I had broken up a good many Sialis larvae that I found out what the slide really was.

[1] W. Evans, *Trans. Entomol. Soc.* (London), iv. 261.

These larvae may be kept alive in small bottles of water, if they are supplied with food. They will eat Chironomus larvae and those of Tanypus. Professor Miall has found that they will eat caddis-worms and May-fly larvae. Probably, no small aquatic creatures that they can overcome are safe from them.

A larva that is full-fed, and ready to change to become a pupa, will measure about an inch in length or a little more (Fig. 85). The general colour is brownish, with dark markings. The legs are powerful, and our lens will show us that they end in two strong curved claws. From each of the first seven segments of the abdomen are given off a pair of jointed tracheal gills or breathing-organs, which are directed upwards and backwards when the larva is at rest—a rare occurrence—but which wave to and fro in the water when the creature is swimming.

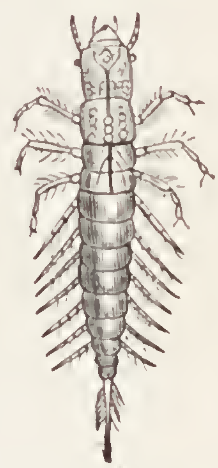


Fig. 85.—Larva of Sialis (enlarged).

From this fact has arisen the statement found in most books that the larva uses these gills not only for respiration, but for locomotion. Professor Miall has come to a contrary conclusion, and, as he has kindly informed me, is confirmed in his opinion by the weakness of the muscles.

It will be well to make repeated observations till we are satisfied on the subject. When these larvae are kept, the conditions necessary to provide them with food and to keep the water aërated by means of growing vegetation are unfavourable to close observation. It will, therefore, be necessary to remove one or more of these larvae to a bottle in which there is nothing but pure water.

The work is now rendered much easier. There is nothing to obstruct. As soon as the larvae reach the bottom they will walk round and round, giving us a good opportunity of watching them. In swimming—which may be backwards as well as forwards—the abdomen is waved from side to side. To see the backward motion one need only put a dipping-tube or a pencil, or the like, in front of the larva, so as to bar its progress. The creature will retreat a step or two, and then, with a flourish of the abdomen, dart back through the water. The larva will sometimes wave the abdomen up and down, just as one may see a Chironomus larva do when it has affixed its dwelling to the side of the glass, and this motion probably assists the process of respiration.

When the larvae have been watched under the conditions above described, I have never been able to detect independent motion of the gills. But it is better that every one should observe for himself, and draw his own conclusions from what he sees.

Now let us examine a specimen more closely with the lens, or under the dissecting microscope. The mouth parts may be broken up separately, or a little careful manipulation will enable us to see the chief features without injuring the specimen. The head is strong and massive, and the group of ocelli, or simple eyes, may be clearly made out. The antennae bear a small pencil of hairs, no doubt sensory in function, at the extremity, but careful management of the light will be required to distinguish them. The mandibles are extremely business-like instruments, and each bears two strong teeth on the inner side. Next come the maxillae, with their palps, each of which has an appendage, while each maxilla carries three strong spines. The labium, with its palps, and the mentum, with its saw-like notchings, may be plainly seen.

The three segments of the thorax offer no difficulty. The legs are worth more than a cursory examination from their apparatus of spines and double fringe of hairs. Nine body-segments succeed to the thorax, and behind these is a long tail-like organ, which some authors consider represents a tenth segment.

The gills are seven on each side, and are given

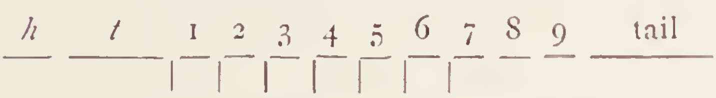


FIG. 86.—Diagram of Sialis larva, showing arrangement of gills (represented by vertical lines). *h*, head; *t*, thorax; 1–9, segments of abdomen.

FIG. 87.—Pupa of Sialis.

off from the spaces in front of the first seven segments of the abdomen. Each gill is five-jointed—an unusual arrangement, for the gills of the larvae of Limnobia and Gyrinus are without joints. With the half-inch Leitz the branching tracheal tube in the gill may be seen, as well as the double fringe of hairs and the long hairs at the extremity. The tail-like organ, though without joints, bears a close resemblance to the gills. It has two tracheal tubes running through it, and it is fringed on both sides with hair. Indeed, Professor Miall, F.RS., compares it to 'two ordinary tracheal gills completely fused together.' The first glance will convince the observer that the comparison is just.

The pupa (Fig. 87) need not detain us, for the larva undergoes its transformation in the ground, not in the water, where it could be watched. But it is interesting to notice that the legs and wings are enclosed in separate cases, and that the segments of the abdomen bear spines. These spines are extremely serviceable to the pupa when making its way out of its cell to emerge as a perfect insect, which is well known, especially to fishermen, as the Alder-fly. It may be found near streams, and rarely uses its wings.

Ptychoptera paludosa is a small Crane-fly, with an aquatic larva which will repay observation. It is one of the group generally called 'rat-tailed maggots,' from the peculiar character of the breathing apparatus, which consists of a retractile tube at the end of the abdomen. It is, I believe, better known to some dealers than the larva of the Drone-fly, the rat-tailed maggot of Réaumur. A few months ago I wanted some Drone-fly larvae, and asked a dealer to supply me. When the larvae arrived and were turned out for examination, they proved to be Ptychoptera larvae—which I did not want. I naturally wrote to point out the mistake; and was told, in reply, that the larvae sent were the only 'rat-tails' known to my correspondent.

This larva is a mud-dweller, and is best captured by scooping up surface mud near the banks of pools and ditches, just where the water shallows on to the shore. This should be washed in a small dish or saucer, so as to carry away the mud and leave the larvae wriggling on the bottom. They may be picked up with a brush and dropped into a bottle for transport home.

There is not the slightest difficulty about keeping them for observation. A bottle of the capacity of six or eight fluid ounces will make a good aquarium for a dozen or even twenty. The bottom should be covered to the depth of about an inch with mud fairly rich in organic matter. My own plan has been to use the accumulation from the bottom of a large aquarium. In this the larvae will bury the body, and feed, the tail protruding and thrust up to the surface of the water, of which there should be about two inches above the mud.

This is a liberal allowance of space. A couple of these larvae lived with me for some months in a glass capsule two inches in diameter and three-quarters of an inch in height. The mud at the bottom and the water covering it together measured about half an inch. Both pupated, and in due time from the pupa cases a perfect insect came out.

But that larvae may pupate, they require to be well fed. How shall we know when the bulk of the nourishment has been extracted from the mud? From the castings of the larvae; and these, though of a different shape, are as easy to be distinguished as the castings of the earthworm in the garden or those of the lobworm on the seashore. All the mud that passes through the bodies of the larvae is discharged in the form of tiny hard, cylindrical pellets; and when the mass consists of these pellets it should be changed, or the larvae will go short of food. They will, however, support long fasts.

From Fig. 88 we may get a good idea of the appearance of the larvae when kept in confinement. The figures are rather less than natural size, and all the attitudes were sketched from life. One is seen extended on the bottom; two are partially buried in the mud, with the breathing-tube protruding. The larva on the mud, and bent into curves, is just about to rise to the surface; others are shown in the act of rising, while one has its breathing-tube raised above the surface, and another is attached by the breathing-tube to the side of the glass vessel. The larva with the star-like process at the end of the tail is that of Odontomyia, a large bee-like fly.

FIG. 88.—Larvae of *Ptychoptera paludosa* (from life).

A larva of good size, like that of Ptychoptera, is especially easy to examine; and by reason of its transparency the tracheal tubes may be clearly traced. The under surface of the larva should be first looked at, and its adaptation for existence in the mud of a pond-bottom will be evident. The creature is legless, but possesses three pairs of false legs armed with dark-coloured hooks, and each body-segment bears a circle of stiff hairs, which enable the larva to travel through the mud, in the same way that the earthworm moves through the soil. Moreover, the segments between these circles are pretty thickly set with hairs.

The tracheal tubes run down on each side of the body, not in a direct line, for there is a most ingenious arrangement by which contraction and expansion of the larva, and the protrusion and retraction of the tail, are provided for. One can easily discern that in most of the segments the tubes are large, and that these large portions are connected by smaller tubes, whence others are given off into the body. These connecting-tubes are loop-like when the larva is of the normal length, but are straightened out, thus adding to their length, when the larva is extended.

The opening and closing of these loops may be observed at leisure if a larva be put in a long excavated slip, with some water, and then covered with a plain glass slip. The two slips, fastened together with small elastic bands, should then be laid on the stage of the dissecting microscope for examination ; or they may be held in the hands, and the movements of the larva watched with the hand lens.

In the posterior segments of the body the tracheal tubes run side by side, while in the tail itself they are, so to speak, intertwined. When the tip of the tail pierces the surface-film a fresh supply of air is taken in.

At the base of the extensile portion are two processes which diverge, one on each side, at an angle of 45 degrees. These, according to a German observer, are tracheal gills, and they are absorbed just before the larva enters the pupal condition.

Réaumur found these larvae plentifully in the

Bois de Boulogne, and gives a figure [1]. He was not, however, successful in rearing the fly. Lyonnet not only took the larvae and kept them in an aquarium, but watched their change into the pupal condition, and saw them emerge as perfect insects. An abstract of this description will probably be of interest.

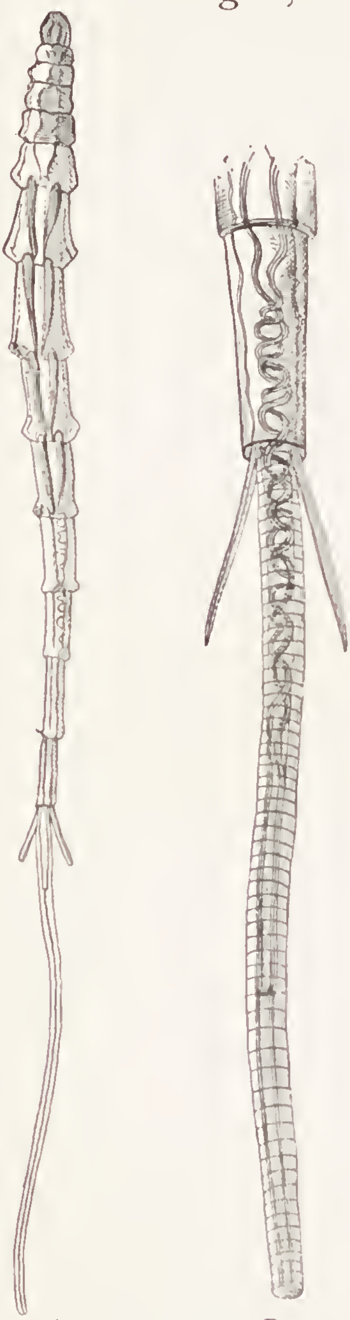


FIG. 89.—*A*. Ptychoptera larva (enlarged). *B*. Tail, showing air-vessels (still more enlarged). (After Lyonnet.)

He tells us that the larvae showed signs of changing into pupae in June. The change was made without the larvae leaving the water, and they underwent all their transformations in less than a fortnight. At the approach of the change the larvae became whiter in colour, but less transparent. Then they cast their skin, leaving therein the air-vessels, or rather their external covering. After this last moult was over, he was surprised to find that the tube which formed the tail of the larva, and by which it took in a supply of air, though it serves the same purpose in the pupa, is

[1] *Mémoires pour servir*, t. vi. Plate 31.

attached to the thorax, near the top of the head [1]. Lyonnet appears to have overlooked the fact that there was a second and shorter tube given off from the thorax, which most observers consider to be functionless (Fig. 90).

Strange as is the larva, the pupa is stranger still, and seems even better adapted for existence in the mud. The hinder part of each segment of the abdomen is thickened and studded with chitinous

FIG. 90.—Pupa of Ptychoptera. (After Lyonnet.)

projections. This thickening is more marked, and of greater extent in each succeeding segment, reaching its greatest development in the last segment, which is armed with hooks. The body part of each segment bears rows of smaller spines, so that this pupa should have little or no difficulty in moving through pretty thick mud.

Several of these Crane-flies have passed through

[1] *Mémoires du Muséum*, t. xix. pp. 103, 104.

all their stages with me, and in nearly every case the transformation from pupa to perfect insect was made in water—in a tube three inches long, with a diameter of about an inch. The larvae were taken about the middle of September. My notes show that the first pupated on November 17, and the first fly came out on November 25.

The long breathing-tube of the pupa was several times purposely displaced from its position on the surface. The creature was evidently incommoded, and twisted itself into strong curves; the head was thrown from side to side till part of the breathing-tube was raised above the surface and adhered to the side of the glass tube. Nor did the efforts cease till a considerable portion of the tube was in free communication with the air. This would seem to show that the air-supply is taken through the bladders which appear at irregular intervals in the breathing-tube, and not at the tip, where the keenest observers have failed to find an opening.

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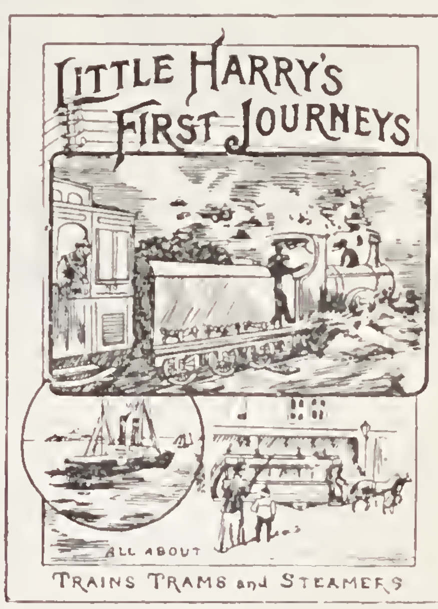

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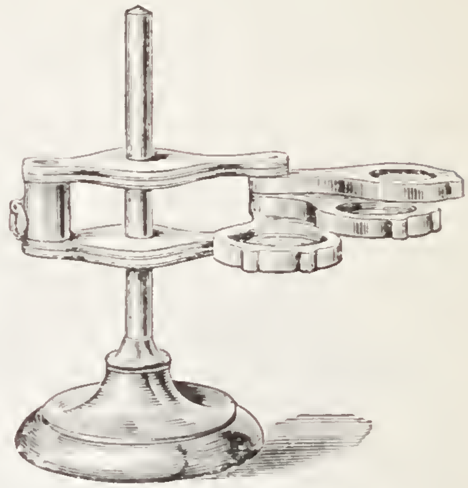

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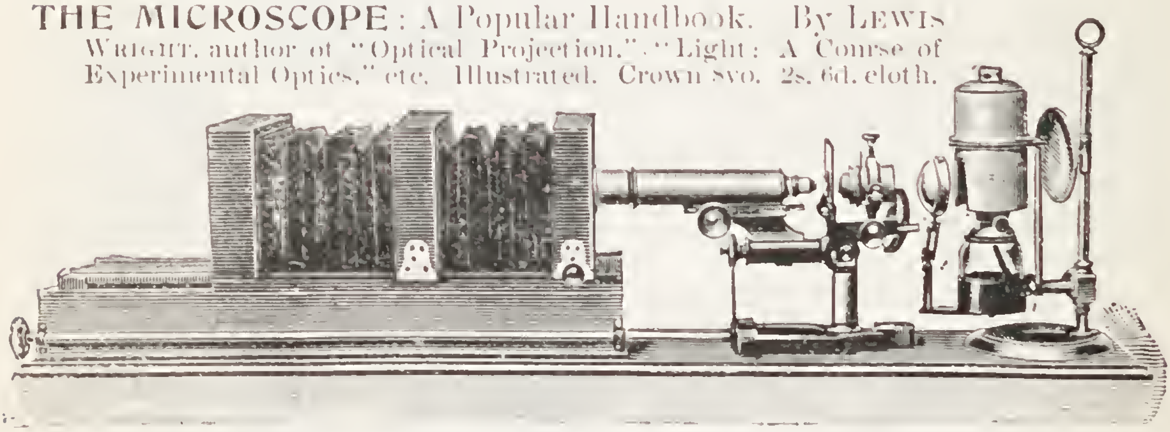

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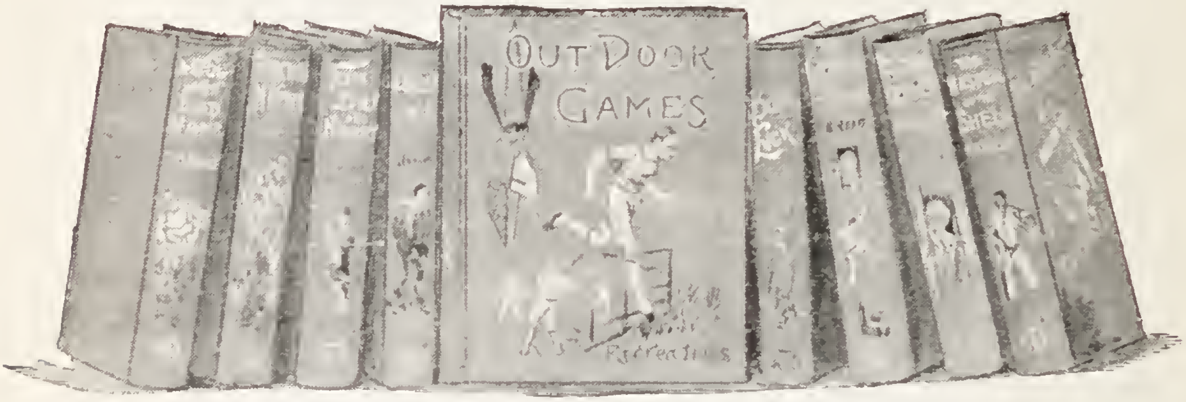

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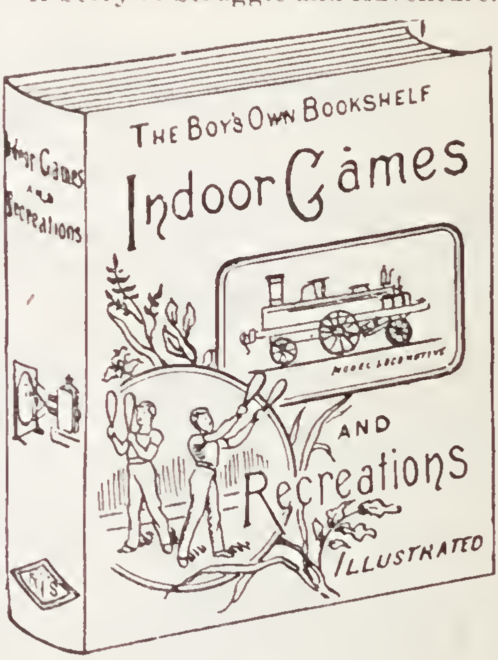

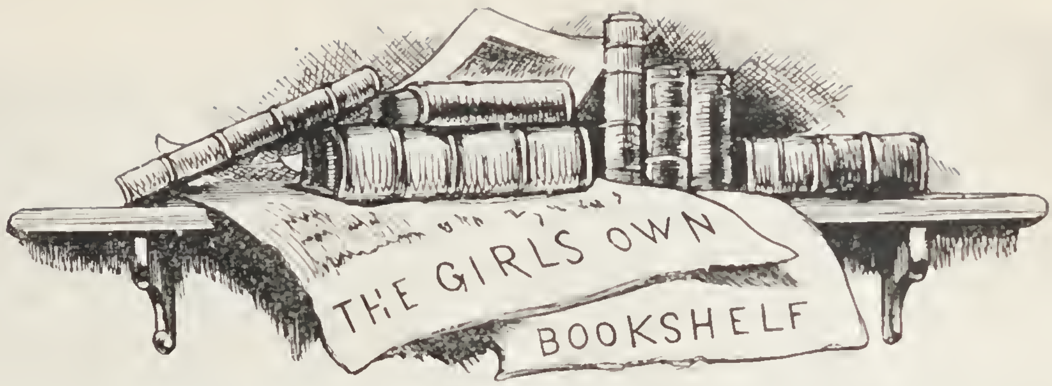

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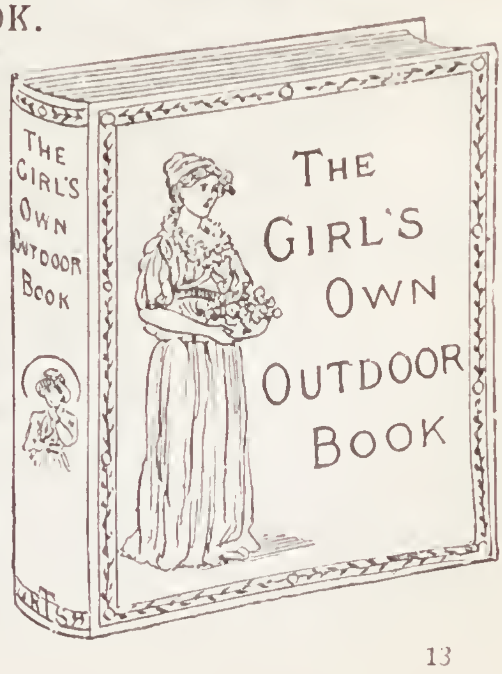

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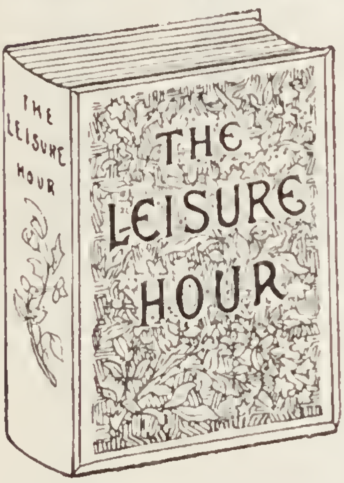

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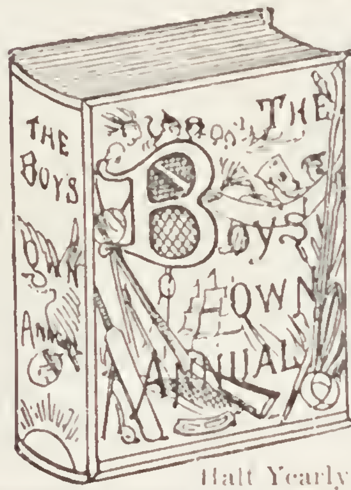

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