A. OUTER SHELL OF MUSSEL

B. VIEW OF MANTLE AFTER REMOVAL OF LEFT VALVE

Many of the organs named in C are here visible through the semi-transparent mantle.

C. EXTERNAL VIEW OF ORGANS AFTER REMOVAL OF LEFT HALF OF MANTLE

1. Foot. 2. Mantle.
3. Outer Gill.
4. Inner Gill.
5. Labial Palps.
6. Exhalant Siphon.
7. Inhalant Siphon.
8. Anterior Adductor Muscle.
9. Posterior Adductor Muscle.
10. Pericardium.
11. Keber's Organ.
12. Anterior Retractor Muscle.
13. Posterior Retractor Muscle.
14. 14. Lesser Retractor Muscles.
15. Protractor Pedis Muscle.
16. Mouth.

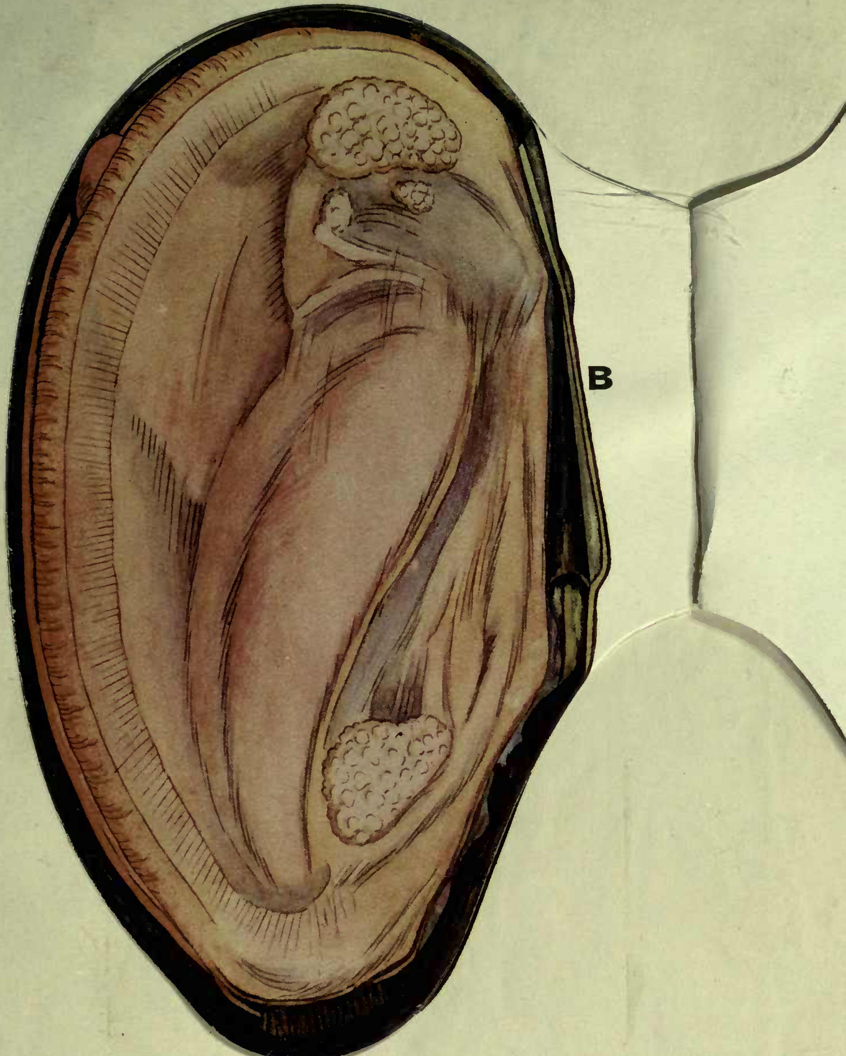
D. GENERAL VIEW OF INTERNAL ORGANS

1. Foot.
2. Anterior Adductor Muscle.
3. Posterior Adductor Muscle.
4. Pericardium.
5. 5. Nephridium.
6. Aorta.
7. Ventricle.
8. 8. Intestines. 9. Rectum.
10. Anus.
11. Mouth.
12. Gills.
13. Stomach.
14. Liver.
15. Auricle.
16. 16. Genital Gland.
17. Nerve Commissure.
18. Cerebro-Pleural Ganglion.
19. Pedal Ganglion.
20. Visceral Ganglion.
21. Posterior Retractor Muscle.
22. Reno-Pericardial Opening.
23. Opening of Nephridium.
24. Opening of Genital Gland.
25. Siphon.

E. INTERIOR OF SHELL, SHOWING ATTACHMENTS OF FOLLOWING MUSCLES

1. Anterior Adductor.
2. Posterior Adductor.
3. Anterior Retractor.
4. Posterior Retractor.
5. Pallial Muscles.

6 and 7. Anterior and Posterior Lesser Retractors.
8. Protractor Pedis.



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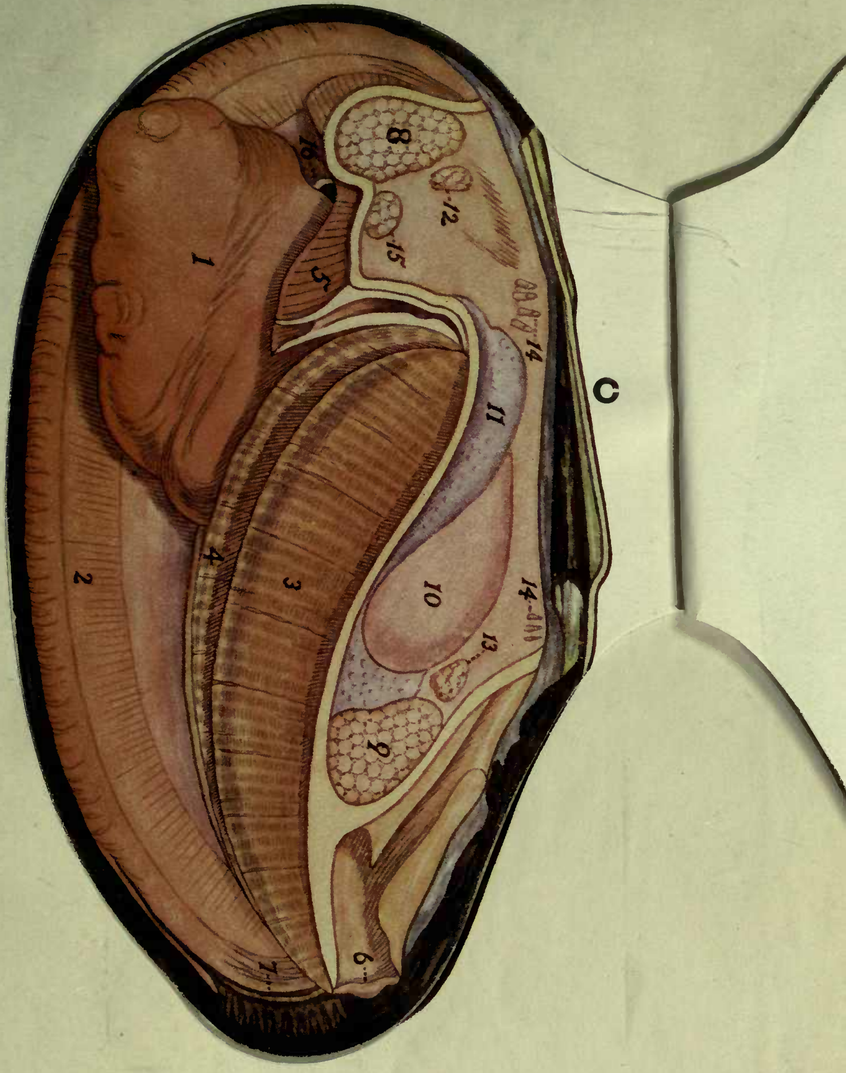

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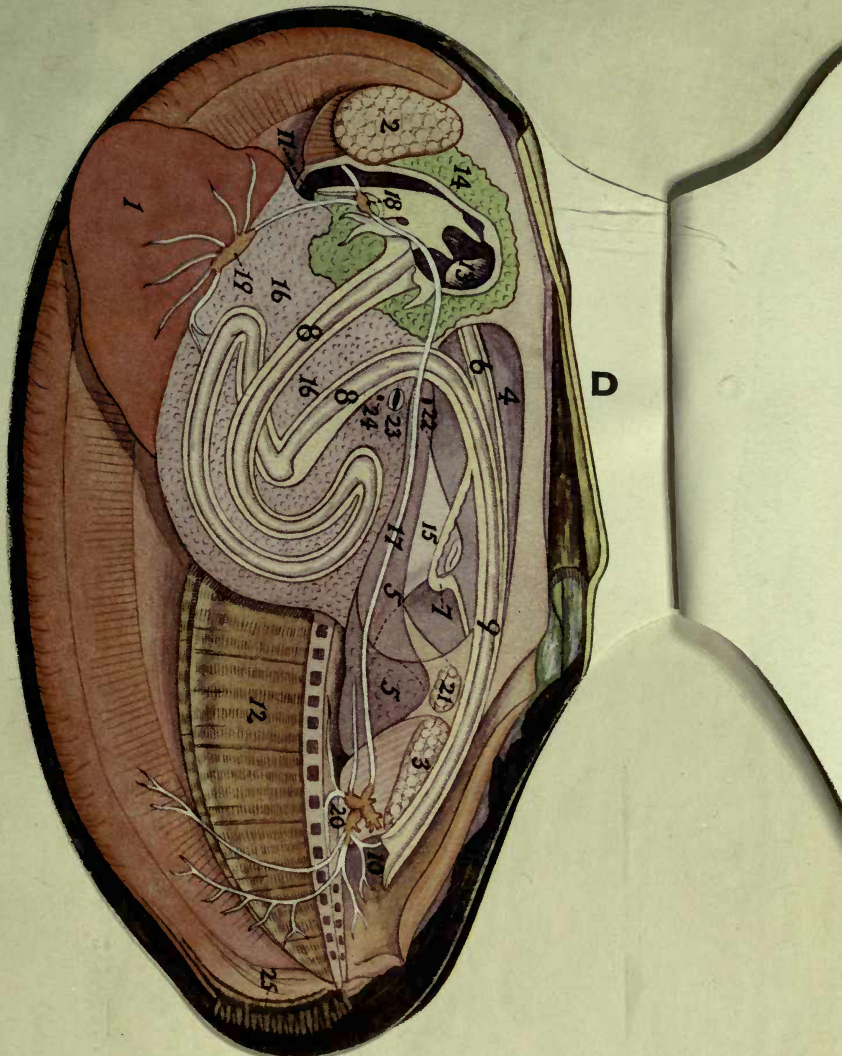

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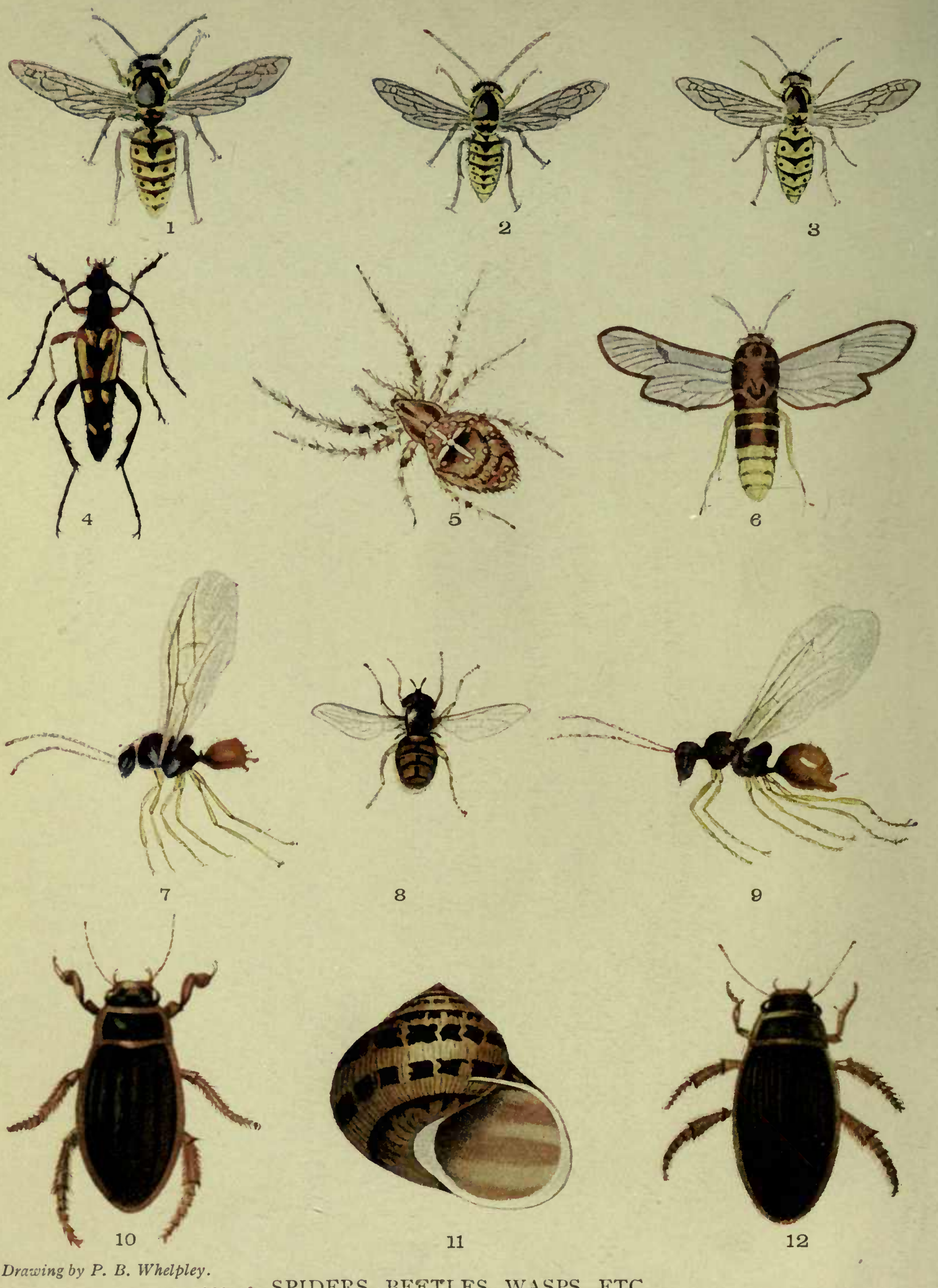
THE BOOK OF NATURE STUDY



Drawing by P. B. Whelpley.

SPIDERS, BEETLES, WASPS, ETC.

1. *Vespa germanica* (queen). 2. *Vespa germanica* (drone). 3. *Vespa germanica* (worker). 4. *Strangolia armata* (a beetle mimicking a wasp). 5. *Epeira diadema* (the garden spider). 6. *Sesia apiformis* (a moth mimicking a wasp). 7. Male; 9. Female (*Trigonaspis crustalis*), a gall-fly frequenting oaks. 8. A two-winged fly mimicking a wasp. 10. Male; 12. Female (*Dyticus marginalis*). 11. Shell of *Helix aspersa* (the garden snail).

THE BOOK OF NATURE STUDY

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ASSISTED BY

A STAFF OF SPECIALISTS

FULLY ILLUSTRATED

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THE BOOK OF NATURE STUDY

INSECTS, SPIDERS, WORMS, &c.

By Oswald H. Latter, M.A.Oxon.
Senior Science Master of Charterhouse School

CHAPTER I

Bees

Over two hundred species of bees are found in this country. The lower members of the group do not surpass the social wasps in the complexity of their structure, and fall distinctly below them in matters of domestic economy. The females construct simple tubular nests in the earth, or in walls or stems of plants, and in these they rear a few young, which are nourished on the pollen and nectar of flowers, but never upon animal food. Each female is entirely responsible for her own house and offspring; there are no "workers" (sterile females), but simply fertile females and males. In habits they vary greatly; some merely excavate burrows in the soil, others construct their nests of mud, of woolly fibres, or of pieces neatly cut from leaves of rose trees, sallows, privet and other plants, employing wall crevices, door-locks, spaces beneath roof-slates or tiles, or holes in the earth or in trees as safe hiding-places for their young. Others again build no nest, but cuckoo-like deposit their eggs in the nests formed by other species.

On the other hand, the higher bees, such as the humble-bees, and especially the honey-bee, exhibit extensive modifications of the structure of the mouth parts and legs in accordance with their habits, and form social communities consisting of fertile females, sterile females, and males.

The chief external differences between the workers on the one hand, and the "queens" and drones on the other, are as follows. The drone is much larger and more heavily built, his eyes occupy the entire side of the head, his antennæ possess thirteen joints, the hairs on the thorax are short and dense, the abdomen is blunt posteriorly, the outer surface of the posterior tibiæ is rather convex and covered with very short hairs. The queen more closely resembles the worker, but the abdomen is more elongate. She has no pollen-brush on the first tarsal joint of the hind-legs, nor pollen-baskets on their tibiæ; in fact, the hair on the legs is so sparse that the colour of the chitinous exoskeleton is plainly visible and gives the legs a reddish-brown tinge.

The body of all bees is built upon the same general plan as that of wasps already described. There is, however, one constant point of difference, in that the hairs which cover the body, or at least the thorax, of bees are branched, whereas those of wasps are always simple. These plumose hairs doubtless serve the better to entangle and hold pollen grains, and in many instances they are arranged in dense patches on which the gathered pollen is conveyed home to the nest.

The honey-bee exhibits the highest degree of perfection both in bodily structure and in social economy, and to that species alone attention will now be confined. Inasmuch as the structural modifications are all directly concerned with the habits of these insects it will be convenient first to describe the latter.

A hive of bees contains one fertile female (the "queen"), several thousand sterile females (the "workers"), and, at any rate during summer, a much smaller number (300 to 400) of males ("drones"). The duty of the "queen" is solely to lay eggs; of the drones, to mate with and impregnate young "queens" that may be reared in this or in other hives; of the workers, to construct the combs of cells, tend and feed the "queen" and her larval offspring on the collected produce of flowers, lay up stores of honey for winter consumption, cleanse and ventilate the hive, and defend it against marauding intruders.

Thus almost the entire welfare of the community is entrusted to the workers, and it is in these that structural adaptations are most pronounced. The combs of cells are composed of wax that is secreted by glands in the abdomen, and which passes through membranes on the ventral side of the second to the fifth abdominal segments, to appear upon the surface as thin plates projecting between the segments. On the hind pair of legs the workers possess a special apparatus in the form of a pincer, whose two limbs are the distal edge of the tibia and the proximal edge of the first tarsal joint. With this tool the wax plates are removed from the abdomen and transferred to the mandibles, by which they are worked up and applied so as to produce the well-known hexagonal cells. The combs are very different from those of wasps; in the first place, as stated, they are not constructed of foreign material gathered outside the nest, but of the waxy secretion of the bees themselves; secondly, the cells do not open downwards nor in single sheets, but horizontally, though with the outer open end slightly higher than the inner, and in double sheets placed back to back; thirdly, honey and bee-bread (*vide infra*) are stored in many of the cells, and thus the community is able to pass safely through the winter. The combs are attached to the roof and sides of the hive, or of "frames" provided by the bee-keeper, by means of wax; but to stop up cracks and holes through which wet, draughts, or enemies might enter, a substance obtained by the bees from the sticky covering of buds and from the crevices of trees, and known as "propolis," is employed. This gluey material is also used to imprison such intruders as snails or even mice.

The legs and the jaws are the external organs most modified in adaptation to the needs of the community, for it is by these that pollen, propolis and nectar are gathered and conveyed to the hive. When a bee visits a flower more or less pollen becomes attached to the hairs covering the body. The grains are then brushed out by the pollen-brushes—nine rows of hairs on the inner surface of the first tarsal joint of the hind-legs. The brushes being full of pollen, the hind-legs are crossed while the insect hovers in the air, and spine-like bristles that fringe the posterior margin of the tibia are employed to comb the pollen masses together and remove them from the brushes. Thence they are transferred to the "pollen-basket" (corbiculum) upon the outer surface of the tibia, moistened in some way that is not quite ascertained, and there patted and pressed down by the middle pair of legs. The basket is constituted by the smooth somewhat hollowed surface of the tibia and the long curved hairs which lie on its anterior border. On returning laden to the hive the bee pushes its hind-legs into a selected cell, and by means of the spur on the tibia of the middle legs disengages the pollen pellets so that they fall loose into the cell. Some other bee then packs the material tight, and thus the cell becomes charged with what is known as bee-bread, a store of food for the sustenance of the grubs. Cells are occasionally loaded partly with bee-bread and then filled up with honey; honey-cells when full are sealed over with wax for better preservation of their contents. The "corbicula" present on the legs of workers are absent both from those of the "queen" and of drones.

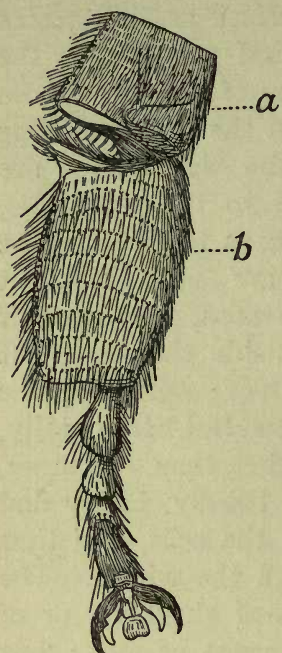

FIG. 1. — Hind-leg of "worker" bee. *a*, tibia; *b*, first tarsal joint bearing the pollen brush: the opposed edges of these two joints constitute the wax-plate pincer.

To enable honey-bees to reach the nectar that is often stored in deep and narrow recesses of flowers, the mouth parts have been profoundly altered from the simpler type found in the wasp, and together constitute a long trunk or proboscis. The labrum and mandibles do not exhibit any very marked peculiarities, but it is the first, and particularly the second, maxillæ (labium) that have undergone change. On the under side of the head is a long and deep groove in which, during repose, the basal part of the proboscis is sunk, while its anterior portions are doubled back upon the basal, so as to reach backwards beneath the thorax. In this position the true front end or tip of the proboscis is its most posterior part. When the mandibles are separated and the labium lifted the proboscis is unfolded and thrust forward, and then its great length becomes evident. The elongated first maxillæ, or rather their respective laciniæ, form on the right and left a loose sheath round the basal half of the central portion ; their stipites are disposed as in the wasp, but are longer, and so give more extended to-and-fro movement as they swing on the attachment to the head ; the maxillary palps are reduced to a single or incompletely divided joint, but are just visible at the apex of the stipes on the outer side ; the galeæ, present in the wasp, cannot be recognised. The basal portion of the labium lies between the sheathing maxillæ, and is attached to them by a special structure, so that maxillæ and labium move forward and backward together. The labial palps are very long, the elongation affecting their first (especially) and second joints, which are again sheath-like, while the two terminal joints stand out almost at right angles to the second and retain the ordinary cylindrical shape of most palpal joints. Between the labial palps and the greatly elongated central organ, the ligula, there is a pair of delicate processes called "paraglossæ." The ligula is a delicate, flexible, hairy, tubular organ which is thrust out from the sheath afforded by the labial palps below and maxillæ above ; it is filled with fluid, and its lower half can be tucked in inside the upper so as to produce a long groove, or on the other hand can, by increased pressure of the contained fluid, be everted, so that a transverse section of the organ is then ∞-shaped. At the extreme tip of the ligula is a minute "bouton" or spoon. By means of this complicated apparatus, assisted by other smaller parts not here described, the bees are able to drink the sugary nectar of the flowers. The liquid passes into the crop or honey-sac, and while in the body of the bee undergoes certain chemical changes ; eventually it is regurgitated and stored in one of the cells of the combs as honey. Even then it requires to undergo "ripening" by evaporation of water before it is in a fit state for lengthy preservation. The final product differs from nectar in containing far less water, in the chemical character of its sugar (grape instead of cane-sugar), and in the presence of certain antiseptics, of which formic acid is the chief. When a cell is full of honey the opening is sealed with a covering of thin wax. Cells in which "brood" is reared become darker in colour and thicker owing to the accumulation of portions of food and cast skins left behind by their successive tenants, and not completely removed by the workers.

Brood.—The eggs from which workers are developed are fertilised, as also are those from which "queens" result; drones, however, are the product of unfertilised eggs. Workers are raised in ordinary small cells, drones in somewhat larger, but "queens" in very large cells projecting like thimbles from the

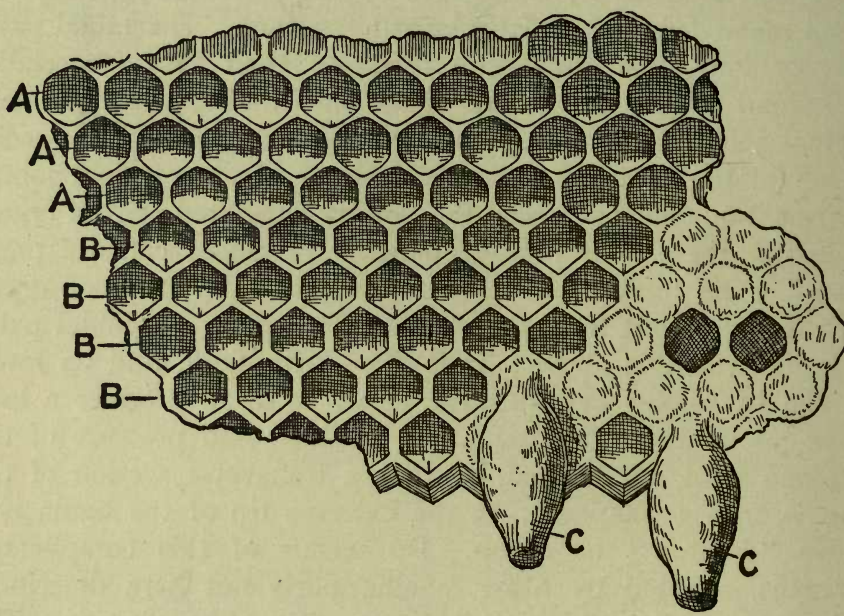

FIG. 2.—Piece of honey-comb. A, drone cells; B, worker cells; C, queen cells.

surface or edges of the comb. On the third day after an egg has been laid a small white larva issues from it; for three days the young larva is supplied with food which has been digested in the "chyle stomach" of adult workers, and is then regurgitated for the benefit of the young. Later, worker larvæ are supplied with honey, drone larvæ with undigested pollen, and subsequently pollen in increasing quantities is supplied to both sorts of larvæ. "Queen" larvæ, however, are given the chyle-food ("royal jelly") throughout the whole period of feeding.

Eventually all cells containing larvæ are filled up with liquid honey and pollen, so that the larva is bathed in its food, and a cap rendered porous by admixture of pollen with the wax is built over it by the workers. A worker is fed for five days, and in about twelve days after sealing, or twenty-one from the time the egg was laid, the imago, having passed through a brief pupal period inside a silken cocoon woven by the larva within the closed cells, emerges and begins to take her part in the business of the hive. At first the young bee acts as a nurse to the larvæ; after about a fortnight she flies abroad in search of pollen and nectar, and undertakes the production of wax. The length of life of a worker

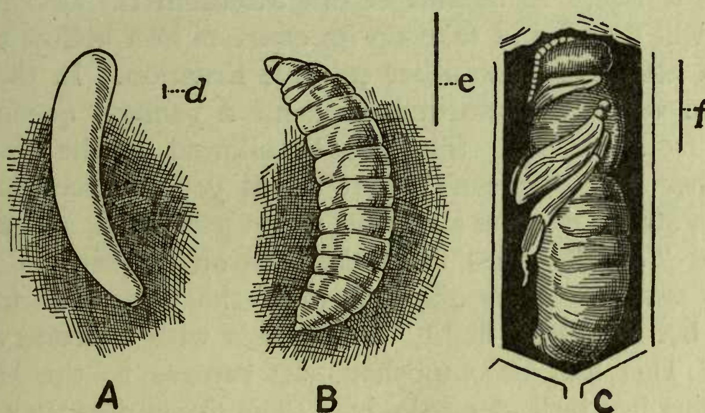

FIG. 3.—A, egg; B, larva; C, pupa of honey-bee; *d*, *e*, *f*, representing the actual lengths of A, B, and C respectively.

is about two months, excepting those which pass through the winter. Unfertilised eggs require twenty-four days before the emergence of the resulting drones; whereas a "queen" can be reared in only sixteen days. The larva from any fertilised egg may be converted into a "queen" if appropriately fed by the workers on "royal jelly" before weaning. Hence if the reigning "queen" die, the bees are able in a short time to rear a successor. This, however, frequently takes place without the death of the "queen," and gives rise to the phenomenon of swarming.

Swarming.—The occupants of one or more "queen" cells being ready or nearly ready to emerge, the old queen issues forth from the hive, preceded by many, and accompanied by the majority of the workers, who have previously filled their crops with honey, and by some drones. Great excitement possesses the creatures, and they fly agitatedly round, emitting a characteristic note readily recognisable by the bee-keeper. This occurrence usually takes place in the earlier part of the summer, on a fine sunny morning. At length the bees begin to gather in a great cluster upon a branch of a neighbouring tree on which the " queen " has settled—though sometimes they will fly to a great distance before alighting, and here they may hang for several hours. At this stage they may be secured without difficulty and conveyed to a hive. In default of this attention the swarm sooner or later will fly off and take up its quarters in a hollow tree, the roof of a house, or some other suitable situation. In the parent hive from which the swarm have come a young " queen " soon emerges from her cell. She may be allowed by the workers to slay all her sister " queens " that are as yet not free, but if the stock is a strong one the slaughter is not permitted, and a second swarm or " cast " issues from the hive on the ninth day after the first swarm. After about a week she flies forth from the hive on her " nuptial flight," and mates with a drone while in the air. This feat accomplished, she returns to the hive and soon begins her task of egg-laying. The drone dies very shortly after pairing. A " queen " is capable of laying as many as 2000 to 4000 eggs in a single day. Her length of life may amount to five years, though but one act of mating is sufficient for the fertilisation of the eggs produced during the whole period.

There is no difficulty in keeping a hive of bees in an ordinary room under such conditions that all the internal arrangements of the community are readily visible. " Observatory hives " are usually made narrow, so that only one comb stands at any one level, though there may be two or three combs placed one above the other. It is thus possible to see both sides of every comb. The sides of the hive are made of glass, usually double, in order to retain the warmth ; while the outside is covered with movable doors or thick curtains to exclude the light. The bees pass in and out along a tunnel whose inner end enters the bottom of the hive, while the outer goes through the woodwork of the window-frame or through one of the panes. There is thus no inconvenience caused by bees getting into the room itself.

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CHAPTER II

Ants

Ants, by reason of their diligence and intelligent behaviour, have been notorious since the days of Solomon. There are more than thirty species in this country, and many of them are extremely common. In their most important structural features these insects resemble the wasps and bees, and are, together with the saw-flies and some others, included with them in the one order *Hymenoptera*. The most striking peculiarity about the body of an ant is the extremely slender form of the first, or the first and second, abdominal segments. Thus the "waist" is very decided, and great mobility of the abdomen attained. Further, the mandibles are capable of being used in total independence of the rest of the mouth parts; as a rule, too, the scape of the antenna forms a sharp angle with the remaining joints.

As in the Wasps and honey-bees, an ant community is composed chiefly of workers (sterile females), on whom falls the responsibility of the welfare of the nest. There may be one or more "queens" in a nest, and their eggs are tended by the workers. Males and daughter queens may be present also, but only at the season of swarming (*i.e.* from mid-August to mid-September). Both these last are provided with wings, and on a suitably hot day they rise in clouds into the air and there mate during the nuptial flight. At times these swarms of "winged ants" are so dense as to cause much inconvenience to human beings; occasionally, too, swarms have been swept out to sea by a sudden breeze and drowned, appearing at the succeeding

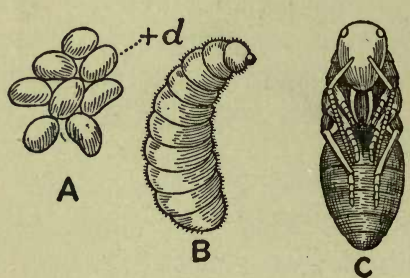

Fig. 4.—A, cluster of ants' eggs; B, larva; C, pupa. The +*d* represents the actual dimensions of the cluster A.

high-water mark as a black line along the shore, so prodigious are their numbers. The males usually die soon after their flight, but the fertilised "queens" cast their wings, or may be deprived of them by "workers," and become founders of new communities.

In the construction of nests the ants are very different from the other social insects. No comb either of wax or of "paper" is made, nor are the larvæ reared in cells; but a complicated

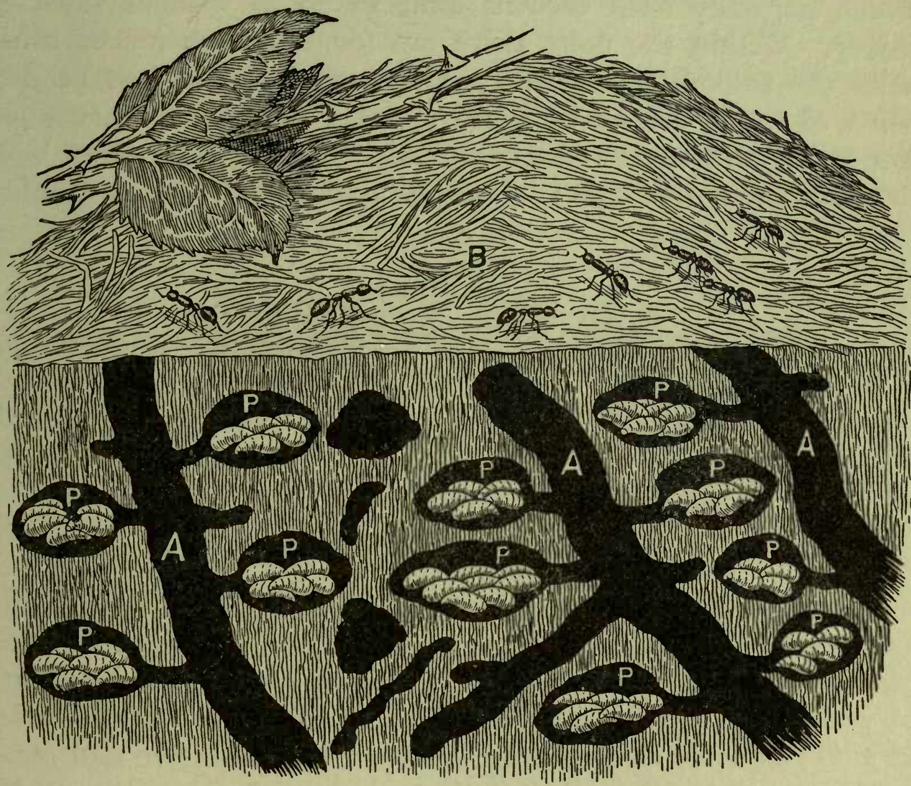

FIG. 5.—Diagram of nest of the red wood-ant. A, main galleries; B, heaped-up fir-needles, twigs, etc.; P, "nurseries" at ends of side galleries.

system of galleries and chambers is excavated in the soil, or in decayed wood (*Lasius fuliginosus*), and in these the eggs and young are kept in clusters and moved by the workers from chamber to chamber as moisture, temperature and other physical requirements demand. In addition to the subterranean passages there are often extensive heaps of earth or of pine-needles, etc., above the surface; these also are penetrated by winding galleries.

If a nest be disturbed or broken into, the workers will be seen hurrying about and carrying in their jaws larvæ of various sizes, and cocoons containing pupæ, in an endeavour to convey them to a place of safety. It is these cocoons which are commonly sold as "ant's eggs" for feeding pheasants, gold-fish, etc. The larvæ of some species do not spin cocoons, but become pupæ without any protection; and occasionally members of species which normally form cocoons omit to do so without suffering injury. Within the nests there are found many animals other than the responsible tenants; these include (1) various beetles, some of which are never found in other situations, while some are blind, and some remarkably like the ants themselves both in colour and movements; (2) various aphides (green-fly) and other

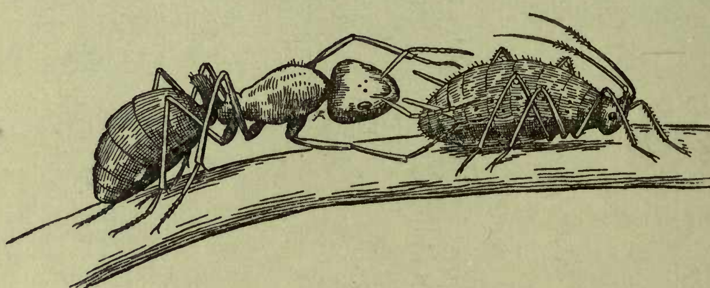

FIG. 6.—Ant "milking" an aphis.

insects of the bug family, these are brought in by the ants and kept for the sake of the sugary liquid which they emit when caressed by the antennæ of their captors; (3) a peculiar kind of wood-louse, which is both white and blind; (4) other species of ants; in some cases these have been taken captive and serve as slaves, but in others the relation subsisting between the species found in the same nest is as yet unknown.

The food consists of honey, fruit, the "honey-dew" secreted by aphides, in fact any sugary substance; also of caterpillars and other insects, and of the flesh of dead animals; indeed, skeletons of animals are sometimes obtained by placing the carcase in or near an ant-heap in order that the flesh may be stript from the bones; and in parts of Norway and Iceland clothes, especially furs, are cleaned by putting them over ant-hills. None of our English ants lay up stores of food for the winter, but they retire deeper into the soil, out of reach of the frost, and there, collected in little masses, remain quiescent until the return of warm weather. The writer has found such clusters of the common garden ant (*Lasius niger*) more than three feet below the surface in midwinter.

Ant communities can very easily be kept under observation in captivity. The simplest cage for this purpose consists of two sheets of ordinary window glass, about eight or ten inches square, laid one on top of the other but kept apart by narrow slips of the same, or thinner glass placed between them all round the edges. One of these slips should be a little shorter than the rest, so as to leave a small space, about half an inch, through which food and moisture can be inserted. The interval between the two main sheets should be just sufficient to allow the ants room to move freely ; if it is deeper, earth will be piled over the chambers and galleries and will hide the ants from view. The included space must now be filled with very finely sifted earth, which should then be moistened. The top plate of glass should be securely fastened to the lower by spring paper-clips. A nest of ants may now be dug up, care being taken to secure a "queen," who may be recognised by her much larger size and distended abdomen. The ants and any earth gathered with them may then be put into a large biscuit tin, at the bottom of which the glass cage already prepared should be placed. As the loose earth dries up the ants will migrate into the cage, and as soon as they are all housed the space at one corner must be plugged with cotton wool to prevent their escape. The cage may then be removed from the tin and kept wherever convenient. It is, however, necessary to cover it with some dark opaque material to exclude the light, and not to allow the sun to shine directly upon it in any case. A wooden frame placed round the whole adds neatness, but is not necessary. In a short time the ants set to work excavating their passages and chambers, and in a few days all will be going on as it does out of doors. From time to time it is necessary to remove the plug of cotton wool and push in some sugar or honey to supply their needs, and care must be taken to keep up a moderate degree of moisture by pouring in water at the same spot. Such captive nests may with care be kept in a prosperous condition for several years.

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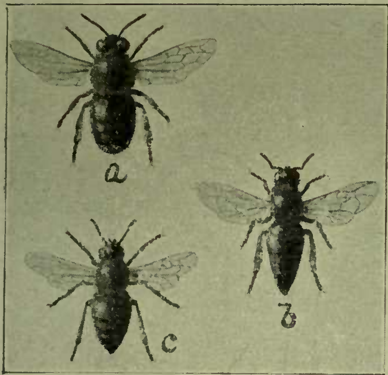
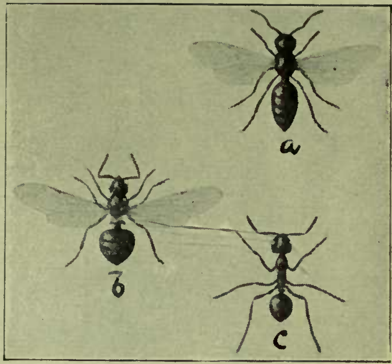
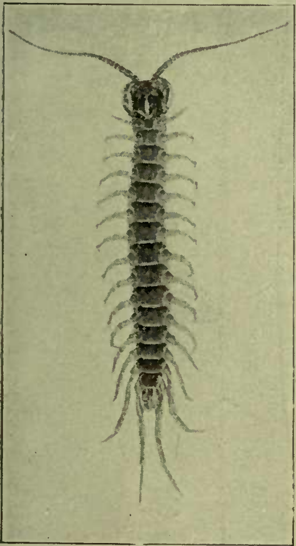


(*a*) Drone ; (*b*) Queen ; (*c*) Worker, of Honey Bee. (Photo by W. P. Westell.)

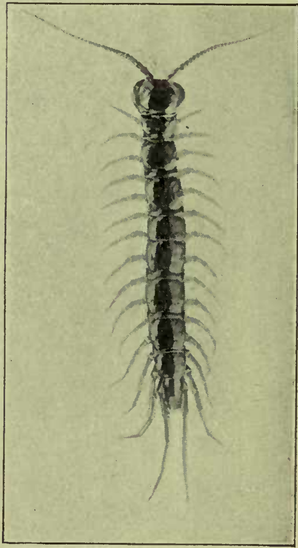


(*a*) Male ; (*b*) Female (queen) ; (*c*) Worker of Wood Ant. (Photo by W. P. Westell.)



Ventral view of Centipede × 2, *Lithobius forficatus.* (Photo by H. Main.)

Millipede, *Julus Terrestris* × 2. (Photo by W. G. Berridge.)



Dorsal view of Centipede × 2, *Lithobius forficatus.* (Photo by H. Main.)

THE GARDEN SNAIL, *Helix Aspersa*, hibernating. (Photo by H. Irving.)
Note the calcareous epiphragm by which the shell is closed ; and, in the solitary specimen, the hole which permits respiration to take place.

CHAPTER III

Plant-Lice and Gall-Flies

The minute insects known as "green-fly," "black-fly," or collectively as "plant-lice" and "blight," are but too familiar to everyone possessing a garden, however small, while one species, the *Phylloxera*, is of world-wide notoriety. There are many species of these *Aphidæ*, and they are found in abundance during the summer on rose, cherry, apple and many other trees and shrubs, and likewise on broad-beans, carrot leaves and many

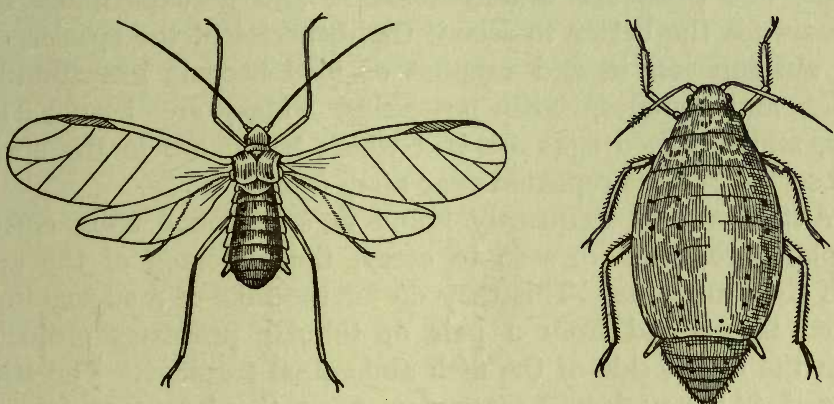


Fig. 7.—Green-fly.

kinds of "wild plants." They especially frequent the young shoots and leaves, into whose juicy tissues they plunge their piercing proboscis to suck the nourishing sap. Zoologically, they belong to the same subdivision of insects as do the bed-bug, "stinking-bishops," frog-hoppers, cuckoo-spits, scale-insects, mealy-bugs, water-scorpions, water-skaters, and oarsmen. The subdivision is termed "Hemiptera"—half-winged, from the fact that many of its examples have the basal part of the fore-wing horny, but the apical membranous, so that the wing appears divided into two halves. The plant-lice, however, are usually found in a wingless condition, and when winged do not exhibit the peculiarity mentioned. They owe their extraordinary abundance to the special powers of reproduction during favourable weather. The eggs are laid in the autumn in crevices of the bark or other sheltered positions ; they hatch in the following spring, producing wingless females only. These females give birth to others like themselves, and that without any intercourse with males, for at this season there are no males, and without depositing eggs, but produce their daughters alive—viviparously. This viviparous, parthenogenetic (virgin-birth) method of reproduction continues for several generations ; the daughter aphis herself becoming a mother in about ten or fifteen days. Hence the offspring of a single individual become in a few weeks extremely numerous. In the course of these generations there may occur some individuals with two pairs of well-developed wings, but these are usually females, and perhaps make their appearance the better to secure the dispersal of the species. As the autumn sets in and supplies of food become less abundant males and females, both possessing wings, are born. These pair, and fertilised eggs are laid which hatch out in the spring, and so the cycle is repeated year after year.

Ants are very frequently found in attendance upon clusters of plant-lice, and are seen to caress the abdomen of the aphis with their antennæ. This they do for the sake of a sugary liquid which is secreted from a pair of tubular processes projecting from the dorsal side of the fifth abdominal segment. The sticky deposit (" honey-dew ") often found on the leaves of trees, or even dripping on to the ground, is of the same origin.

There are many insects which feed themselves and their young upon plant-lice, and which are therefore the friends of the gardener ; chief among these are wasps, lady-bird beetles of all sorts, and both as larvæ and *imagines*, and the larvæ of the lace-wing fly, and of syrphid dipterous flies (hover-flies), not to mention minute hymenopterous parasites that live within the body of the aphis itself.

Some of the plant-lice, including *Phylloxera*, are responsible for the formation of galls by plants, the insects passing part or the whole of their lives in these curious excrescences. One of the commonest of such galls in this country is the " false cone" of the spruce-fir or other coniferous trees. This gall is caused by an aphid named *Chermes*, which so affects a bud or young shoot of the tree that it fails to develop in the ordinary manner and gives rise instead to an abnormal growth resembling a small fir-cone. Other galls of different form, but caused by the presence of plant-lice, are found on the yew, elm, hawthorn and on many native herbaceous plants.

Plant galls are, however, caused by many other creatures than aphids, for many species of dipterous flies, hymenoptera, beetles, a few small lepidoptera, eel-worms, mites (relatives of spiders) and some fungi are known to give rise to them by the irritation set up by their presence in plant tissues. A very large number of different kinds of galls are found upon the oak alone, the majority of them being due to the attacks of small four-winged hymenopterous insects belonging to the family *Cynipidæ*.

The female cynipid is provided with a very long and slender ovipositor, which is doubled back on itself within the body, so that only a short portion projects posteriorly, except when the organ is actually in use. The extremity of the ovipositor is armed with saw-teeth, which the insect uses to cut or pierce a passage into the leaf, stem, bud or root attacked. The egg is then pushed in by the ovipositor, and left in or close to the layer of growing cells in the plant. A fresh passage is usually pierced for each egg. Sometimes the gall begins to form immediately after the egg has been introduced, but is usually delayed for some time until the larva is hatched, and the emergence of the larva is in turn deferred until the plant resumes its activity after the winter. It is not known with certainty why the presence of the developing cynipid or other larva should give rise to these abnormal growths.

It is a singular fact that many of the *Cynipidæ* cause two distinct kinds of galls to be formed, and they themselves exist in two distinct forms in the course of their life-cycle. Indeed, there are several instances where the insects previously regarded as two quite separate species are now known to be but two generations of one and the same. In such cases the individuals of one generation reared in one variety of gall are all females, and produce their eggs parthenogenetically; but the larvæ resulting from these eggs cause a totally different gall from that of their parents, and eventually produce males and females of a different appearance. In some species, however, no males have ever yet been discovered.

If galls are gathered when fully formed, and kept in a box, or if they be enclosed in fine muslin bags while still attached

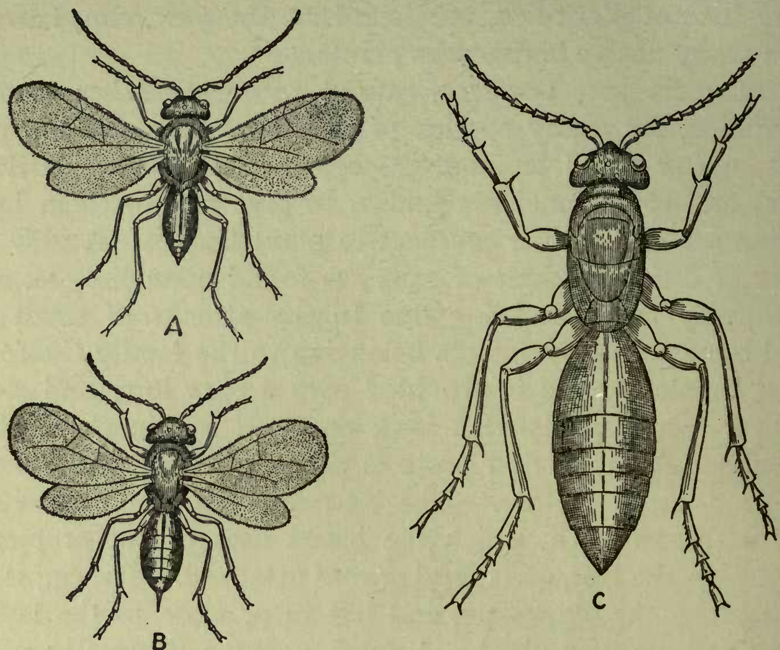


FIG. 8.—Oak apple gall-fly. A, male ; B, female ; C, wingless female of second generation.

to the plant, the gall-flies will in due course be obtained. But in addition to the rightful tenants there will also emerge from the gall a number of other insects. Of these some are parasites upon the gall-flies, and others are thieves whose parents have taken advantage of the rich succulent character of the gall and have chosen to deposit their eggs there. Hence care is needed to discriminate between the genuine provoker of the gall and the intruders.

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'OAK-APPLES': galls caused by the presence of the grubs of the hymenopterous insect *Teras terminalis*, and (inset) 'PINE-APPLE GALL' on spruce fir, caused by the presence of the Aphid insect, *Adelges abietis*. (Photos by H. Irving and A. W. Dennis.)

(Left) 'ARTICHOKE GALLS' caused by the presence of the grubs of *Aphilothrix fecundatrix*. (Right) 'MARBLE GALL' caused by the presence of the grubs of *Cynips kollari*. Both insects are hymenopterous, and deposit their eggs in oak twigs. (Photo by H. Irving.)

'WITCHES' BROOM' ON BIRCH
A 'gall' caused by the presence of the mite, *Eriophyes rudis*. (Photo by H. Irving.)

CHAPTER IV

Gnats

Although the majority of insects are terrestrial and aërial in their habits, yet there are not a few which pass part or the whole of their lives in water. The system of tracheal tubes by which most insects breathe is obviously suited to life on land. Hence aquatic insects exhibit numerous interesting modifications of structure, in adaptation to the special conditions imposed upon them by life in water.

The most abundant and most easy to rear and observe of all these insects are the gnats, of which there are very many species, from which we select two for the present work—namely, *Culex* and *Chironomus*. The eggs, larvæ and pupæ of both these forms are to be found in almost any stagnant water, even when occurring in such small quantities as may accumulate in old tins, jam pots, etc., to say nothing of exposed water-butts, cattle-troughs and natural sheets of standing water. They can be reared without any difficulty in shallow vessels, *e.g.* saucers, pie-dishes and similar

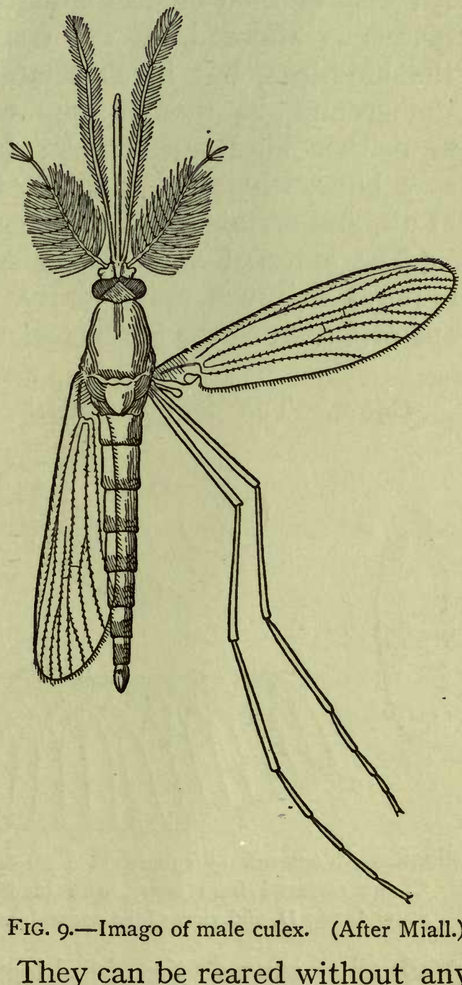

Fig. 9.—Imago of male culex. (After Miall.)

utensils, if provided with stagnant water, preferably some of that in which they were found.

The adult insects are much alike. In common with the true flies, daddy-long-legs, and other gnats, mosquitoes and midges, they have only one pair of well developed wings—whence the name "Diptera" (two-winged) for this class of insects. It is the front pair of wings which is functional; the hind pair being represented merely by two short club-shaped processes, the halteres. The males are distinguishable from the females by their large eyes and by their beautifully plumed antennæ. An easy method of discriminating between a culex and a chironomus is afforded by the resting attitude adopted: in culex the hind-legs, but in chironomus the front legs are raised off the ground, as though they were used as feelers. The males of neither kind suck blood; but the female culex is notorious as a biter, whereas the female chironomus probably never feeds at all, and certainly not on blood.

The external anatomy of such delicate and small creatures requires so much manipulative skill that we shall here confine our attention to the life-histories.

Culex.—The female culex deposits her eggs early in the morning during summer upon the surface of standing water. Using her first two pairs of legs to support her on the margin, or on some floating object, she crosses her long hind-legs, and passes her eggs one by one from the end of the abdomen into the angle between them. At first the eggs are sticky, and so adhere to one another in a mass which gradually causes the hind-legs to move wider apart. At length some two hundred or three hundred eggs are fastened

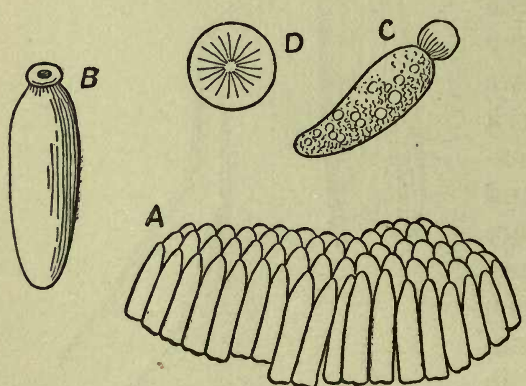

FIG. 10.—A, egg-raft of culex; B, a single egg; C, egg removed from ovary, with bladder-like appendage; D, end view of the appendage.

together, and left to float upon the water as a raft about $\frac{1}{8}$ inch in length. The individual eggs are roughly cigar shaped, and stand upright side by side; the upper end is more pointed than the lower, which is provided with a lid through which the larva eventually emerges into the water, head first. The eggs are so closely packed together that the water cannot penetrate between them, even if they be forcibly submerged; and they are so buoyant that they always float on the surface in the correct position. The eggs round the margin of the raft stand a little higher than the more central, and these act as a bulwark. Thus the eggs are in reality entirely above the water and completely surrounded by air, so that respiration takes place freely through the egg-shell.

The larvæ which emerge are commonly known as "wrigglers" from their method of locomotion. When undisturbed they live at the surface of the water, hanging head downwards. If alarmed they dive to the bottom, travelling with a peculiar wriggling, lashing movement of the body. At this stage the animal has a large head and thorax and a rather tapering, more slender abdomen of ten segments. The head bears a pair of compound eyes, a pair of short antennæ, and jaws which are provided with numerous vibratile bristles. These bristles are employed in sweeping minute particles of food into the downwardly directed mouth, and also at times to row the animal along without alteration of the bodily attitude. The thorax has no limbs, neither legs nor wings; but the fact that it is composed of the usual number of segments is indicated by three pairs of tufts of conspicuous bristles one behind the other. The segments of the abdomen are clearly marked off by constricting grooves; the first seven present no remarkable features, each being provided with a pair of bristly tufts. From the eighth, however, there projects a peculiar and very conspicuous organ—the respiratory siphon. This is a cylindrical structure enclosing two air-tubes which open at its extremity and pass along the whole length of the body to supply all parts with air. In the resting position the tip of the siphon is thrust through the surface of the water, so that its cavities are in free communication with the air above. The ninth segment is small; the tenth larger, and furnished with strong bristle tufts of which the ventral serves as a propeller, and a group of four long, thin, narrow plates surrounding the anus at its apex. These plates contain tracheal tubes, and are probably supplementary respiratory organs capable of taking in the oxygen dissolved in the water. On the tip of the respiratory siphon there are hinged five pointed valves; these can be approximated so as to form a five-sided pyramid, and this is their arrangement when the larva is completely below the water. On reaching the surface the apex of the pyramid pierces the virtual film (due to surface tension) and the five flaps are immediately thrown apart above the surface, so that a shallow basin results in open communication with the air above and with the two large tracheal tubes below. Thus the larva is suspended to the surface film, and uses it for support in a manner analogous to that employed by the whirligig beetle, water-skaters, and other insects which move on but above the surface, without, however, being wetted. Many species of water-snails make the same use of the surface film as does the culex larva, applying their "foot" to it and crawling in an inverted position upon it.

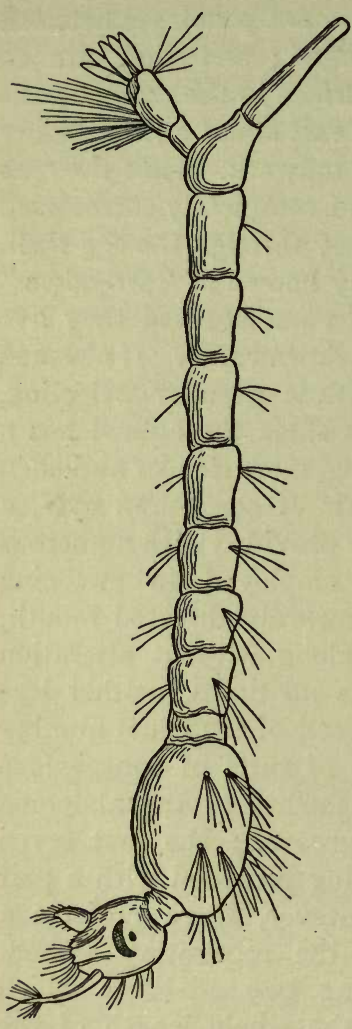

FIG. 11.—Side view of larva of culex. (After Miall.)

The larva casts its skin three times, and when full grown is about 1 cm. long and of a brownish-grey colour. At the third moult it passes into the pupa stage, which differs greatly both in form and attitude from the preceding. Since the pupa takes no food, it is no longer necessary for the head to be turned downward into the water, whence the larva obtained its supplies. It is thus not surprising to find the animal now resting with the anterior end upwards and the tail directed downwards. The thorax is at this stage very large and rounded, and is placed nearest to the water surface ; the head being bent down ventrally and the abdomen hanging, not straight, but bent under the thorax. From the top of the thorax project upwards two respiratory trumpets or "horns" which, in the resting position, open through the surface to the air. Just inside the lips of the trumpets lie numerous fine hairs, which prevent the entrance of water when the animal dives. Fastened down against the sides of the thorax are the large flat wings, and behind them small triangular plates, representing and containing the halteres. The antennæ, eyes, and legs are all visible on the ventral surface of the enlarged anterior region, and within them can be seen the corresponding organs of the adult. The abdomen has a few bristles on its dorsal surface, and at the end of its last undoubted segment, the eighth, a pair of large fins, beneath which is a small projection bearing two blunt processes directed backwards. This represents the ninth and tenth segments. The terminal fin is a powerful swimming organ, and is employed in a manner that recalls the tail-fin and telson of a crayfish or shrimp ; for by rapidly flexing the abdomen the pupa is able to dart rapidly through the water, the first stroke of necessity drawing the animal away from the surface. Subsequent strokes cause erratic darts in the depths, but very soon the pupa floats up to the surface again, owing to the presence of a large air-space within the upper part of the thorax. Pupæ exhibit a preference for

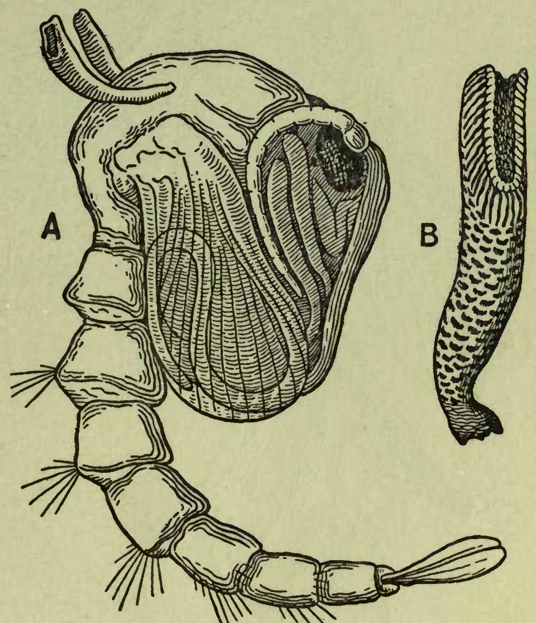

FIG. 12.—A, pupa of culex ; B, one of the respiratory tubes.

the margin of the water, and, when in vessels, are generally to be found close to the sides.

At the close of pupal life the animal usually swims away from the side into open water, and at once straightens out the abdomen so as to bring it horizontal and flush with the surface. The skin of the thorax then splits open dorsally, and the thorax, head, legs, and wings of the adult gnat are lifted clear of the husk, and at length with the withdrawal of the abdomen the whole animal is free. The empty pupal husk now serves as a raft upon which the imago stands while the wings enlarge a little and dry. In a few minutes the gnat flies away. The whole process from the time when the pupa strikes out away from the edge until the imago takes wing occupies under five minutes. The exact duration of each stage is subject to much fluctuation; *e.g.* a batch of eggs obtained by the writer in the middle of September 1906 yielded a number of larvæ some of which passed right through to the imago by the end of October, while others of the same family were still larvæ in the third week of November.

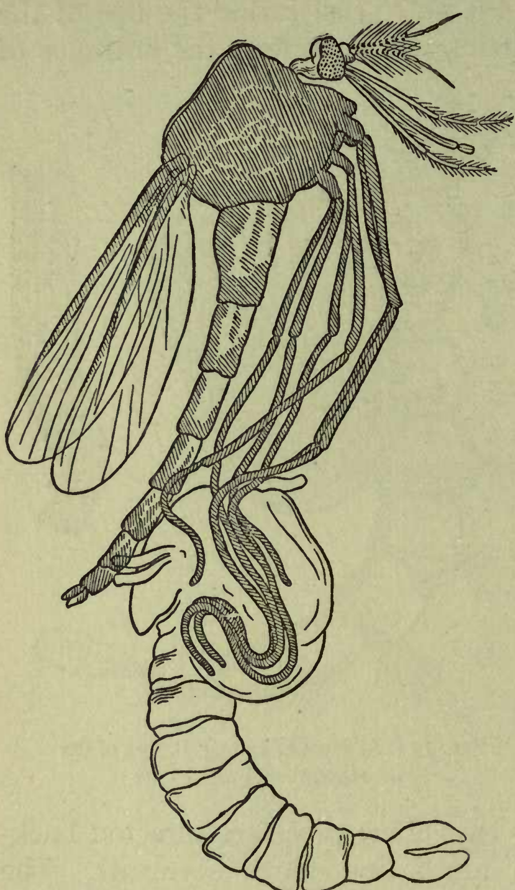

FIG. 13.—Imago of culex emerging from pupa skin. (After Miall.)

The adult gnats may be kept alive in captivity if fed on slices of banana or other fruits whose juices they can suck. It is probable that vegetable fluids, rather than animal blood, are their normal food, and why they should seize the opportunity of sucking blood is a mystery.

Chironomus.—The eggs of chironomus are laid in gelatinous rope-like masses about $\frac{3}{4}$ inch long, each of which contains a large number of them. Their arrangement differs in the various species, but in those which frequent flowing water the mass is attached by a tough thread to some fixed object and is then secured against the currents. The eggs are elliptical in outline, and so transparent that the formation of the embryo within

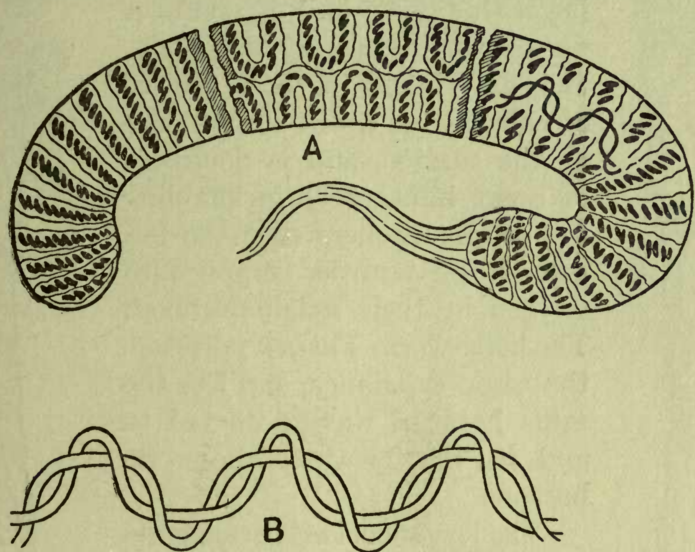

FIG. 14.—A, spawn of chironomus : the mass is divided into sections so as to show both sides ; B, twisted fibres which traverse the spawn-rope. (After Miall.)

can be watched through the microscope. The larvæ hatch in under a week from the time of egg deposition. At first they are of a transparent grey colour, and have a moderately large head. After the first moult of the skin the head becomes relatively smaller, the brain retreating into the prothorax, and a red tinge pervades the whole body. The full-sized larva is about an inch long and of a brilliant red colour,—whence the popular name of "blood-worm." The animal constructs a tube for itself by glueing together particles of earth and vegetable matter, or of the green slime that often covers the sides of vessels which have long contained water. It moves up and down rhythmically inside the tube, or projects its head to procure food, or waves its tail about so as to change the water around it and so assist respiration. At times the larva quits its tube and swims through the water with a peculiar lashing movement, repeatedly bending the body into the shape of the letter S. The red colour of the blood-worm is due to the presence of a colouring matter called hæmoglobin—the same as occurs in the red corpuscles of our own blood. This substance has an especial power of combining with oxygen and of giving it up to the tissues of the body. It is only found in those species of chironomus which do not live at the surface, and is doubtless of great importance in enabling the deeper dwellers to make full use of the scantier supplies of oxygen in their neighbourhood. The little worm *Tubifex* possesses the same substance, and has the same habit of waving its tail to and fro in the water above its burrow.

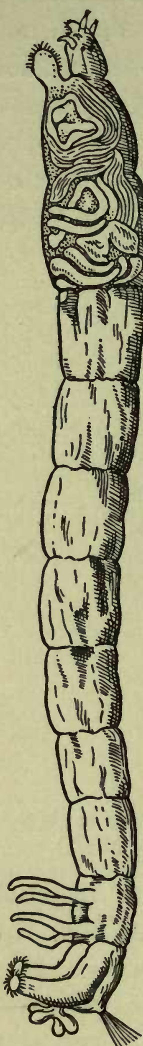

FIG. 15.—Larva of chironomus. The rudiments of the wings and legs of the imago are visible beneath the larval skin. (After Miall.)

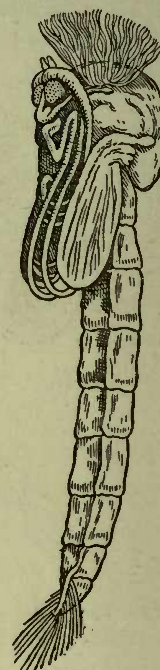

FIG. 16.—Side view of pupa of chironomus. (After Miall.)

The larva has twelve segments behind the head. The head bears a pair of short antennæ, two pairs of black eye-spots, a pair of strong, jagged mandibles, very rudimentary maxillæ, and a flat crescentic labium or lower lip (second maxillæ), whose edge is provided with teeth of several different and peculiar shapes. The upper lip, or labrum, is furnished with a remarkable array of hooks and bristles, which are thought to be of service in directing the silk threads used in the construction of the tube. The appendages of the body are few; the prothorax has a pair of feet tipped with hooked bristles which secure a firm hold; the next nine segments are devoid of outgrowths. The eleventh has two pairs of delicate tubes projecting from it: these are filled with blood which circulates through them, and are special respiratory organs. The twelfth segment also has

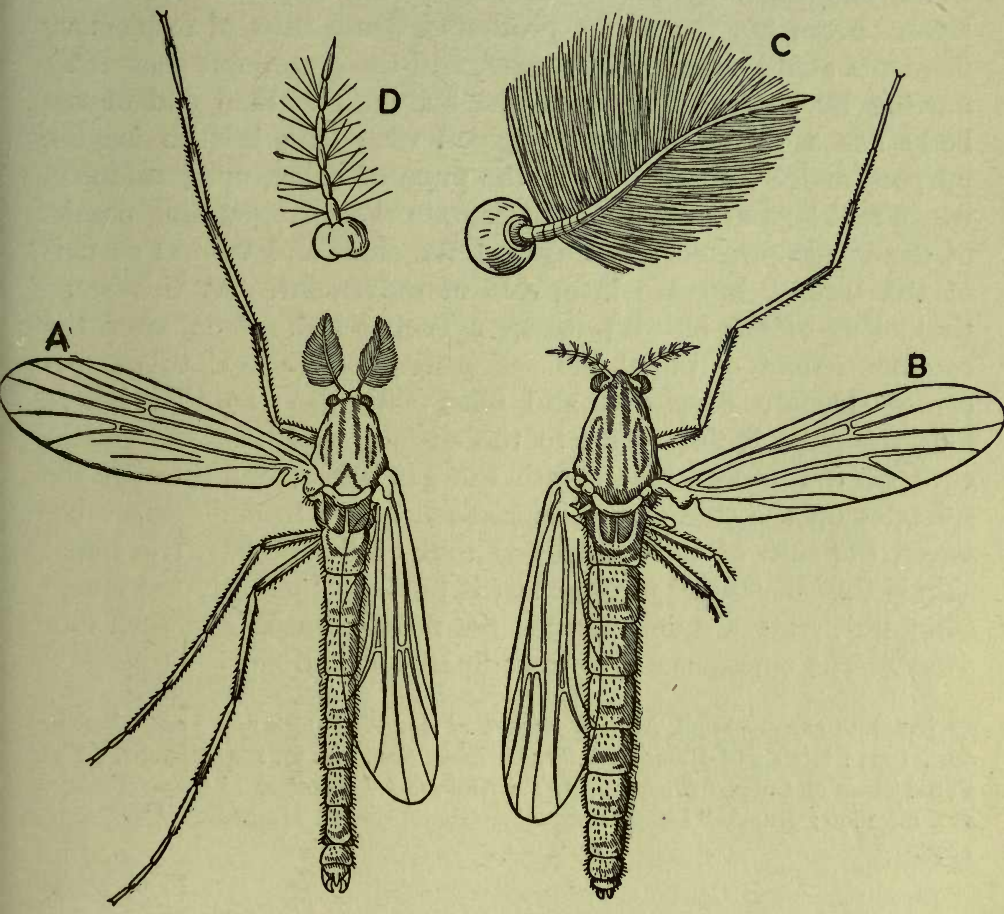

FIG. 17.—A, male; B, female; C, antenna of male; D, antenna of female chironomus.

four similar though small tubes, and also a pair of "feet" armed with hook bristles for the sake of attachment to the walls of the tube. On the dorsal surface of the twelfth segment are two tufts of long bristles which are probably tactile in function.

The "blood-worm" then differs from the "wriggler" in its power to abstract oxygen from the water, and in having no apparatus which necessitates life at the surface in quest of the atmospheric oxygen itself.

Towards the end of larval life the prothorax becomes distended, and the appendages of the future gnat can be faintly discerned through the skin. The pupa itself lies in the mud or slime, allowing only the head and thorax to project above its level. From the top of the prothorax dense tufts of respiratory filaments stand out into the water, and these are kept constantly moving by gentle swaying of the body. The hind end of the body has a paired tail-fin margined with long bristles for the purpose of locomotion. As in the pupa of culex, eyes, antennæ, wings and legs are present, and contain the corresponding organs of the imago pressed down against the sides and ventral surface of the throax, but are incapable of movement. At this stage the colour of the blood becomes a deeper red. Soon after the commencement of pupal life the system of tracheal tubes becomes strongly developed and filled with gas; so that before long the pupa is floated up to the surface ready for the emergence of the imago. At length the gas passes out through the spiracles on the side of the imprisoned imago into the space between the skin of the imago and that of the pupa. The pupal skin is thus distended until at last it bursts. Instantly the imago steps out, rests a moment upon the floating husk, and then flies away. The emergence is extraordinarily rapid.

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CHAPTER V

Dyticus marginalis—A Water-Beetle

The beetles, or *Coleoptera*, constitute the predominant order of insects, there being about 150,000 known species, of which about 3300 are British. The name of the order has reference to the sheathing character of the front wings: for these organs, known as elytra, are not used in flight, but serve solely as covers for the hind- (flight) wings when these are folded and at rest. In some species, however, the wings and elytra are so reduced

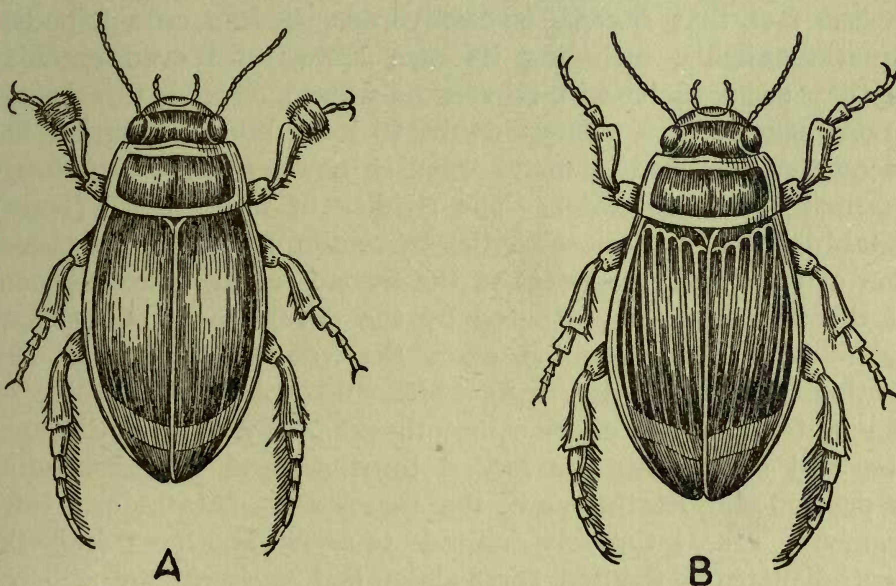

Fig. 18.—Adult *Dyticus marginalis*. A, male; B, female.

as to be useless, or, indeed, are entirely absent; while in others the elytra are fused together over the back so as to be incapable of separation. The prothorax is far more freely movable upon the mesothorax than is the case in other insects; but the mesothorax is very small, while the metathorax, except in flightless species, is largely developed.

The majority of beetles are terrestrial in their habits; but a fair number have become aquatic, and of these the largest and one of the most abundant is *Dyticus* (often wrongly spelt "Dytiscus") *marginalis*. The mature insect is more than an inch long; its dorsal surface is of a deep brown-green colour, excepting a yellow margin bounding the sides of the thorax and outer edges of the elytra; the ventral surface is of a lighter brown tint. The surface is smooth and polished, and the outline that of a long oval, the head being partly sunk into the thorax, so that the "lines" of the animal suffer no interruption at the neck. Along the mid-ventral line of the body, especially in its anterior regions, is a ridge, or keel; while the dorsal surface is gently and evenly rounded. It will then be seen that the form of the animal is admirably suited for swift passage through the water. The success of the design of this living boat is testified by the fact that *Dyticus* is carnivorous, feeding on soft-bodied aquatic animals, including its own larvæ, and even catching as they swim such swift movers as fishes; indeed, this beetle, whose ancestors we cannot doubt to have been terrestrial, has become so modified in many ways as now to be very perfectly adapted to life in water. The rigidity of the "hull" (body), notably deficient in most beetles by reason of the loose articulation of the first (prothorax) to the second (mesothorax) segment of the thorax, is here secured by the development of a strong backwardly directed spine upon the ventral surface of the prothorax, and a slot, into which the spine fits firmly, on the anterior edge of the mesothorax. By this contrivance pro- and mesothorax are locked together, and lateral bending is prevented. Furthermore, the meso- and metathorax (third segment) are intimately united to one another, and the ventral plates of the first three abdominal segments are soldered together so as to prevent all movement; while the flexible joint between thorax and abdomen is strengthened partly in the mid-ventral line by a long and forked backward process from the ventral plate of the third thoracic segment (metasternum), and partly by the very large and flattened coxal (first) joints of the hind pair of legs, being so placed as to overflap the fore part of the abdomen, and, moreover, being firmly and immovably welded to the ventro-lateral portions of the metathorax.

Just as the body itself is well shaped and fashioned for easy passage through the water, so, too, are the hind-legs modified to form efficient oars. Their femora are flattened so that they work easily to and fro upon the fused ventral plates of the anterior abdominal segments and upon their own coxæ; their tibiæ and the five joints of the tarsus are likewise flattened to present a broad face to the water, and are further furnished with fringes of long hairs along each edge. These hairs are so arranged that they spread out and meet the water, thus broadening the face of the oar during the backward stroke, but yield and are pressed together during the forward "recovery." The forward movement is also facilitated by the articulation of the tarsus with the tibiæ being such that the former can be slightly rotated upon its own axis so as to present its narrow edge to the water in the same way as a "feathered" oar presents the edge of its blade to the air. The claws upon the last tarsal joint of the hind-legs are smaller and weaker than those of the other legs. The middle-legs are also employed a little in swimming, but they are shorter and stouter than the hind, and far less modified in form; for the tibia is nearly cylindrical; and while the three first tarsal joints are somewhat flattened and fringed with short hairs, the fourth and fifth are cylindrical and devoid of hairs, and the claws are well developed, as, too, are those of the front legs. These claws are of service to the animal in enabling it to lay hold of weeds and other objects beneath the surface of the water, and so to keep submerged; for since the body is relatively lighter than water, immediately the hold is released the animal floats obliquely, tail uppermost, to the surface.

The tarsus of the front leg of the male has its first three joints peculiarly modified. All three joints are very broad and flat, and their lower surface is thickly studded with minute cups raised on short stalks; but on the first joint there are two much larger, though unequal, cups of similar structure. Similar minute cups are also present in large numbers upon the under surface of the first three tarsal joints of the middle-legs. These remarkable organs are used by the male as adhesive suckers with which to maintain a grasp upon the female in the act of mating. In this process the cups are flattened down upon the smooth surface of the prothorax of the female, and from each there exudes a sticky, coagulable fluid which, passing down the stalk of the cup, escapes by a minute hole, which pierces the centre of the cup itself, into the now flattened cup-cavity. The adhesive power is apparently in no way dependent upon atmospheric pressure.

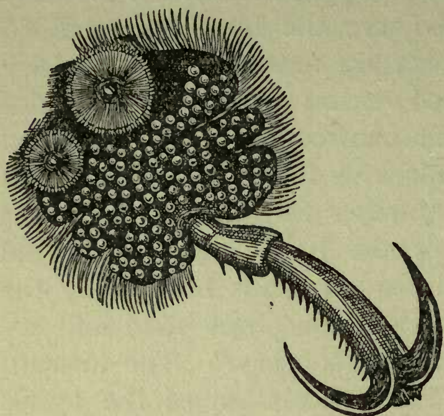

FIG. 19.—Tarsus of front leg of *Dyticus*, showing the large and small suckers.

This sexual modification of the front tarsi affords a ready means of distinguishing the male from the female. A further differentiating character is usually, though not always, present upon the elytra. Those of the male are smooth and polished, and but faintly marked by those longitudinal rows of minute punctures; whereas the elytra of the female are deeply furrowed by a number of longitudinal grooves. But males with furrowed, and females with smooth, elytra are sometimes found.

The mature animals spend the greater part of their lives in the water, and take flight merely for the purpose of flying to some other piece of water, occasionally plunging into even such small quantities as are contained in a drinking trough or stable bucket.

Respiration.—Inasmuch as *Dyticus* is unable to extract the oxygen dissolved in the water, periodic visits to the surface for purposes of respiration are necessary. On these occasions the animal floats, tail uppermost, to the surface, and exposes the tip of the abdomen to the air. At the same time the abdomen is separated from the elytra at the apex so as to open a broad cleft leading into the space enclosed between the tightly fitting elytra and the body. A fresh supply of air is thus taken into this chamber in exchange for the vitiated air which escapes. The elytra and abdomen are then brought again into close contact, and the animal descends once more beneath the surface, there to remain until the store of air is exhausted. The respiratory stigmata open into the chamber beneath the elytra, and the most posterior pair is unusually large, so that a plentiful supply may be taken in by them direct during their brief exposure to the air.

Life-History.—The female *Dyticus* lays her eggs in the leaves and stems of Potamogeton and other water plants during the early spring. Her ovipositor is provided with two sharp plates with which a slit is cut deep into the plant ; a single elongate egg is pushed into each incision. The larvæ emerge in about three weeks, and in the course of another five weeks, after several moultings of the skin, attain their full size. The full grown larva is about two inches long, yellowish-brown in colour, and tapering slightly towards the neck, but decidedly towards the tail. The head is flat and somewhat circular in outline. Very conspicuous upon its anterior margin is a pair of powerful sickle-shaped mandibles with which this voracious larva seizes the tadpoles, fish and other animals which form its food. Near the tip and on the inner side of each mandible is an elongate slit fringed by fine bristles and leading into a tube which opens posteriorly at the base of the limb near the mouth. Through these passages the juices of the prey are sucked and passed into the very narrow mouth. Solid particles of food are, however, swallowed occasionally.

The tip of the abdomen bears a pair of small fans fringed with hairs ; similar fringes being also present on the lateral margins of the two last abdominal segments. These structures enable the larva to dart rapidly through the water by vigorous lashing strokes of the abdomen ; in swimming leisurely the legs, which are rather long and likewise fringed with hairs, suffice as organs of propulsion.

Unless the larva maintains a hold upon weeds, etc. beneath the water it floats to the surface tail uppermost. On arriving at the top the tail fans are thrust through and suspend the larva to the surface-film. It is in this position that the creature normally rests, the tail attached the surface, the back hollowed ready for a vigorous stroke, the head directed downwards, and the eyes, of which there are six on each side, ever on the lookout for victims. At the extreme tip of the abdomen are two spiracles leading into large tracheal tubes which run forward in the body. Through these openings respiration is carried on while the animal hangs at rest. The seven pairs of spiracles which are visible on the sides of the body do not become functional until the pupal stage is reached.

When the larva is full fed it leaves the water and buries itself in the moist soil near the margin. Here it constructs a rounded chamber, then casts its skin and becomes a pupa. In this stage it is shorter and broader than it was when a larva, and exhibits through the thin transparent cuticle of the pupa the limbs and other parts of the imago. If pupation takes place in summer time the perfect beetle emerges in about a fortnight ; but if later in the year, then hibernation takes place, prolonging the pupal stage till the following spring. In either event the full-formed beetle is at first soft and of a pale colour ; nor does it attain its final aspect until several days have elapsed. Although provided with strong jaws, the perfect insect relies for defence upon an evil-smelling milky fluid which can be discharged from glands situated in the front part of the thorax, and upon a yellow ammoniacal liquid secreted by a pair of glands at the end of the abdomen.

FIG. 20.—Pupa of *Dyticus.*

BIBLIOGRAPHY.—Miall, *Natural History of Aquatic Insects* ; Furneaux, *Life in Ponds and Streams ; Cambridge Natural History*, vol. vi. ; Fowler, *The Coleoptera of the British Isles*, 5 vols. ; Rye, *British Beetles.*

CHAPTER VI

Centipedes and Millipedes

These animals are found in a great variety of situations, in the earth, among heaps of vegetable refuse, beneath the bark of decaying and dead trees, among the roots of grasses and other plants, and under stones and logs, some even occurring under rocks on the seashore below high-water mark. There are at least some fifty or sixty different species to be found in England, and probably more, for comparatively little attention has been bestowed upon them by collectors. The term "Myriapod" is employed to include both centipedes and millipedes, but none of these words should be understood too literally to indicate the number of legs present in these animals.

Like insects and spiders, the myriapods possess a hard external skeleton and jointed limbs, and they breathe (with the exception of one subgroup) by means of tracheal tubes which open on the lateral surface of the numerous segments into which the body is divided. They differ, however, from both the other groups in having true jointed legs upon the posterior segments, and in the far greater number of legs; from the insects, in exhibiting no distinction between thorax and abdomen; from the spiders, in possessing antennæ and clearly marked segmentation extending right to the end of the body.

The centipedes have a rather flattened body; each segment carries only one pair of legs; the bases of the legs are wide apart; the reproductive opening is on the last segment of the body, and the antennæ possess at least fourteen joints. The majority are swift running, ferocious, carnivorous creatures, feeding on worms, flies, beetle-grubs, etc., which they seize and slay with their sharp and poison-bearing mandibles.

At least one species (*Geophilus electricus*) has the peculiarity of being phosphorescent, at any rate in the autumn. This centipede is very slender and relatively long; indeed, it might be mistaken for a worm. The light which the creature emits is like that of a glow-worm, though feebler; and it persists for a short time as a luminous trail upon the ground, being evidently due to some substance emitted. The phenomenon is probably associated with the breeding season, but we need more exact observations on this point.

The most familiar member of this division is the ordinary red centipede, *Lithobius forficatus*, a swift, active creature that may be seen hurrying away into safety when a large stone, log, or any similar object that has been lying for some time upon the ground is uplifted. The animal has fifteen pairs of legs and possesses eyes. Its food consists of earth-worms, blue-bottle-flies, and many other small animals which are captured alive. Earthworms are pursued, as rabbits by a ferret, along their burrows. This species may be kept in captivity, but is rather shy of observation. Dr. D. Sharp has, however, succeeded in determining the following facts regarding its habits. The breeding season begins in June and goes on till August. The eggs pass from the body singly, and as each arrives at the genital opening it is grasped by two small hooks on the ventral surface of the body of the female, and by these organs it is quickly rolled round and round on the earth until it is covered with soil adhering to the slime with which the spherical egg-shell is covered; the hind-legs also take part in this operation. The purpose of this manœuvre is to conceal the egg from the male, who will, if possible, seize it from the female at its first appearance and devour it. The female frequently has to run hastily away from the greedy male, holding the egg in the special hooks until she can find a quiet spot free from his molestations, and there convert the appearance of the egg into that of a pellet of mud.

The millipedes are of very different shape and habits. Their body is, in the commonest species, cylindrical, but in others flattened and with lateral projections from the segments; only the first few anterior segments possess but one pair of legs each, the remainder carry two pairs each, and thus give the appearance whence the popular name is derived; the bases of the legs are close together, near the mid-ventral line; the reproductive opening is not at the posterior end, but on the ventral surface of the third segment behind the head; and the antennæ have but seven joints. These are all slow-moving, inoffensive creatures, except in so far as they possess a disagreeable odour and inflict some damage on crops, and are vegetarian in their diet. Their mouth appendages are adapted for biting and chewing, or, in some cases, for sucking vegetable tissues. There are no weapons of offence, but along the sides of the body are special "stink-glands" which give a disagreeable odour, and presumably taste, to the animals. The chitinous exo-skeleton is strengthened with quantities of chalky matter, so that the whitened skeletons of dead specimens are often found on the surface of the ground.

One of the most common species is *Julus terrestris*, sometimes called the "wire-worm," but not to be confused with the larvæ of the "click-beetle," *Elater lineatus*, to which the same popular term is also applied. *J. terrestris* can be kept captive in shallow glass vessels with a layer of moist earth at the bottom, and will thrive and breed if freely supplied with such food as slices of apple, leaves and grass. When disturbed the animal rolls itself up into a close ring.

The breeding season is in the earlier summer months. The female constructs, at some distance from the surface of the earth, a hollow sphere of particles of earth glued together by the sticky secretion of her salivary glands. The whole nest is about as large as a hazel nut, and is rough on the outer but evenly smoothed on the inner surface. At the top a small hole is left through which the eggs are passed up to the number of sixty or one hundred. The eggs are very small, and are covered by a sticky fluid which causes them to adhere in a cluster. The egg-case having received its complement of eggs, the hole is closed by earth moistened by saliva, and the eggs are left untended. The young millipedes hatch out in about twelve days.

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CHAPTER VII

Spiders

About five hundred different species of spiders are known to occur in this country. As is to be expected among so large a number, there is considerable diversity in their habits and modes of life. The best known spin silken snares, webs, in which to entangle the flies and other insects on whose juices they subsist. The forms of the webs are very various, but remarkably constant in their main features for any particular species. Some spiders spin beautiful wheel-shaped webs, others arrange their snares in horizontal sheets or form a tangled maze of threads; others again construct silken tubes in holes in the earth, crevices or corners, and spread out a diffuse net horizontally in front of the entrance.

There are, however, several ways by which spiders catch their prey without the use of a snare: some species of *Lycosa* (wolf-spiders) run their victims down in fair, open chase, while others of the same genus pursue their prey upon the surface of water, and can tolerate with impunity a lengthy submersion. Others again search carefully for the animals on which they feed, and, having descried their quarry, stop short and leap upon it. The most familiar examples of this method of capture are the jumping spiders (family *Salticidæ*), among which one, *Epiblemum scenicum*, is very common on walls, in the cracks and crevices of which it dwells. This is a small spider, nearly black and white in colouring; and, like most of the *Salticidæ*, has the four anterior eyes of very large size, as is to be expected in an animal which relies upon vision for the discovery of its food. The prey consists of flies and other small insects which frequently settle upon walls and there bask in the sunshine; and it is only in bright weather that the spiders go a-hunting. At the moment of leaping upon the prey the spider fastens down on to the surface of the wall the silken thread which is always trailed behind the body from the spinnerets. The force of the leap draws out the thread, and thus the spider swings back again on to the perpendicular face of the wall and is saved from falling headlong to the ground. Other spiders, especially members of the family *Thomisidæ*, conceal themselves among flowers, particularly on plants whose blossoms are closely clustered together as is the case in dead-nettle, mignonette, composites of all kinds, orchids and others ; and there lie in waiting for any insect that may chance to visit the flowers in search of nectar or pollen. Many of the spiders which exhibit this habit are of the same colour as the blossoms among which they lurk, and are thus very perfectly concealed. For example, the spider found among the dead-nettle flowers is white, that among the mignonette green ; while the curiously shaped *Thomisus abbreviatus*, frequenting pink orchids and heather and also yellow flowers, is sometimes pink and sometimes yellow, and generally, though not invariably, is found to select flowers of the same colour as itself.

A remarkable fact, and one that has not yet been fully worked out, but would well repay careful study, is the manner in which the darker and lighter tints of colour are arranged upon the bodies of spiders. A very common scheme of colour among all animals is the disposal of darker shades upon the upper surface which receives the strongest light, and of the paler tints upon the lower surface which is naturally in the shadow cast by the body itself. The effect of this arrangement is to neutralise the high lights above and also the cast shadows beneath, and thus to lessen or completely do away with the bold relief in which the animal would otherwise stand out. Now, many spiders spin more or less horizontal webs, and rest upon the under surface of the snare in an inverted position. Hence it is the ventral side of such spiders that receives the strongest light, and the dorsal that is in the deepest shade. It is thus most interesting to find here a reversal of the common colour scheme, the ventral surface being the darker and the dorsal the paler.

A singular method of seizing the prey is found in the rather scarce spider *Atypus piceus*. This animal forms a silken tube in a deep cylindrical hole excavated by itself in the earth, and generally on the projecting ledge of a bank covered with some vegetation. The outer end of the tube often hangs loosely for some two or three inches upon the surface, but is sometimes upright among the herbage, and appears slightly inflated if the spider be within. The tube has no aperture, but the prey is seized by thrusting the powerful mandibles through the silken walls of the tube itself. The food of this remarkable and powerful spider consists chiefly of earth-worms, but the nests also contain at times shells of small snails and remains of beetles, earwigs and other insects.

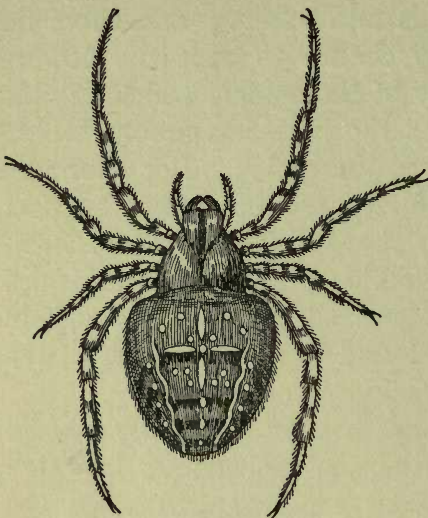

FIG. 21.—The garden spider, *Epeira diademata.*

The body of a spider is divisible into two parts only, there being no neck to separate head from thorax. Hence the anterior region is termed the cephalo-thorax, and behind it, and separated by a well-marked "waist," lies the soft and unsegmented abdomen. It is important to note that the abdomen of true spiders exhibits no traces of segmentation ; for there are certain animals, *e.g.* the long-legged "harvestmen" (*Phalangida*), which might be mistaken for spiders, but are readily distinguishable by the segmented character of their abdomen, and by absence of a definite "waist." The limbs are six pairs in number, and are all attached to the cephalo-thorax. The first pair is the falces (cheliceræ) ; in the garden-spider, whose habits are presently to be described, these are two-jointed, the second joint being bent down on to the first except when in use ; the tip is sharply pointed, and pierced by a hole through which poison flows into the wound inflicted on victims. The second pair of limbs is known as the "pedipalpi" ; these are leg-like, but have only six joints, and are either destitute of claws or provided with one only. In

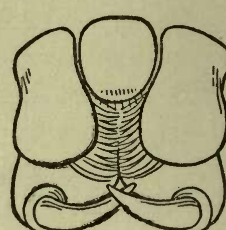

FIG. 22.—Falces of spider.

mature males the pedipalps are highly modified in connection with the reproductive functions. The basal joint of these limbs carries a blade-like expansion, "maxilla," on its inner face, and the two maxillæ can meet across the mouth, which is very small; these processes are used to squeeze the juices out of the body of victims into the spider's mouth. No solid food is swallowed. The dorsal portions of the pedipalps are more or less hairy, like the legs, and doubtless both these sets of limbs perform delicate sensory functions, and thus compensate for the absence of antennæ. Behind the pedipalps come the four pairs of true walking legs, whose number is as constant in the spiders as are the three pairs in insects. Each leg is composed of seven joints, and terminates in two or in three curved claws which are generally pectinated (provided with comb-teeth). In some spiders the penultimate joint of the last leg bears a long series of closely set bristles (the calamistrum) which are used for teasing out a peculiar kind of silk produced from the extra "spinner" possessed by such species. This silk becomes, when so treated, very fluffy and adhesive, and is then spread on the other strands of the snare.

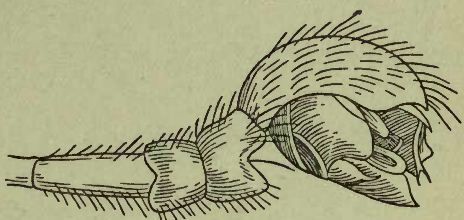

FIG. 23.—Pedipalp of a male spider.

The eyes are placed on the front region of the cephalo-thorax, sometimes on its dorsal, sometimes on its anterior surface, sometimes on both. They are usually eight, though in some only six in number; they cannot be moved, nor are they compound like those of insects. Their relative sizes and positions differ greatly in various species, so much so that these features are of great importance in the classification of spiders.

FIG. 24.—Dorsal view of head of garden spider, showing the arrangement of the eyes.

The abdomen is always soft and unsegmented, but exhibits great diversity of shape. On its ventral surface, just behind the waist, is a small plate, generally notched in its middle, which is the lid covering the genital opening. The plate represents two abdominal appendages fused together. On each side of this is a narrow slit (in some species two slits are present on each side), the opening to the respiratory organ, or "lung-book." The lung-books are chambers whose cavities are occupied by numerous thin plates somewhat resembling the pages of a book, but hollow; blood circulates in the hollows of the plates, while air passes in and out between them and thus supplies the oxygen, which is carried away to all parts of the body. In some species, however, there are in addition tracheal tubes resembling those of insects.

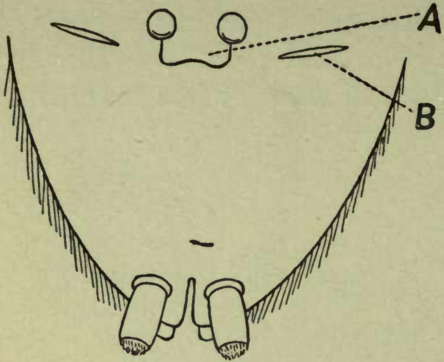

FIG. 25.—Under side of abdomen of spider. A, genital flap; B, opening of lung-book.

At the apex of the abdomen is situated, on a small pimple, the posterior opening of the digestive organs. Just in front of this aperture is a group of six nipple-like projections—the spinners—from which the silk issues. In those spiders which possess the calamistrum already mentioned there is a short, broad and partly divided extra spinner just in front of the cluster of six. The size, length, number of joints and direction of the spinners is subject to much variation. At or near their extremities the spinners are furnished with numerous fine tubes, through which the semi-liquid silk is discharged in delicate threads. It is noteworthy that whereas those insects which produce silk discharge it from openings near the mouth, *i.e.* at the anterior end of the body, it is at the posterior extremity that spiders secrete it.

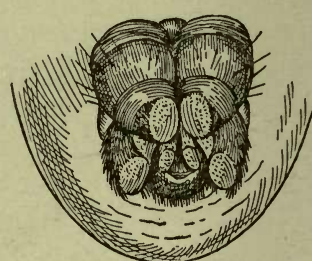
FIG. 26.—Apex of abdomen of garden spider, showing the spinnerets.

In *Epeira diademata* there are no less than five different sorts of silk produced for the manufacture of the snare strands, capture of prey and the custody of eggs, for the different grades of threads are not all for the same purpose. The radiating spokes of the wheel-web form a framework on which the sticky circular lines, destined to catch insects, are fixed. A third kind of silk is used to smother and enfold the captive victim, and yet another for the walls of the egg-cocoon. The abdomen of this spider varies in colour from pale sandy yellow to dark brownish black; down the middle of the dorsal surface runs a chain of creamy white spots of varying shape, the anterior part of this line is cut at right angles by another series of similar spots, so that a distinct white cross is formed; farther back there may be two other fainter transverse white lines. All three cross-lines are liable to much variation. The female is nearly half an inch long; the male smaller.

Web of E. diademata.—The first step in the construction of the web is to lay a cord roughly horizontal between two relatively firm points, or sometimes the spider accomplishes this by fixing one end of the thread, which is composed of many strands, and then descending to the ground and mounting to the second point selected for attachment, and then hauling in the slack before fastening the free end. At other times the spider spins out into the air a long cord, which is wafted and as it were drawn out by the wind until it touches and adheres to some neighbouring object. A few sharp tugs by one of the legs assures the spider of the security of the far end, the slack is hauled in, and the other end fastened down. From this first line a roughly four-sided framework is suspended, within which the wheel-web is to be placed; the side lines are frequently furnished with "stays" attached to the top and bottom lines, or to external objects. The framework ready, the spider goes to the middle of the part of the top horizontal side included in the frame, attaches a thread to it with the spinnerets, drops perpendicularly to the lower horizontal line, paying out across the space a thread, whose lower end is at once fastened, and so connects the top and bottom lines.

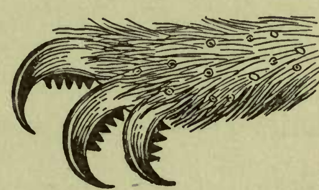

FIG. 27.—Foot of spider.

A return journey up the new thread is now made; at its centre a fresh thread is attached and spun out as the spider runs on up to the top. One of the hind-legs is used to steady the newest thread and prevent it from adhering to that on which the spider is travelling. On reaching the top horizontal line the spider walks along it a little way, still holding the new line loose, until the interval between two of the future main spokes has been traversed, and then fixes the thread. There are now in position the first three spokes of the wheel, namely, two formed by the bi-

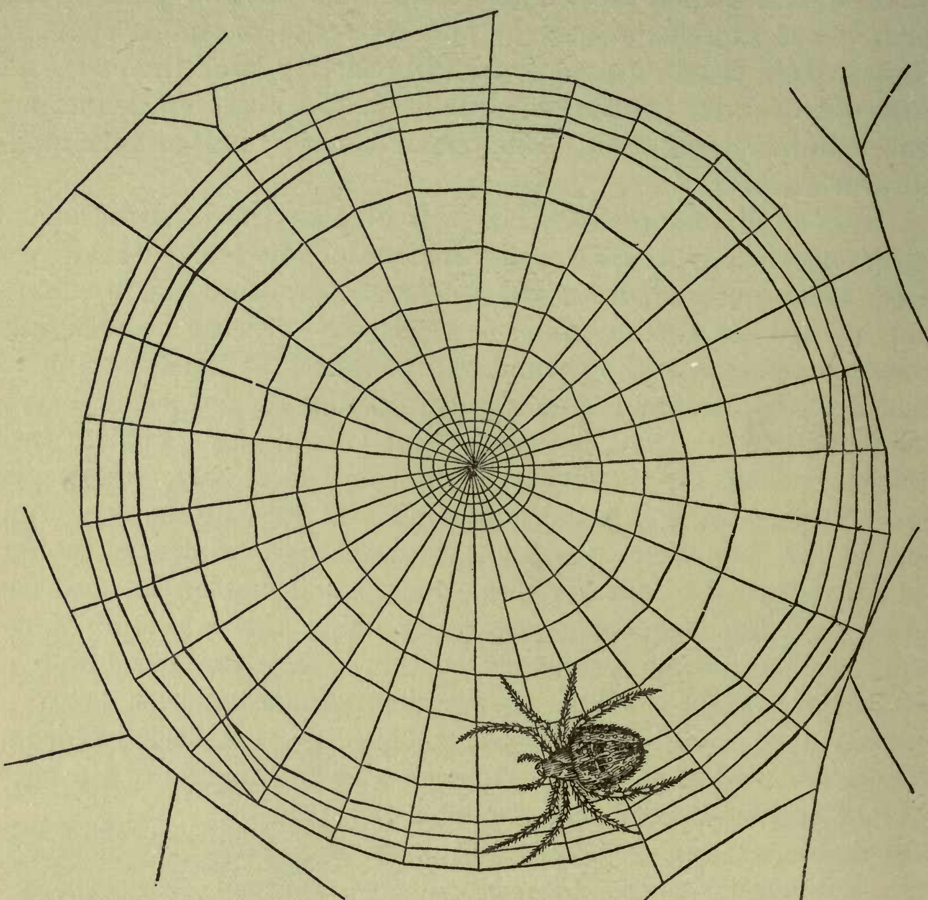

FIG. 28.—Web of garden spider: the second spiral line has been begun.

section of the first perpendicular thread at the point where the newest thread, the third spoke, was attached. The animal now returns to the centre along the last spoke, attaches a fresh thread, travels back to the frame along the same spoke, walks along the frame a little distance and then fastens the next spoke. This process is repeated until the whole area within the frame is traversed by the spokes radiating from the centre. The spider does not always work steadily round the frame in the same direction, but may construct spokes alternately to right and left of the first perpendicular. The web is now ready for the lines connecting the spokes. These are arranged in a spiral manner. The spider proceeds to the centre, attaches a thread, turns round, emitting silk all the time from the spinnerets, and with these organs, assisted by the hind-legs, fastens the line to spoke after spoke, travelling farther and farther from the centre until the spiral has attained sufficient size. The intervals between the successive turns of this spiral are relatively wide. A second spiral is now begun, but in the reverse direction from the circumference, inwards towards the middle. If at the margin the spaces between the spokes are too wide for the spider to stretch across, it runs up the spoke to which attachment has been made until, by the convergence, it is possible to step across to the next. Along this it runs outwards to the desired spot, then inwards again along the same spoke, and so on repeatedly until it has reached a region where these laborious to-and-fro journeys and frequent turnings are no longer necessary. As the second spiral is made the first is removed bit by bit, and the second is more closely set, so that its meshes are narrower than those of the first. The writer has observed individuals which did not maintain regularity of direction in tracing the second spiral, but after spinning a few turns in one direction did a few meshes, or perhaps several complete circles, in the other. The central part of the web is usually cut away, so that the spokes do not actually meet at a point, and the space is filled in with irregular meshes of non-adhesive silk upon which the spider frequently rests, head downwards. The silk used for the spirals is far finer than that of the spokes, and is covered with microscopic globules of sticky material; whereas the spokes when dry are hardly adhesive. The whole process of constructing a complete web may be completed in half an hour. When at rest the spider keeps each leg in contact with a distinct spoke, and then is able at once to detect the vibration caused by the struggles of an entangled insect, and the whereabouts of the victim. If a high-pitched tuning fork be struck and held near the web the spider is deceived into imagining that an insect has been caught, and will rush hurriedly over the web in search. Some species of *Epeira*, but not as a rule *E. diademata*, leave clear spaces not crossed by the spirals on either side of one spoke which is thus isolated; others carry a similar detached line obliquely out from the centre of the web in a plane other than that in which the "wheel" itself lies. In such cases the solitary line leads to a hiding-place near by among the foliage, etc., and here the spider rests, keeping, however, at least one foot in contact with the one thread.

The eggs of *E. diademata* are produced in the autumn, and placed as a flattened mass in a cocoon, which is about ½ inch in diameter, yellow, and more or less spherical. The young emerge in the following spring or early summer, and immediately spin a maze of very fine lines in the midst of which they cluster together, forming a golden-brown ball suspended in mid-air. If touched or alarmed the several hundred minute spiders scatter themselves in all directions along the mazy lines, and the ball melts away into space, only to form again when the cause of alarm has passed away. The methods of disposal of the eggs adopted by spiders are very many; some form graceful bell-shaped cocoons and leave them attached to the stems of grasses and other plants; others bedaub their cocoons with mud, while many carry the cocoon about with them attached to the ventral side of the abdomen, and some exhibit considerable affection for their young until they are old enough to shift for themselves.

FIG. 29.—Egg cocoon of garden spider.

Gossamer.—The young spiders of many species get carried away and dispersed over wide areas by a remarkable method of travel. Standing, so to speak, on tiptoe, the little spider elevates the tip of the abdomen and spins out into the air a thread of silk, which floats upwards and is drawn out by the breeze. When the thread is sufficiently long the spider gives a slight jump into the air, and is launched forth on an aërial voyage sustained by the parachute thread. For the starting-point the top of post, rail, wall, or some moderately elevated object is selected. These floating threads and their little burdens sooner or later come to earth or are entangled in vegetation, and give rise to the filmy substance commonly known as gossamer.

Many species of spiders are easily kept in captivity in breeding cages such as are used for caterpillars. It is of course necessary to keep them regularly supplied with insects for food, ~~but a~~ supply of water is also essential, for all spiders drink large quantities. In the course of life the skin is cast several times, and slight changes of colour take place after the moultings. It is also noteworthy that limbs lost by accident can be grown again; moreover, spiders have the power of voluntarily throwing off a limb when attached, and doubtless thus escape by sacrificing a part for the whole.

The length of life is very varied; probably most do not long survive the laying of the eggs or rearing of a family; but there are recorded instances of certain species living as long as four years.

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CHAPTER VIII

SNAILS AND SLUGS

THE largest species of our common shell-bearing Gastropod molluscs is the garden-snail, *Helix aspersa*. The animal is to be found hiding in the crevices of stone walls, heaps of stones, etc.; or in warm damp weather crawling among vegetation and doing considerable damage to low-growing foliage. The shell is of a brown colour crossed by transverse darker patches; its "lip" is nearly white. It is spirally coiled, and exhibits numerous fine "lines of growth" which run parallel with the margin of

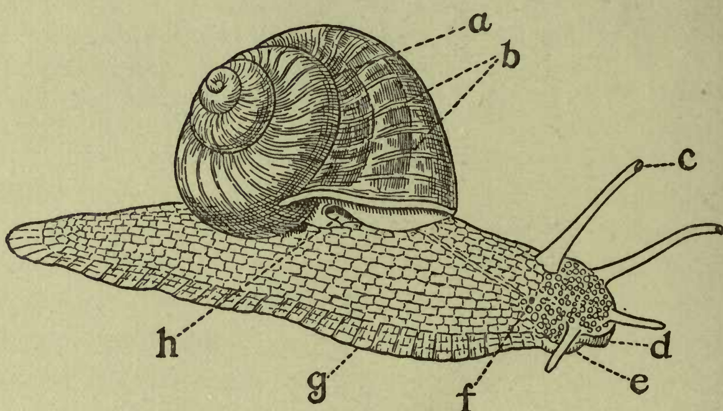

FIG. 30.—Garden snail. *a*, suture; *b*, lines of growth; *c*, eye; *d*, mouth; *e*, pedal gland; *f*, genital opening; *g*, foot; *h*, pulmonary opening.

the shell ("lip"), and indicate the successive positions occupied by the free edge during growth. The increase of one year can usually be determined by the interval between more pronounced lines of growth, and sometimes by slight differences of colour. The length of life probably never exceeds five years. When growth does take place it is very rapid, as much as a centimetre of shell being known to be added in five days. The fresh portion is very thin and flexible for some days while consisting only of the coloured outside layer ; later a backing of calcareous matter is added, and the strength thereby increased. From the apex of the shell a spiral " suture " runs round and round the shell to the upper edge of the " mouth " ; this suture is the line along which the growing shell-margin has become united with the already existing portions. Starting from the apex and travelling down the suture, the direction of growth is seen to be always towards the right hand. If the reader will imagine himself to be walking down the suture he will at once perceive that he is continually turning to his right. Such shells are known as " dextral." A few of our land snails, *e.g. Clausilia*, possess " sinistral," left-handed shells.

On the under surface of the shell a portion of the " lip " is reflected so as to cover a small opening, the " umbilicus." This leads into a hollow pillar, the " columella," formed by the union of the successive turns (" whorls ") of the shell. In some species of *Helix*, e.g. *pomatia* (the Roman snail), *caperata*, which is common on dry short-turfed downs, and others the umbilicus is quite conspicuous. If a shell be cut in half with a fret-saw, or carefully chipped away with scissors, the columella is exposed as the axis of the spiral.

The outer, coloured, horny layer of the shell, the periostracum, is formed only by the skin just behind the thick fleshy edge, or " collar," of the mantle which is visible in the living animal all round the lip of the shell. The calcareous middle layer is also formed only in the same region ; but the innermost mother-of-pearl or nacreous layer is added by the entire surface of the mantle. Hence if the shell be injured the animal is able in a short time to patch up the hole with a white layer of mother-of-pearl, but cannot renew the coloured periostracum. Such repairs are affected in a very short time—a few hours being sufficient for the formation of a new serviceable piece. Normally, however, the shell is thickest near the lip, except when growth is in progress. The chalky matter is derived from that contained in the plants eaten ; in limestone districts the shells are very much thicker than those found on soils deficient in calcareous salts.

As is well known, the snail can at will either extend a large portion of the body beyond the limits of the shell, or on the other hand withdraw entirely within it and almost pass out of sight round the bend of the last formed whorl. At the anterior end of a well-expanded specimen is the mouth, bound by soft fleshy dorso-lateral lips and by a short horizontal lower lip. Dorsal to the mouth are two pairs of tentacles ("horns" in popular language); the more posterior and dorsal of these are the larger, and bear at their extremities a black spot—the two eyes. The lower tentacles are tactile, and perhaps also olfactory in function. All the tentacles can be withdrawn into the body. When this occurs the tip sinks down first into the part behind it, and gradually the whole structure disappears much as the finger of a glove might be drawn down into the glove-hand by a string inside attached to its tip. A slip of muscle running up the hollow of the tentacle and fastened to the summit performs this action in the snail. On the right hand side, a little ventral to the large tentacle, is the inconspicuous opening of the reproductive organs; a grooved line leads obliquely down to this from the margin of the shell. The ventral part of the animal is flat and very muscular and is known as the "foot." This special ventral thickening extends along the entire length of the animal, beginning immediately below the mouth and reaching nearly as far behind as in front of the shell; posteriorly it tapers off to a blunt point. It is by means of this organ that all snails and slugs creep along. The shell is carried on the dorsal surface, with its "mouth" to the right. The cream-coloured "collar" is conspicuous between the edge of the shell and the dorsal surface of the projecting anterior portion of the body. In the "collar" on the right side is a large hole, which is alternately closed and opened in a rhythmic manner. This hole leads into the space which is enclosed between the single mantle-fold and the true dorsal surface of the body. The upper (mantle) wall of this chamber is richly supplied with blood vessels, and the lower can be alternately depressed and elevated so that air passes in and out through the opening. In this way the animal breathes, the blood receiving fresh supplies of oxygen after it has coursed through the body and just before it re-enters the heart. Thus the cavity enclosed by the mantle-fold acts as a lung. Close to the pulmonary opening, but a little behind it on the right side, are the openings of the excretory system and the anus. These apertures are so concealed in the fleshy substance of the collar that they are difficult to see.

When a snail crawls along it leaves behind it a slimy trail. This slime is partly derived from the general surface of the body, but a large portion of it is discharged from a special opening situated between the anterior edge of the "foot" and the lower lip. From this aperture a bed of slime is laid down over which the animal crawls, partly by means of cilia covering the sole and partly by a series of waves, some 30 to 50 per minute, of muscular contraction and expansion which sweep over the "foot" from before backwards. The fine undulatory movements of the ventral surface impress upon the slime a series of transverse wavy ridges and furrows. These can be made evident if a snail is made to crawl up an inclined sheet of glass viewed from below; or the animal may be enclosed in a lamp chimney for the purpose. A track of a different kind is often left by a snail which has been feeding as it slowly moves along; for instance, at times the "green" is removed in this way from the bark of a tree or surface of a paling, or again the whitening may be eaten off the glass roof of a greenhouse. If the slime-trail of a snail be followed it will generally be found that the animal has returned to the hiding-place whence it set out; thus showing that a good sense of direction is possessed.

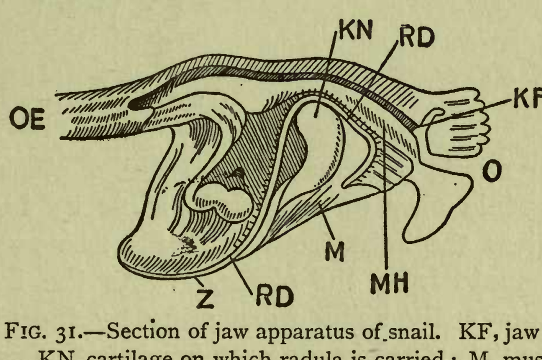

FIG. 31.—Section of jaw apparatus of snail. KF, jaw; KN, cartilage on which radula is carried; M, muscles of radula; MH, mouth cavity; O, mouth; OE, gullet; RD, radula; Z, sheath of radula.

The food of snails and slugs consists of vegetable matter as a rule, either leaves or young shoots or fruit; but some slugs are carnivorous, *e.g.* the shell-bearing slug *Testacella*, which eats earthworms, while some devour fungi, and others are not averse to the droppings of birds. In all cases the food is attacked by means of a hard crescent-shaped horny jaw upon the roof and a rasp-like band upon the floor of the mouth; the latter is termed the "radula." It is a horny ribbon covered with numerous fine, backwardly directed teeth, and capable of being worked to and fro against the jaw above by special muscles. At each bite the upper lips are retracted, the jaw brought forward, and then the radula pushed upward and backward with a rasping stroke. The vegetable matter caught between the radula and jaw is thus torn off. This process is most easily observed in water-snails when they are browsing upon the algæ that grow upon the glass sides of a fresh-water aquarium. If small land-snails, whose skin

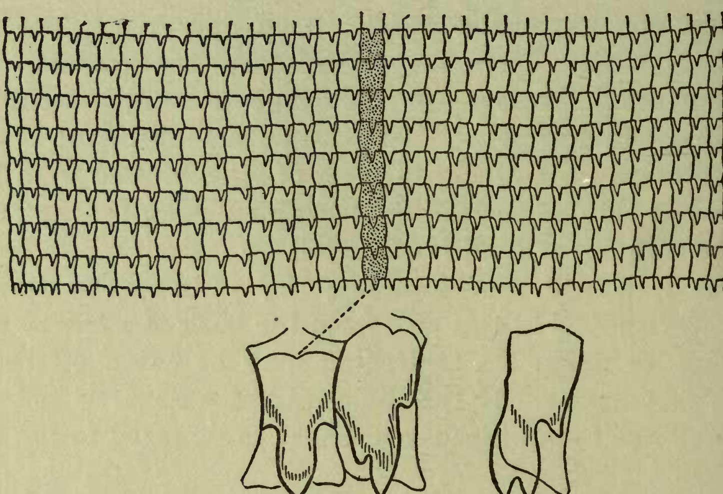

FIG. 32.—Portion of radula of snail, magnified ; and three individual teeth of same, more highly magnified.

is nearly transparent, be under observation, the action of the radula may be rendered visible by focussing with a magnifying glass the light from a candle flame upon the side of the animal remote from the observer. As the front part of the radula is constantly being worn away by the friction which it encounters so it is steadily renewed by growth from behind, the whole horny sheet slowly sliding forward over the floor of the mouth.

Every snail is hermaphrodite, *i.e.* it contains both male and female organs, but pairing is probably always necessary for the fertilisation of the eggs. Prior to the act of mating a remarkable bayonet-like dart of calcareous material is discharged by the snail into the body of its mate. The form of the dart differs in different species. A new dart is produced subsequently for use on future occasions. The spawning season is in July and August, but the eggs of one season are not all deposited simultaneously, but in patches of thirty or more at a time. They are placed in moist spots, under stone heaps, dead leaves, etc. Each egg is contained in a leathery, calcareous shell, is spherical and about $\frac{1}{6}$ inch in diameter. The young snails emerge in about four weeks time, and by the time winter sets in have attained a diameter of nearly $\frac{1}{2}$ inch. When one year old their diameter is about 1 inch. Sexual maturity is reached when three years have elapsed. The shell of an old snail can always be distinguished by the fact that the margin of the shell " lip " is rolled back.

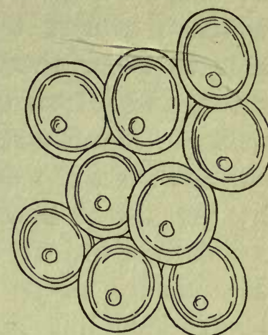

FIG. 33.—Eggs of snail within their shells.

In winter time the snail retreats into some sheltered crevice or buries itself in the earth, and closes the mouth of the shell by secreting a lid (the " epiphragm " or " hibernaculum "), which is largely calcareous in composition. This is at first liquid slime charged with chalky matter, and fills the shell-mouth. The animal then blows a bubble of air from the pulmonary aperture, and so separates the calcified slime from the body, at the same time causing it to bulge outwards. At the same moment the body is withdrawn deeper into the shell, and external atmospheric pressure flattens the epiphragm or even drives it in a little. Sometimes several epiphragms are made one behind the other. The dry, hardened lid is porous, so that respiration can take place through it.

Slugs in their general organisation resemble snails. It is true that they have no protecting shell to cover the part of the body which contains the major part of the internal viscera, as have snails; but in the yellow cellar-slug (*Limax flavus*), and a large pale grey species spotted with black (*L. maximus*), a small shell is present in the skin of the dorsal region, and in *Arion ater*, the large black slug, calcareous crystals are found in the same region; while *Testacella* carries a small but plainly visible shell as a little cap on the hinder part of the body.

As a rule slugs are more active than snails; their rate of progression is about a mile in eight days, but snails would take over a fortnight to traverse the same distance. Some species which frequent trees and bushes, *e.g. Limax marginatus*, are able to lower themselves head first to the ground by a cord of slime, and return to the branch whence they set out by the same means. Some water-snails (*Lymnæa*) are able to ascend to the surface from the depths and travel down again to the same spot by the aid of a similar slime-cable anchored for the purpose to some firm object on the bottom. In the last case the animal ascends by virtue of the buoyancy of a bubble of air which is protruded, but not detached, from the pulmonary aperture. The object of the ascent is to obtain a fresh breath of air.

The slugs which occur in this country are classified into two main groups, the *Arionidæ* and the *Limacidæ*. Members of these families may be distinguished by the following features. *Arionidæ* possess a slime gland on the tail, and the pulmonary opening lies in front of the centre of the margin of the mantle; whereas *Limacidæ* are devoid of a slime gland, and their pulmonary opening is situated behind the centre of the mantle margin.

The largest and one of the most common examples of the former family is the "Black Slug," *Arion ater*. This species occurs in a great variety of localities, being not only abundant in gardens and cultivated fields, but also on moors and boggy peat lands where other molluscs are seldom found. Its food consists of decaying rather than fresh vegetation. At times the animal becomes carnivorous, even to cannibalism, and will even descend to devouring the excrement of other creatures. The young are usually pale yellowish white, but gradually assume a darker colour as they grow older. The deepening colour first appears upon the tentacles, whence it spreads downwards to the back and edge of the foot. Mature individuals vary greatly in colour, some being red, others lead colour, others quite white, while many exhibit mixtures of colours. The cause of these variations in colour is not known; probably several factors contribute. It is, however, noteworthy that specimens from the warmer regions of our islands are as a rule more brilliantly coloured than those obtained in the colder northern districts. This slug and its relative, *Arion minimus*, are the only species capable of contracting the body into a hemispherical lump when alarmed. *A. minimus* may be distinguished from juvenile examples of *A. ater* by the presence of bands of colour on the sides of the body, and by the regular symmetrical rows in which the pointed warts covering the surface are arranged.

The cellar slugs, *Limax maximus* and *L. flavus*, are familiar examples of the family *Limacidæ*. As their popular name indicates, they are frequently to be found in cellars, but they also occur in holes in walls and beneath logs in damp situations. As in *Arion ater*, the colour of these species too is very variable, but the bluish colour of the tentacles of *L. flavus* will serve to distinguish that species from *L. maximus*. Another member of the same genus is the "Tree Slug," *L. marginatus*, which is more abundant in the north than in the south of England. Reference has already been made to the habits of this snail.

The "Snail Slugs," or *Testacellidæ*, form a third family intermediate between the snails and slugs proper. As already

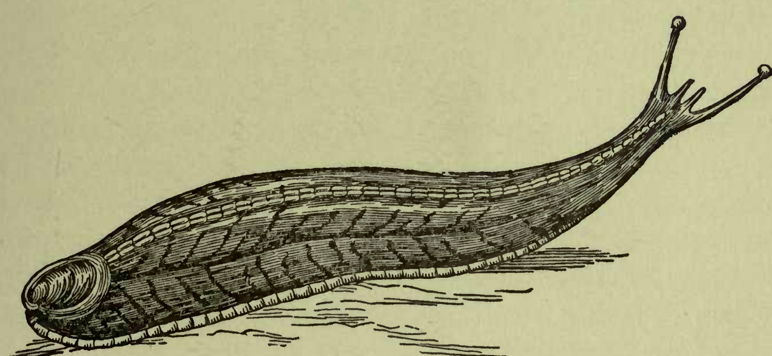

FIG. 34.—Testacella.

mentioned, these animals bear a small though quite distinct shell, and are carnivorous in their diet. In habits they are nocturnal and subterranean, burying themselves deeply in the soil. They may, however, be found upon the surface and upon walls after heavy rains, when the earth has become saturated with moisture, and in consequence the process of breathing difficult.

Neither snails nor slugs are difficult to keep in captivity. Almost any vessel with a lid will serve as a cage, and they will devour lettuce, cabbage, and other leaves readily. Or they may be kept out of doors and confined to a limited area by a small moat full of water. In either case it is important to provide cool shady spots for them, and a fair degree of moisture.

The Roman snail was a favourite article of food with the ancients, and is still held in esteem on the Continent, and in our own country there is demand for the garden snail in the Western counties and in Yorkshire.

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CHAPTER IX

Freshwater Mussels

The freshwater mussels are the largest of all the molluscs that occur in this country. They are exceedingly common, being found in nearly all ponds, canals and streams; but frequently escape notice owing to their habit of burying themselves in the mud and dead leaves at the bottom. The broken shells brought to the bank by various water-fowl which devour them will usually betray the presence of others in any given piece of water. The living animals can be scooped up in a strong landing net, or often obtained by hand if the water is sufficiently shallow to permit wading. A little practice will enable any one to detect the gaping valves and short siphons of the mussels as they project from the mud; and if a finely pointed stick be thrust between the valves, the animals will close the shell so firmly upon it that they can be pulled up and safely landed without wading or using a net. In captivity the mussel should be kept in shallow vessels in order that the whole mass of water may be well aerated. It is not necessary to provide mud in which they can burrow, for they will live many weeks lying on their sides in clean water contained in earthenware vessels; but care should be taken to prevent the temperature of the water becoming high. It is best to place the vessels in permanent shade. If, however, the natural conditions are desired, the mussels must be put in a glass-sided aquarium at the bottom of which a layer of river sand, 3 or 4 inches deep, has been placed. The water should be not more than 6 inches deep, and should contain a fair supply of water-weeds to maintain the supplies of oxygen. It is then possible to watch the animals move about, bury themselves in the sand, and, if a few sticklebacks are also placed in the same aquarium, to see some of the early stages of the life-history.

Four species of freshwater mussel occur in the British Isles;

three of these belong to the genus *Unio*, the other to the genus *Anodonta*. These generic names happily indicate a feature by which the animals can be distinguished. The *Unios* have strongly marked hinge-teeth (union) uniting the two valves of the shell, whereas *Anodonta* is without these structures (Greek, *an* = devoid of, *odontes* = teeth). A further distinction lies in the fact that all *Unios* have a very thick, but *Anodonta* a thin shell.

There are several varieties of *Anodonta*, differing from one another in the shape of the shell and other slight features, but they are now regarded as all belonging to one species, namely, *Anodonta cygnea*, the swan-mussel. It is to this species that the present account is confined; though *Unio* is so like in all main characters that if it be used in practical work no difficulty will arise in consequence of slight differences.

The shell of the swan-mussel is roughly oval in shape, from 4 to 6 inches long, 2 to 3 broad from dorsal to ventral side, and from 1 to 2½ thick from right to left. In colour it is greenish brown, though often dotted with white patches owing to removal of the coloured surface layer. The two valves lie on the right and left of the body, and resemble each other as a reflected image in a mirror resembles the real object. The anterior end of the shell is more rounded and blunter than the posterior. Along the straight dorsal side the valves are held together by a strong elastic ligament; but elsewhere and along the gently curved ventral margin they are free from each other. The concentric lines running parallel with the margin and marking the outside surface are known as "lines of growth." They indicate the positions successively occupied by the margin of the shell during its growth, and are divisible into sets by more pronounced lines which probably represent periods of rest. The interval between any two of the stronger lines is the increase effected during one year. When the shell was very small the lines of growth were close together, and there is thus marked out on the dorsal region of each valve a sort of boss or "umbo." This is the oldest part of the shell, and the thickest. The elastic ligament tends to pull the dorsal edges of the valves together, each umbo serving as a fulcrum upon which the other valve turns. Thus in the resting position the valves gape apart ventrally, and are so found in dead specimens. A definite muscular effort is required to close the valves.

Upon the inner surface of each valve is a number of marks where, in life, muscles are attached. These muscular impressions are more conspicuous in shells of *Unio*, but can be seen without difficulty in *Anodonta*. In the anterior region is a large shallow pit caused by the anterior of the two powerful muscles which run across the body, and which by their contraction bring the margins of the two valves together; this pit is therefore termed the impression of the anterior adductor muscle. In the posterior region is a similar depression due to the attachment of the posterior adductor muscle. Just behind the ventral end of the anterior adductor impression is a smaller pit, where is inserted a muscle by whose action the animal can move backwards or, if the shell be fixed, draw the foot forwards. As a matter of fact, the former movement is the normal, but the latter has served to give the name of "protractor of the foot" to this muscle. A similar inverted view of the fixed and free ends has unfortunately influenced the names given to all the muscles concerned with the locomotion of these animals. Confluent with the dorsal part of the anterior adductor impression is the mark of one of the muscles which pull the shell forward (the anterior retractor of the foot); and just dorsal and anterior to the posterior adductor impression is the scar of the other (posterior retractor of the foot) employed for the same purpose. Towards all these impressions there lead from the region of the umbo faint tracks marking the path along which the several muscles have shifted as the shell has increased in size. From the anterior to the posterior adductor impression there runs, parallel with the margin of the shell and at a slight distance from it, the "pallial line." This is caused by the insertion of numerous muscle fibres (pallial muscles) lying in the mantle; their use will be explained later. Besides these larger there are two groups of smaller impressions in the dorsal region, one near the anterior and the other near the posterior end of the ligament. The small muscles which cause these marks run down into the mantle and pull the shell in a ventral direction. If the shell be broken and the fractured edge examined it will be seen, even with the unaided eye, to be composed of three layers.

The outside layer alone is coloured; it is of horny matter (conchiolin), and is termed the periostracum ; the middle and innermost layers are both white, in consequence of the abundance of calcareous matter which they contain, but have a different "grain." The middle layer is made up of a number of calcareous prisms, hence it is known as the "prismatic layer," but the innermost is of alternating sheets of pure conchiolin and of calcified conchiolin. This last arrangement produces the characteristic iridescence of the innermost layer, which is therefore known as the "mother-of-pearl" or "nacreous" layer. The periostracum is formed only at the margin of the mantle, and if injured elsewhere cannot be repaired; along the margin, where freshly formed, it exists as the sole layer, and is quite flexible in the absence of all calcareous "backing." The nacreous layer, on the other hand, is continuously formed by the whole surface of the mantle, and if the shell be cracked or injured in any way it is this layer that is used to repair the rent. Pearls, which are often found, though of inferior quality, in mussels are made of this material. The animal may be killed instantly by plunging into boiling water. In order to see the soft parts of the animal it is necessary to force open the shell-valves. This may be done by inserting a blunt flat instrument, *e.g.* the handle of a scalpel or of a pair of forceps, edgeways between the valves, and then turning it through a right angle. The valves will thus be thrust apart sufficiently far to allow instruments to be inserted. The next step is to separate one valve from the soft mantle-flap which lines and is attached to it. This should be done by passing the handle of another scalpel between the two structures and running it all round the margin so as to sever the pallial muscles. The handle should then be used to ascertain the position of the two adductor muscles, which should then be cut through as close to the shell as possible with the scalpel blade. The valve will then spring open and may be detached. It is then an easy matter to remove the second valve in the same manner. The soft animal thus extracted should be placed in a dish of water for examination, and may possibly require to be washed under the tap to remove the slime if this be abundant.

Covering the whole of the outside is the mantle, to which reference has already been made. It is really a pair of thin folds of the dorsal surface hanging down to right and left, and through it can be seen many of the other organs. The ventral edges of the mantle are thickened, and opposite the posterior adductor muscle they are united for a short distance. Below this region of fusion each edge is pigmented, and bends away from its fellow twice in quick succession. Thus at the posterior end of the animal two slits are left between the right and left mantle-flaps. The lower slit is provided with a fringe of short tentacles, and through it during life a stream of water is constantly wafted in within the space between the mantle-flaps. After circulating through this space along a definite course the water passes out through the dorsal slit. The two slits are respectively known as the inhalant and exhalant siphons. The tentacles bordering the inhalant siphon test the quality of the entering water. It will thus be seen that all supplies of food and of oxygen enter the shell at the hinder end; as indeed is inevitable, seeing that the front end is deeply plunged in the mud. These water currents can be made evident in the aquarium specimen by placing some carmine or other coloured but innocuous liquid near the inhalant siphon with the aid of a pipette. Care must be taken not to shake the aquarium, and still more not to touch the animal itself, as the valves will be shut and all action cease for some time. On turning the mantle-fold of one side back the gills, "foot" and labial palps are exposed. The gills are brown in colour, two on each side of the body, and marked with fine horizontal and vertical lines. Each is composed of two sheets which enclose a long narrow cavity between them. In section the cavity is V-shaped, open dorsally but closed ventrally. The two sheets are, however, united to one another at frequent intervals, so that the enclosed space is divided into a number of compartments. In development each gill-plate is made up of a large number of separate V-shaped filaments, which produce the finer vertical lines; these filaments are united to one another by horizontal lines of fusion—causing the horizontal stripes; and at intervals the two limbs of the same V are united by transverse vertical fusions—causing the more pronounced vertical stripes. Between these several fusions there are left spaces which are the remains of the clefts originally existing uninterruptedly between the separate filaments. Thus the whole gill-plate of the adult is a closely knit trellis. If examined under the microscope the entire surface of the gill is seen to be covered with thousands of minute and vibrating hair-like processes, termed cilia; these also clothe the inner surface of the mantle, "foot," labial palps, and indeed the entire body. The action of the cilia is to waft currents of water in at the inhalant siphon forwards into the space ventral to the gill-plates, through the lattice-work of the gills into the gill-cavity, then dorsalwards into the space above the gills, and lastly backwards and out of the shell at the exhalant siphon. The filaments of the gills are hollow structures, and contain blood which is supplied with oxygen and gives out carbon dioxide gas through the thin, ciliated walls of the filaments as it courses through them. Respiration is also carried on through the surface of the mantle-folds, and probably in some degree through the skin of the "foot." The orange-yellow colour which pervades the whole animal is due to a pigment analogous to the hæmoglobin of our own blood, which has a marked affinity for oxygen.

The attachments of the gill-sheets should be noticed, for they effect the separation of the inward and the outward current of water. The outer sheet of the external gill is united along the entire length of its dorsal edge to the mantle-fold; its inner sheet is similarly united to the dorsal edge of the outer sheet of the internal gill. The inner sheet of the internal gill is attached in its anterior region to the visceral portion of the "foot"; in its mid region it is free from all connections, and may be reflected so as to expose the dark purplish-brown surface of the excretory organ (nephridium); but in the posterior region the dorsal border of this sheet is fused with its fellow of the opposite side. Thus a transverse section through the gills, taken behind the "foot," has the appearance of two W's joined together (WW), the two outside strokes being joined at their summits to the right and left mantle-lobes respectively. The inflowing currents travel ventral to (below) the various parts of the W's; the outflowing dorsal to (above) them. A blunt probe, *e.g.* a knitting needle or wax taper, can be passed backwards along the exhalant passage from the point where the two inner sheets first unite, and dorsal of their union, and will appear posteriorly at the exhalant siphon.

The "foot" is the large, orange, tongue-like organ lying between the gills of the right and left sides. Its dorsal part is softer than the ventral, and contains the reproductive glands and large portions of the digestive system. The ventral part is, when contracted, hard and very muscular. From the dorsal posterior angle there passes backwards a strong thong of muscle, whose fibres spread out fanwise over the "foot," to be inserted into the shell and there cause the impression known as that of the posterior "retractor muscle of the foot." The other muscles which find attachment to the shell lie in the anterior dorsal region of the foot, and can be recognised by their fan-like radiating fibres; their ends, cut in opening the shell, are visible behind the anterior adductor muscle. The ventral, muscular portion of the foot is capable of being greatly distended, so as to project like a blunt axe-head between and in front of the two valves. The distension is brought about by the pressure of blood within the "foot," there being a valvular arrangement whereby blood is prevented from flowing out of it, in spite of the fact that the heart continues to force blood into the pedal vessels and spaces. Thus the whole organ becomes turgid and relatively firm, though flexible. When crawling along the mussel slowly thrusts forward the swollen "foot" into the mud, perhaps as much as 3 or 4 inches. There is thus made in the bottom a furrow against whose sides a firm hold is obtained by mere pressure. When the "foot" is fully extended its tip swells so as to press harder against the sides of the furrow; the valves are drawn forcibly together so as to clip the upper part of the foot and

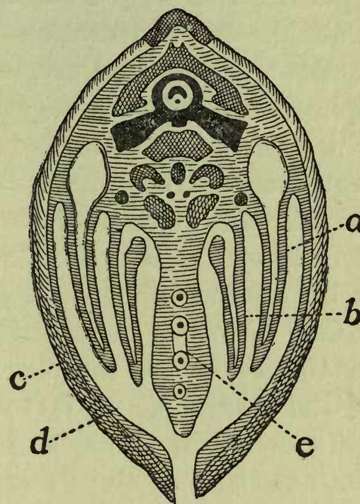

FIG. 35.—Diagram of section through mussel. *a*, outer gill; *b*, inner gill; *c*, shell; *d*, mantle; *e*, foot with cut ends of coils of intestine.

prevent either the shell from slipping down over it or the foot itself from being drawn back into the shell ; then with a convulsive heave the shell rides forward on the foot, and finally is pulled a little downwards as the adductor muscles relax and the valves gape apart. At the end of each "step," although the valves separate, the free edges of the mantle-folds remain in contact, probably by contraction of the pallial muscles. There then results a diminished pressure inside the shell, and the protruding siphons are crushed together by the excess of outside pressure, which perhaps thrusts the shell down into the mud. The forward movement of the shell (*i.e.* the whole animal) is brought about by the contraction of the so-called retractors of the foot. As already stated, it is the "foot" which is fixed, the shell movable. If by chance the animal gets into a "tight place" between the stones or other obstructions it is able to crawl out backwards by the use of the muscles which draw back the shell (protractors of the "foot"). It is to be noted that locomotion is effected by a series of steps, and not by the steady gliding movement characteristic of slugs and snails. The rate of movement is very slow—about a mile a year. The withdrawal of the "foot" is accomplished by the contraction of the numerous muscle fibres in its ventral region, accompanied by the simultaneous release of the valve which dams up the blood within ; it is possible that the "retractors" may assist in pulling it back within the shell. The furrows made by mussels are often plainly visible along the bottom of still waters. The labial palps lie on the sides of the foot in its anterior dorsal region ; in appearance they rather resemble the gills, but are yellow rather than brown. There are two of these organs on each side ; they are triangular in shape, and those of one side are united dorsally so as to enclose a narrow gutter open ventrally. The gutters lead into the mouth just below the anterior adductor muscle. The labial palps are richly ciliated, and appear to produce a special slime for the purpose of catching the microscopic vegetable and animal organisms contained in the water brought in through the inhalant siphon, for the top of the inverted groove is usually occupied by a band of slime heavily charged with organic matter. The food is thus led into the mouth and driven along the alimentary canal by cilia. The anus is situated on a conspicuous spout a little anterior to the exhalant siphon. The position of the excretory organs (nephridia) has already been mentioned. Their external openings lie, one on each side, just anterior to the free dorsal edge of the inner sheet of the internal gill. The aperture is very small, but has yellow, rather swollen lips by which it may be distinguished on the otherwise dark external nephridial surface. The internal openings of the two nephridia are in the ventral anterior region of the space surrounding the heart (pericardium).

The heart itself lies inside the clear transparent walls of the body, a little way in front of the posterior adductor muscle and in the dorsal region. Its central part is yellowish and muscular, and appears to be pierced by the last portion of the intestine; this part, the ventricle, is the force-pump which drives the blood all through the body. On each side of the ventricle is a very thin-walled, triangular auricle, the apex being attached to the ventricle. The auricles receive blood from the large veins which return the blood from the body, and pass it on to the ventricle. If a living animal be removed from its shell the beating of the heart can be seen, and will continue for many hours. The rate of the beat is about five per minute, but is very variable.

Mussels have but few sense organs. They possess no eyes, but the tentacles which surround the inhalant siphon can appreciate the difference between light and darkness; they are also exceedingly sensitive to touch, and to the quality of the water, which they in some way taste. The surface of the foot is also sensitive to light, but no special optic organs have been discovered.

Reproduction and Life-History.—The sexes of mussels are separate, but there is no external distinction between the males and females. The genital glands in either case lie in the dorsal part of the "foot," and their openings are close to those of the nephridia, being slightly ventral and posterior to them, but very difficult to detect. The spawning season is in May and June with *Unio*, but later, extending even into September, with

Anodonta. The eggs of the female pass from the genital opening backward to the exhalant siphon, but, instead of leaving the shell, they then are driven forward into the cavities of the external gills. This forward movement is probably achieved by a sort of gulp effected by the sudden relaxation of the adductor muscles, while the whole gape of the valves is blocked by the mantle, except at the siphons, where there consequently results a violent inrush of water. The eggs are fertilised while in the external gills, the sperms from the males being conveyed thither by the currents of water, though it should be stated that at the spawning season the animals congregate in the shallower water. The production of eggs continues for about ten days, and during that time about half a million eggs pass to the external gills. There they undergo their development within their egg-shells, nourished at first upon the yolk contained, but subsequently by a nutritive slime discharged by the gill itself. At one period the embryo is furnished with cilia, and slowly swims round and round within the egg-shell. This ciliated stage (veliger) is a heritage from the days when the ancestors of *Anodonta* lived in the sea. Many marine molluscs emerge from the egg-shell at this stage and, swimming in the open sea, become spread out over far wider areas than could be the case if their powers of dispersal were confined to the adult stage, which is often stationary. But now that *Anodonta* lives in fresh water, freedom of the ciliated young would be fraught with the peril of being washed down stream and eventually into salt water, which would be fatal. Hence we find, as so often in freshwater animals, that the young are retained within the shelter of the parent until a far later period, and gain dispersal by other less risky methods.

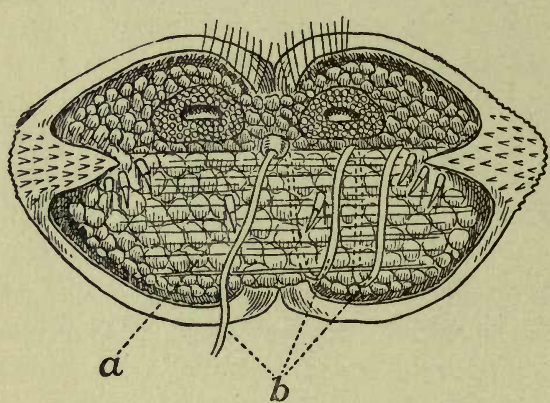

FIG. 36.—Ventral view of glochidium. *a*, adductor muscle showing through mantle ; *b*, byssus.

Eventually the young animal arrives at the stage known as the "glochidium." It now possesses a bivalve shell, furnished with remarkable and movable teeth at the ventral extremity of each valve, and with a single adductor muscle by which the valves can be forcibly drawn together. The shell is lined by a mantle on which are peculiar sensory organs ; and round the adductor muscle is wound a sticky thread, the byssus, whose free end passes out some distance beyond the shell margin. At this stage, which may be found during February, March and April, the animal escapes from the egg-shell, but is still retained in the parental gills until the water in the neighbourhood is disturbed by some passing fish, such as a stickleback, and possibly by tadpoles. The parent then discharges the glochidia through the exhalant siphon in long granular looking cords held together by the entangled byssi. Sticklebacks take a lively interest in the masses of glochidia, and make frequent dashes at them as though to devour them. This, however, they appear not to do, but rather spit them out in disgust. Meanwhile the glochidia, thanks to their special sensory organs, become aware of the presence of the fish, and maintain a rapid snapping to and fro of their valves. Their sticky byssi have become attached to the fins and tail of many of the sticklebacks, and the fish swim away, trailing behind them strings of glochidia. Sooner or later many of the glochidia succeed in grasping a piece of the fish's skin between the shell-teeth, and, having accomplished this, they never loose their hold. The irritation set up in the skin of the stickleback causes a blister to form around the glochidium, further securing it from falling off. For the next three months the glochidium lives as an external parasite upon the fish, nourished by the fluid which fills the cavity of the blister. During this time profound changes take place in the tissues of the parasite, resulting in the disappearance of the byssus, whose work

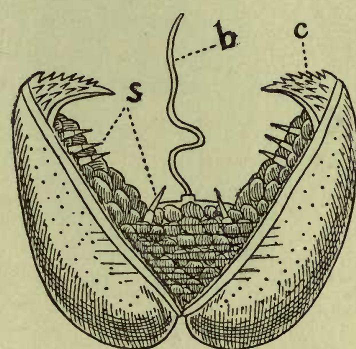

FIG. 37.—Posterior view of glochidium. *b*, byssus ; *c*, shell teeth ; *s*, sensory organs.

is ended, the establishment of two adductor muscles, of the alimentary canal, of the beginnings of the gills and other organs, and eventually of the permanent shell. The last is formed underneath the glochidial shell, and is at first quite transparent. These changes accomplished, the animal drops off the fish, and begins an independent life as a very small mussel.

Thus *Anodonta* secures a wide dispersal, despite the sacrifice of the free-swimming, ciliated (veliger) stage, by calling to its aid an active, strong-swimming creature that is well able to make headway against natural currents of water and avoid being carried out to sea. It is not known whether glochidia can survive immersion in salt water when attached to fishes which go down to and return again from the sea. When attached to tadpoles they usually, perhaps always, perish.

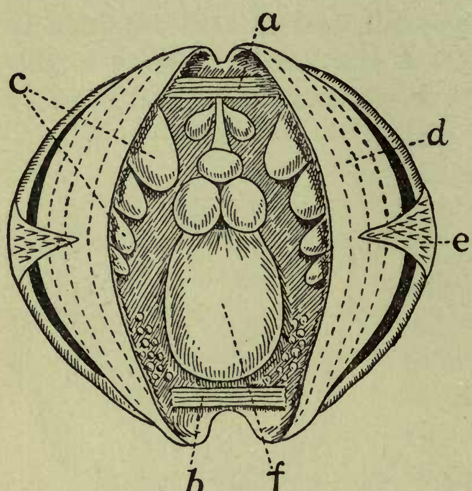

FIG. 38.—Ventral view of young mussel shortly after the commencement of free life. *a*, posterior adductor muscle ; *b*, anterior adductor muscle ; *c*, gill filaments ; *d*, permanent shell ; *e*, teeth of glochidial shell ; *f*, foot.

In Central Europe, but not in these islands, there is a curious exchange of compliments between the mussels and a small carp-like fish, the "bitterling" (*Rhodeus amarus*), to which the glochidia there become fastened. The female bitterling has at the spawning season a very long ovipositor, which she insinuates between the gaping valves of the mussel shell into the gill-cavities and there deposits her eggs. The young bitterlings undergo their early development under the protection of the mussel, though apparently not at her expense in any way, and leave their host when they have attained a length of about 1 cm.

Oysters, cockles, edible (marine) mussels, clams, and all bivalves belong to the same division of molluscs as do the freshwater mussels. The division is known as the Lamellibranchs (*lamella* = sheet ; *branchia* = gill), or sometimes as Pelecypods (Greek, *pĕlĕkūs* = axe ; *pous* = foot).

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THE AQUARIUM

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CHAPTER X

The Principle of the Aquarium.—As a considerable number of the plants and animals which the teacher is likely to use for the giving of lessons are aquatic in habit, and as many can only be obtained on special excursions, the idea of keeping some of these in captivity readily presents itself. In this way not only are the specimens at hand when required, but also their habits can be studied in an amount of detail which is impossible in a state of nature. It should, however, be noted that an aquarium in the strict sense means something more than this. In theory at least it means the keeping together of plants and animals in such a way as to demonstrate their interdependence in nature. It was the proof of this interdependence which gave such an extraordinary impetus to aquarium-keeping some sixty years ago, and it is in itself so striking a generalisation that no course of nature study would be complete without some mention of it.

Some very simple preliminary experiments may prepare the way for its complete formulation. Take a handful of green seaweed from a shore pool, or some water-weed from a pond, and put it in a glass vessel with water, salt or fresh according to the plant, in the sunlight in a warm room. In a very short time small bubbles form over the surface of the weed, and these then coalesce, thus becoming larger, and rise through the water to escape at its surface. If, for example, a piece of green laver (*Ulva latissima*) be taken from a pool and tested in this way, the gas as it comes off will buoy up the weed, which then floats in the water near the surface, the rapid discharge of bubbles giving a beautiful effect. If the glass containing the weed be placed in the dark the discharge of gas will cease. Similarly, if the water be boiled for a considerable time, in order to drive out the contained air, and then, after being allowed to cool, poured into the vessel as gently as possible, to avoid aeration, no bubbles will appear when the weed is placed in it. This shows us that light is necessary for the evolution of the gas, and that it is only water containing air which allows the process to go on. If we add the contents of a bottle of soda-water to the vessel containing the weed the evolution of gas is more rapid. The gas which is contained in the soda-water, and which gives it its sparkle, is carbonic acid, and we thus reach the presumption that carbonic acid is the constituent of the air which the plant is utilising in forming the bubbles of gas.

The next point is to ascertain the nature of the gas given off by the green plant in sunlight. This may be done without any special apparatus, in the following way. Fill a shallow pie-dish with water and place it in the window. Then take a wide-mouthed bottle, place a small piece of weed in it, fill up with water, and cork carefully. The bottle should be filled to overflowing, and care taken to avoid more than a mere bubble of air being left in. Then invert the bottle in the pie-dish, removing the cork when the mouth is completely submerged. Place a weight on the upturned base of the bottle to prevent capsizing, and leave the whole in the sun for some days if necessary. As the bubbles rise they will displace the water, and the gas will thus accumulate at the base of the bottle. If the bottle is of no great size the water will soon be virtually all displaced. If it is not desired to wait so long as this the bottle, with the aid of a little dexterity, can be corked under water, without the admission of air, and if then suddenly inverted will contain part water and part gas, which latter has now, of course, risen to the top. Take a splinter of dry wood and light it. After it has burnt for a few minutes, blow it out, open the bottle quickly, and thrust the glowing end of the wood into it. The wood will burst again into flame, showing that the gas evolved by the green plant in sunshine is oxygen.

The next point is to provide a vessel filled with lime-water, made by pouring water on a little quicklime, and after a time pouring off the clear layers of fluid, leaving the undissolved residue behind. Take this clear fluid, and by means of a glass tube allow the pupils to breathe into it. It rapidly becomes turbid owing to the formation of carbonate of lime, due to the carbonic acid of the breath. We thus reach the conclusion that animals in breathing produce carbonic acid, while green plants in sunlight evolve oxygen. This is the basal principle of the aquarium, for if we succeed in stocking an aquarium with animals and plants in the right proportions, then as fast as the animals produce carbonic acid in the process of breathing, the plants will seize this and, breaking it up in their tissues, will give off the oxygen which the animals require, and thus there will be an eternal balance between the two. Further, while plants retain their waste within their bodies, or only get rid of it very slowly, animals, with rare exceptions, have special organs whose function it is to remove nitrogenous waste from the body and discharge it to the exterior. Now the nitrogenous waste of animals is one great source of food to plants. The protoplasm or living substance of plants consists of the same elements as that of animals, but whereas animals require solid food, such as, for instance, is furnished by plants, green plants, on the other hand, make a considerable part of their food from the carbonic acid of the air, which they build up into starch or sugar, and take in the remainder in the form of salts, dissolved in water. Theoretically, then, we could establish an aquarium containing animals and plants which would be in a permanent condition of equilibrium. The animals would eat the plants, they would pass out into the water nitrogenous and other waste products, and also carbonic acid. The plants would absorb the carbonic acid, would break it up, returning the oxygen to the water for the respiration of the animals, and building up the carbon which they had retained, with the elements of water, into starch. With this starch added to the nitrates and other substances absorbed from the water, they would build up new organic substance, and so reproduce fast enough to make up for the loss due to the amount of plant life consumed by the animals. Now this conception is a sufficiently striking one to make it worth while to keep going, for at least a time, a simple form of aquarium, containing some plants, some vegetarian animals such as pond-snails, and a few other forms of animal life, which shall require little or no attention beyond the adding of fresh water as the old evaporates in the warm room. One would like to drive home the fact that ultimately the whole round world swings round the green plant, that all flesh is grass, or, as it has been put by a modern, all fish is diatom. Without the green plant life would come to a standstill. It alone has the power of drawing fresh energy from sunlight, and it is upon that energy that all living things ultimately depend.

In practice, however, the state of perfect balance is excessively difficult to preserve within the limits of a practicable aquarium, and we must consider the difficulties which arise. To begin with the plants—what difficulties confront the aquarium keeper in regard to them ? We may say first that though they may suffer from lack of light and warmth, they never in captivity suffer from a lack of carbonic acid. Nor, in an ordinary aquarium, are they at all likely to suffer from a lack of nitrates and other necessary salts in the water. On the other hand, they are quite frequently poisoned by an excess of food substances, by the presence in the water of products of decomposition far in excess of the amount which they can absorb, or even tolerate. As to the animals, their untimely death in the aquarium may in the general case be ascribed to one of two causes — either to the presence of an excess of carbonic acid, combined with a paucity of oxygen, or to the presence in the water of products of decomposition to a poisonous extent. Of these the first is by far the most frequent. Take a little fish from a swift-running stream and put it into your collecting bottle. In a very few minutes, probably, especially if the bottle contains other animals, the fish will begin to gasp, it will rise to the surface in the attempt to get air there, it will show by its change of colour, and the paling of its gills, that it is suffering from oxygen starvation. Waste products or products of decomposition do not accumulate in lethal doses with such rapidity—the little fish suffers because there is too much carbonic acid and not enough oxygen. If the bottle is deep in proportion to its circumference even the addition of water-weed may not save the little creature, for the weed cannot produce oxygen fast enough for its requirements. It is clear, then, that in nature the purifying action of the plants is assisted by other agents. Watch the water tumbling over a waterfall, the waves dashing on the beach, the rapids in a streamlet, the rise and fall of the tide, and it will become clear to you that in nature water is for the most part in movement, and this movement, which means mingling with air, means the through oxygenation of the fluid apart from its plant inhabitants. You may say, however, that the still ditches may be full of animal life, that the stagnant ponds are often crowded, that the rain-water barrel even, or the neglected horse-trough, contains its quota. To which the reply is, that quite often the animals contained in these receptacles, though they live in the water, yet are true air-breathers, rising to the surface for the purpose of breathing. Again, the pond or ditch usually exposes a large surface of water in proportion to its bulk, its surface also is raised into ripples by the wind, and a considerable diffusion of oxygen takes place in this way. Many apparently stagnant ponds or ditches have also affluents or effluents, or both, which cause currents to flow through them and have an aerating effect.

In the sea the rise and fall of the tides is of great importance in purifying the water, and there is another factor of some importance, which also acts, though to a less degree, in fresh water. Everyone has heard of the coral reefs of warm climates, which are built up of carbonate of lime, and even in our seas the curious little seaweeds known as corallines contain much of this substance, and there are an enormous number of shell-forming molluscs and crustaceans. Think of the shells in a mussel-bed or an oyster-bed, or even of those of the periwinkles and whelks of the shore, and you will realise that in the sea the formation of carbonate of lime goes on with some rapidity. Now if a shell be taken, and a few drops of weak acid be poured upon it, a rapid effervescence of course takes place, and the test with lime-water shows that carbonic acid gas is being given off. It is then, under natural conditions, not only the green plants which remove the carbonic acid from the water; all shell-forming organisms are playing their part in the same process. In England great masses of limestone occur, which may build up hills and mountains, as in the Pennine Range. This limestone was formed at the bottom of the sea, and the carbonic acid which it contains was removed by shell-forming animals from the water. The same thing is true of the chalk of the South of England. Though such shell-forming animals do not, of course, produce oxygen like the green plants, yet they have a negatively purifying action in removing the carbonic acid. The point is that in nature the water is purified and aerated by agents which are not active in the aquarium, and that therefore the balance in the latter between the plants and animals can never be anything but precarious. The result is that in all large aquariums some mechanical agency is added to the purifying action of plants, or even substituted for this. In saltwater aquaria, for instance, sea water is pumped through the tanks containing the animals, and in freshwater aquaria water is introduced under pressure, so that in its rush it carries abundant oxygen with it. The conditions of the school aquarium prohibit any elaborate mechanism for aeration, but if it be possible, at least temporarily, to place the vessel beneath the drip of a tap, or even beneath the drip of a rainwater barrel in the open, the overflow being of course provided for, the more active aquatic animals, like fishes, which for the most part demand much oxygen, and will not tolerate stagnant water, can often be kept alive for some time. In the rare cases where abundance of water is available, and the somewhat troublesome business of arranging for an overflow possible, various ingenious arrangements of fountains have been suggested. For details of these reference should be made to the books mentioned at the end of this chapter. In the general case, however, the teacher who wishes to keep in captivity and observe a considerable variety of animals will do well to frankly face the necessity for the periodic renewal of the water of the aquarium, and therefore for the reduction of this to such a degree of simplicity as to make the renewal, combined with cleansing of the vessel and its contents, a relatively simple matter.

It may be said, indeed, that if the object is observation of habits, the simpler the aquarium the better. As to its form, a large pie-dish forms a capital receptacle for a few special forms, whether marine or fresh water. The glass bowls sold for keeping goldfish often suffer from the disadvantage of being relatively narrow at the top as compared with the base and the depth, whereas the ideal vessel should be wide at the top and shallow, so as to expose the water as fully as possible to the air. An earthenware milkpan has many advantages, and, like a pie-dish, is easy to obtain and keep clean. Both admit light from the top only, which is the natural condition, while the disadvantage of a glass aquarium is that it admits light all round, to an extent which is directly injurious to some forms of life. If a glass receptacle be used the direct rays of sunlight should never be allowed to pass through it, as the resultant rise of temperature of the water will at once destroy many forms of life. Indeed, for an aquarium containing animals as well as plants a north window should always be chosen.

If, however, something more ambitious than the homely receptacles named above is desired, an oblong or square tank may be bought or made. This may be made with all four sides glass and a wooden or metal base, or with only one side of glass and the others wood or metal. Slate has also been recommended, as well as potter's clay. In all cases a good rule is that the depth should not exceed a foot, both because the difficulties of aeration increase with depth, and because with a greater depth it is difficult to reach the bottom, which will be necessary for the removal of dead organisms, surplus food, and so on. Before beginning, the aquarium should be thoroughly cleansed; an odour of pitch from caulking, or the presence of a cement which has not completely set, may be fatal. After the cleansing process, the vessel should be filled with pure water, and left for a day or two, to ensure first that there is no leakage, and second that there are no injurious soluble substances in the interstices. In the simple forms of aquarium these precautions are unnecessary, and all that is necessary is to put the desired animals into the vessel with water and a handful of floating weed, or in the saltwater aquarium a piece of stone with seaweed attached. The tank will require more careful treatment, which will differ according as it is intended for freshwater or marine forms. In the former case the plants will be least chiefly flowering plants whose roots may require to be planted in sand, while in the latter case a more or less elaborate rockwork will require to be built up according to the taste of the owner.

The Freshwater Aquarium.—If we begin with the freshwater aquarium, the first thing is to obtain clean sand, taken from a river or stream by preference. Sea sand should be avoided, as it is difficult to remove all the salt, which would be fatal to the future inhabitants. The sand in any case should be very thoroughly washed, and spread over the bottom to the depth of an inch or two. The next point is to select water plants. Some of these, like the Canadian waterweed, will do quite well if a few branches are simply thrown into the water, others, like water-crowfoot, and some of the pondweeds, require to have their roots fixed in the sand. These should be taken up as carefully as possible, and then planted in the aquarium. After this is done sprinkle a layer of well-washed gravel on top of the sand, especially about the roots of the plants, to prevent these being disturbed when the water is poured in. It will be well also to have some larger stones, of irregular shape, so arranged that those animals which do not live always submerged can raise themselves temporarily above the surface of the water. This is especially necessary if aquatic larvæ, such as tadpoles or insect larvæ, are to be kept. The next point is to introduce the water as gently as possible. This may be done with a watering pot furnished with a fine rose, or by means of a bent-glass tube used as a siphon. The water should be perfectly clear as soon as the coarser particles have settled, and the whole should be left for some days, at any rate, before any animals are introduced, to make sure that all is going well. If the water of the locality is known to be specially hard, tap-water should not be used, but instead that taken from a clean rain-barrel. Many recommend this in any case as an essential for success, but it often happens that the only rain-water available is too foul to be utilised. In this case tap-water must be employed, but it should be noticed that very hard water is a poison to many freshwater animals.

After the tank containing its plants has been left for some days, and all is seen to be going well, the animals may be introduced. Great care should be taken not to add too many of these, and the habits of those chosen should be carefully considered. Do not, for instance, introduce any of the big carnivorous beetles into a tank already stocked with delicate forms of life. If possible the tank should be self-supporting, that is to say it should contain a proportion of larvæ and so forth which can be sacrificed to the appetite of the larger forms. If, however, it is thought necessary to feed any of the inhabitants specially, do this as sparingly as possible, and remove at once any unutilised particles.

The Marine Aquarium.—The marine aquarium is on the whole more interesting, and can be made to contain a greater variety of animals than the freshwater tank. On the other hand, it must always be difficult to manage except near the sea, for artificial seawater is not always satisfactory, and the maintenance of a constant specific gravity is not easy. Again, while variety can be added to the freshwater aquarium by the addition of newts, tadpoles, water-beetles, and even water-tortoises, animals which are air-breathers and therefore very tolerant of foul water, all the inhabitants of the saltwater tank are furnished with organs adapted for breathing air dissolved in water, even if some of them can tolerate a temporary removal from the water, and all must therefore have water of great purity, which is an additional difficulty.

In starting a saltwater aquarium, as in the first case, make sure that your tank is clean and sweet. A layer of washed sea-sand may then be placed at the bottom if desired, but as this is not required for plant roots, it is safer to substitute for it a layer of clean gravel, which is less apt to lodge decomposing particles. Then select some stones or pieces of rock covered with growing weed. Avoid the red weeds, which will not live in the light aquarium and in shallow water. Most of the brown weeds must also be rejected because of their size. The green forms, such as Ulva and Enteromorpha, are most suitable, and if no stone of suitable size can be found bearing them, a piece of rock with weed attached should be broken off with a geological hammer. Place these pieces of rock or stone at the bottom of the aquarium, where the weed will be permanently submerged, and build up other pieces into a loose rockery. The shore crab, and even some of the shore fishes, prefer to spend part of their time out of water, and are more tolerant of moist air than of foul water. The aquarium, further, should not be filled up to the brim, so that limpets and similar forms can crawl up out of the reach of the water, in order to imitate for themselves the ebb and flow of the tide. It need hardly be repeated that all stones placed in the tank should be thoroughly washed in seawater before being introduced. When the stones and gravel have been arranged, pour in the water gently as before, and leave it to settle. If it does not become perfectly clear, it must be thrown out and the washing process recommenced, for the majority of shore animals are very intolerant of muddy water.

If the aquarium is to be established at some distance from the sea, the difficulties are considerably greater, for the temptation is great to crowd the animals during the journey, and they will probably die during transit, or never completely recover. Success is only possible if the animals are placed, in very small numbers, in large jars of clean water—the big bottles used by confectioners for storing sweetmeats do well, and can be bought for a few pence each. In addition a considerable store of clean water should be taken, and as soon after arrival as possible the animals should be removed from their travelling jars, and placed in flat pans with clean water, till their permanent home is ready. In these vessels, as indeed in the aquarium tank, a mark should be made on the side to indicate the height of the water when first poured in. It evaporates with some rapidity in a warm room, and as this means increasing concentration of salt, river water should be periodically added to preserve the original density. Seaweeds, sea-anemones, some of the crustaceans, the molluscs and the Echinoderms are sometimes better sent in closed cases without sea water. The weeds, together with the stones to which they are attached, should simply be packed with refuse weed so that they will not jostle, while the animals should be wrapped in fresh wet weed, and placed loosely in a jar, taking care so to pack them as to prevent damage against the walls of the jar or case in transit.

Whatever care is taken with the marine aquarium established at a distance from the sea, there must always come a time when a fresh supply of water becomes imperatively necessary. If there is no means of obtaining this, the attempt may be made to manufacture artificial sea water, though this can never be so satisfactory as the natural product. Gosse's formula, which he used with considerable success, is as follows :—

Common tablesalt,	$3\frac{1}{2}$ ounces	Avoirdupois.
Epsom salts,	$\frac{1}{4}$ ounce	
Chloride of magnesium,	200 grains	Troy.
Chloride of potassium,	40 grains	

These salts should be placed in a jar, and about four quarts of river water added, until the density of the resultant fluid, as tested by a hydrometer, is just over 1026, pure water being taken as 1000. The cost of the salts named is small. After shaking the mixture up until all the salts are dissolved, the fluid should be filtered, and growing seaweed placed in it for a few days before it is used in the aquarium.

Before leaving the subject of the water, it may be well to note that there are not a few seaside places where the water on the shore is quite unsuitable for aquarium purposes, being much contaminated with mud. In these cases it may be necessary to take a boat and go out some distance before the crystal clearness which is desirable is obtainable. This is particularly necessary where an attempt is to be made to keep the more delicate forms of life.

In concluding this brief consideration of the aquarium it may be well to repeat that the keeping of such a tank as that described above, whether for freshwater or marine animals, can never be an easy matter ; much care and experience is required, and a very brief neglect may have disastrous results. On the other hand, the keeping of a few animals or plants in captivity for a time in a pie-dish, or similar receptacle, is not difficult, and from the teacher's point of view is often far more useful. Better have half a dozen dishes, each containing a small but flourishing colony of animals, than one ambitious tank where the high death-rate of the inhabitants is a constant heartbreak, and the survival of the fittest shows itself in a somewhat melancholy form. It must, however, be admitted, a really successful aquarium tank is a beautiful object, and may be said to be quite worth the trouble necessary to attain it for those who have the necessary leisure.

Those who wish for further information on the subject of aquarium-keeping should consult the following, among other works: Gosse's *Aquarium* (Second edition), London, 1856, a book which can never lose its historical interest; *The Aquarian Naturalist*, by Rymer Jones, London, 1858. Both of these refer to the marine aquarium only, but the Rev. J. G. Wood's little book, *The Fresh and Salt-Water Aquarium*, London, n.d., includes both, and in Furneaux's *Life in Ponds and Streams*, London, 1906, the freshwater aquarium is very fully considered.

CHAPTER XI

Plants for the Aquarium

1. **Algæ, marine and freshwater** — Although some of the mosses grow submerged, and also a few members of the fern alliance, yet in the general case it may be said that aquatic plants are either algæ or flowering plants. These two groups have, however, a very varying degree of importance, from the aquarium-keeper's point of view, in fresh and salt water. With the exception of Zostera, the plants available for the marine aquarium may be said to be algæ only, for the plants of salt marshes are not suitable for the ordinary saltwater tank. On the other hand, as in fresh water a considerable number of flowering plants are available, the freshwater algæ, with the exception perhaps of the interesting Chara and its allies, can be neglected. Their beauties in any case are not those that appeal to the unaided eye, and the flowering plants are much more interesting. We need, therefore, here only speak of Chara and of a few of the marine algæ.

A few words may first be said as to algæ in general. As a group they vary greatly in size. A vast number are microscopic, while others, especially the marine forms, reach sometimes a great size, and considerable external differentiation of form, although they are internally of great simplicity. Without stopping to give any exact account of their peculiarities, we may note that they do not, like higher plants, possess fibro-vascular bundles. This means that if we tear across, for example, a frond of bladder-wrack, we do not find those stringy threads, consisting of food-carrying tubes, which are to be found in a flowering plant or fern, as for example in a fern-rootstock, or in the stalk of a hyacinth. Again, although forms like bladder-wrack, for example, or the beautiful red Delesseria, so often cast up on the shore, or *Bryopsis plumosa*, may to some extent mimic in appearance a fern or a flowering plant with its leaves, stem, and roots, algæ do not possess true roots, leaves, or stems. The whole plant body is called a thallus, and when in the following pages we speak of the "roots," this is merely by analogy, for the fixing organs have neither the structure nor the function of true roots. Algæ reproduce by spores, which often possess the power of locomotion. It not infrequently happens when an aquarium is, by accident or design, well stocked with algæ, that these reproduce so rapidly that the water actually becomes turbid with the minute spores, and these settle on the sides so thickly as to form a slimy green scum. It is the habit of aquarium-keepers to call this scum "confervoid growth," because it is often due to the development of the spores of algæ belonging to the Confervoideæ. The expression has, however, only a generalised accuracy, for the effect may be produced by a variety of algæ. The cure, in both the fresh and salt water aquarium, is to keep vegetarian gasteropods (*i.e.* snails, periwinkles, etc.), who lick up the deposit with considerable rapidity. If this is not sufficient the tank should be emptied and carefully cleaned.

Again, it sometimes happens that specimens, plant or animal, taken from freshwater pools, are coated with a brownish deposit. This is due to the presence of a great number of the little brownish algæ called diatoms, which occur both in the sea and fresh water, and are sometimes extraordinarily abundant. They furnish the food supply of a large number of aquatic animals, and when not in excess are not objectionable. They are objects of great beauty under the microscope, as are also the Desmids, microscopic green algæ found in freshwater pools, especially on moors, but the microscopic forms of life are beyond our scope here.

Considering the marine macroscopic algæ first, we find that they group themselves into three great divisions, according to the colour, which corresponds here to certain peculiarities of structure. These groups are the Red, the Brown, and the Green Algæ. All three groups are necessarily confined to relatively shallow water, because all contain chlorophyll and must have sunlight. Of the three the red weeds extend into the deepest water, for which their colouring specially fits them, and they are therefore on the whole not well adapted for the aquarium.

The brown weeds are often large, and, being frequently exposed to the air at low tide, often produce a large amount of mucus which prevents them drying up, but renders them undesirable inhabitants for the aquarium. The aquarium-keeper is thus wise to confine his attention to the green weeds, which are also the best oxygen producers. In the excursions to the shore to find specimens, however, one would call attention to the bladders of the common bladder-wrack, and their use in enabling the plants to float up near the surface and so get the light, and also to the long stalks of oarweed (*Laminaria*), which have a similar function, in that they bring the long starch-forming fronds up to the surface. The red colour of the red weeds is an adaptation to enable these plants to catch the last rays of light in the misty depths in which they dwell.

The next point is to realise that, with rare exceptions, the seaweeds are inhabitants of the shore-zone, where the ebb and flow of the tide is strong—therefore while the algæ of stagnant freshwater ponds are often without fixing organs, and float at the surface, the seaweeds are fixed to rocks or stones. Free, floating fragments have been torn off, and are dying, or will shortly die. This is an important point to remember, for algæ decay rapidly, and are then apt to poison the water. Do not, therefore, put seaweed into your tank unless it is attached to a stone or fragment of rock.

FIG. 39.—A marine green alga (*Bryopsis plumosa*).

As to kinds, the most useful is the common Green Laver (*Ulva latissima*), also called sea-lettuce. This is bright green in colour, and forms a thin, waved, or curled membrane, from 6 inches to 14 inches long, and attached to the rock by a minute disc. Somewhat similar is the Purple Laver (Porphyra), which is of a purplish colour. Very useful also are the species of Enteromorpha, known as sea-grass, or mermaid's hair, which cover the shore rocks with their long, slender, grass-like fronds, sometimes branched and sometimes unbranched. Much prettier are the species of Cladophora, which are all copiously branched and bushy, often with very rigid branchlets. In the graceful little *Bryopsis plumosa*, which consists of a number of branches rising from a common base, each branchlet is delicately feathered, usually near its summit only, but sometimes nearly to the base. If it is desired to attempt to add a red alga for the sake of the colour, one of the best is perhaps *Phyllophora rubens*, a small form characterised by its fine red colour, and by the leafy lobes which it throws out at the extremity of its flattened branches. Further details in regard to the marine algæ will be found in Grattan's *British Marine Algæ* (London, n.d.).

Freshwater algæ are not uncommon; some forms grow freely on damp earth or float near the surface of ponds, but we need only notice Chara and its allies. These are the highest of the algæ, and mimic flowering plants in appearance. They occur in ditches and ponds, and are especially common in the Norfolk Broads. In *Chara fragilis* the plant reaches 12 inches in length, and is fixed into the mud by the so-called roots. The stem grows upright in the water, and bears whorls of slender leaf-like organs at the nodes. The whole plant is delicate and slender. Some species have a protective deposit of carbonate of lime on their surface, and some have a strong and disagreeable odour. On the leaves are borne the reproductive organs, the male being bright red, spherical and minute, while the female are larger and flask-shaped. They are at first reddish and afterwards become black, drop off the plant, and remains inert until the next spring,

FIG. 40.—A freshwater green alga (*Chara fragilis*). The dots on the whorled leaves are the reproductive organs.

when they develop into new plants. These interesting plants can be kept in an aquarium if the base is carefully inserted in sand or mud. The coated egg-cell is interesting, because it is common for both plants and animals in fresh water to pass the winter within a protective egg-case. In this way they escape the effects of frost, which may destroy the parents completely.

2. **Aquatic Flowering Plants.**—In marked contrast to the algæ the flowering plants to be found in ponds and streams have had a *terrestrial* ancestry. Whereas the algæ in their structure and methods of reproduction show that they have been descended from ancestors which always lived in water, the flowering plants show, both as regards structure and methods of reproduction, peculiarities which we can only explain on the hypothesis that their ancestors lived on dry land. Very little observation in the field will show further that there is an almost continuous transition between plants which can only live in wet places, through marsh plants, to those forms which are permanently submerged. It is only the latter with which the aquarium-keeper as such is, strictly speaking, concerned, for it is only plants some at least of whose leaves are submerged that will generate the desired bubbles of oxygen. In passing, however, one should notice the existence of such interesting marsh plants as pinguicula, sundew, red rattle, bog pimpernel, and so forth, which though they do not grow beneath the surface of the water, yet can only thrive in its vicinity. The next stage, as it were, is found in the duckweed (Lemna), which often forms a nearly continuous covering over ponds. Lemna is of no direct use as an oxygen-generator, for its starch-making organs float on the surface, but it is a useful aquarium plant none the less, for it affords food and shelter to not a few animals, and it also forms a covering over the surface of the water which gives a grateful shade to the animals at the bottom. Duckweed is a very simple plant, consisting of small leaf-like "fronds," really the stems, which float at the surface, and have slender roots hanging down from their under-surface into the water. They multiply by budding, or, more rarely, by very simple flowers. In autumn buds arise which sink to the bottom of the pond and start growth again in the spring. The

common form is *L. minor*; the larger ivy-leaved duckweed (*L. sulca*), with fronds like miniature ivy leaves, is less common in Britain.

The duckweed illustrates some interesting general points in regard to water plants. It will be noted first that it is not attached to any substratum. This is associated with the fact that it lives in stagnant water. Water plants living in running water are furnished with roots which attach them to the bottom, but these roots are often not well developed, and their sole function is often attachment, the water plant when completely submerged being usually capable of absorbing its food over its whole surface, so that the roots have not the same significance as in a land plant. Again, Lemna buds freely, and thus reproduces vegetatively. Water plants have nothing to fear from drought, can usually obtain abundant food, and we find that their vegetative growth is rapid, and they can frequently reproduce by separating buds or branches. Again, the fronds of Lemna float, and it will be found interesting to compare these little structures with the leaves of a big water-lily, for example, and to note that the mechanism for floating is almost everywhere the same in water plants. Note specially the flattened shape, the difficulty with which the floating organs are wetted, and so on. On the other hand, when the leaves are completely submerged, they tend to be either slender and grass-like, or much divided, as in water-crowfoot.

Another point is of importance in enabling us to recognise the species of a water plant. In some cases, as in the water-starwort (Callitriche) family and the Naiadaceæ, all the members of the family are aquatic. In these cases the adaptations to aquatic existence are very perfect. In other cases, one or a few members of a terrestrial family have taken to the water; examples are the water-crowfoot among buttercups, the water-violet among the primroses, the water-lobelia among the campanulas, and so on. In this case the adaptations to the aquatic life are much less perfect, and the structure of the leaves, and especially of the flowers, is of great assistance in identification. In naming water plants recourse should be had to a Flora, such as Bentham and Hooker's *British Flora*. The following account has been restricted to those likely to be encountered, or specially interesting and valuable inhabitants of the aquarium.

Included by Bentham and Hooker in the Naiadaceæ, but often placed in a separate family, are the pondweeds or Potamogetons, common forms found alike in ponds and lakes and in canals or slow-flowing streams. There are a large number of British species not easy to distinguish from one another. The common forms are useful plants for the aquarium. All have rootstocks, which for the most part require to be planted in soil at the bottom of the aquarium. The leaves are opposite or alternate, submerged or floating, usually ribbon-shaped with sheathing bases. The flowers are small, and are placed in sessile heads or spikes which protrude above the surface of the water. The most primitive form is *P. natans*, which is perhaps the commonest. It has leathery floating leaves and filamentous submerged ones. It dies down in winter to the rootstock. Curly pondweed (*P. crispus*, p. 91) has all the leaves submerged; they are narrow and waved at the margins. This form produces interesting winter buds with broad leaves. An attempt should be made to keep these through the winter, or to take them from the ponds in spring in order to note their unfolding. In perfoliate pond weed (*P. perfoliatus*) the

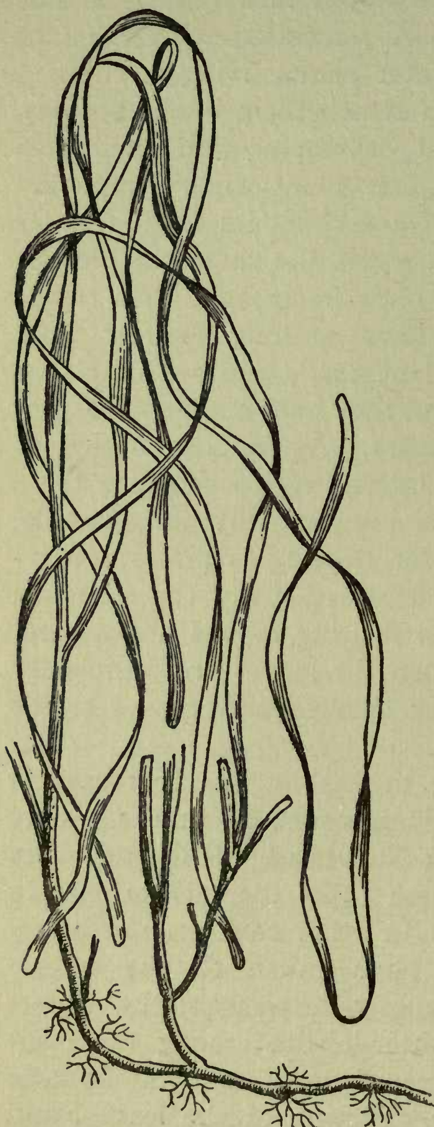
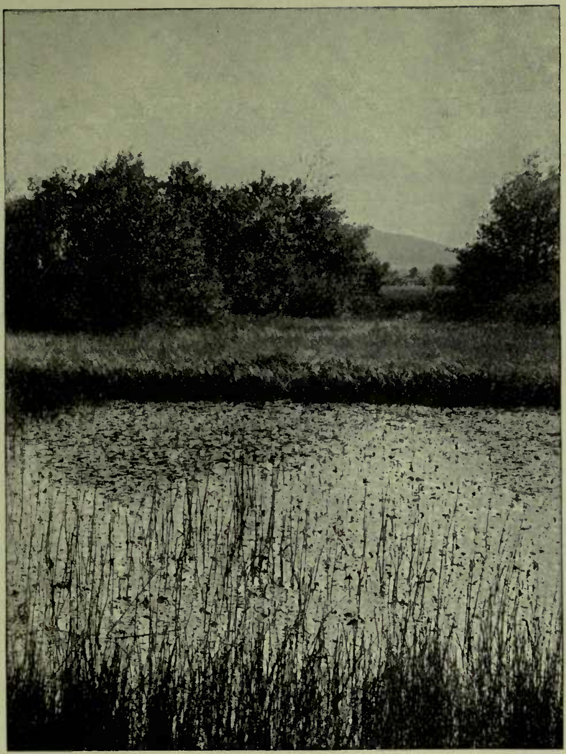


FIG. 41.—*Zostera marina*, showing the creeping rootstock, the fibrous roots, and the long slender leaves which float out in the water.



VIEW FROM SHORE OF LOCH NESS. In the foreground, water-horsetail; beyond, *Potamogeton natans*, with sedge in background. (Photo by George West.)

MARSH SCENE AT URQUHART BAY, looking towards Loch Ness. The vegetation in the centre consists of buckbean (Menyanthes) and *Alisma plantago*, with reeds and sedges. (Photo by George West.)

leaves are again all submerged and are opposite. They clasp the stem, which thus appears to pass through a single leaf.

Related to the pondweeds is Zostera, or grass-wrack, our only truly marine flowering plant, though others occur in salt marshes. Zostera is found at and below low tide-mark, and is important because of the number of beautiful animals which find shelter among its grass-like leaves. It grows on slightly sloping sandy or muddy shores, creeping along in the sand by means of its fleshy rootstock, rooting as it goes. It is very remarkable in that the whole process of flowering and seed-setting is conducted under the water, whereas most flowering plants flower and seed above the water (cf. pondweed). It is therefore one of the most fundamentally modified of the aquatic flowering plants. The leaves grow to a length of from one foot upwards, so that the plant is generally too large for an aquarium, but small specimens may be tried as a curiosity. The teacher should not fail to demonstrate the differences between this plant and the much more delicate and simpler sea-grass (Enteromorpha, cf. p. 84), which is an alga. The nerves or vascular bundles of the leaf will be found to be very distinct, and are numerous and parallel, as in grasses.

All the above are Monocotyledons, and to them may be added *Elodea*, or *Anacharis canadensis*, the Canadian waterweed, which since its introduction into this country has flourished in an extraordinary fashion, and is now to be found in almost every stream and canal. The plant is wholly submerged, and though normally attached by roots will thrive in the aquarium if a branch be simply thrown into the water. The colour is dark green, the leaves opposite or in whorls of three or four, sessile, oblong, and semi-transparent. The flowers are very insignificant, and only the female plants are known in Britain, so that reproduction is purely vegetative. It chiefly occurs by the breaking off of twigs. Accustomed to a colder climate than ours, the plant makes no special preparation for our winter; the ends of the branches with their clustered leaves survive the frost even if the rest of the branch dies.

Leaving the Monocotyledons, we find among the Dicotyledons a purely aquatic family in the Callitriches. The water-starwort

(Callitriche) is a pretty and common plant, which may be usefully added to the aquarium. It is very variable, sometimes creeping along in the mud, and at other times living entirely submerged. The leaves are opposite, the lower ones much narrower than those nearer the surface, while the terminal ones form a star at the summit of the stem. Several species have been recognised, but how far these are constant is not known. The simple green flowers occur in the axils of the leaves. No special arrangement is made for the winter, though the plant may sink down to the level of the mud. Related is the hornwort (Ceratophyllum), which is, however, less common. It floats freely in the water, and is thus like Anacharis a very useful inhabitant of a temporary aquarium, devoid of sand or mud at the bottom. The leaves are much divided, and completely submerged. They are arranged in whorls, and can be

FIG. 42.—Lesser bladderwort (*Utricularia minor*). The little swellings are the bladders or traps in which small aquatic animals are captured.

distinguished from those of Myriophyllum (see below) by the fact that they are not pinnately divided, but once or twice forked. The plant owes its name to the horny appearance of the old leaves.

A very interesting plant, belonging to the same family as the little Pinguicula, or butter wort of bogs, is the bladderwort (Utricularia). It is nowhere very common, but on the other hand it is widely distributed, and may be looked for in deep pools. Bentham and Hooker recognise three British species, differing chiefly in size. Bladderwort floats freely in the water, and thus forms an admirable aquarium plant. It has no true roots, and consists of long (from a few inches to a foot or more) floating root-like stems, furnished with numerous filamentous, much-divided leaves, which bear the characteristic bladders. In these bladders the plant captures small aquatic crustaceans—they are so arranged that entrance is easy but exit impossible, on the principle of the lobster-trap. The small organisms die and decay within the traps, and the bladderwort absorbs the products of decay, which serve to nourish it. The flowers are yellow, and are large and handsome—they are borne on shoots which project above the surface of the water, as in the vast majority of water plants. These plants thus reproduce out of the water as truly as does the water-tortoise (cf. p. 99), and this is one of the indications of a terrestrial ancestry. Like *Potamogeton crispus*, and a considerable number of other water plants, Utricularia forms special winter buds. These arise at the ends of the stems, and consist of a great number of leaves closely packed together and filled with reserve food material. The formation of these may be noticed in the autumn, when the bright green buds are conspicuous among the dying branches. They sink to the bottom of the pond, and spend the cold season in the mud. With the rise of temperature in spring they float up to the surface and grow out into the long trailing stems. The process can be perfectly well watched in an aquarium, and it is very interesting to collect the winter buds and watch the process of unfolding. Any dish of water will serve the purpose, and no more interesting form of simple aquarium can be imagined than a pie-dish containing Utricularia buds and tadpoles.

FIG. 43.—*Potamogeton crispus*, or curly pond-weed. A branch taken in autumn and showing the beginning of the formation of a winter bud at the extremity.

Another plant which hibernates in a similar fashion by means of winter buds is water-milfoil (Myriophyllum), a plant related to the curious marestail (Hippuris), which is a marsh form, the upper part projecting from the surface of the water. Both seem to be related to willow-herbs, but are much modified to fit them for the aquatic life. Water-milfoil creeps along in the mud by means of a rootstock, and sends up stems, which are usually completely submerged. These slender stems bear numerous whorled, pinnately divided leaves, with filamentous segments. The minute flowers are borne on spikes projecting at the surface. The plants occur especially in ditches, and should not be confused with Ceratophyllum (cf. p. 90).

FIG. 44.—Water milfoil (*Myriophyllum alternifolium*).

One must not forget also the water-crowfoot, a common little plant in ditches, streams, and shallow ponds, which has both submerged and floating leaves. The submerged leaves are much cut and divided, while the floating leaves are divided into three or six rounded lobes, resembling those of other buttercups. The flowers are white, and the plant is common and hardy.

One other aquatic plant may be named, the monocotyledon Vallisneria, which is not native, but is very commonly sold by dealers in aquatic plants and animals, and is frequently used in aquaria. It is a plant of great botanical interest, and is also very valuable as an oxygen-producer. Vallisneria has a perennial stem which grows embedded in the mud, and sends up into the water a number of slender grass-like leaves. It reproduces asexually by runners which root on the mud of the bottom. The plants are of two kinds, male and female. The female plants produce a single flower at the end of a long spirally coiled stalk. If the level of the water rises the spiral uncoils, so that the flower always floats at the surface, however deep the water. The male flowers are borne in spikes and are placed on short stalks. When ready to open they drop off and rise to the surface, where they float in among the female flowers and open to shed their fertilising dust. After the female flowers are fertilised the spiral of their stalk

SMALL LOCH NEAR LOCH NESS, covered with marsh plants. The chief plants are *Potamogeton natans*, *Menyanthes* and Water Polygonum.
(Photo by George West.)

PART OF LOCH KEMP, with floating pondweed (Photo by George West.)

contracts, and the flower is thus dragged down again to the bottom of the pond, where the ripening of the seed takes place. The adaptations to the aquatic life are thus very beautifully shown here.

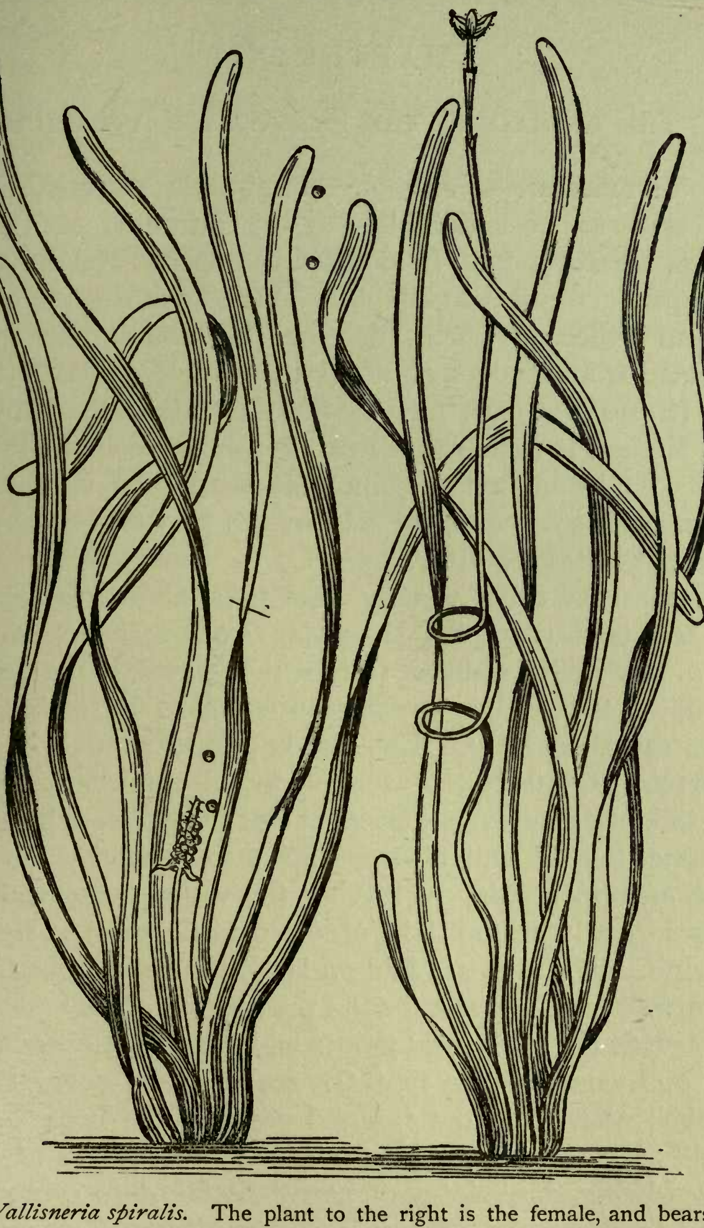


FIG. 45.—*Vallisneria spiralis.* The plant to the right is the female, and bears the seed-producing flower on its long stalk. The left-hand plant is male, and liberates the small pollen-bearing flowers which float up to the surface and there fertilise the female flowers.

CHAPTER XII

The Animals of the Freshwater Aquarium

1. **The Vertebrates.**—None of the aquatic mammals or birds can be said to be available for the purposes of the indoor aquarium, whatever may be done in the open. Nor have we any native aquatic reptiles available. There is, however, one European form which is worth mention, because it can sometimes be obtained from dealers at no great outlay. This is the pond-tortoise (*Emys europea*), now restricted to Southern and Middle Europe, though it occurs as a fossil in peat deposits in the east of England. It is much less commonly seen than its relative the Greek tortoise, so frequently sold in the streets, but is not very rare as a pet in this country.

The pond-tortoise usually measures about five inches in length, and is thus smaller than the Greek tortoise, from which it also differs in its webbed feet, which adapt it for an aquatic life. The shell is either spotted with yellow on a dark ground or shows radiating lines. The diet is purely animal, so that the pond-tortoise should not be kept in an aquarium containing fish or tadpoles, or even insects, unless these can be sacrificed to its appetite. It will also eat meat in captivity, and should be given an opportunity of leaving the water occasionally. The winter is normally passed in hibernation in the mud at the bottom of the pond. The eggs are laid on land, the female digging a hole in the earth near the pond for the purpose.

As regards the structural points which may be observed in the animal, one would notice first the scales which cover the bones of the shell as well as the exposed parts of the body. The tortoiseshell of commerce is obtained from the scales of a turtle, the scales being thin plates of horny tissue quite comparable in structure to the scales of a snake. The "shell" proper of the pond-tortoise is a bony structure, lying beneath the scales, and divided into an upper *carapace* and a lower *plastron*, the two being movably connected by ligament. From the arched carapace the head, tail, and limbs protrude. Though aquatic in its habits, the animal is a true air-breather, having a pair of lungs, and taking in air at the surface through its nostrils. It is, however, a cold-blooded creature, which only breathes slowly, and is capable if necessary of remaining for a prolonged period beneath the surface. Its structure, including the presence of lungs, shows that the aquatic habitat is secondary, and that its ancestors must have been terrestrial forms like the more familiar land tortoises. This is one of the striking distinctions which we shall find to exist between the denizens of the fresh and salt water aquaria. It is generally true that the inhabitants of the sea have been descended from *aquatic* ancestors. There are of course exceptions, such as the porpoises and dolphins among animals, and Zostera among plants, but still the statement is generally true. On the other hand, when we examine a freshwater pond we find that quite a number of the plants and animals give unmistakable signs of having been descended from *land* ancestors; the water-crowfoot, the water-spider, the water-beetles, the pond-tortoise are all examples of this. The proofs of this statement will appear in the course of our studies, but it may be noticed in the particular case of the pond-tortoise that lungs are not the best breathing organs for an aquatic animal, that though the pond-tortoise has webbed feet yet in their general structure the feet are the feet of a land animal, and that the fact that the animal comes on shore to breed shows us that its ancestors must have lived on land. In regard to the plants, note how the majority of aquatic flowering plants flower *above* the water.

One other point is important—as we have already mentioned, the pond-tortoise hibernates during the cold season. Now we shall find that the power of sleeping either through the cold season, or even through the hot season in freshwater animals of hot countries, is very common among freshwater animals. Not only does the mother tortoise sleep through the winter, but the eggs, which are furnished with hard shells, though laid in the late spring, may not hatch till the next spring. This means that the young tortoises sleep within their egg-case through the cold winter. Now some means of protecting the young or eggs through the cold of winter, or the drought of summer, is very common among freshwater animals. In both these respects the freshwater forms differ from their marine allies, which do not need to sleep, because the sea does not become so cold in winter as fresh water, and which do not need special protection for their young, because the sea does not dry up as ponds may do in summer, and except in high latitudes does not freeze. Life, generally speaking, is harder in fresh water than it is in the sea, and we shall find in consequence that there are fewer kinds of animals in the ponds and streams than in the sea. Whole groups like the Echinoderms and like the Cœlenterates are either not represented in fresh water or only represented by very few forms. On the other hand, while quite a considerable number of the higher plants, the descendants of land forms, have succeeded in going back to fresh water, very few of these higher forms indeed have succeeded in going back to the sea.

Though we have no native aquatic reptiles, we have several native aquatic Amphibia. Among these, first of all, for many reasons, must stand the frog. Every child at some period of its life should watch the development of the tadpole, and as the eggs are abundant and the little creatures perfectly hardy, if properly managed, there is no difficulty in his doing so.

In the spring, at a date which varies very greatly with the position of the place and its height above sea-level, the frogs may be found in the ponds, the male clasping the female with his fore limbs, the first finger having roughened pads which aid him to keep his hold. The eggs are fertilised by the male as soon as they are laid, and the females will lay eggs in captivity if a pair of the frogs are taken from a pond. Frogs form charming pets, and live well in captivity. In the case of the common frog (*Rana temporaria*) only a small amount of water should be put in the aquarium, and the animal should be given abundant opportunity of quitting the water. The water-frog of the Continent (*Rana esculenta*), found in a few parts of the east of England, is much more aquatic in its habits, never travelling far from ponds or ditches, while the common frog only seeks the water at the breeding season. The eggs of the two species may be readily distinguished by the fact that while those of the common frog float, those of the water-frog sink to the bottom of the pond. In both the eggs are numerous: 1000–2000 in the common frog; 5000–10,000, it is said, in the water-frog. In both cases each egg is surrounded by a sphere of jelly, which diminishes the risk of drying up. Those of the common frog are black and white, those of the water-frog grey and pale yellow. If spawn is collected, only a small amount should be taken, and it should be lifted carefully from the water so as not to damage the eggs. In the ponds the eggs of the common toad may also be found. These are laid in long strings, not masses, and the eggs being entirely black, the whole has the appearance of strands of wet wool (cf. vol. i. p 128).

The spawn should be placed with clean water in a dish; an ordinary pie-dish does perfectly, if no aquarium be available.

The rate of hatching varies with the temperature, but may be expected from a week to a fortnight after laying. The eggs do not all hatch at once, and as a general rule a considerable proportion do not hatch at all. It is therefore well to remove the little tadpoles as they hatch, by means of a pipette or watch-glass, to a clean dish. In this a small amount of waterweed should be placed, and unless the receptacle is large it is advisable to change the water frequently. As the tadpoles grow older they should be supplied with small pieces of meat or white of egg, but if kept in an aquarium with other forms of life they will probably find abundance of food for themselves. The water should not be allowed to get foul, and care should be taken to avoid overcrowding, which induces disease. The tadpoles are very intolerant of heat, and to leave a vessel containing them in full sunshine in a warm room is to court disaster. If these few simple rules are borne in mind there is no difficulty in rearing the animals through the metamorphosis, when the little frogs should be given their liberty.

The whole course of development is completed in about three months, and as in natural conditions the little frogs take the opportunity of wet weather to quit their native pools, a thunder-storm in the middle of summer is sometimes followed by the appearance of myriads of the little black creatures, still furnished with stumps of tails.

We may follow first in outline the course of the development and then point out its special interest. After hatching, the tiny tadpoles wriggle out of the mass of jelly, and swim to a piece of waterweed to which they attach themselves in rows by a sticky substance produced in the head region. At this stage they remain more or less motionless, only swimming a short distance from the weed if disturbed. After a few days, however, external gills develop, and as the internal store of food on which the little creature has been living is exhausted, it becomes more active, swimming about in search of food, which consists at this stage of waterweed. Growth is rapid; the little tadpole acquires a better developed tail, and the external gills disappear, being replaced by more efficient internal gills, like those of a fish. Though theoretically vegetarian, in captivity at least, the tadpoles will begin at an early stage to take animal food also—they will devour their dead brethren, and nibble clean the skeleton of a small animal put into the water. They often occur in ponds in enormous numbers, and their graceful evolutions in the water are well worth watching.

After about two months of larval life, the hind limbs begin to appear as buds. They increase in length, but for long are useless and helpless, trailing behind the tadpole as it swims, and being apparently incapable of being bent. At this stage the tadpole begins to come to the surface to gulp in a bubble of air, a fact which shows that the lungs are developing, and that the animal is ceasing to depend solely upon its gills. In captivity, especially if the water is allowed to get foul, the lungs seem to develop rapidly, and the animal depends upon them largely. On the other hand, if excessive care be taken to keep the water pure the lungs will develop slowly, and it is even possible to delay their appearance for months by stretching a fine net immediately below the surface of the water, and thus preventing the tadpoles from coming to the surface to breathe.

After the hind limbs have reached their full size, the fore limbs appear suddenly, usually in the course of a single night. Growth at such a rapid rate is of course impossible, and it will be noticed that after the appearance of the limbs the anterior part of the body is much thinner than before. This is because they develop within the shelter of the gill chamber, and burst through when full formed. After their appearance the tadpole becomes sluggish, often resting on a stone, half in and half out of the water. It no longer feeds, and diminishes in size, the diminution especially affecting the tail, which shrinks rapidly. It is this shrinking tail which is supplying the little creature with food, just as it was the internal store of yolk which supplied it with food during the first quiescent period. At the same time it loses its tadpole-like appearance, and becomes more and more frog-like, with a wide mouth, prominent instead of fish-like eyes, the beginnings of the adult coloration, and in general the attributes of the frog. As these changes approach completion and the food supply in the tail becomes exhausted, the animal recovers its activity, leaps on shore, and begins the free insect-eating life of the frog. The whole process is so remarkable that it is only its familiarity which prevents us from perceiving its extraordinary nature.

Let us consider next what all these changes mean. Contrasting the frog with the water-tortoise we may perceive that while the latter is a land animal which has gone back to the water, the former is a water animal which is beginning to fit itself for life on land. You will notice that while the tortoise leaves the water to breed, like the seal, the frog goes back to the pond for this process ; that while the frog (tadpole) has gills when it is young, the little tortoise develops within an egg-shell, where it has a special membrane (called the allantois) enabling it to breathe through the walls of its prison ; that while the tortoise has claws at the end of its toes like land animals in general, the frog has not. These are only a few of the characters which enable us to conclude that while the immediate ancestors of the pond-tortoise were certainly terrestrial, the immediate ancestors of the frog were certainly aquatic. Without stopping to consider here the question why land animals should want to adopt the aquatic life, we may consider the other point as to the meaning of the frog's voluntary abandonment of the element in which it was hatched, and for which it is in many respects best fitted.

We must note in the first instance that neither the tadpole nor the frog is a powerful swimmer, neither can make continued progress against a strong current. Therefore the animals are necessarily inhabitants of pools and not streams. Now, if we examine any region of pools and marshes in summer, we shall find that these show a strong tendency to dry up. Very often, indeed, one may see such ponds drying up before the tadpoles have had time to run through their development, and in this case we may see hundreds or thousands of the little creatures dying of drought. One view, then, of the metamorphosis of the tadpole is that it is an adaptation to obviate the risk of drought in summer. In Africa there is an interesting fish called Protopterus which inhabits marshy regions, where there is a similar danger of drought at certain periods. The true home of Protopterus, indeed, is the overflow regions of the tropical rivers, the regions which are lakes after the rains, and dry land or swamp in the dry season. Now Protopterus has solved its problem in this way: in the wet season it is a true fish, breathing by gills, swimming by paired fins, and having the circulation of a fish. When the dry period comes, it buries itself in the mud to sleep till the rains. But in its mud-case it could not breathe by its gills, and it has for use at this period a pair of lungs, by means of which it breathes. But the tadpole is in one respect worse off than Protopterus, for it has to provide for a cold period as well as for a period of drought. It could not sleep through both periods. Therefore as summer comes to its height it develops legs ending in feet and toes, it loses its gills, it becomes an air-breathing, terrestrial animal, only returning to its pond to sleep through the winter, and, as it becomes mature, to breed. From one point of view, then, the metamorphosis of the frog may be said to be an adaptation to obviate the danger of drought.

Once again, because of the existence of strange transitional fishes such as Protopterus in Africa, as well as for certain structural reasons, zoologists believe that the frog has been descended from a fish-like ancestor. The rocks tell us that we can look back to a period when the fishes were the highest living animals, and from some type of fish the first Amphibian arose. Now, it is to the zoologist a fact of great importance that in many points the tadpole is much nearer a fish than is a frog. Not only has it gills like a fish, but it has a heart like a fish, it has unpaired fins like a fish, and so on. When the young of an animal occupies the same environment as the presumed ancestors of that animal, we frequently find that it is much nearer in structure to this ancestor than the adult form. Many examples of this may be quoted. The young of the shore-crab (p. 145) lives in mid-water and not on the bottom, it is much more like the crab's ancestors than it is like a crab, the caterpillar is more like the supposed ancestors of insects than is the butterfly, and so on. This is what is called the Recapitulation Theory, the view that when the young of an animal is very unlike the adult, the ancestors of the adult are to be sought among the forms which resemble the young rather than among those which resemble the adult.

The Recapitulation Theory, also known as Von Baer's law, was formulated in the early days of the Evolution Theory, and it was regarded as being, what it undoubtedly is, an extraordinarily illuminating interpretation of facts which are otherwise a complete puzzle. It has been since pointed out, however,—a fact easy to observe for oneself,—that the recapitulation, the repetition of the ancestral characters, is never complete. The tadpole is fish-like, but it is not a fish—it has no scales, no paired fins, and so on. In other words, it possesses only those fish-like characters which are necessary to it during its short aquatic life. If the frog did not lay its eggs in water, as happens with some Amphibians, we should expect to find, what we do then find, that the fish-like characters would be reduced in number. In other words, they are present, not, as some of the early evolutionists seemed disposed to think, to give us information about the ancestors of the particular form, but because they are necessary to the life of the animal.

The development of the eggs of the toad does not differ very notably from that of the frogs. On the other hand, newt tadpoles differ in several respects, and should be reared also, if circumstances permit.

Neither the common newt (*Triton molge*) nor the larger and handsomer crested newt (*T. cristatus*) will thrive in water except at the breeding season, so that neither comes strictly within the range of this chapter, but a female of the common form, taken from a pond while breeding in spring, can be kept for a few weeks in order to obtain eggs. For this purpose the aquarium should be abundantly furnished with waterweed, and should contain stones or some other contrivance to permit the newt to quit the water at will. Fertilisation is internal, and the female will therefore lay fertile eggs for a considerable period after her separation from the male. The process of egg-laying is extremely interesting, and should be watched with care ; it is a much more elaborate process than in the case of the frogs. The sticky eggs are laid singly, and are carefully placed by the female on the leaves of water plants. The egg is first deposited on the leaf, and this is then folded by the hind feet, with the result that the egg is sheltered between the two halves of the leaf. The little tadpoles hatch in about a fortnight, and have external gills, at first simple and later branched, with processes in front of them by means of which the larva can attach itself to waterweed. The fore limbs are present in rudiment, and their development precedes in time to a considerable extent that of the hind feet. The most interesting point about the animals is, however, the development which the gills speedily attain. They become greatly branched, and as they are delicate, transparent organs they serve to demonstrate the circulation of the blood much better than the web of the frog's foot, the classical object of text-books. All that is necessary is to put a little tadpole in a watch-glass filled with clean water, place it under the low power of the microscope, and focus on the gills. If the experiment is prolonged, the water should be renewed or a fresh specimen taken from the aquarium at intervals. For class purposes this is infinitely to be preferred to the ordinary experiment, which necessitates keeping a frog in a constrained position, and is often conducted with needless cruelty, which is specially undesirable with a class of children.

The female of the common newt may be recognised by the fact that the festooned crest of the breeding male is absent, and that the under surface of the tail is orange instead of being red, with a blue band and dark spots, as in the male. The female crested newt has not the high serrated crest of her consort, and is again more soberly coloured. Female specimens taken in April, May, or June may generally be relied upon to spawn ; the exact period varies with the altitude, the weather, and the local climate.

After the Amphibia we come to the fishes, which as animals demanding for the most part well oxygenated water, are never easy to keep in confinement, where the water is always still and tends to stagnate. A few small and hardy forms may, however, be kept with special care.

Among these we may perhaps begin with the goldfish, a somewhat uninteresting but beautiful form which has been acclimatised to captivity by long generations of breeding. The goldfish is an artificial variety of a species of carp found native in China and Japan, where it has been domesticated for a long period. Accustomed to warmer waters than our climate supplies, the goldfish will only breed in warm ponds in hot-houses or similar places. As ordinarily kept in a glass bowl, it is a somewhat sluggish and uninteresting creature, which may, however, be usefully employed to demonstrate the points in regard to respiration in a fish. The water, as usual in the bony fish, is taken in by the terminal mouth and expelled beneath the gill-cover. As it passes out it washes the gills and purifies the blood contained in them. One would also notice the graceful movements effected by the tail fin, the main organ of locomotion, the paired fins being used in steering movements. All the organs of the body have been, as it were, shifted forwards, and the result is that the tail region is a solid mass of muscle, serving for locomotion. The contrast between the fins of the fish and the jointed limbs ending in fingers and toes found in the newt or frog, illustrates one of the distinctions between aquatic and terrestrial animals. As there are no lungs, the nostrils are not used for breathing purposes, and they are mere pits which do not open into the mouth cavity.

Much more interesting are the sticklebacks, alike from their habit of nest-building and their very remarkable tolerance of both fresh and salt water. The large and interesting fifteen-spined stickleback (*Gastrosteus spinachia*) is found in the sea or in brackish water (see p. 133), but the three-spined, four-spined, and nine-spined forms all occur in fresh water, though they may also extend into tidal pools. The fifteen-spined form is very different from its allies in appearance, but any stickleback may be recognised by the presence of a variable number of spines in front of the dorsal fin, by the more or less elongate and compressed body, and by the oblique mouth cleft. They are hardy forms, and can be kept in an aquarium with the usual precautions. The three freshwater forms (named *G. aculeatus*, *G. spinulosus*, and *G. pungitus* respectively) may be recognised by the number of the spines in front of the dorsal fin. The three-spined form is by far the commonest, and shows well the large plates at the sides of the body which are one of the characteristics of the genus. In the breeding season the male takes on bright colours, and constructs a nest in which the female lays the eggs. The nest is made of weeds and twigs, woven together by slimy threads. It is shaped like a tiny barrel, and has openings at each end to permit the passage of currents of water over the eggs. More than one female often lays her eggs in the same nest, and these are watched with the utmost zeal by the male, who ventilates them by fluttering his pectoral fins so as to cause a current of water. The females, on the other hand, appear perfectly indifferent to the fate of the eggs, and will even devour them. As the males are exceedingly pugnacious, only one should be kept in the tank at a time. The common stickleback varies in length from about two to four inches, and is thus about the same size as the other very common small freshwater fish, the minnow (*Leuciscus phoxinus*). The last-named is of the same family as the goldfish. It may be distinguished from the sticklebacks by its imbricating scales and the absence of spines. The lateral line, or row of sense organs at the side of the body which is characteristic of fish, is here incomplete. Eels are also hardy in captivity, and small specimens form admirable inhabitants of the aquarium, where their graceful movements are well worth watching. The little bull-head or miller's thumb (*Cottus gobio*), with its huge, unwieldy head, its gaping mouth, and its large eyes, may also be added to the aquarium, but its voracious appetite makes it a not very desirable acquisition. In general also it must be admitted that fish are not easy to keep alive for long in the aquarium as it is available in the schoolroom, and the attempt should not be made with forms captured in swift-running streams.

2. **The Invertebrates of the Freshwater Aquarium.**—Passing now to the invertebrates, we may begin with the MOLLUSCS, the highest of the series. Of the three classes of Molluscs, the highest, the cuttles, are purely marine, and the bivalves, as a general rule, are so difficult to keep alive for any length of time in captivity that they can hardly be attempted in the school aquarium. This leaves us with the Gasteropods, or Univalves, including some hardy and interesting animals which form useful inhabitants of the aquarium.

The available species of Gasteropods fall into two groups, whose differences are interesting. Without stopping to consider

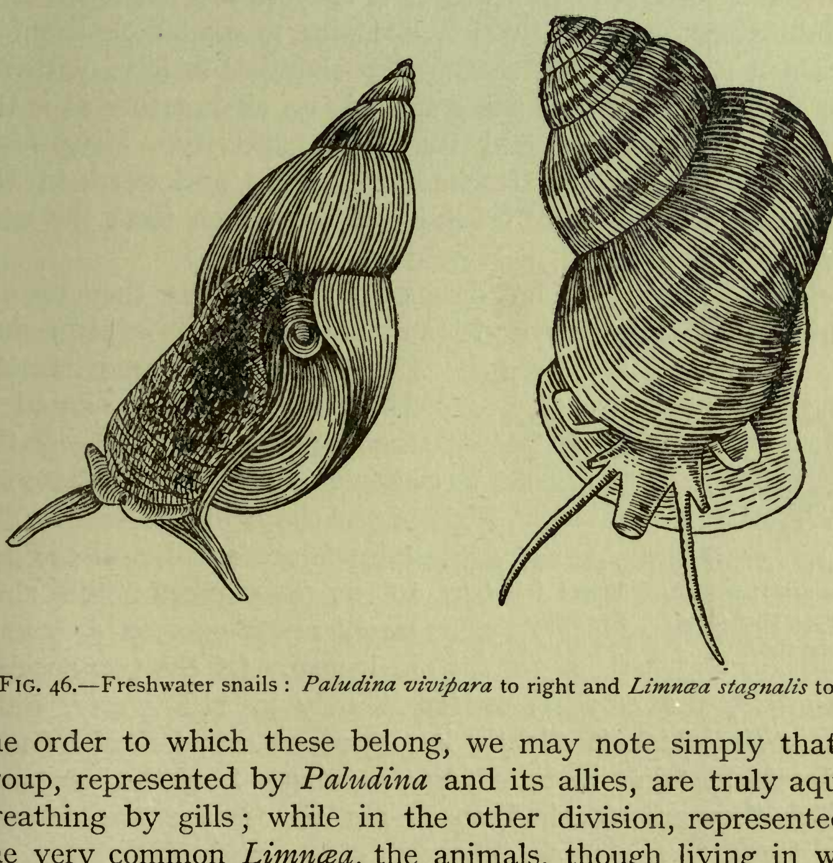


FIG. 46.—Freshwater snails : *Paludina vivipara* to right and *Limnæa stagnalis* to left.

the order to which these belong, we may note simply that one group, represented by *Paludina* and its allies, are truly aquatic, breathing by gills; while in the other division, represented by the very common *Limnæa*, the animals, though living in water, breathe by a pulmonary chamber, like a snail or a slug, and must therefore be regarded as terrestrial forms which have gone back to the aquatic life. We have already emphasised the frequency of this condition among freshwater plants and animals, and here, as always, the habit of breathing air, and not air dissolved in water, makes the animals much more tolerant of the special conditions of aquarium life than forms with gills.

A considerable number of species of *Limnæa* occur in British waters; the commonest as well as the largest is *L. stagnalis*, to be found in nearly every stagnant pool or ditch. The shell is thin, spirally coiled, conical in shape, and reaches a length of from 1½ to 2 inches. The animal is fond of taking advantage of the surface tension of the water and creeping shell downwards along the surface, with the under part of the muscular foot exposed. As it creeps in this way it is easy to see the opening of the pulmonary chamber, which occupies a similar position to that which it does in the snail. The chamber is filled with air at the surface, the animal being as truly an air-breather as is the garden-snail. Eggs are laid freely in captivity. They form little gelatinous masses attached to stones and weed, in the middle of which the little crystal globules which form the eggs proper are clearly seen.

Related to *Limnæa*, but less common in that they do not extend to the north of these islands, are the species of *Anchylus*, the so-called freshwater limpets. They are not nearly related to the limpets of the sea, and the name is given merely on account of the shape of the shell. The animals are small, and are apt to be overlooked; the shell rarely much exceeds a ¼ inch in length. Of the two species, *A. lacustris*, the smaller, is found only in still water, while *A. fluviatilis*, which is slightly larger, occurs in streams. Great care should be taken in detaching the animals from the substance to which they are attached, so as not to damage the delicate shell.

FIG. 47. — *Bithynia tentaculata*; notice the operculum closing the shell.

FIG. 48.—Freshwater limpet (*Anchylus fluviatilis*).

To the same family belong the members of the genus *Planorbis*, which have flat, spirally-coiled shells which have been compared in shape to a St. Catherine's wheel. The size varies considerably, the largest forms being about 1 inch in diameter, while the smallest are minute. Several species live well in captivity, if the aquarium contains a sufficient supply of vegetation for their needs, and they will breed there freely, provided the tank is not stocked with carnivorous insects or other forms likely to prey upon the young.

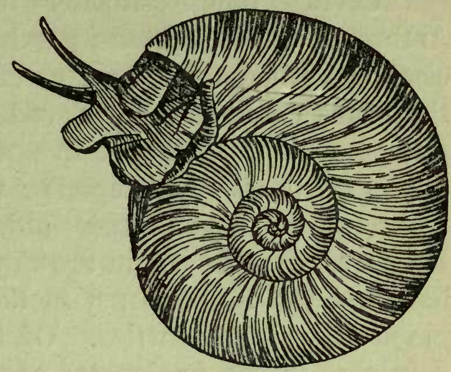


Fig. 49.—*Planorbis corneus.*

The Gasteropods breathing by gills may be represented in the aquarium by species of *Paludina* and *Bithynia*, both handsome and attractive genera, but both unfortunately only common in southern England; *Paludina*, indeed, does not seem to occur in Scotland and Ireland. The species of *Bithynia* have shells varying from $\frac{1}{4}$ to $\frac{1}{2}$ inch in length. The shell is spirally coiled, and conical, and when the animal withdraws into it it closes the aperture behind it by a plate, called the operculum, which just fits the mouth of the shell. The presence of this operculum is a distinction from forms like *Limnæa* and its allies, where no such structure occurs. In *B. tentaculatus*, the larger and commoner species, the shell has about six coils; the animal is to be looked for in slow-moving bodies of water, such as canals and ditches. In captivity it frequently lays eggs on the surface of the glass, and the process should be watched in detail. The eggs are laid in regular bands, the process being very leisurely. They have the usual rounded shape and are like little globes of jelly.

On the other hand, *Paludina* retains its eggs within the body till they hatch, and the tiny snails emerge from the body of the parent furnished with a shell resembling that of the adult in spite of its minute size. The adults are very snail-like, the shell being considerably over an inch in length, and nearly an inch in width. An operculum is present as in *Bithynia*. The commonest species is *P. vivipara* (see Fig. 46).

Leaving the freshwater molluscs, we come next to the Arthropods, or jointed-footed animals, in which the body is clothed with a thick coat or cuticle. This coat is so thick that the limbs could not be moved were it not for the joints or soft places, which permit of free movement. For our purposes we may regard the Arthropods as consisting of three classes,—the crabs, shrimps and their allies forming the CRUSTACEA, the INSECTS, some of whom are aquatic during at least part of their life, and the ARACHNIDS, including the spiders, mites and scorpions of warm countries. Of these the insects will largely predominate in the freshwater aquarium, for whereas the Crustacea furnish some of the most interesting inhabitants of the marine aquarium, there are but few which can be utilised in the freshwater tanks.

The most interesting of the freshwater Crustacea is undoubtedly the crayfish (*Astacus*), very common in parts of England. It is, however, a form naturally inhabiting swift-flowing streams, and therefore difficult to keep alive in captivity unless the tank has a more or less constant flow of water through it. As a schoolroom tank is not likely to fulfil this requirement we must leave the crayfish out of account.

The next two common Crustacea are hardy enough, but they are carrion feeders and not particularly attractive. It is a bad sign if they flourish well in an aquarium, for this means that the tank contains much decomposing vegetable and animal matter, which is not a condition favourable to the continued existence of other more interesting animals. These two animals are *Asellus aquaticus*, sometimes called the water-hog louse, and *Gammarus pulex*, often incorrectly called a freshwater shrimp. It is much nearer to the sandhoppers of the seashore than to the true shrimps. In Asellus the body is flattened from above downwards, and the animal closely resembles the wood-lice found beneath decaying wood, or in the dark corners of the greenhouse. It reaches a length of about ½ inch, and may be found creeping over the weeds at the bottom of ponds. The sessile eyes are a notable distinction from Crustacea like crayfishes, in which the eyes are mounted on stalks. As in wood-lice, breathing is effected by means of delicate outgrowths on the under surface of the abdomen, which are covered over by two protective plates. The abdomen is very small, and the legs are numerous ; if possible the mode of action of the breathing plates should be observed in the living animal, the way in which their covering plates are raised and lowered being interesting.

The freshwater shrimp is very common in fresh water, where it swims about actively by means of its numerous appendages. Its body is flattened from side to side, a marked point of distinction from *Asellus*.

Another group of Crustacea which are copiously represented in fresh water are the water-fleas, of great importance as part of the food of many of the larger animals. With the unaided eye, however, these are hardly more than specks, which swim through the water with a characteristic jerking movement. The water-fleas are often extraordinarily numerous in fresh water, so much so that a glassful of water may seem turbid owing to their abundance. A neglected aquarium will also sometimes swarm with them.

Far more numerous and interesting are the insects of fresh water. Some of these are permanently aquatic, alike as larvæ and adults. In this case, as for example in the water-beetles, the adults generally possess wings by means of which they may make their escape if the pool dries up, or may seek mates at a distance from their native pool. Others, like the larvæ of caddis-flies and may-flies, of gnats and of dragon-flies, are only aquatic when young, and leave the water at the time of the advent of the winged stage. In many of these cases the larvæ can very easily be reared up to the time of the metamorphosis, and every child should be given an opportunity of watching the changes of the commoner forms, just as of watching the progressive changes of the tadpole and its final conversion into a frog. As some of these larvæ are exceedingly voracious, it is in many cases advisable to rear the different kinds separately, and as many others form very acceptable food for fishes, etc., it is easily seen that the general aquarium is not the most suitable place for rearing the animals.

The number of aquatic insects is so large that some process of selection must necessarily be exercised. We shall consider here first a few which should be studied for the sake of observing the salient facts in regard to the metamorphosis of insects, and secondly a few permanently aquatic forms. Before beginning it may be well to point out that, since insects are terrestrial animals, furnished with a beautiful system of air-tubes (tracheal tubes), by means of which they breathe, all forms found in water, without exception, have had terrestrial ancestors, and show secondary modifications which fit them for the aquatic life.

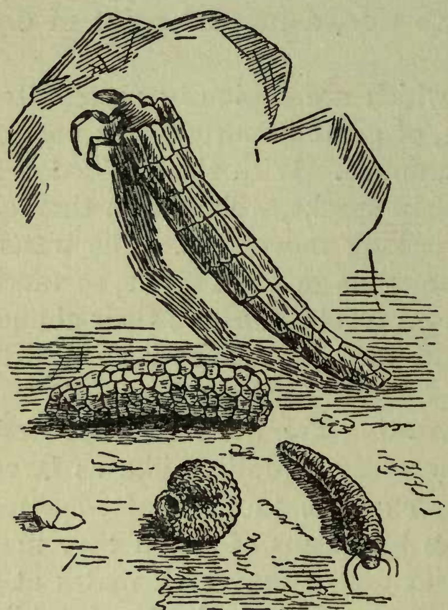
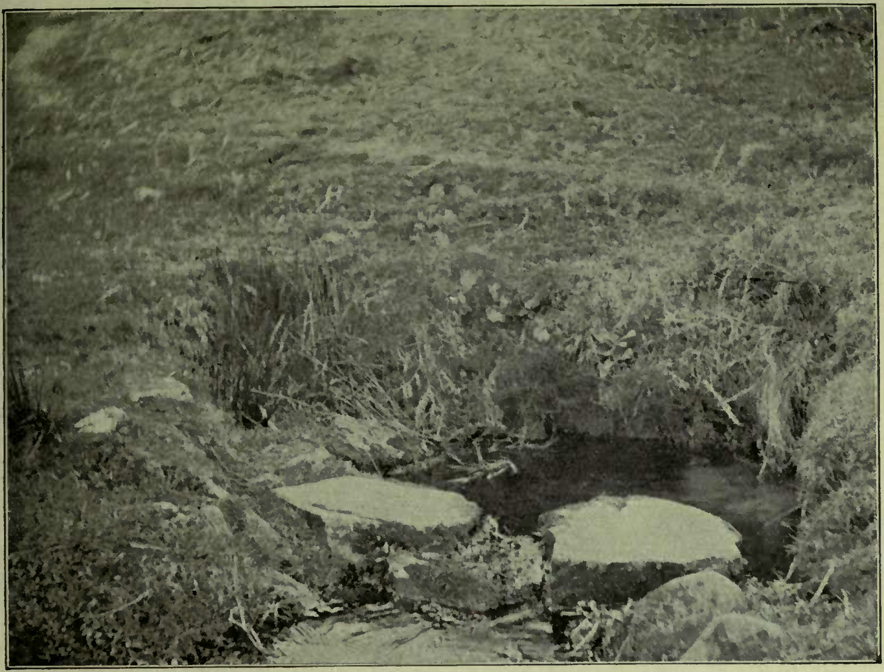


FIG. 50.—Caddis-worms, showing characteristic types of cases.

As examples of aquatic larvæ we shall consider caddis-worms, dragon-flylarvæ, and gnat larvæ. These are only a few examples of the numerous insect larvæ which pass their early life in water, but they are easy to rear and illustrate the essential points. We shall begin with the caddis-worms, as being forms easy to obtain and very interesting to watch.

There is no difficulty in finding caddis larvæ; any pond or stream in summer will show a number of curious cases, an inch or more in length, sometimes attached to stones, but oftenest free, constructed of pieces of aquatic plants, of sand particles, of shells, or of little stones. Take some of these home in the collecting bottle, and place them in a flat dish with plenty of water weed, taking care not to overcrowd the vessel. When the contained larvæ have recovered from the shock of transportation they will be observed to protrude from their cases the head of an insect, followed by the anterior part of a body bearing the three pairs of legs characteristic of insects. The larvæ move about rapidly, climbing over the water-plants with much dex-



A SPRING ON THE MOOR (Photo by L. Newbigin.)
Note the occurrence of aquatic vegetation round the spring.

A POOL CONTAINING CADDIS-WORMS (Photo by L. Newbigin.)
The plants at the margin are Luzula, primroses and ferns.

terity, in spite of the often heavy case which must be dragged behind them. Much as in the case of the hermit-crab (*q.v.*), to which the caddis show certain analogies, the part of the body which can be extruded is covered with a firm coat, while the remainder is soft and delicate. Again, much as the hermit is fixed to its borrowed shell by a strong hook in the posterior region, so the caddis is fixed to its case by two posterior hook-like processes. In both cases, therefore, a direct attempt to extract the creature leads to disaster. In the caddis, however, the tube is open at the posterior as well as at the anterior end, and fishermen have long since found that the insertion of a blade of grass into the posterior end will cause the larva to relax its hold and leave its tube. It will then speedily build a new one, and the process may be watched in detail. The above operation is not, however, really necessary in order to see the caddis build, for if they be put into a vessel containing any building material different from that abundant in the pond from which they came, they will be seized with a desire to replace the old material on their backs by the newer. The teacher who shows caddis to her class will, of course, also draw the attention of its members to its very charming description of their habits to be found in Kingsley's *Water-babies*.

For the teacher's purposes the specific names of the caddis are of very little importance, but for convenience of reference to systematic books it may be well to note that cases neatly constructed of tiny particles of sand, and having a conical and slightly curved shape, are due to the activity of *Sericostoma multiguttatum* ; those ornamented with short pieces of vegetation, or of fragments of stick, are inhabited by species of *Phyryganea* ; in *P. lunaris* the pieces are laid side by side running parallel to the long axis of the case. Very curious are the cases of the species of *Limnophilus*, which are often constructed of the shells of living molluscs, who may be seen vainly endeavouring to extricate themselves from their very constrained position. Other caddis again content themselves with the hollow stalk of an aquatic plant, or merely weave together any kind of débris. The most interesting forms are those whose cases are unattached, but as already mentioned some fasten their houses to stones.

These are as a general rule those inhabiting running as opposed to still water, and the teacher should not fail to point out the predominance of caddis cases among the rubbish found at the sides of streams after floods, and to emphasise the dangers to which the forms found in running water are subject. A very interesting case is that constructed by the stream-dwelling *Halesus auricollis*, which is made of vegetable matter, but is weighted at the lower end by a tiny pebble, or even fastened down if the current is very strong.

Very little observation will show that the particles of which the case is composed are woven together by a silky substance which is secreted by a gland which opens on the under surface of the head, and is quite similar to that which secretes the silk in a caterpillar. As the object of the case is to protect the lank soft body from possible enemies, such as fish, the caddis, whatever their natural tastes, will avail themselves of any building substance supplied to them. It is thus possible to make them build nests of beads, little fragments of brightly coloured minerals, or even transparent glass. In the last case the resultant tube allows the movements of the larva to be discerned through it, which is justifiable if a detailed study of habits is to be made; but otherwise the teacher will be well advised to limit herself to substances which occur naturally in the ponds and streams in which the caddis live.

The case is added to as the contained larva grows, and is always considerably larger than its inhabitant, so that not only can the caddis completely withdraw into its tube, but it can even turn in it and cut off the posterior end as this becomes too narrow for the abdomen. Larvæ ejected from their tubes, or which have been supplied with fragments of glass out of which a transparent tube can be manufactured, will show the interesting breathing organs. These consist of delicate filaments borne on the abdomen, which in the water have a feathery appearance. The filaments are abundantly supplied with branches of the tracheal system, which are so modified as to permit the larvæ to take advantage of the air dissolved in water. As the respiratory filaments lie permanently within the case they must be liable to suffer from the stagnation of the water, especially in the case of caddis found in still water. To remedy this the larva undulates its abdomen, and so causes a current of water to flow through the case, much as a crayfish causes a current of water to flow through its gill-chamber by movements of certain of its appendages. The movement in the case of the caddis, even when the animal is enveloped in an opaque tube, may be demonstrated by putting some fine particles into the water, when they will be stirred by the intermittent respiratory current. It is the existence of this current which explains why the tube is permanently open at its posterior end.

Caddis live nearly a year in the water, so that if your specimens are taken from the ponds in early spring, and are then of considerable size, they may be expected to pass into the pupa stage in early summer. The approach of this condition is indicated by the little creature ceasing to feed (it has hitherto fed freely on vegetable matter) and ceasing to be active. It no longer protrudes the anterior part of the body from the case, and the ends of this may be observed to be closed by a delicate web, so arranged as to permit of the continued entrance and exit of water for respiratory purposes. Sometimes, to make security doubly sure, the ends are partially blocked by minute pebbles or morsels of stick. The caddis in their case should at this stage be removed to a separate dish, if they have hitherto been in the general aquarium. Within the closed case extraordinary reconstructive processes go on. These changes go on within the case and also within the larval skin. They result in the formation of what is called the nymph, which has in general terms the structure of the adult caddis-fly. As the nymph is formed the larval skin is shed piecemeal within the case, and the nymph skin, at first soft, gradually hardens. When the changes are completed, after a period of some weeks, the nymph eats its way out of the case by a pair of strong jaws which it bears for the purpose, and swims through the water in search of some weed, stick or stone by means of which it may crawl to the surface of the water. Once raised above its level, the skin of the nymph splits and allows the perfect insect to emerge. It dries its wings in the sun, and flies away to begin the free aërial life. The perfect insect is moth-like in appearance, and does not travel far from the pond in which the larval life was spent. All four wings are covered with fine hairs, and the antennæ are long.

The chief object of the adult life is to provide for the propagation of the species. The female lays a mass of eggs contained in a jelly in a pond or stream, and from these eggs the little larvæ emerge. They are at first very active, and begin at once to construct a case. With the approach of winter they become sluggish, and hide under stones, etc. In spring they again become active, and pupate, as stated above, in early summer.

As we have given the life-history of the caddis with some fulness, less detail is necessary in the case of gnats and dragon-flies.

The dragon-fly is interesting because the metamorphosis is of the type called incomplete; in other words, no quiescent pupa stage separates the larva from the winged imago.

To obtain specimens of the larvæ recourse should be had to a pool over which the beautiful adults have been seen flitting. From such ponds take with the net a good supply of mud and water weeds, and some of the larvæ will be probably found among the contents of the net. Put the larvæ in a shallow dish, with a layer of mud at the bottom, and some weed, and supply them with abundant animal food, such as aquatic worms, beetle larvæ, or almost any pond creature of suitable size, and there wili be no great difficulty in rearing them to the imago stage. They are, however, dangerous inhabitants of the general aquarium, if this contain delicate animals, as they are exceedingly voracious.

Two types of dragon-fly larvæ occur, the large dragon flies, like *Libellula*, having larger and much more powerful larvæ than the more delicate form belonging to the *Agrionidæ*. Taking one of the former first, we find that the body is broad, especially in the abdominal region. The large head has two distinct eyes and short antennæ, and is also furnished with a peculiar organ known as the mask. This is the means by which the larvæ obtains its food, and is a development of the lower lip of other insects. In the resting position it is carried over the face, being bent and doubled upon itself. If some small animal capable

FIG. 51.—*Libellula* larva with extended mask.

THE HAUNT OF THE DRAGON-FLY (Photo by L. Newbigin.)

The floating-plants are species of *Potamogeton*.

A POOL ON AN UPLAND STREAM (Photo by L. Newbigin.)

Note how the water is ærated by the little waterfall.

of furnishing food approaches, however, it is suddenly shot out, and proves to bear two prehensile "jaws" at its tip, by means of which the animal is seized and brought within reach of the mouth. The process, which is very interesting, should be carefully watched in a captive form. The larva is naturally sluggish, moving about but little, and spending most of its time lying in wait for its prey in the mud at the bottom of the pond. Very curious also are its respiratory organs. The posterior part of the alimentary canal is furnished with abundant air-tubes, and in order that these may be constantly supplied with fresh oxygen, water is made to flow in and out of this region by gentle pulsations of the abdomen. If, however, the larva be startled it suddenly ejects this water of respiration, and as a result it darts suddenly forward, often with great swiftness. A very peculiar feature of the larva, as compared with the caddis, is that rudimentary wings are present from the first. In the other type of larva, respiration is carried on in a somewhat different fashion. In this case the end of the body is furnished with three transparent leaf-like plates, whose primary function is to enable the larvæ to swim, but which seem also to have a respiratory function. These forms are much more active than their allies, for not only do they swim through the water by means of these delicate appendages, but they also climb actively about by means of their long legs. The larva of *Calopteryx virgo*, the demoiselle dragon-fly, is a good example (see Fig. 52).

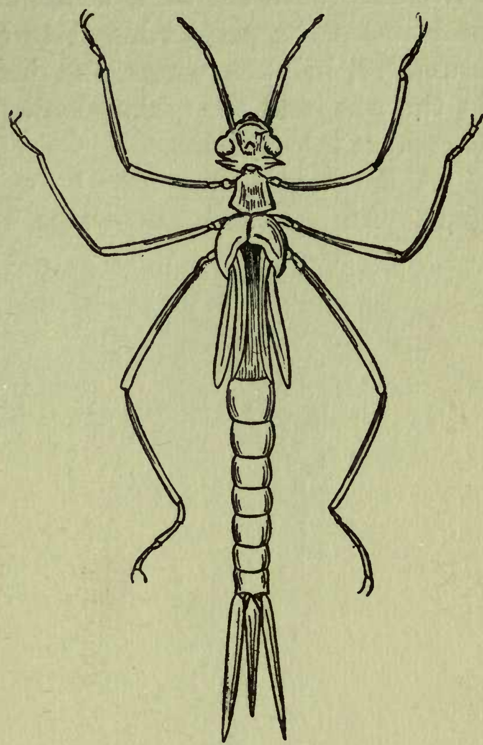


FIG. 52.—Mature nymph of the demoiselle dragon-fly (*Calopteryx virgo*).

As already mentioned, no striking change in form occurs during the larval life. The wings become more and more conspicuous with each successive moult, but otherwise the structure remains tolerably uniform during the whole nine or ten months of aquatic life. When pupation is expected, as in the case of the caddis, some means should be provided by means of which the pupa can reach the top of the water. There it remains nearly stationary until the skin, which has become hard and dry, splits and allows the perfect insect to emerge. At first soft and with crumpled, helpless wings, the insect rapidly dries and hardens in the sun, and then, abandoning for ever its empty pupa case, it escapes into the air.

A few words may now be said as to the life-history of the gnat. An exposed rain-water barrel, or any receptacle left

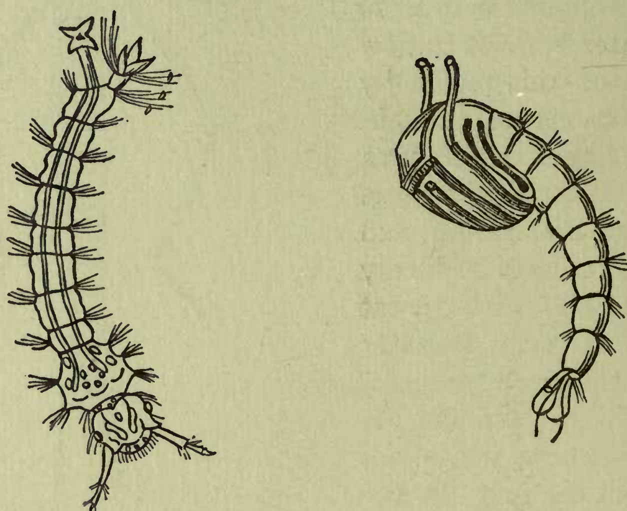


FIG. 53.—Larva and pupa of the common gnat (*Culex pipiens*). The larva is to the left, head downwards, the natural position, and the pupa to the right, head upwards, showing the two thoracic breathing-tubes.

exposed in the open and filled with stagnant water, may be expected to yield the egg-rafts of the common gnat. These consist of a great number of little eggs, each like a minute cylinder in form, and fastened together so as to form a floating mass on the surface of the water. The way in which the egg-raft floats, and its resistance to the little ripples which the wind makes, which might be expected to capsize or submerge it, are well worth special study. The larvæ, also common in water-butts or stagnant pools, are limbless creatures which hang head downwards into the water, protruding the tail through the surface film of the water. This tail contains respiratory organs adapted for breathing air, so that you will notice that the gnat larva is much less definitely aquatic than that of caddis or dragon-fly. The hanging head enables it to seize food particles in the water. If alarmed the larvæ sink down below the surface; soon, however, it rises again by wriggling movements of the body. After several moults the creature becomes a pupa, in which stage it can move but not feed. The pupal skin then cracks, and the perfect gnat emerges. It does not require any solid body on which to rest during the process, like caddis or dragon-fly, for it thriftily utilises the floating pupa skin from which it has just emerged, standing on this until the drying of the wings enable it to take its flight.

Instead of the gnat larvæ the so-called blood-worms, which are the larvæ of a gnat-like fly called Chironomus, may be studied. They live at the bottom in soft mud or decaying matter, and their history generally resembles that of the gnat.

In discussing some representatives of the insects which are aquatic as adults, as well as in larval life, it will be necessary to exercise an even more rigorous selection than in the case of the larvæ. The following have been chosen as good animals for the aquarium, and also illustrate well the special peculiarities of structure to be found among the aquatic insects.

We may begin with *Dyticus marginalis*, a large and handsome water-beetle, to be found in nearly every pond or ditch. It is a true air-breather, and may be seen swimming through the pond with great rapidity, and ever and again rising to the surface and protruding the tip of its abdomen above the water in order to take in a supply of air. It should not be introduced into an aquarium containing delicate or defenceless animals, for it is a most voracious feeder, and will attack animals much bigger than itself. In captivity it will eat meat, raw or cooked, and should be abundantly supplied with food. It has powerful wings, and therefore the vessel in which it is placed should be covered, or the captives may disappear in the course of the night, flying to other more promising localities than that in which they find themselves, or setting forth on a nocturnal search for a mate.

As to structure, the sexes differ from one another to a considerable extent. Both are powerful-looking creatures, well over an inch in length. They bear the three pairs of legs characteristic of insects in general, but while the anterior pair are short, clawed, and function for the most part only as grasping organs, the others, especially the last pair, are flattened and serve as swimming paddles. As in beetles in general, the body is covered by the hard elytra or wing-covers, beneath which lie the mem-

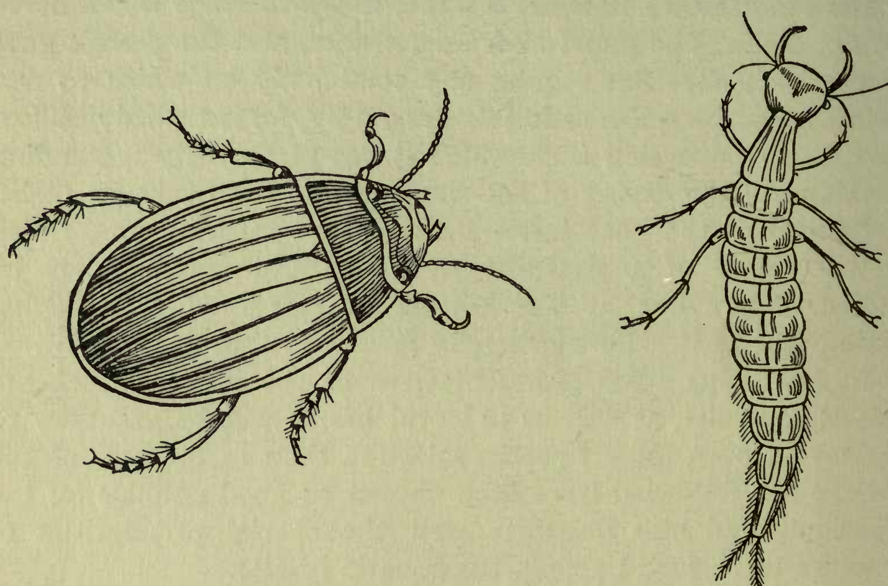


FIG. 54.—*Dyticus marginalis* (female) and its larva

branous wings, used only during flight, and at all other times completely concealed beneath the elytra. In the male the elytra are a dull black, bordered with a yellow streak, which extends forward into the anterior region (thorax). The elytra are smooth and polished. In the female the marginal streak is somewhat less distinct, and in place of being smooth the elytra are deeply grooved. Further, the male has the end joints of its anterior legs curiously dilated and furnished with suckers. This modification, like the roughened pad on the finger of the male frog, enables the male to clasp its mate.

The two most interesting points in regard to the beetles are, however, certainly the adaptations which enable them to swim swiftly, and their methods of breathing. As to the first, note that the animals are peculiarly helpless on land, where they cannot walk but only execute ungainly scrambling movements. Put them back into the water and notice the power of swift swimming, and the adaptations which make it possible. A few points only can be noticed here. First of all, note that the last pair of legs is inserted very far back. You will of course not omit to draw the attention of the class to the fact that this also occurs in the ducks, and makes them at once clumsy on land and graceful in water. If a museum be available it will serve to demonstrate the further point that in the penguins the legs are inserted even farther back than in ducks, and the result, as in the water-beetles, is an extraordinary clumsiness on land; the true seals afford another example of the same thing. Again, the water-beetle really rows itself along by means of its flattened legs. You will note that the power of movement of the leg, like that of an oar, is limited to one plane; ordinary insects can move their legs vertically as well as horizontally, but the water-beetle only possesses the latter power. Again, a skilful rower feathers his oar to diminish the resistance in his preparation for the next stroke; do not omit to notice that the beetle's legs are furnished with a series of bristles which can be raised or lowered so as to increase or diminish the resistance, the lowering of which is equivalent to the feathering of the oar. If a freshwater crayfish can be kept for a day or two in the aquarium an adaptation on similar lines may be observed in its tail-fan, which can be spread out or folded into very small compass, according as the creature is giving the effective stroke or merely getting into position for the next stroke.

In regard to breathing, we have already noticed how the beetle breathes at the surface. The wing-covers are somewhat curved, while the body beneath is flattened. There is thus a space, an air-chamber, left between the tightly fitting wing-covers and the surface of the body. Into this space the breathing tubes open by pores or stigmata, and it thus forms a reservoir of air which the beetle may take with it during its excursions through the water.

Under exceptionally favourable conditions the female *Dyticus* may lay eggs in captivity. The eggs are laid in early spring, and are inserted into the stems of aquatic plants by means of the ovipositor. From them the larvæ hatch in a few weeks. In any case, however, the larvæ are to be found abundantly in the ponds in which the adults occur. When full-grown they reach a length of about 2 inches. Growth is very rapid, and is completed in less than two months, and in consequence the young are as voracious as their parents. They are much less active, and hide their lank brownish bodies in the mud. Breathing is effected at the surface, the tail being thrust through the surface film much as it is in the gnat larva. Three pairs of slender, non-swimming legs are present, and also a pair of long but slender jaws. The mouth is minute, the little creature living on the juices of its prey somewhat after the fashion of a spider.

As the larva is a true air-breather no less than the adult, and as it must rise periodically to the surface to breathe, it is obvious that the pupa cannot remain within the water. In point of fact, the full fed larva quits the water and becomes a motionless pupa after burying itself in the ground near the pond in which it has hitherto lived. The winged adult returns to the water, but, as already indicated, uses its wings to make its escape if the conditions are unfavourable. It thus does not require any special adaptations to fit it to resist drought, for example.

A more useful inhabitant of the general aquarium than *Dyticus marginalis* is the Silver Beetle (*Hydrophilus piceus*), which is largely vegetarian and therefore does not cause such widespread havoc. It is unfortunately rarer, but can be readily obtained from dealers, and should be liberally supplied with water-weed. This beetle reaches more than 1½ inch in length, with a width of ¾ inch. It is of a dark green colour above and black below, but the under surface is largely covered with closely set yellow hairs, in which the air becomes entangled, and which thus shine like silver under water. The antennæ are short, instead of being long as in *Dyticus*, and the short fore-legs end in two sharp claws. The last pair of legs are turned into swimming paddles as in *Dyticus*, but they move alternately instead of together, and the animal is a less swift swimmer than its carnivorous ally. One reason, no doubt, is that it seeks its food on water-weed, over which it clambers, and does not attack moving prey like *Dyticus*. Like that species, it breathes at the surface. The mechanism is somewhat similar, in that there is again an air-space beneath the elytra, but the down on the under surface of the thorax, as well as that on the antennæ, plays an important part in the respiratory process.

The female spins a cocoon for her eggs—a somewhat curious fact. In the rounded bag which she spins many eggs are enclosed, and with them a bubble of air. The cocoon soon hardens, and after the lapse of some weeks the larvæ hatch and swim

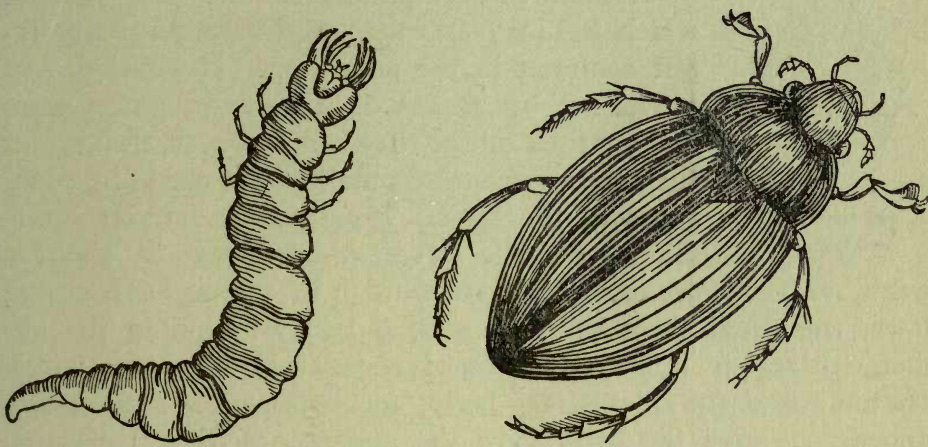


FIG. 55.—The silver beetle and its larva.

away in the water. They are soft, fat creatures, reaching a length of 2 inches, and furnished with strong jaws by means of which they obtain their prey. They seem to feed largely on molluscs. Like the adult, the larva is obliged to come to the surface to breathe. As in *Dyticus*, pupation takes place at the margin of the pond.

In searching the ponds for water-beetles one may often come across numbers of the whirligig beetles, so called because of the curious rotatory movements they perform at the surface. A common form is *Gyrinus natator*, which whirls about at the surface, its small black body shining in the sun like burnished metal. If an attempt is made to capture these beetles they will be observed to sink down at once, for the two posterior pairs of legs are flattened structures fitted alike for swimming and for propelling the light body on the surface film. The fore-limbs are considerably longer, and are used for grasping. The antennæ have a characteristic double appearance, and the eyes are worth special note. They appear to be double, being divided into two parts to enable the beetle to see both above and below the water. Whirligigs are not very easy to keep in the aquarium, first because they are very apt to spread their wings and escape; and second, because it is difficult to supply them with sufficient food. Their activity at the surface seems to be determined by the fact that they largely depend upon small insects, such as flies and beetles, which fall into the water, and these naturally are not common in the aquarium. If well-fed, and prevented by means of a piece of gauze from making their escape they will, however, thrive, and the active movements make them engaging occupants of the tank. The eggs are laid on water-plants, and the larvæ, which hatch in about a week, are very curious. They are whitish in colour, have strong jaws, the usual three pairs of legs, and in addition in the abdominal region a paired series of respiratory processes, which stretch out at the sides of the body, and because of their leg-like appearance give the little larva the appearance of a centipede. Pupation is carried on outside the water on the stem of a water-plant, where a little greyish cocoon is formed. The whirligigs, of which we have a number of species, are much smaller than the beetles previously mentioned; the commonest species is not more than about ¼ inch in length.

FIG. 56. — A whirligig beetle (*Gyrinus natator*).

The whirligigs and *Dyticus* and *Hydrophilus* all belong to the Coleoptera, or Beetles. Very different are the water-boatman and its allies, which, though as beautifully adapted for aquatic life as the water-beetles, are yet really related to the bugs. These insects have a suctorial instead of a biting mouth like a beetle, have the anterior wings partly hard and partly membranous, and have an active pupa stage,—or in other words, an incomplete metamorphosis.

The water-boatman (*Notonecta glauca*) is very common in pools. It can swim actively through the water, but on fine summer days is often seen sunning itself at the surface, either lying on the back in the ordinary position when swimming, or half out of water and with the wings partially unfolded. Whereas the water-beetles cannot fly out of the water unless they find some supporting point from which to make the start, the water-boatman can jerk itself out of the water with a sudden movement of its powerful swimming legs, and then, unfolding its wings, take its flight. In addition to these points, captive specimens will show the interesting method of obtaining food, which consists of other aquatic insects. These are seized by the prehensile fore-limbs, and the juices sucked by means of the beak, which can be driven deeply into the body of the prey. In addition to serving to seize the prey the anterior legs, like the second pair, are used to anchor the creature when it is at rest at the bottom; for, being lighter than the water, it tends to float upwards to the surface unless it grasps some solid body. The lightness is due to the large amount of air entangled beneath its wings, and in the hairs at the sides of the body. This film of air serves for respiratory purposes. The third pair of legs are very strong, and are the organs by which the creature propels itself vigorously along while lying on its back. Here, as in water-beetles, the legs are flattened and furnished with bristles, which change in position during swimming, offering the maximum resistance to the water in the effective stroke, and the minimum in the non-effective stroke. The eggs are laid on water-plants, and the larvæ resemble the adults save in the absence of wings.

FIG. 57.—The water-boatman.

Related to *Notonecta* are the species of *Corixa*, which closely resemble the water-boatman, but are smaller, have flattened instead of keeled dorsal surfaces, and swim with the under surface downward instead of on their backs like *Notonecta*. The fore-limbs also are not so markedly prehensile, and in natural conditions *Corixa* prefers to keep near the bottom, in place of swimming actively through the water like *Notonecta*.

Two other water-bugs may be mentioned—the two insects to which the name of water-scorpion is applied. The commoner form, *Nepa cinerea*, is frequent in ponds, where it crawls over the bottom, and is often missed on account of its close resemblance to a withered leaf. Its body is flat and of a dull brownish colour, but the most interesting peculiarity is the nature of the fore-legs. These are exclusively organs of prehension, and are carried bent on themselves, so as to offer some resemblance to the grasping claws of the scorpion. The two other pairs of legs are used for walking. The water-scorpion breathes by two slender thread-like appendages which protrude from the tail region. It is sluggish in habit, lurking about near the bottom until some unsuspicious larvæ, deceived by the leaf-like appearance, approaches within reach. The prehensile fore-limbs are then suddenly straightened, the prey seized and sucked dry. The other form, *Ranatra linearis*, has a long slender body, stick-like in appearance, long slender legs, and long breathing filaments.

FIG. 58.—The water-scorpion, with fore-legs extended.

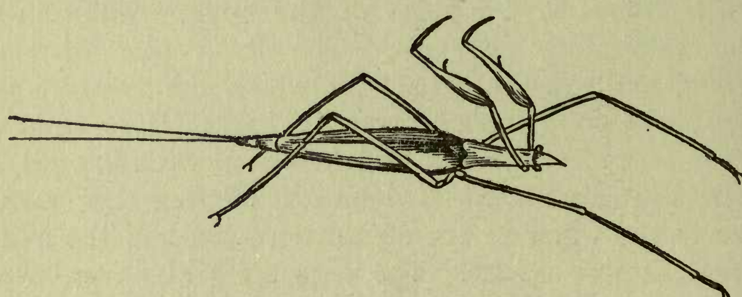


FIG. 59.—*Ranatra linearis*.

It is more active than its congener, walking about on its stilt-like limbs, and seizing its prey in the same fashion with the raptorial fore-limbs.

Leaving the insects, we may mention in passing the interesting water-spider (*Argyroneta aquatica*), always a favourite with aquarium-keepers. As a spider, and therefore an Arachnid, it may be readily distinguished from an insect by having four pairs of legs instead of three, and by having no antennæ on the head region. Like an insect it is, however, an air-breather. The method of breathing is not dissimilar to that adopted by many aquatic insects,—that is, the under surface of the abdomen is covered with fine hairs in which bubbles of air become entangled at the surface. As the spider descends in the water therefore it shines like quicksilver, owing to the film of air which it carries with it. This supply is only limited, and therefore it must rise to the surface frequently. To obviate this it has the curious habit of spinning a little cell like an inverted cup, attached by threads to water-weed. As it is formed this cell naturally fills with water, but the spider ascends to the surface and descends repeatedly with a cargo of air bubbles which are discharged into the cup, displacing the water in the same way as the oxygen in the experiment, recommended on page 71, displaces the water in the bottle. When the cell is filled with air the spider rests in it, finding for a time enough air to enable it to dispense with frequent ascents. Here also the eggs are laid in a little cocoon, and are watched over by the mother until they hatch. The spider shows relatively few adaptations to the aquatic life, and the fact that it may leave the pond and run about on its banks in search of prey suggests that the aquatic habit is of relatively recent origin.

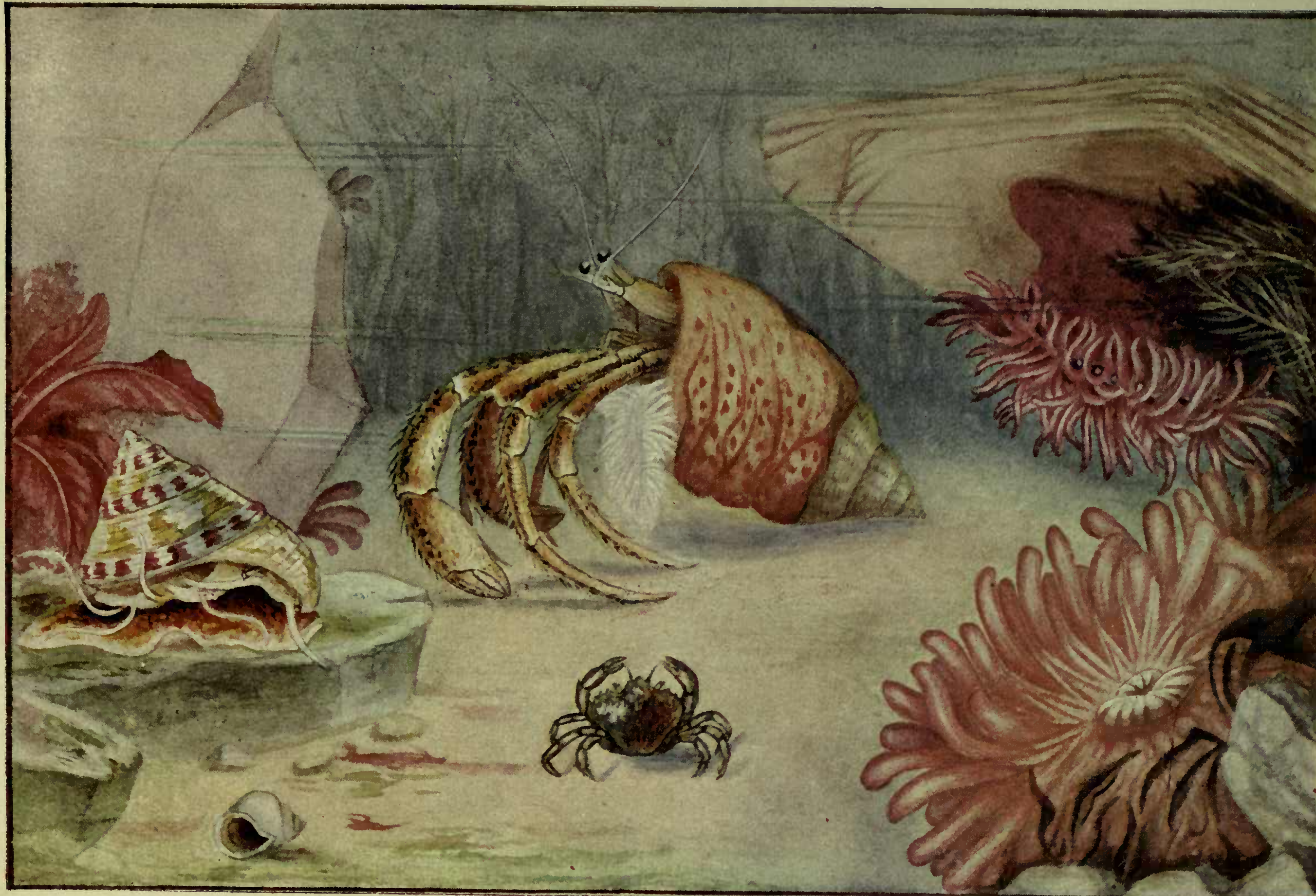
Of the animals simpler in structure than insects and spiders not many are available for the purposes of the school freshwater aquarium. If desired the ringed worms may be represented by the medicinal leech purchased at the chemist's, or by the horse-leech so commonly found in ponds, but neither is very interesting. The horse-leech, which has not the beautiful bands of colour seen on the upper surface of the body of the medicinal leech, sometimes attacks frogs, but feeds for the most part on worms and larvæ, while the medicinal leech is purely a blood-sucker. Both are chiefly interesting because of their adaptations to a parasitic or semi-parasitic mode of life, and this is a point on which it is hardly advisable to dwell in the case of junior pupils. Again, though we have some beautiful freshwater Polyzoa, yet the fact that it is not possible to make anything of the structure without the aid of a microscope excludes them from our survey here. The same objection applies to the interesting Rotifers, and to the whole of the Protozoa. The Coelentera, or hollow-bodied animals, are only feebly represented in fresh water, but in spite of its small size a word or two may be said about Hydra. Take a handful of water-weed from a pond in summer-time, selecting especially ponds covered with duckweed; or better, allow water and weed to flow into a wide-mouthed bottle. Empty the contents of the bottle into a glass vessel and put the vessel in a good light. You will quite probably see on the weed some tiny thread-like green creatures, whose slender delicate bodies float out in the water, showing the bunch of tentacles at the free extremity, and ever and again, at the faintest alarm, cower down close to the weed to which the other end is attached. This is hydra, an animal of very interesting simplicity of structure, and one which has been the subject of a great number of experiments. Without a lens one can make very little of the structure, but it is quite visible to the naked eye, and one can also see the green colour. Not all may be green, however, for there is also a brown hydra in our ponds. The point of greatest interest is that this little creature is all that our ponds have to represent the sea-firs and jelly-fish, the anemones and sea-pens which are so abundant in the sea.

As aids in identifying the animals of fresh water the following books of reference may be mentioned:—Vol. viii. of the *Cambridge Natural History*, "Amphibia and Reptiles," by Gadow (London, 1901), gives an account of all our British Amphibia. Fishes may be identified from Day's *Fishes of Great Britain and Ireland* (London, 1880–4), which includes both marine and freshwater forms. Molluscs, both marine and freshwater, are treated of in Forbes and Hanley's *History of British Mollusca* (London, 1853), as well as in Jeffrey's *British Conchology* (London, 1863–9). For insects many books are available, both technical and popular; we may mention Wood's *Insects at Home* (London, 1883) as a simple and interesting book, not costly, as are most of the more elaborate works mentioned above. In the same author's *Homes without Hands* (London, 1889) there are chapters on the habits, etc., of aquatic animals. The two volumes on "Insects" in the *Cambridge Natural History* (vols. v. and vi., 1901) are full of interesting facts, while both for insects and for other aquatic invertebrates the volume on "Invertebrates" in the *Royal Natural History* (London, 1896) may be consulted. This *Natural History*, which is not costly, despite its six volumes, is a good book for a school reference library, and shows much more consistency of treatment than the more expensive *Cambridge Natural History*, whose ten volumes are of unequal merit, and treat their respective subjects from very different standpoints. Vol. ii. of this work ("Worms, Rotifers and Polyzoa," London, 1896) may be consulted for the members of the "Worm" alliance, which have been very briefly treated above.

CHAPTER XIII

The Animals of the Marine Aquarium

While there is almost no part of the British Isles where the teacher cannot keep a freshwater aquarium, at least on a small scale, the marine aquarium, as already indicated, is difficult to manage successfully except near the sea. In spite, therefore, of the fact that our coast-line is relatively enormous, there must be many places where it is virtually impossible. Again, though, as we have suggested, there are a considerable number of fresh-water animals which do not occur in the extreme north, and are common in the south, yet a large number of common forms may be expected in any body of fresh water. In the case of the marine animals, on the other hand, the difference between the species found in the east and the west, the north and the south, is so great that one can make relatively few general statements about rarity or commonness. It is true generally that the western shores, washed by much warmer water than the east, are richer in interesting animals than the other parts, and this is especially true of the south-west. On the other hand, the fact, with which everyone is well acquainted, that the northern waters are the richer in food-fishes suggests, what is indeed the case, that those northern waters must also be rich in the organisms on which the food-fishes prey. The sojourner at the sea whose lot is cast on the north-eastern shores is thus not without his compensations. Finally, to obviate disappointment, it may be well to emphasise the fact that at least the majority of the animals which can be made to thrive in an aquarium are the inhabitants of rocky pools. The teacher, therefore, who has available only a long stretch of sandy beach cannot hope to do much in the way of aquarium keeping. It is true that by digging in the sand at extreme low-water quite a considerable number of sand-borers, such as burrowing molluscs like razor-shells, cockles, otter-shells, and so on;



THE AQUARIUM (I)

Top-shell (*Trochus zizyphinus*) Hermit crab with th

burrowing worms like *Arenicola*, *Nerine* and so on; burrowing sea-urchins like *Echinocardium*; even burrowing sea-anemones like *Peachia* may be found, but in the general case the natural conditions of sand-burrowers are not easily imitated in an aquarium, and one can hardly hope to keep them there for more than a short time, and then under somewhat unnatural conditions. Again, though these same sandy shores are sometimes, after heavy gales, found strewn with interesting forms, these are for the most part dead or moribund, never in the best condition for introduction into the aquarium, though of course the zealot will omit no opportunity of studying the habits of marine animals.

The ideal collecting ground is furnished by a considerable extent of rocks, interspersed with pools, and in collecting notice should be taken of the haunts of the animals selected. The most obvious peculiarity of the conditions of life on the shore is the ebb and flow of the tide. When it ebbs a certain proportion of the shore animals go with it, while another proportion lurk beneath weed, under stones and in dark damp recesses, until its return, both for safety and because if not water at least damp air is necessary to their well-being. Now, as a general rule—to which, of course, there are exceptions—success in the aquarium is more apt to be attained with the forms which linger in the pools than in those which habitually wander seawards with the ebbing current. If you find in the pools little fish, for instance, which are not reluctant to bury themselves in wet weed instead of remaining in the water, you are more likely to keep these alive in your aquarium than the strong swimmers who never voluntarily leave the water. In general, success is more probable with the relatively sluggish forms than with those which are strong enough to swim against the currents, or so delicate and helpless that they must float passively with it because they cannot resist its action. The reason is that the latter two sets require a more constant supply of oxygen than it is generally possible to give them in the ordinary aquarium tank.

After these preliminary hints we may run through a few forms in each of the great classes, selecting those which may be kept in the aquarium with more or less prospect of success.

CHAPTER XIV

FISHES

IN beginning with a few common and hardy shore fishes it may be well to repeat that the swift swimmers among the fish all require large stores of oxygen. These forms have a characteristic shape of body which is readily recognised. A haddock or a mackerel will illustrate this shape, and you will notice in them the tapering body, the strong tail fin, the smooth scales, the skin without bony plates, the flat eyes, the keel-like edge of the body above and below,—in general the whole structure is such as to diminish resistance to swift movement in the water. Now, in the shore pools at low water fish of this type are normally absent, but on the other hand there may be a number of forms whose shape, weak tail fins, bulging eyes, or other characters render them obviously unfit for continued rapid movement in the open sea, even if they can swim actively enough within the small area offered by the pool. It is among these forms that success in the aquarium may be hoped for, and not the least interesting point about them is the way they are adapted for creeping through narrow spaces in the pools, hiding beneath rocks, burying themselves in the weed or even in the sand, or attaching themselves to stones to avoid being swept away by the tide. In taking home specimens of these kinds of fish, however, be careful to choose small examples, which are most easily kept alive.

Quite common under weed in the tidal pools is the little Father-lasher or Lucky Proach (*Cottus bubalis*), to be preferred on account of its smaller size to its ally the sea-scorpion (*Cottus scorpius*). The father-lasher is a little greenish fish, usually only a few inches in length, with a big ugly head, a wide mouth and a narrow tapering body. The head is furnished with spines, and is flattened so that the eyes are on the upper surface, not at the side. The operculum or gill-cover is large, and is prolonged into a membrane furnished with rays. If the fish is attacked it possesses the power of inflating the mouth cavity, with the result that the spines on the head are erected, which prevents a bird, for example, from readily swallowing it. The two species

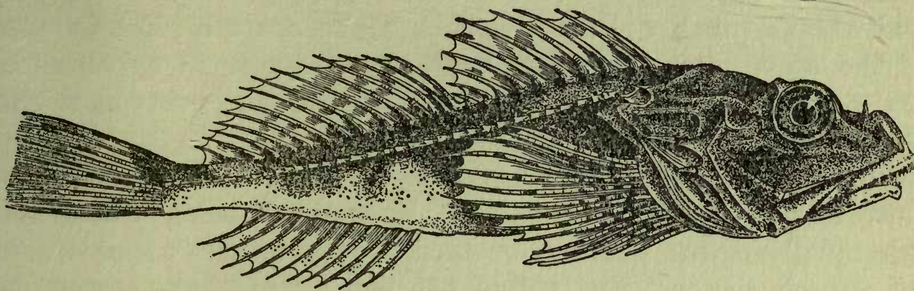


FIG. 60.—The sea-scorpion or bullhead (*Cottus scorpius*). (After Day.)

of Cottus differ in the number of their spines as well as in their size. In both the body is destitute of scales, a condition not uncommon in shore-haunting fishes.

Another fish whose young are easy to keep in captivity is the Lumpsucker (*Cyclopterus lumpus*), an ugly unwieldy creature,

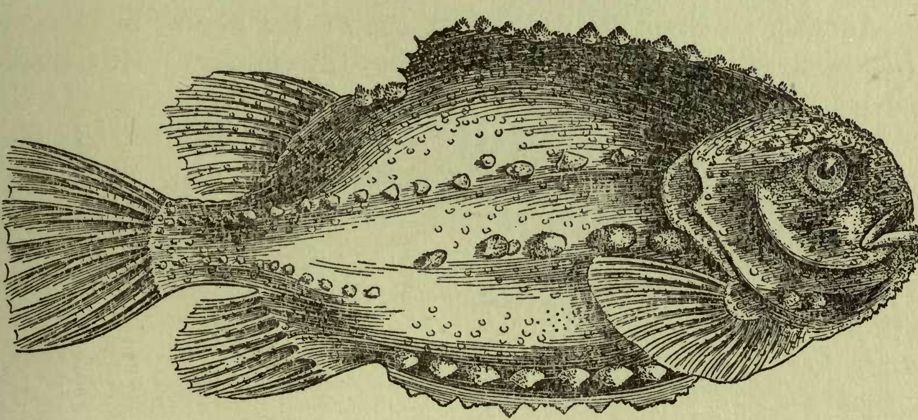


FIG. 61.—The lumpsucker (*Cyclopterus lumpus*). (After Day.)

commoner on Scottish than on English coasts. The eggs are laid in spring in the shore pools in great masses, and are carefully guarded by the male, who may often be found half out of water in the rock pools, because he is too zealous to leave his charge when the tide ebbs. The lumpsucker reaches a considerable size, and has a short, thick body marked by a median and three lateral rows of tubercles. It is readily recognised also by the strong sucker on the under surface, by which it can fix itself to rocks and so prevent itself from being washed away by the ebbing tide, for it is a very poor swimmer. The young have no tubercles, and when an inch or less in length make charming inhabitants of the aquarium. They are very like tadpoles in appearance, and dart vigorously through the water, stopping every now and then to fix themselves by the ventral sucker.

Related to the lumpsucker, but of more normal shape, in that their bodies are elongated instead of being thick and "lumpy," are the gobies, of which several species are common off British shores. The pelvic fins can be pressed together to form a sucker by which these little fish can anchor themselves temporarily, but they are also capable of swimming about actively, and form interesting occupants of the aquarium. All the species are small, the biggest, the Black Goby (*Gobius niger*), may reach 5 or 6 inches, but is usually much less. Very common off many parts of England is the smaller Two-spotted Goby (*G. flavescens*). All the species are hardy in the aquarium.

Another common fish in the rock pools is the Blenny or Shanny (*Blennius pholis*), a small animal prettily marked with black

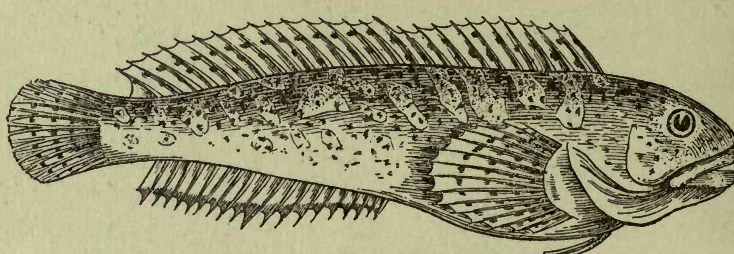


FIG. 62.—The common shanny (*Blennius pholis*). (After Day.)

on a greenish ground, which changes in colour according to its surroundings. It may be recognised by its long continuous dorsal fin, which has a median depression, and by its curious thick, swollen lips. It has sharp teeth, and the strong muscles of the jaws enable it to tear off the shellfish, acorn-shells, etc., on which it feeds. It is an active creature, swimming freely, and also using its large pectoral fins (which correspond to the fore-limbs of a terrestrial vertebrate) to clamber about over the rocks. Not a few shore fish do this, and if a storm throws up upon the beach a specimen of the curious fishing-frog or angler, it will be noted that in that interesting fish the pectoral fins are almost leglike in function, being used to enable the fish to "walk" over the bottom, though they retain the structure peculiar to fins, as contrasted with the terrestrial type of limbs bearing fingers and toes.

In captivity the shanny should be given an opportunity of climbing partially out of the water; it will be found also to thrive much better in shallow pans than in a relatively deep aquarium.

Related to the shanny is the Butter-fish or Gunnel (*Centronotus gunnellus*), interesting because of its peculiar shape, but not so attractive an occupant of the aquarium as the shanny. Unlike the shanny, which has no scales, the butter-fish has very

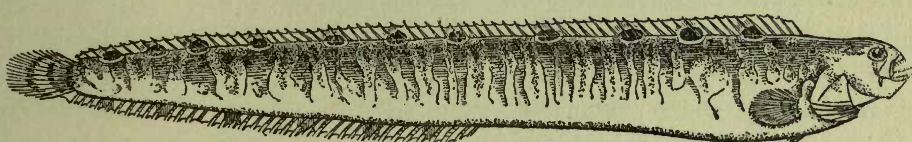


FIG. 63.—Gunnel or butterfish (*Centronotus gunnellus*). (After Day.)

small ones. Its body is peculiarly slimy, and, being compressed and long, not only enables the animal to glide through narrow crevices, but also no doubt helps it to escape from its enemies. The butter-fish is very eel-like in appearance, but may be readily recognised by the row of dark spots, of which there are usually about twelve, placed at the base of the long continuous dorsal fin. The tail fin is small, as are also the paired fins, but there is a long unpaired fin in the region of the anus. At low tide the butter-fish is usually found beneath weed or stones, but it can swim readily. The young are white, almost transparent creatures, but neither they nor the adults are so easy to keep alive in captivity as the blenny.

We have spoken under freshwater animals of the sticklebacks. Of these the common three-spined form may sometimes be found in the high rock pools, especially in the vicinity of freshwater streams. The stickleback *par excellence* of the shore pools is, however, the fifteen-spined form, which is hardy and interesting, and should not be omitted from any marine aquarium. This form reaches a length of 6 or 7 inches, but the aquarium keeper will do well to confine himself to the young, which often swarm in the rock pools in spring and early summer, and with ordinary care will live well. The fifteen-spined stickleback (*Gasterosteus spinachia*) is readily recognised. The body is elongated and slender, and terminates in a small mouth at the end of a long snout. Very characteristic is the way the little creature roots about with this snout in the crevices of the rock pools searching for food in a way which suggests the pipe-fish, which has a somewhat similar habit. The first dorsal fin is represented by fifteen spines, the body is ornamented at each side by strong plates, while the tail fin, that near the anus, and the second dorsal, have all a characteristic fanlike appearance. Like the other sticklebacks, the fifteen-spined form makes a nest, which may sometimes be found in sheltered pools.

Among other shore fish mention may be made of the flounders and their allies, or flat-fish (*Pleuronectidæ*), young specimens of which are very common with shrimps in the shallow sandy pools. Young flounders are not very easy to keep alive ; they do best in a wide shallow dish with a thick layer of sand over the bottom. The most interesting point is first the extraordinarily close resemblance in colour between the upper surface of the fish and the sand in which it lives. The same close resemblance is seen in the shrimps, in company of whom the flounders live. Just as the shrimps normally lie half buried in the sand, from which in colour they cannot be distinguished, so the flounder lies normally with only its head protruding, this head looking like a mere elevation of the sand. When the little creature is disturbed, however, the silvery colour of the under surface is seen as it glides rapidly away. The next point to be noticed is the curious flattened shape which obviously fits the "flat-fish" for their life on the bottom. Not a few fish are similarly adapted for life on the bottom, the skate and the fishing frog mentioned above are examples. But in these two cases the flat surfaces are, as one would expect, the upper and lower surfaces of the fish, the upper or dorsal having the backbone running down it, and the lower or ventral being that which lodges the heart and other viscera. But if the structure of flounder, sand-dab, plaice, sole or any of the true flat-fishes be examined when the animals are being eaten in the ordinary course of events, it will be found that the condition of affairs is here quite different. Here the *under* surface is the *left side* of the animal, the *upper* surface the *right side*, not the back. In other words, if an ordinary haddock, for example, be laid on the table on its left side, that is, with the right side uppermost, and we then supposed ourselves to flatten it out by slow, long-continued pressure, we should get the conditions of affairs represented in the flounder, which lies permanently on one side. Look again at the flounder, and notice that of the two pectoral fins which a fish possesses, and which in the haddock, for example, lie one on either side of the body, one in the flounder is on the upper, coloured surface and the other on the lower, uncoloured surface. An obvious difficulty is that if this is so, then the flounder should also have one eye on the coloured surface and one on the uncoloured surface, which represent the two sides of the body. This is the actual position of the eyes at an early stage of development, but as development proceeds the eye which is originally on the left side begins to migrate, actually moves round the head, until in the little flounder of the pools, as in the adult, both eyes come to lie close together on the upper side of the body. This migration is one of the most curious facts in connection with the development of fishes, and can naturally only occur when the bones of the skull are soft, so that it is completed at a very early stage. The result is that the bones are curiously distorted. This distortion is quite noticeable even to persons with no training in anatomy, and the head of a big flounder, plaice or sole should be claimed from the cook, boiled to get rid of the flesh, and compared with the undistorted head of cod or haddock prepared in the same fashion. The very young flounders and dabs, in which the change in shape of the body and position of the eye occurs do not live on the sea bottom but swim in the open water, where they are not obtainable without a tow-net. Further, they cannot be kept alive under the ordinary conditions of a school aquarium, so that it is not possible to demonstrate the actual process of metamorphosis.

Dwellers on the west and south-west coasts of Great Britain may add to the aquarium the very interesting pipe-fishes, of which we have several species. In the south-west of England the great pipe-fish (*Syngnathus acus*) is not uncommon. It reaches a length of a foot or more, and may be recognised by the long slender body, ending in an elongated tubular snout whose jaws are devoid of teeth. The body is clothed with plates instead of bearing scales, the gills are small tufts, and the male carries the eggs about with him in a pouch in the tail region. The pipe-fishes are feeble swimmers, and their natural habitat is rock pools, where they pick up food particles out of the narrow crevices. Their swaying bodies have often a curious resemblance to seaweed, which must help to protect them from their enemies. Related is the sea-horse, rarely found off the coasts of southern England and Ireland, but not uncommon in the Channel Islands.

CHAPTER XV

Molluscs

As already mentioned, the molluscs of the sea are far more numerous both in individuals and in species than those of fresh water. The highest class indeed, the cuttles, occurs only in the sea. The cuttles are by far the most interesting of the molluscs, and it is unfortunate that they are generally difficult to keep alive in the aquarium. They are all capable of swimming rapidly, and are highly differentiated forms, whose needs are difficult to satisfy in captivity. Many are indeed too large for success to be hoped for, but such forms as the common squid (*Sepia*), *Loligo*, or *Ommastrephes*, which may be found cast up on the beach after spring storms, or are sometimes obtained from fishermen, may be kept for a day or two in a tub of water to demonstrate the essential points of structure. In some parts of the coast the very pretty little octopus known as *Eledone cirrosa*, which only reaches a few inches in length, occurs in the rock pools, but it is not very easy to keep alive for long. The points of interest about the cuttles are first of all the power of colour change, which persists even after the animal is apparently dead, so that a portion of the body of a cuttle which has been torn to pieces by the gulls as it lay on the beach will still show the phenomenon. To demonstrate this it is only necessary to pass the hand over the skin, when the curious flushing and paling can be observed. In a living cuttle under natural conditions the colour shows a general resemblance to the surroundings, and this doubtless protects the animal, or enables it to steal unperceived on its prey, for the cuttles are predaceous animals. Another interesting point, easily demonstrated in a captive Eledone, is the power of throwing out a cloud of ink which darkens the water. The method of swimming should also be observed. Some cuttles have fins at the sides of the body and can swim slowly by movements of these, others crawl over the surface by attaching and loosening the suckers with which their arms are so abundantly furnished, but all possess the power of rapidly jerking themselves backward on an alarm by ejecting water from the so-called siphon, a tube placed not far from the head and communicating with a space known as the mantle chamber. As one of the big cuttles will readily show, this mantle chamber is a comparatively large space containing the two feathery, plume-like gills. It can be widely opened to allow for the entrance of water, and is then capable of being closed by a curious hook-and-eye arrangement. When this is done the only exit is through the siphon, and it is by this that the water is suddenly ejected, with the result that the animal shoots backward. The eyes are large and prominent, and within the mouth two large parrot-like jaws lie concealed. The rows of suckers on the arms, which themselves number eight or ten, are worth careful note. These arms are really equivalent to parts of the *foot*, that is, of the flat surface on which, *e.g.*, the garden-snail creeps. The cuttles are not only the highest of the molluscs, but also of the invertebrates, and show many peculiarities of structure.

From the cuttles we pass to the bivalves, of which not a few forms will live well in captivity. Among these we may begin with the edible mussel, small specimens of which make pretty inhabitants of the aquarium. The dark blue shell is probably familiar to all, no less than the habit of growing in companies to form mussel beds. Tear off a few small specimens and put them in a dish with water. As they grow accustomed to their new surroundings they will be observed to open their shells, which close tightly on an alarm. From the gaping shell each protrudes a small whitish foot by means of which the mussel can slowly creep along, and also the fringed margin of the

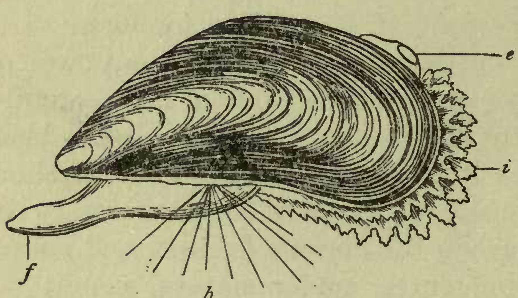


FIG. 64. — The edible mussel (*Mytilus edulis*). *f*, the foot ; *b*, the byssus ; *e*, the inhalant siphon ; *i*, the exhalant siphon.

mantle. This mantle is a double fold of skin which lines and makes the shell, whose folds also form a chamber in which lie the gills. When undisturbed the mussel causes a constant current of water to flow in and out of its mantle chamber; this current bringing oxygen and food and carrying away waste. The incoming current enters by a wide (inhalant) aperture, while the outgoing one leaves by a comparatively narrow (exhalant) opening, to be seen at the side of the shell opposite the foot. By the time these observations have been made the mussel will probably have satisfied its exploratory instinct, and will have settled down on one spot, to which it fixes itself by the so-called byssus,—a mass of silky threads secreted by a gland which is the equivalent of the mucus gland of the garden-snail, that is, of the gland which secretes the trail of slime that animal leaves behind it as it creeps. When we remember that the mussel cannot swim, and that it lives in tidal water, the use of this power of forming anchoring threads is obvious. Again, as despite the threads the mussels are always liable to be carried away by a specially strong current, it is obviously an advantage that they have the power of rapidly weaving new threads.

Prettier than the mussels are the scallops or clams, whose gaily-coloured shells are prized by children under the name of dolls' fans. In adult life the scallops live in comparatively deep water, whence they are dredged for market, but small specimens of the common form (*Pecten opercularis*) are frequent on the shore rocks. The shells are of a reddish-orange colour, and are almost circular, each valve having two projections or ears near the hinge. When the valves of the shell open one sees that the edge of the mantle is beset with a great number of simple eyes, as well as with delicate filaments. The eyes are apparently associated with the power of swimming, for if alarmed the scallop

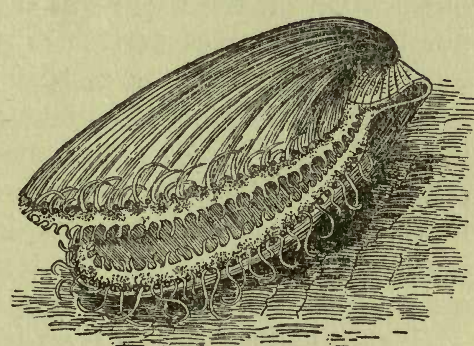


FIG. 65.—The common scallop (*Pecten opercularis*). Note the eyes and the processes on the mantle.

does not merely close its shell like most bivalves, but seeks to make its escape by flapping the valves together, with the result that it is jerked rapidly through the water. It has a slender foot, and is capable of spinning a slight attaching byssus. One of its relatives, *Lima hians*, generally found in deeper water, which has a white shell but a bright red mantle, has a similar power of swimming, but uses its byssus to weave together particles of stone and weed into a nest, within which it finds shelter.

Another common bivalve which is readily kept in captivity is the Carpet shell (*Tapes pullastra*), which has a solid shell, rhomboidal in form, prettily marked by numerous close-set bands crossed by longitudinal striæ. It has the mantle folds prolonged into two tubes or siphons, of which the one near the hinge is inhalant and the one near the free margin of the valves exhalant. Owing to the presence of these siphons the carpet shell is able to live buried in sand or mud so long as the tip of the tubes protrudes at the surface. A very little observation on the shore will show that there are a considerable number of bivalves furnished with siphons, which live buried in sand, mud, or, in the case of forms like *Pholas* and *Saxicava*, in rocks. The former is found especially in limestone rocks, where it forms deep burrows and may be recognised by the bright-red siphons which it protrudes. The species of *Pholas* occur in various kinds of rocks, especially in shale, and have beautiful pure white shells of delicate texture, marked by prickles which are supposed to be used in the process of boring.

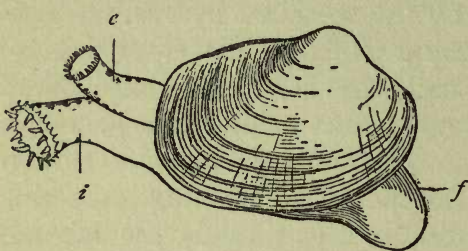


FIG. 66.—The carpet shell (*Tapes pullastra*). *f*, the foot; *i*, the inhalant siphon; *e*, the exhalant siphon.

Before leaving the bivalves it may be noted that it is possible to tell from the appearance of the empty shell whether the animal has had siphons or not, *i.e.* whether it has been a burrowing or a surface form. Any bivalve shell shows near the margin of each valve a line where the mantle was attached to the shell. If this line follows uniformly the margin of the shell, the animal had no siphons. If, on the other hand, it has a deep bay or sinus in it, then siphons were present, and the living animal is to be sought in sand, mud or rock. The shells of edible mussel and Tapes show this contrast well.

The Gasteropods of the shore are very numerous, and include both forms with and those without shells. Before proceeding to mention a few common and hardy forms we may say something about the spawn, connected with which are many points of great interest. In wandering over the rocks in early spring one may often find curious white structures like ladies' frills, which stand up from the surface of the rock, and consist of a gelatinous matrix in which are lodged innumerable minute eggs. These are the egg ribbons of sea-slugs, species of *Doris* being common forms. If a little of this spawn be placed in the aquarium, or preferably in a dish by itself, in course of time the minute larvæ will hatch out, and are just visible to the naked eye. If the spawn has been placed in a glass vessel, and the water is well oxygenated, it may become absolutely turbid with the tiny larvæ, who are free-swimming, not sluggish like the adults, and jerk themselves through the water. In the sea, however, they cannot swim against the currents, and are carried passively about, thus serving as a means of distribution. Look at the pools in which the egg-ribbons naturally occur, and note how vast a number of the larvæ must die prematurely by being flung up on the sides of the pool, no less than as the result of the appetite of the many animals who feed on minute forms of life. Endeavour with a lens to make a rough calculation of the number of eggs in each ribbon, or each inch of ribbon, and you will realise that the enormous numbers are necessary because of the waste of larvæ. To contrast with this type of spawn take the little vase-shaped capsules of the dog whelk, found attached separately to the rocks, or the great egg masses of the common whelk, both common objects on the shore. In the whelk the capsules are glued together to form great masses, each capsule being of irregular shape and having a tough wrinkled skin. The whole is glued to a stone, and when first laid each capsule contains several hundred eggs. The older capsules are empty and show merely the little hole through which the young whelks made their escape. When they escape they are not, like the larvæ of *Doris*, minute, shell-less, free-swimming creatures, but are like miniature adults. In other words, there is here no special provision for distribution. As the young have to spend a much longer time in the egg-mass, the special protection of the tough capsule is necessary, while those of *Doris*, which are thrown upon their own resources very early, have no special protection. Again, the *Doris* larvæ must seek their own food from a very early period. The young whelks within their egg-case cannot do this, and we find that in each capsule a few larvæ get the start of the others and proceed to feed upon their aborted brethren. The result is that of the five hundred or so eggs in a capsule, perhaps five, or one per cent., may develop, all the others being sacrificed. On the other hand, the chance of survival of these five at hatching is very many times greater than the chance of survival of any particular *Doris* larva. The subject has been dwelt upon in a little detail, because these two conditions tend to occur in almost all groups of shore animals. On the one hand, we have forms which produce myriads of minute, prematurely hatched, free-swimming larvæ, any particular one of which has a small chance of surviving, but whose object seems to be to ensure the distribution of the species. On the other hand, again, we have forms which produce fewer young, which are in some way protected and fed until they approach the adult in structure, which do not serve to distribute the species, but whose chance of survival is relatively great. The antithesis is found in both simple and complex animals. Thus in fishes the dab and flounder, as mentioned above, produce young different from the parents, which swim about in the open water instead of haunting the bottom like the adults; while the skate, another bottom-haunting form, lays its eggs in capsules from which the young does not emerge until it has the form and habit of the parent. In this case the little skate is furnished with a supply of food in the form of yolk to feed it within the capsule, and very much fewer eggs can be produced by the parent than in the case of the flounder where much less yolk is necessary; but the little skate at hatching has a better chance of survival than the flounder.

Among the molluscs, in addition to the types named above, the conditions seen in the periwinkles should be noted. The common edible form lays its eggs in little jelly-like masses on sea-weed, where they are easily seen and studied. On the other hand, there is an interesting form which lives higher up on the shore, which does not lay eggs, but gives birth to shelled young. Why? Because it lives higher up on the beach than the bladder-wrack zone on which its cousin lays its eggs, and if it were to lay its eggs on the rock the risk of their drying up under the hot sun at low tide would be too great, so it retains them within its body until they hatch. Similar observations can be made with a number of Gasteropod molluscs. It may be said generally that the eggs of these molluscs are easy to hatch in confinement, in which also many species can be readily induced to spawn, and there can be no more interesting exercise than to watch the spawning and hatching processes, and to endeavour to correlate the peculiarities in any particular case with the conditions of life of the species.

Only a few words can be said about the common shore Gasteropods themselves. Interesting because of its simple structure and its geological age is *Chiton*, a very common little form, easily recognised by its eight shell plates. On the under surface one sees the flat creeping foot, and at its side the paired gills. One may also easily see that, much as in a worm, the mouth is near one end of the body, and the anus near the other. Most other Gasteropods, as, for example, the common limpet, have the anus at the right-hand side of the body near the head, that is, show, as compared with worms or with *Chiton*, a curious twisting of the body. For this and some other reasons naturalists believe that *Chiton* is a very primitive form, and that from forms like it the other Gasteropods were evolved.

FIG. 67.—Chiton, showing the eight shell plates.

As a general rule the common limpet, with its ugly cap-shaped shell, does not thrive in an aquarium, where it seems to miss the ebb and flow of the tide, but success may sometimes be obtained with its more beautiful allies, as with the delicate *Helcion pellucidum*, which lives on the fronds of oarweed far out on the rocks, or with the tortoise-shell limpet (*Acmæa testudinalis*), whose mantle is of a pale green colour.

The periwinkles, dog-whelks and whelks proper, though, as noted above, their spawn is interesting, are rather disconcerting in captivity because of their tendency to crawl out of the water and get lost, but the tops or trochi, with conical shells, often prettily marked, are more satisfactory. They are vegetarian forms like the periwinkles, but the animal, which has long tactile processes or cirri, is more attractive in appearance. As to the bewildering complexity of sea slugs or Nudibranchs, we cannot do much more than urge the teacher if possible to consult the beautiful plates of Alder and Hancock's *Monograph of the British Nudibranchiate Mollusca* (Ray Society), or make a

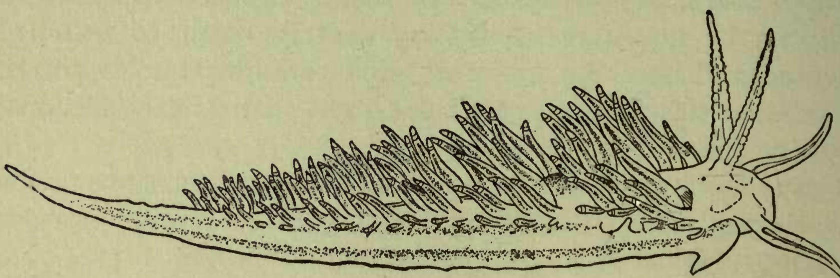


FIG. 68.—A common nudibranch (*Eolis rufibranchialis*). (After Alder and Hancock.)

pilgrimage to Newcastle-on-Tyne Museum to see the originals, before beginning to hunt the pools for specimens. As these plates will show, there are a great number of British species. Not a few are quite common on the rocks in spring when they lay their eggs, while others are common all the year round, but are apt to be overlooked because of their small size. They are carnivorous, feeding especially on zoophytes, and a capital way of obtaining the more delicate forms is to take at random a handful of sea-firs from a pool, and put them into a dish when some delicately coloured sea-slug may quite possibly reveal itself. The commonest form is perhaps *Doris*, already mentioned which has a circlet of gill plumes round the dorsal anus, but the species of *Eolis* with the back covered by numerous slender papillæ are also abundant in pools. (See also the coloured plate.)

CHAPTER XVI

The Arthropods

After the molluscs we come to the Arthropods, which are represented in the sea as typically by the Crustacea as they are by insects in fresh water. The shore Crustacea include some very interesting forms, and where fishes are found too difficult to keep alive we must rely largely upon the Crustacea to give animation to the aquarium. We may begin with that invaluable animal the common shore crab (*Carcinus mœnas*), which is not only very common but is very hardy, and will thrive under the most untoward conditions. Do not attempt to keep the large forms so common both off rocky and sandy shores, but select a few small specimens, and put them in flat dishes with stones projecting out of the water. The animal is too familiar to need description, but very little collecting experience will show that the colour is very variable. Take a few young specimens from the same pool, which will probably have roughly the same type of coloration, and put them separately into pie-dishes with differently coloured surroundings—red weed in one, green in another, dark pieces of shale in another, and so on. In the course of a few days—if young and small specimens have been taken—it will be found that the colour of each crab is in harmony with its surroundings. The specimens can then be changed, and the experiment repeated *ad lib.* The crabs are actively carnivorous and should be well fed—their tastes are very catholic. Note in your specimens the short feelers or antennæ, as compared with the long ones of a lobster, the fact that the animal has no power of swimming though it has a small tail, habitually carried bent in under the body, and not capable of being straightened like that of the lobster. As more subtle points note the constant flicker of the appendages round the mouth; the object is to cause a current of water to flow over the gills, which are sheltered beneath the shell or carapace. It is because the gills are sheltered in this way that the crab can tolerate the absence of water in a way that would be impossible for a prawn, for example, where the gills are not so thoroughly protected, and where they would consequently soon dry up if the animals left the water, while those of the crab, which are enclosed in a special chamber, retain their moisture for a long time. Note also the movable stalked eyes, and the way in which they are placed in sockets into which they can be withdrawn if danger threatens. The same thing is true of the antennæ. In short, a crab is a typical shore animal, well adapted for life between tide-marks, but not well suited for the open water where its cousin the Norway lobster is quite at home.

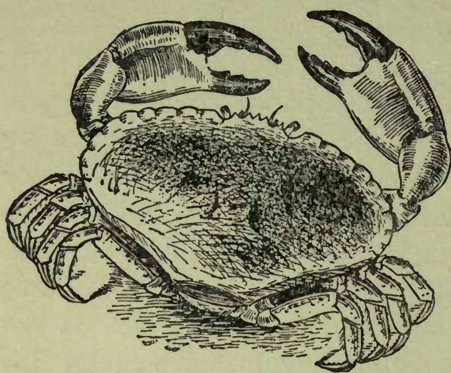


FIG. 69.—The edible crab (*Cancer edulis*).

Very young specimens of the edible crab (*Cancer edulis*) are also not uncommon on the shore, and may be kept in confinement without difficulty. They do not, however, show the interesting colour change of the shore crab.

Related are the various spider-crabs, of which we have a considerable number. All are recognisable by the elongation of the legs which gives them their popular name, and which is a great assistance to them in crawling about the rocks and stones of the pools. The smaller forms live well in captivity. They do not show the

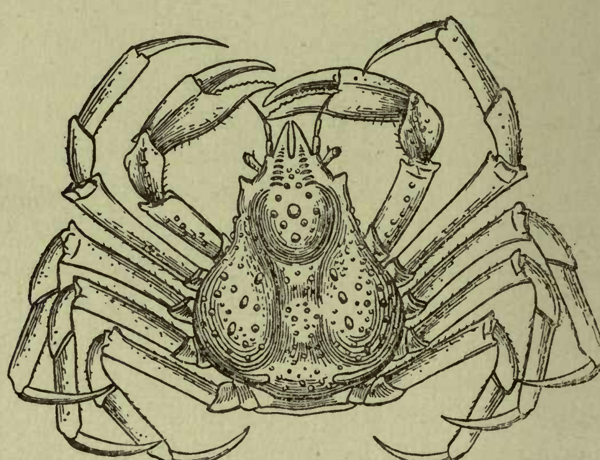


FIG. 70.—The common spider-crab (*Hyas araneus*). A cleaned specimen with most of the hairs removed.

colour change of *Carcinus*, but have an even more interesting peculiarity—that of actually planting on their backs seaweed or sea-firs. That this is intentional and is done with a desire for concealment—*i.e.* is not a mere accidental growth—is readily seen by taking a spider crab from a pool and putting it into a pie-dish containing weed or zoophytes differing in colour from that already on the animal's back. In a very short time it will be seen that the crab has carefully fixed the new weed in place of the old, so that it is no longer conspicuous but resembles its surroundings. The back of the crab is furnished with hooked hairs to which the weed is attached. Spider crabs are sluggish animals, with none of the restless activity of the shore crab. A common form is *Hyas araneus*, most abundant on the east coast, while on the west the much larger *Maia squinado* occurs, being especially abundant in Cornwall. We have also a considerable number of other species.

The crabs just mentioned show striking distinctions from lobsters and their allies, but we have a series of small but interesting forms which are in some respects transitional between the two. Search under stones in muddy pools, turning over those of the stones which have a cavity between them and the mud beneath, and you will probably find specimens of the hairy porcelain crab (*Porcellana platycheles*), with its large flattened claws, deeply fringed with bristles. The carapace is curiously rounded, and striking differences from the true crabs are the fact that the antennæ or feelers are long, not short, and that there are only three pairs of walking legs behind the great claws, the fourth pair of the true crabs being represented here by a pair of slender rods, generally kept folded beneath the carapace, which end in a brush of hairs. Our other species of porcelain crab (*P. longicornis*) is to be found on the attaching roots of the great oarweed. Tear up a plant of this from the rocks to which it is fixed, and you will probably find a little reddish crab climbing about the base. It generally resembles the hairy form, but is without

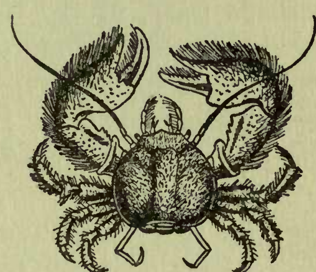


FIG. 71.—The hairy porcelain crab (*Porcellana platycheles*).

the hairs, and is smaller. Take specimens of both crabs home to the aquarium, where they can be readily kept, and watch the habits of both. The most interesting point about the smaller form is that though it usually climbs about weeds like a crab, it possesses also the power of swimming like a lobster. The tail is generally kept folded beneath the body like the tail of a crab, but can upon occasion be straightened and bent, so that its vigorous flapping propels the little creature through the water. The most interesting point about the other and more sedentary species, is the way it protects itself from particles of mud. We have already emphasised the fact that most marine animals are very sensitive to mud, deposits of which, especially on the gills, are often rapidly fatal, for they prevent the proper action of these organs. Now the hairy porcelain crab lives in muddy pools, so that at first sight it would seem to be an entire exception to this rule. A little observation will, however, show that the object of its covering of hairs is to prevent the mud from reaching sensitive parts of the body. In point of fact the little creature spends most of its time over its toilet. Do not fail to notice how the great fringe of hairs on the claws acts as a sieve to prevent mud being swept into the gill chamber with the water of respiration, how the rudimentary hind legs, with their terminal brush of hairs, are used to clean out the posterior part of the gill-chamber, how the feelers are periodically brushed and cleaned by the hairy appendages near the mouth. If with a camel's-hair brush you try to clean the mud from the crab's hairs, to make it a more presentable occupant of the aquarium, you will find that the particles stick very closely, and a lens will show that the reason is that the hairs are branched and serrated so as to give them the maximum sifting action.

Related to the porcelain crabs but more lobster-like in appearance is Galathea (*G. squamifera*), sometimes called the squat-lobster. It is common in the rock pools, especially those near low-tide mark, and reaches a length of about 3 inches. Do not attempt to keep full-grown specimens in the aquarium, but select a few small ones, often found in company with the small porcelain crabs on the roots of oarweed. These small specimens are often brilliantly coloured in blue and red, and their power of swift swimming renders them delightful occupants of the aquarium, where, however, they demand some care. Note that the great claws are here carried stretched out as in a lobster, not in the bent position as in the porcelain crab and the true crabs. As in the porcelain crab, however, the last walking leg is rudimentary, and the body is much broader and flatter than in the lobster. In detail you will notice a number of curious resemblances to porcelain crabs and differences from a lobster.

More distantly related to the porcelain crabs, and more familiar if not commoner forms are the hermit crabs, of which one species (*Pagurus bernhardus*) is very common in shore pools. The most interesting point in regard to it is that the abdomen or tail is not here tucked up out of harm's way as in the porcelain crabs, but trails lank and soft behind the hard anterior part of the body. As it is this soft tail which contains many of the organs of the body, and as it is useless for swimming and only a danger if exposed, the hermit seeks some means of protection. This is usually found in an empty gasteropod shell. Examine an empty shell of periwinkle or whelk, and you will note that the shell is coiled round a central pillar called the columella. The hermit's tail is twisted so that it fits readily into the shell, and it ends in a strong hook which can be fixed to the columella of the shell, and so attaches the hermit to its borrowed house. The chief disadvantage is that the hermit grows and its borrowed shell does not, so that periodic house-moving is necessary, and also that certain fish with a keen appreciation of hermits will swallow shell and all in order to obtain the desired morsel. Hermits oppose various devices to this last danger. Some decorate their shell with a sea-anemone having powerful stinging cells. The anemone would sting the lips of the fish, and thus no doubt protects the hermit. The difficulty is that when the hermit moves it must take its anemone with it. Others decorate the shell with sponge, which being full of prickles is again distasteful to fish, but in this case it is difficult to move the messmate to a new shell, and the hermit has to abandon its shell as this grows too small, and content itself with living in a hollow of the sponge. Other hermits live in shells covered with zoophytes (see Fig. 83, p. 166), which fish again dislike, but here also moving must be a difficulty. Again, in some localities, shells are difficult to obtain, and the hermits are obliged to resort to all sorts of devices—they may be found in hollow cabbage stalks, in mere broken fragments of shell and so on.

Hermits are not very easy to keep alive in captivity, perhaps because the borrowed shell makes respiration difficult, at any rate the first symptom of *malaise* that they show is an insane desire to move from one shell to another, even if the new shell is no better than the old. In dying also they always leave the shells. Specimens for the aquarium should be small, and the vessel in which they are placed should not be crowded. Do not attempt to keep more than two or three specimens at once. The habits are interesting. Note that one claw is bigger than the other so as to fit the animal to its borrowed shell, note also the long antennæ, the sudden recoil into the shell on the approach of danger, the reduction of the functional walking legs to two pairs, and the very mobile stalked eyes. Large specimens, inhabiting big shells, have sometimes in the shell with them a large worm, which is not a parasite, for it does the hermit no harm beyond taking perhaps a share of its food, but merely a messmate, seeking shelter from its enemies in the hermit's roomy house.

The above contains some mention of the more important types of the higher Crustacea, but there are various simpler forms of which a few words may be said. As a general rule, the shrimps and prawns are not easy to keep alive in captivity, but the attempt should be made, if only to give an opportunity of studying their structure. The common shrimp is interesting because of its close resemblance in colour to the sand in which it lives. As everyone knows, boiling changes the sandy tint into a reddish-brown colour. Very interesting also is the shrimp's method of burying itself. It first makes an excavation by rapid movements of its legs, and then completes the

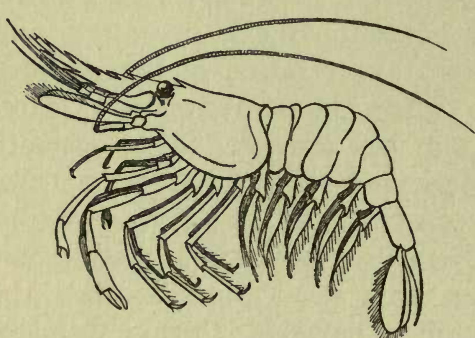


FIG. 72.—A common prawn (*Palæmon squilla*).

process by shovelling sand over its back by the help of the large scales which occur at the base of the feelers. Prawns should be studied especially from the point of view of their methods of swimming. They can either swim slowly by the appendages of the abdomen, or jerk themselves suddenly backwards by flexing the tail. They show many interesting points of contrast with crabs and their allies. All the above are called decapod or ten-legged Crustacea, but there are a number of simpler forms also. Thus forms like *Asellus* in fresh water are represented in the sea by forms like *Idotea tricuspidata*, which is found on seaweed, especially bladder-wrack, which it closely resembles in colour. Forms like the freshwater shrimp are represented by sandhoppers and many related species. More interesting than these carrion-feeding forms are the species of skeleton-shrimp (*Caprella*), found on red weed. The body here is of a very curious shape, and in life the little creatures are the exact colour of the weed over which they climb. The lank body sways in the water as do the branches of the weed, and it takes a sharp eye to discern which is shrimp and which is weed.

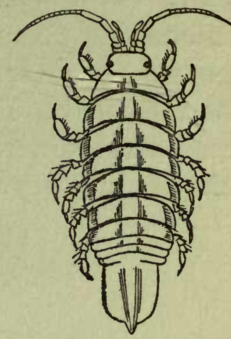


FIG. 73.—*Idotea tricuspidata.*

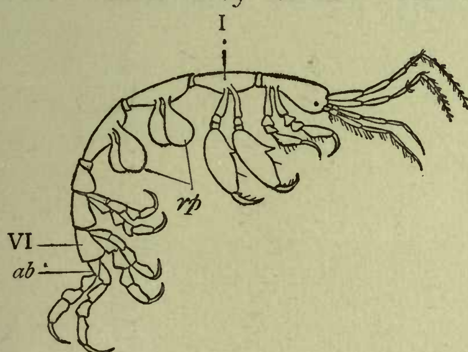
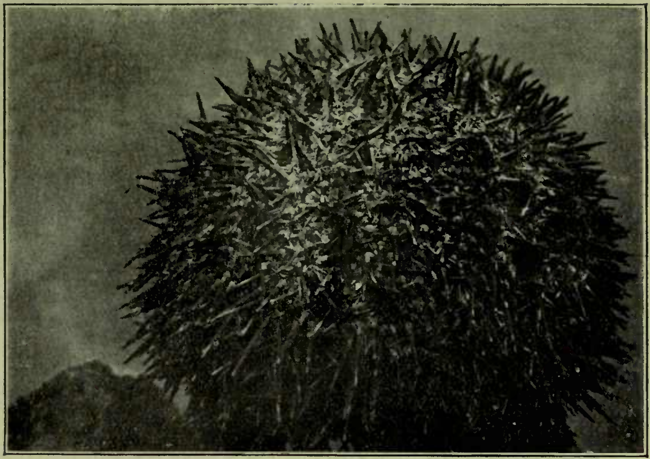


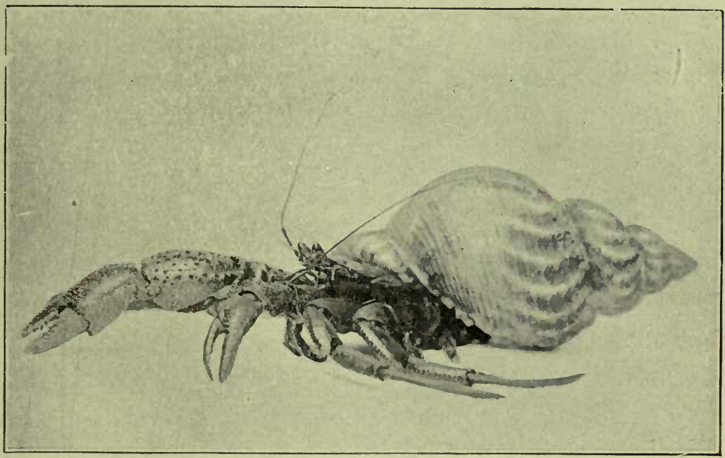
FIG. 74.—The skeleton-shrimp (*Caprella*). I and VI, the first and sixth free thoracic segments ; *ab*, the rudimentary abdomen ; *rp*, the respiratory plates by means of which the skeleton shrimp breathes.

Leaving out of consideration many other forms, we may just mention the little acorn-shells which often stud every rock and stone on the shore, and which are small degenerate crustaceans. Dead as they look at low tide, when the water flows each opens its shell and protrudes slender branched feet, by means of which an energetic fishing for food is carried on. The acorn-shells are, however, difficult to keep in confinement.

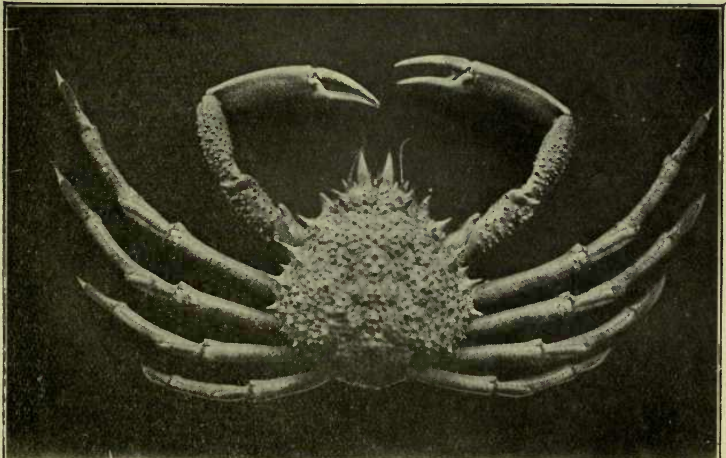
Finally, when searching for skeleton-shrimps among red weed, one may find instead slender spidery animals, with four pairs of walking legs. These are the so-called sea-spiders, interesting because their structure is still something of a puzzle to naturalists, who are not quite sure how they should be classified. They live well in captivity, and some species show an extraordinarily close resemblance to the weed over which they habitually clamber.



COMMON SEA URCHIN *(Echinus esculentus)*



COMMON HERMIT CRAB *(Eupagurus bernhardus)*



SPINY SPIDER CRAB *(Maia squinado)*
(Photos by Edward Step.)

CHAPTER XVII

THE ECHINODERMS

THE Echinoderms, or prickly-skinned animals, are exclusively marine, so that they have no representatives in the freshwater aquarium. At the present day five kinds occur in our seas. Of these, the sea-urchins, the starfishes, the brittle-stars and the sea-cucumbers, are all represented in the shore pools, but the fifth kind, the beautiful sea-lilies, are only to be found in deep water. On some parts of our coast, however, fossil sea-lilies are to be found abundantly in the shore rocks, even in such rocks as shale, which is merely the hardened mud of an old sea beach. This shows that in the geological past the sea-lilies must have lived in shallow water, and the fact that at the present time the vast majority live in the great ocean depths, suggests that they have been thrust out of the shallow water by the competition of modern, highly specialised forms like the brittle-stars. Some interesting facts are therefore suggested by putting into the aquarium a piece of shale with fossil sea-lilies (Crinoids) in company with living starfish and brittle-stars.

If we begin with the sea-urchins we find that the common urchin (*Echinus esculentus*) is nowhere frequent in the shore pools, though it may be occasionally taken there ; its habitat is normally just below low-tide mark. In any case it is too large to be readily kept alive in confinement. On the other hand, its ally the purple-tipped urchin (*E. miliaris*), which is very much smaller, is really common in the pools, and may be kept without difficulty in the aquarium. It should be looked for in the Laminarian zone, where so many interesting animals are to be found, and therefore a low spring tide should be utilised for the expedition in search of it. The diameter of the shell, or test, is often about that of a penny piece, but specimens of a considerably larger size may also be found. The test is depressed and is clothed with green spines tipped with purple. The urchin has, however, the habit of concealing itself by attaching fragments of weed, etc., to its spines, so that it is very liable to be overlooked. A specimen cleaned from these adventitious particles will show the five double rows of slender tube-feet, which protrude among the spines, and which are the organs of locomotion. These tube-feet are filled with sea-water, and communicate with an elaborate system of canals, forming together the water-vascular system, into which seawater enters by a perforated plate, called the madreporite, placed near the anus on the upper surface of the test. The mouth is placed in the middle of the under surface. Within its cavity is contained a curious system of hard bars, or ossicles, which carry five teeth. These five teeth can be protruded through the mouth opening and enable the urchin to obtain its food. The structure which bears these teeth was first described by Aristotle in the common urchin, and is still called Aristotle's lantern.

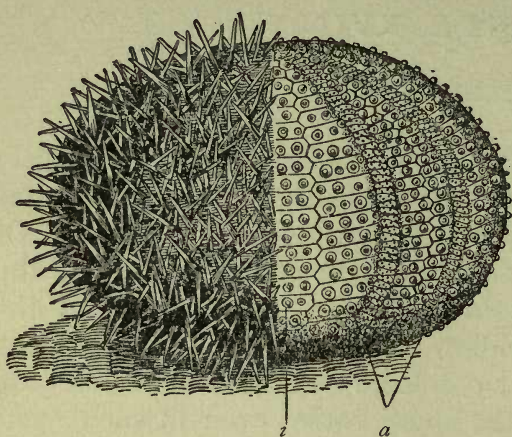


FIG. 75.—The common sea-urchin (*Echinus esculentus*). The spines have been partially removed to show the structure of the test. *a*, an ambulacral area, *i.e.* one where the tube-feet emerge ; *i*, an area without tube-feet (inter-ambulacral).

The purple-tipped urchin is the only urchin with which much success is likely to be obtained in the aquarium, but there is one other form which may be kept temporarily to show its special adaptations. This is *Echinocardium cordatum,* or the heart-urchin, whose fragile tests, scrubbed clean by the waves, are nearly always common on sandy shores after storms. At the same period one may sometimes find specimens still furnished with their golden spines, but for the living animal it is necessary to dig in the sand close to low-tide mark. Here the spade will turn up many of all sizes, all clothed with silky golden spines. An attempt should be made to keep some of the smaller forms in a vessel with plenty of sand for a few days, with the object especially of studying the method of burrowing, which is effected by certain curious flattened spines, and the method of feeding. The heart-urchin feeds on minute particles in the sand, and there is a very elaborate arrangement of spines, grooves and tube-feet whose object is to sweep the particles into the toothless mouth.

A considerable number of starfishes occur in the rock pools, the number and kinds varying with the locality. It is sufficient for our purpose to note the distinction between the five-fingered forms, of which *Asterias rubens*, the common starfish, is perhaps the commonest, and the forms with more than five arms or fingers, of which the sun-star (*Solaster papposus*) is an example. In either note the central disc which passes insensibly into the tapering arms. On the dorsal or upper surface of the disc notice the conspicuous madreporite, or perforated plate which allows water to enter the water-vascular system. The under surface is more interesting. In the centre notice the mouth, which has no lantern like that of the urchin. The under surface of each arm is deeply grooved, and in the groove lie the tube-feet, which are capable of considerable elongation. Each ends in a sucker, and by fixing these suckers the starfish can crawl up a perfectly perpendicular surface just as a fly can. The delicate tube-feet are protected by spines at the sides, and if destroyed can be readily re-grown; if a sea-urchin, for example, be torn suddenly from the rock to which it is clinging, it will be often found to leave some of its tube-feet behind it, but this is not of great importance, for the feet quickly grow again.

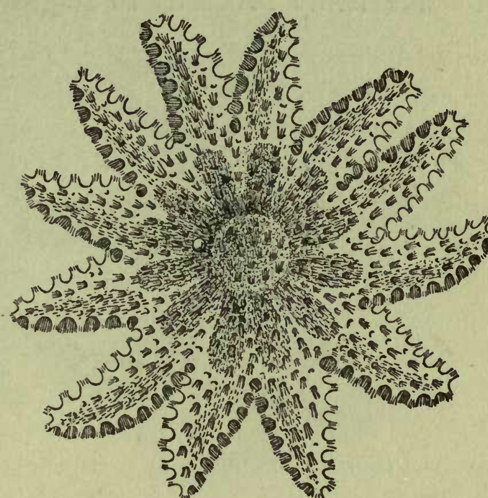


FIG. 76.—The sun-star (*Solaster*). Note the madreporite to the left of the central disc.

We have noted above that normally the common star has five arms or rays, but every now and again one may come across specimens with more or less rays, or with one large ray and the beginnings of four small ones. These are forms which have had their rays destroyed in some way, and which are in process of re-growing them; for it is characteristic of the Echinoderms in general that they have an extraordinary power of regenerating lost parts. In most of the starfishes it is parts which have been accidentally lost that are re-grown in this way, but in the brittle-stars the animal itself throws off parts of its own body, and then unconcernedly proceeds to re-grow them. Turn over a stone in a pool, and you may possibly see a wriggling brittle-star beneath. Seize it by one of the five arms, and the arm will drop off, the brittle-star making its escape while you remain with the actively moving fragment. So prone to self-mutilation indeed are the brittle-stars that it is often very difficult to obtain a perfect specimen for the aquarium. However gently they are handled they are always liable to throw off some part of the body. The common brittle-star of pools (*Ophiothrix fragilis*) is the worst offender in this respect, while the little sand-star (*Amphiura elegans*) found under stones in the sandy pools, which does not mutilate itself quite so readily, is to be preferred on this account for the aquarium. In any brittle-star note the sharp distinction between the arms and the disc as compared with starfish. The arms are more slender and much more active, the animals moving by them and not by their tube-feet. They consequently move more rapidly and more actively than the starfish, and so make more interesting inhabitants of the aquarium. The tube-feet of the brittle-star are small, and are not placed in a groove as in the starfish; they occur at the sides and not on the under surface of the arms.

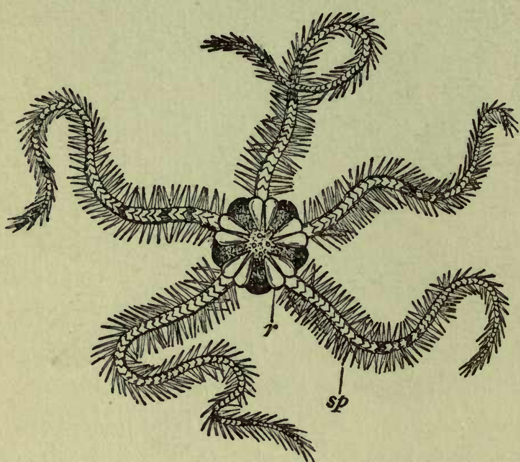


FIG. 77.—Common brittle-star (*Ophiothrix fragilis*). *sp*, spines; *r*, plates at base of arms.

The last group of the Echinoderms, the sea-cucumbers, are not well represented in the shore pools, but species of *Cucumaria* do occur there. In *C. lactea* the body is about an inch long, and the animal has a worm-like appearance which makes it very different in appearance from its allies. The skin is tough, and contains very much less lime than that of sea-urchins or starfish. Down the cylindrical body run five rows of tube-feet, which are short and much less freely movable than in the sea-urchins. The mouth is at one end of the body and is surrounded by beautiful branched tentacles, while the anus is at the other. A great difficulty in keeping the sea-cucumber in an aquarium is that it mutilates itself, especially by throwing out the internal organs, upon such trifling provocation that it is very difficult to get a perfect specimen to place in the aquarium. In the brittle-stars the habit of throwing off the arms is as clearly protective in function as is the lizard's habit of throwing off the tail when this is seized. In both cases the separated part continues to move actively, and distracts the attention of the enemy while the animal makes its escape. It is, however, much more difficult to see the value to the animal of the sea-cucumber's habit of throwing out its internal organs on an alarm, even if these can be rapidly regrown.

CHAPTER XVIII

The Marine Worms

As contrasted with the comparatively few kinds of worms which live in fresh water, we find that the sea is rich both in segmented and unsegmented forms, which reach a considerable size, and are often beautiful in colour. Perhaps the majority indeed are beautifully coloured, as compared with the ugly earthworm, and some are genuine ornaments of the aquarium. Only a few can be mentioned here, and it should be noticed in the first place that, as a general rule, the worms of the sea are prized as food by fishes and other animals. The consequence is that very many make for themselves special protective tubes, sometimes of fragments of sand, sometimes of lime, while others bury themselves in the sand or mud, or hide under rocks and stones. The result of this again is that the marine worms require to be carefully looked for, and may be readily overlooked. As a rule, the sand and mud-haunting forms are not suitable for the aquarium, and one is thus practically limited to the tube-inhabiting species and a few of the free-living forms. Many of the latter will not thrive in captivity, and those which can be induced to live there are so persistently shy in their habits that not much can be made of them. The tube-inhabiting forms, on the other hand, must protrude part of the body from the tube into the water in search of food, and in order to expose the gills to the purifying action of the water, and where they can be made to flourish are instructive and interesting.

Of the free-living worms we shall mention only the leaf-worms, which if not the commonest are at least very common, and are easy to keep in confinement. There are a considerable number of these leaf-worms, and all can be recognised by the leaf-like plates at the sides of the body. The marine worms as a general rule have attached to each ring of the body a pair of outgrowths, called parapodia by the naturalist, because although leg-like they are not jointed like the true legs of the crabs and their allies. In the leaf-worms these parapodia bear expansions, shaped like leaves, by means of which the animals swim. The

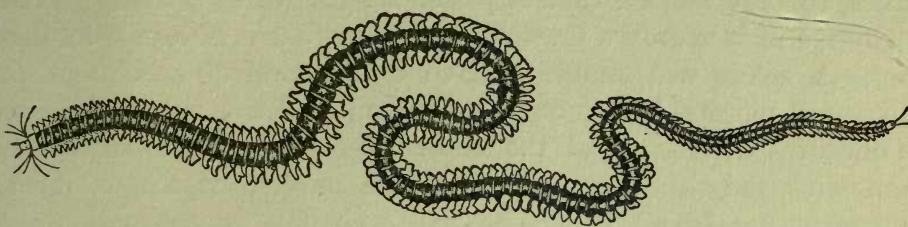


FIG. 78.—The paddle-worm (*Phyllodoce lamelligera*). Note the leafy plates at the sides of the body.

leaf-like effect is increased by the fact that the plates are sometimes green, as in *Eulalia viridis*, common in rock crevices, which reaches a length of about 3 inches. The larger paddle-worm (*Phyllodoce lamelligera*), which is sometimes 2 feet long, is of a darker green with an iridescent shimmer. A much smaller form (*P. macualata*), which lives in sandy places, is on the other hand delicately marked with brown. It is 3 or 4 inches long, but is very slender in proportion to its length.

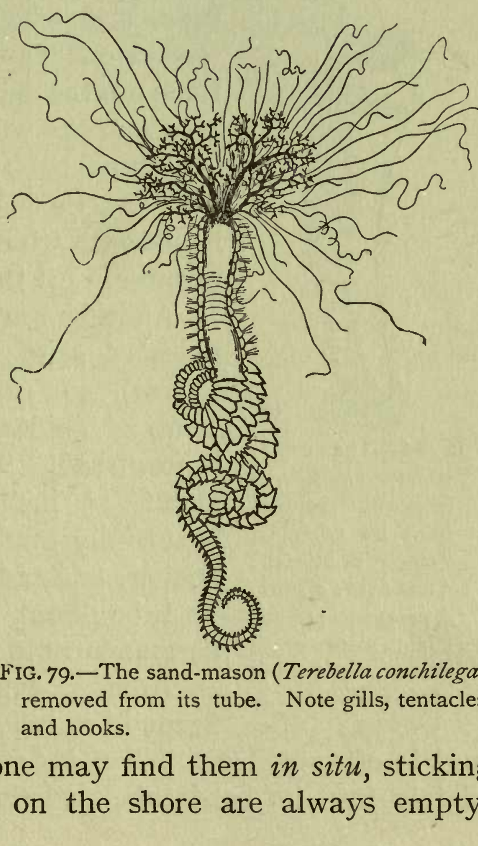


FIG. 79.—The sand-mason (*Terebella conchilega*), removed from its tube. Note gills, tentacles, and hooks.

Of the tube-inhabiting forms we may mention first the sand-mason (*Terebella conchilega*), a type of those who build long tubes of particles of sand, stone and shell, the mouth being fringed with sandy threads. These tubes are often very abundant after storms, and among the rocks one may find them *in situ*, sticking up through the sand. Those on the shore are always empty, and the attempt to pull up one of those in the natural position in the sand will also merely produce a fragment of empty tube. The reason is that the worms reach a considerable length, 10 inches or so, and their tubes are always much longer than themselves, so that when a tube is pulled up the worm retreats to the bottom, and it is only a few inches of tube that is obtained in this way. A spade will enable you to obtain perfect specimens of tubes and worms, but success in the aquarium is more likely to be obtained with some of the smaller species found under stones than with the sand-mason proper, the most conspicuous form. The structure of all the common Terebellids is approximately similar, and the points to observe are, first, the tube, which is made by the long red tentacles which the uninjured worm can protrude from the mouth of its tube. When the worm does this in the aquarium it is possible to see how the delicate red tentacles are sheltered within the sandy fringe of the tube, and when the tentacles are fully protruded one can make out that mingled with them are the delicately branched gills, by means of which the worm breathes. On an alarm it can shoot back again into its tube with great rapidity, by means of a wonderful series of hooks with which the body is furnished for the purpose. All these points are shown in Fig. 79.

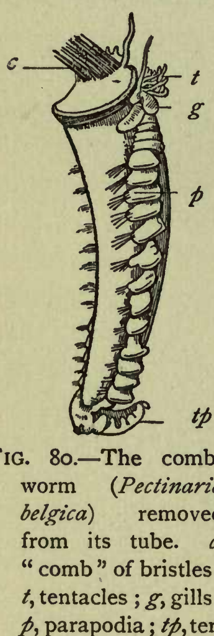


FIG. 80.—The comb-worm (*Pectinaria belgica*) removed from its tube. *c*, "comb" of bristles; *t*, tentacles; *g*, gills; *p*, parapodia; *tp*, terminal plate which closes posterior end of tube.

Another worm which makes a tube of particles of sand is the comb-worm (*Pectinaria belgica*), so called because of the beautiful comb of golden bristles with which the head is furnished. The tube in this case is short, about 1½ inch in length only, but is most beautifully made, and the animal shows some analogy to a caddis-worm (*q.v.*) in that it carries its tube about with it, and does not remain permanently in one spot like the Terebellids.

Another type of tube is that found in the Serpulid worms. Here the tube is made of lime, and is often coiled. When the worm is alarmed it retreats completely into its hard tube and closes the opening with a curious plug, but when it considers that all is safe this plug is pushed through the opening together with a crown of beautifully fringed and coloured gills. Some of the Serpulids are common on the shore rocks, and can be made to live for a time in the aquarium.

Those named above are a few representatives of the marine bristle-worms, but in addition to them a number of other types of worms occur on the shore rocks. Thus we have numerous ribbon-worms or Nemertea, in which the body is not ringed or segmented, and which move with a curious gliding motion. As a rule, they are somewhat difficult to keep alive in the aquarium. Then we have also the Polyzoa, which though they do not look like it are allied to the worm series. The most conspicuous is perhaps Flustra, the sea-mat, so often thrown on shore after storms, and popularly called seaweed, though one may notice in its "fronds" the little holes in which the tiny polyps live. The sea-mat is a colony of minute animals, and like its allies requires the aid of the microscope for its investigation.

CHAPTER XIX

THE SEA-ANEMONES AND THEIR ALLIES—COELENTERA

LEAVING some more difficult forms we may pass finally to the sea-anemones and their allies, forms which always strongly attract the aquarium-keeper. As a general rule, the animals belonging to this great alliance are conspicuous and easily seen, as compared with the shy and retiring worms. The meaning of this is that they characteristically bear tentacles furnished with stinging cells, which cause them to be disdained as food by most other animals, especially fish. They thus do not need to seek shelter like the edible forms. We shall begin this series with the sea-anemones proper, because they are the most familiar forms. The number of those available varies very greatly with the particular part of the coast studied, persons placed on the south-west coast being far more favoured in this respect than those on the eastern side of Great Britain. Only a few of the commoner forms can be mentioned by name, but those specially interested should endeavour to obtain a copy of Gosse's *Sea-Anemones*, which can sometimes be picked up cheaply from a second-hand bookseller, and has fine coloured plates.

Commonest and most suitable for the aquarium is the smooth anemone (*Actinia mesembryanthemum*), which occurs in red, green and brown varieties, and can always be recognised by the row of blue beads to be seen at the base of the tentacles, when these are fully expanded. These blue beads are clusters of stinging cells. To obtain specimens of this anemone for the aquarium it is only necessary to search under overhanging rocks in the shore pools, choosing if possible forms attached to small stones or to shells, so that the animal need not be disturbed. If such a specimen cannot be found, great care should be taken in detaching the base from the rocks, for if this be injured the anemone will not thrive in captivity.

Much handsomer than the smooth anemone is the thick-horned form (*Tealia crassicornis*), which unfortunately in the experience of most people is much more difficult to keep alive. Part of the difficulty lies in the fact that this anemone attaches itself very firmly, not to one stone or rock, but usually to several, so that it is exceedingly difficult to detach it without injury. It is a larger form than the smooth anemone, having often a diameter of several inches across the disc. The tentacles are short, thick and banded, and the animal has the habit of covering its body with particles of stone and shell, which in the contracted condition make it very inconspicuous. It lives farther out on the rocks than the common smooth form.

We have also numerous species of *Sagartia*, of which *S. troglodytes*, the cave-dwelling anemone, is a common and widely distributed form. It lives either among the sand of mussel beds, or in rock crevices, and as it does not fix itself very firmly it is easily detached and lives well in confinement. The colour is very variable, but there is always an elaborate system of banding, and one of the most interesting points in regard to this anemone is the close resemblance its colour shows to its natural surroundings. Sand-coloured in sandy pools, green in weed-containing pools, and so on, it occurs in numerous colour variations.

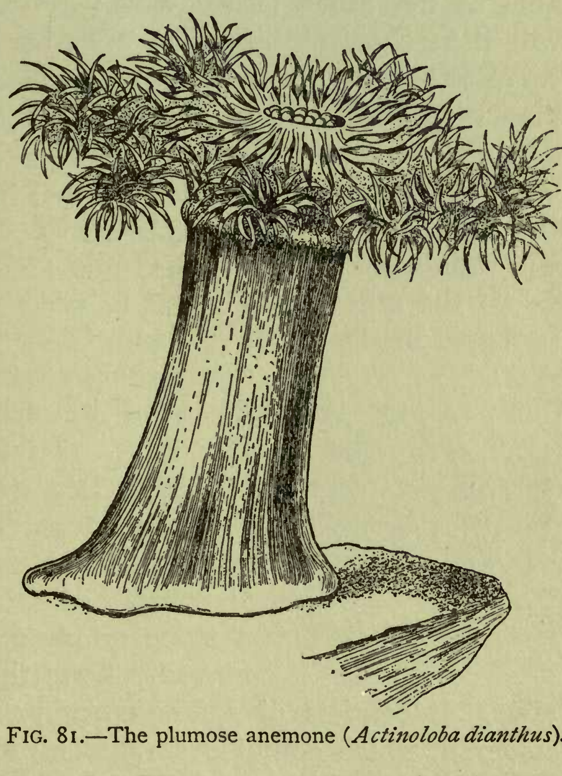


FIG. 81.—The plumose anemone (*Actinoloba dianthus*).

Another beautiful form is the Plumose anemone (*Actinoloba dianthus*), which occurs in white, yellow and flesh-coloured varieties, and has small tentacles and a curiously frilled or puckered disc. Large specimens of this anemone occur in deep water, but on the shore rocks one may find small specimens of an inch or so in height, growing in company with dead men's fingers.

On the west coast, but not on the east, a very beautiful and common anemone is *Anthea cereus*, which has many advantages in the aquarium. It is hardy, never completely retracts its tentacles like other anemones, is much more active than most, and can be readily detached without injury. In the south its long, snaky tentacles are of the most beautiful green colour, tipped with crimson, but in the north they are brownish, the whole colouring being much more sober. On the east coast the animal, unfortunately, does not occur at all. Where it does occur it should certainly be kept in confinement to show its striking beauty, for the ever-exposed tentacles make it greatly preferable to the other forms, which may often sulk for days, and will then show nothing but a fleshy knob, the tentacles being completely retracted. It requires no special care, but a good plan with an animal so common and so tolerant of change is to keep specimens for a few days only at a time, and then, as they begin to show signs of suffering from confinement, take them back to their pool, and replace them by others, knowing that they will rapidly recover perfect beauty in their native habitat.

Of the other forms allied to the sea-anemones, mention may be made of dead men's fingers (*Alcyonium digitatum*), so repulsive-looking after death, and so beautiful in life with its delicate translucent polyps. It occurs occasionally in the rock pools, but as it is always attached and will not thrive if removed from its substratum, success in the aquarium will depend upon the chance of obtaining a specimen fixed to a stone or piece of rock which can be removed. Even then it is not easy to keep alive. It consists of a fleshy mass, usually yellowish or flesh-coloured, which contains cavities in which are lodged numerous glassy polyps which can be withdrawn completely into the fleshy substance, but which when undisturbed protrude their bodies, ending in eight feathery tentacles, in the water in search of food.

FIG. 82.—A sea-fir (*Obelia*) on weed.

Each polyp has a general resemblance to a sea-anemone, so that the whole is a colony of sea-anemones, analogous to those colonies which form coral reefs in warm seas.

On the shore rocks there occur also a considerable number of sea-firs, which are colonies of polyps of much simpler structure than those in dead men's fingers. The polyps are supported by a horny substance, which has a general resemblance to sea-weed, so that the sea-firs are often mistaken for plants. The individual polyps are usually, though not always, very small, so that it is not possible to make much of their structure without a microscope. One cannot, however, omit on this account all mention of the sea-firs, because their life-history includes a phenomenon of such interest that a few words must necessarily be said about it. We have spoken above of the frequent occurrence in the life-history of shore animals of free-swimming young, which, like the winged seeds of the great forest trees, carry the species to fresh localities. The same effect is produced in the sea-firs by a totally different method. Look over the edge of the rocks or the side of a boat on a clear summer's day, and you will see floating in the water crystal bells, which swim with a pulsating movement, not strong enough to propel them against the current, so that they are swept to and fro with the tide. These swimming-bells are buds which have been produced by the sea-firs of the pools. From their sedentary brothers they differ in that they reproduce themselves by eggs, and not by budding like the former. They float seawards with their load of minute eggs, and being carried by the tidal stream as it sweeps along the coast, they serve as a means of distributing the sea-firs. Each little egg, if it be fertilised, is capable of producing not a swimming-bell like its parent, but a sea-fir like its grandfather. To this very curious phenomenon of alternative inheritance we give the name of alternation of generations ; it is known among plants as well as among animals.

In speaking of gasteropod molluscs, we noted that while some produce enormous numbers of delicate, free-swimming young, others produce relatively few young of greater complexity and more sedentary habit. If the whole reason for the difference is still unknown, we saw that one clue may be found in the fearful waste—the unselective waste—of life in the first method of reproduction. The waste of life among the swimming-bells is less obvious than among their larger allies the jelly-fish, which are more nearly related to the sea-anemones. We may see every summer what fearful havoc untoward currents and winds play with these by the myriads which strew the beach. But if the little swimming-bells for the most part perish unseen, we have no reason to doubt that the slaughter among them is as great, and therefore it is not surprising to find that some of the sea-firs have abandoned the habit of producing free-swimming bells. The little *Hyractinia*, so often found on the shells of hermit crabs, is an example of this. On the other hand, *Obelia* (see Fig. 82), which often covers bladder-wrack with its delicate tracery, is an example of a form which does produce swimming-bells. These two may be added to the aquarium for the sake of the story they tell. Another form, which may be named is *Clava squamata*, a pretty pink zoophyte, found on seaweed, in which one can see with the naked eye the sessile buds which replace the swimming-bells of *Obelia*.

FIG. 83.—The common hermit-crab in a whelk-shell covered by hydractinia. (After Allman.)

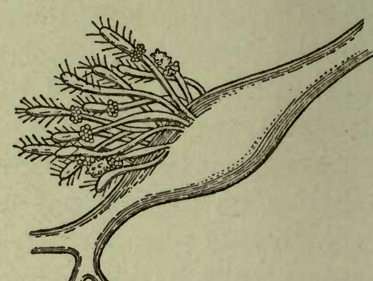


FIG. 84.—*Clava squamata* on seaweed, with sessile buds. (After Allman.)

We have said nothing above of the sponges, for under the ordinary conditions not much is to be learnt by keeping them in an aquarium, and they are very liable to pollute the water for other more interesting animals.

In conclusion, we may note that a considerable number of

Drawing by F. M. Newbigin.

THE AQUARIUM (II)

Sea-slug (*Ancula cristata*) Spawn of *Doto coronata* Sea-slug (*Doto coronata*) Sea-anemone (*Sagartia rosea*) Barnacle (*Lepas anatifera*)

marine animals have been named above, because, as already explained, the conditions are so varied at different parts of our coasts that comparatively few animals can be said to be equally common in all parts. It has been thought best to include here a selection of those only common in certain parts. It may therefore quite well happen that the teacher at some particular part of the coast may find only a very small proportion of the animals here described. But in this case the poverty of the shore should not be regarded as a reason for neglect—rightly looked at, the few, commonplace, hardy forms found may rival in interest all the anemones of Devonshire. As points to which in this case the teacher may usefully direct attention are, for example, on a wave-swept coast, with few or no sheltered coves, the means of protection from current action adopted by the animals which do occur. Thus, the common anemone *Tealia,* if living in wave-swept spots where the stones and gravel it loves are absent, quite changes its tactics, and attaches itself to the rock-face instead of sinking its body in gravelly sand. Again, if the coast-line is predominantly sandy, with occasional belts of rock, a problem of great interest is how the rock-loving, sedentary animals, which are absent from the sandy reaches, get from one belt of rocks to another. We have offered above some suggestions as to the solution of this problem, and by the help of the aquarium the teacher may hope to solve it for all the common forms. Again, generally speaking, coast towns or villages have been determined by the occurrence of a harbour or sheltered cove. If the prime industry was fishing, there will be bait beds in the neighbourhood, for long before man came the fish were there, and they must have found food. Here is a sequence which may be made the basis of useful lessons—a fishing village means shelter, which often means rocks, the rocks mean rock-haunting animals, and these bring food-fish ; the aquarium is not being properly kept if it does not suggest and make vivid such sequences. Again, if the village or town be on a river or estuary, it will be noted that the river brings down silt, which is deposited somewhere near its mouth. The silt means mud-inhabiting animals, for the land waste carried down by the river is capable of feeding many marine animals. If muddy water is fatal to many animals, how is it that others can live and thrive in it? We have suggested above an answer for one mud-haunting animal, but there are many others which should be similarly studied.

We have given in this article scientific names and references which will enable the teacher well placed with regard to libraries to name or further study his finds, because there are a considerable number of persons who are strongly attracted towards systematic work, but it must not be supposed that this is the only kind of work which can be done on the shore. The study of adaptation, of the fitness of animals to their surroundings, and the problems as to how this fitness has originated, and how it is maintained, are problems which appeal to many who are totally uninterested in systematic work. An attempt has been made above to show how these problems may be approached, and how the aquarium may be used to aid their investigation.

BOOKS OF REFERENCE.—In the list of books relating to the freshwater animals, mention has been made of some books dealing also with marine animals. Of other books the author's *Life by the Sea-shore* (London, 1901) may be named; it includes references. A very cheap and useful little book is Wood's *Common Objects of the Sea-shore* (London, 1864). In identifying the members of the different groups, in addition to the books named on p. 126, the following may be used:—Hincks' *British Hyroid Zoophytes* (London, 1868), Gosse's *History of the British Sea-Anemones* (London, 1860), *Catalogue of Echinoderms in the British Museum* by Jeffrey Bell (London, 1892), Bell's *History of the British Stalked-eyed Crustacea* (London, 1853).

THE HAUNTS OF ANIMALS

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CHAPTER XX

Introductory Note.—Prominence has been given in this book to "plant associations," and to the adaptation of plants to particular surroundings. Animals must be considered from the same point of view. This has been done in part in treating of the several classes, *e.g.* of birds and mammals, and in part in that section of the book which deals with the observational study of animals in aquaria. What is proposed in this chapter is to indicate briefly how the distribution of animals in various kinds of haunts may be brought within the scope of reasonable "Nature Study."

The Chief Haunts of Animal Life.—It is useful to begin by recognising, as vividly as possible, that there are *six* chief haunts of animal life,—namely, the seashore area in the wide sense, the open sea, the deep sea, the fresh waters, the dry land, and the air. There are, it is true, other haunts of animals, *e.g.* in brackish water, in caves, inside other creatures, and so on; but the *chief* haunts are the six which we have mentioned.

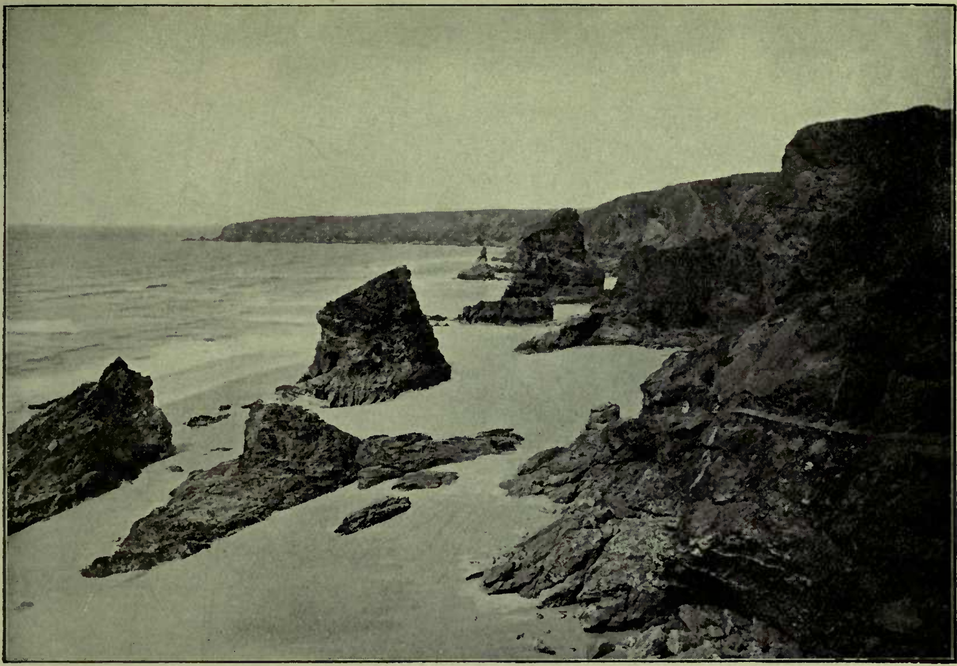
1. The seashore, with its littoral fauna.
2. The open sea, with its pelagic fauna.
3. The deep sea, with its abyssal fauna.
4. The rivers, lakes, ponds, etc., with their freshwater fauna.
5. The dry land, with its terrestrial fauna.
6. The air, with its aërial fauna.

It would be interesting to have a cupboard with six shelves, with typical representatives of the various faunas. One would put some birds and insects (6) uppermost, a deep sea sponge and a few corals (3) lowermost, and so on for the other shelves.

The Seashore

Characteristics of the Shore Fauna.—By the shore — the littoral region—is meant not simply the narrow area between tide marks, but that and much more; in fact, the whole of the shallow-water shelf around the dry land. It includes (*a*) the upper littoral zone or beach exposed at low tide, with its acorn-shells (*Balanus*), periwinkles (*Littorina*), dog-whelks (*Purpura*), limpets (*Patella*), cockles (*Cardium*), and mussels (*Mytilus*); (*b*) the median laminarian zone, down to fifteen fathoms, with its sea-slugs or nudibranchs, its starfishes and oysters; and (*c*) the lowest or coralline zone, from fifteen to forty fathoms, where the green and olive sea-weeds are replaced by red sea-weeds, and where the carnivorous buckies, for instance, are at home. Generally speaking, we mean by the littoral area the relatively shallow shelf where sea-weeds grow, which is not deep enough to be dark.

The animal population in this large area is exceedingly rich and varied, representative of most of the classes of the animal kingdom. There are microscopic infusorians and Foraminifera; sponges with skeletons of lime, or of flint, or of "horny" matter, or of the two last together; zoophytes and sea-anemones and alcyonarians; a mob of worms of many different kinds; starfishes and sea-urchins; a legion of Crustaceans, from sandhoppers to crabs; a few insects about high-tide mark; quaint sea-spiders (or Pycnogonids) clambering on the sea-weed; abundant bivalves and gasteropods and occasional cuttle-fishes; sea-squirts fixed to the rocks and sea-weed; many shore fishes, such as gunnel (*Pholis gunnellus*), and father-lasher (*Cottus bubalis*); on foreign shores a few reptiles; numerous shore birds, such as gulls and terns, oyster-catcher, dunlin, ringed plover, and sandpipers; and an occasional



ROCKY SHORE AT LOW TIDE

ROCKY SHORE AT HIGH TIDE.
(Photos by Firth.)

mammal. The broad fact is, that the shore fauna is *very representative.*

We must not, of course, include among the shore forms those pelagic animals, such as jelly-fishes, which are often stranded in enormous numbers. On the other hand, we have to remember that many of the truly littoral animals spend their youthful life in the open sea; they are delicate larvæ, quite unsuited for the rush and tumble of the shore, but safe as swimmers or drifters in open water. Many seashore Worms, Echinoderms, Crustaceans, and Molluscs have pelagic larvæ.

The characteristic of the shore area as distinguished from other haunts of life is its variety and changefulness. "The conditions of life on the shore are in some ways the most stimulating in the world. It is the meeting-place of air, water, and land. Vicissitudes are not exceptional, but normal. Ebb and flow of tides, freshwater floods and desiccation under a hot sun, the alternation of day and night felt much more markedly than on the open sea, the endless variations between gently lapping waves and blasting breakers, the slow changes of subsidence or elevation,—these are some of the vicissitudes to which shore animals are exposed." [1]

Partly because the conditions of life on the shore are very changeful, partly because of the dense population, and partly because of the self-assertiveness natural to vigorous, lusty creatures, there is much struggle and competition on the shore. The heron standing alert by the water's edge is on the outlook for fishes, which are on the outlook for shrimps, which are on the outlook for still smaller fry, and so on it goes. The oyster-catcher seeks with a neat stroke of its strong bill to knock the limpet off the rock; the limpet does its best not to be taken by surprise. There are combats between rival shore-crabs, such as *Carcinus mœnas*, and between hermit-crabs (*Eupagurus bernhardus*). There is the quieter kind of non-competitive struggle—of the living organism against the vicissitudes of its environment,—when shore animals adjust themselves, or re-act in the direction of adjusting themselves, to unfavourable conditions.

[1] See (Thomson) p. 222.

The struggle for existence seems to be keen in the shore area, and some of the illustrations of it are striking. The dog-whelk (*Purpura lapillus*) lays its eggs in neatly shaped vases, at first pinkish, afterwards straw coloured, which are found abundantly in spring on the ledges of the low-tide rocks. Inside these vases a strange infantile struggle occurs — "cannibalism in the

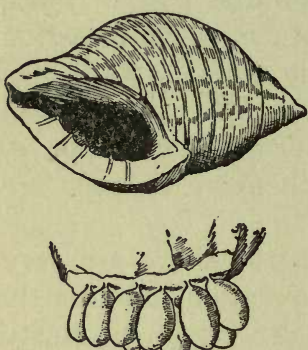


FIG. 85.—The empty shell of the dog-whelk (*Purpura lapillus*), a carnivorous gasteropod, abundant on the shore rocks. Beneath is a cluster of its vase-like egg capsules which are attached to the rocks, often to the under side of ledges.

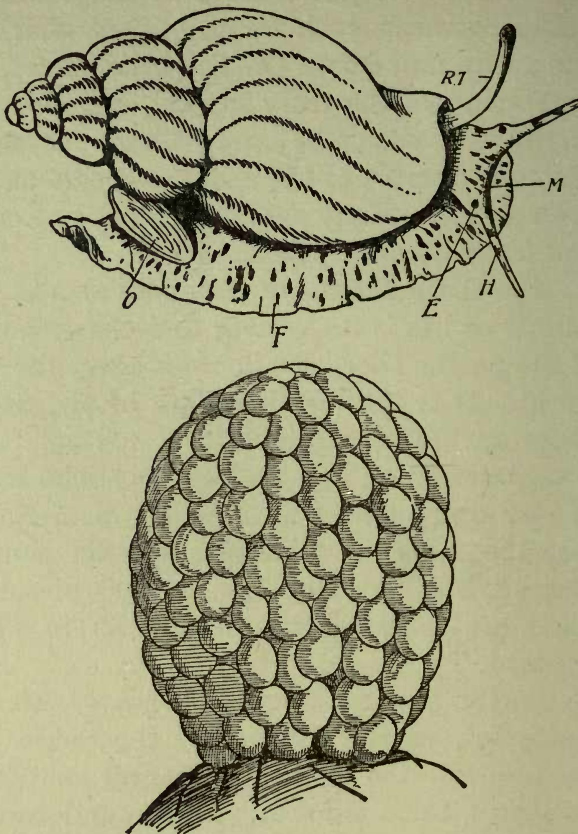


FIG. 86.—The common buckie (*Buccinum undatum*). The protruded head shows the mouth (M), the horns (H), and the eyes (E). Protruding from the notch at the mouth of the shell—which is a mark of carnivorous gastropods—is the respiratory tube or siphon through which water enters and leaves the gill-chamber. The flat muscular ventral surface on which the animal creeps along is called the "foot" (F). It bears posteriorly a flexible lid or operculum, which closes the shell when the animal retracts itself (O). Below the animal is a small cluster of its chaffy egg-capsules, which it attaches to rocks and stones in the Laminarian zone.

cradle," for some embryos eat their neighbours till only an elect few are left. The same story is true of the embryos inside the larger egg-cases of the buckie (*Buccinum undatum*) and of the great whelk (*Fusus antiquus*), which are fixed to rocks at a lower level, and are often cast up on the shore. In the fresh bunches which have been torn off the rocks by the storm the yellowish yolk of the eggs can be seen shining through the chaffy capsules. In those from which the surviving embryos have been hatched it is easy to find the door of escape.

There is no finer field than the shore area for the study of fitness. Everywhere we see temporary adjustments or permanent adaptations of structure and habit which secure for their possessors a firmer foothold, a more comfortable subsistence, a longer life, a larger family, or what not. Here a crab masks its bad reputation—for that it has something corresponding to this we cannot doubt—under a cloak of sea-weed which it fixes to its carapace; there a starfish escapes from its captor by surrendering one of its arms, having, in spite of its utter brainlessness, somehow learned that it is better that one member should perish than that the whole life should be lost; the hermit-crab which has had its claw badly damaged throws off the injured limb always across one line near the base—the so-called "breaking-joint," — and then regenerates the whole, as the starfish does its arm; the sandhopper "feigns death"; the cuttle-fish throws dust in its enemies' eyes, as it were, by a discharge from its ink-bag; the flat-fish assumes the tint of the patch of sand on the floor of the pool in which it lies. And thus one might continue through hundreds of instances.

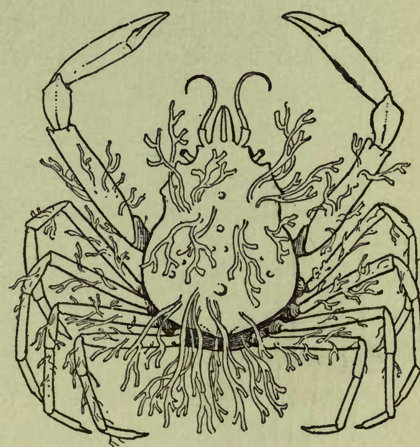


Fig. 87.—A sand-crab (*Hyas araneus*), showing a growth of seaweed on the back of its shell. This forms a useful disguise, which the crab apparently attaches to itself, as it were planting a garden on its back. The device is a far-off hint of "the walking wood of Birnam" and similar tricks in human history.

Hints as to Shore Excursions.—An account of many of the common shore animals, and suggestions as to the ways in which they may be profitably used in school Nature Study, will be found in the chapter on Aquaria. What we propose to do here is simply to make a few suggestions in regard to some possible excursions.

A few general hints may be useful. (1) If only a few excursions can be taken, it is important to choose the time of low tide; otherwise those to whom shore-hunting is a new thing will be disappointed. (2) One should always go out as far as possible first, and retreat as the tide comes in. On many coasts it is absolutely necessary to keep a sharp lookout lest one's retreat be cut off. (3) It is desirable to choose as varied a piece of shore as possible, especially if one cannot have more than a few school excursions in the year. Spurs of land running out into the sea, with rock-pools and gullies and ledges, with abundant seaweed, with a sandy bay on either side, are often very productive. (4) Two sorts of vessels should be taken for holding the animals while they are being studied,—flat vessels of the soup-plate type to look down into, and high glass vessels with flat sides — of the museum-jar type — for looking through. The animals must be studied in this way because they often live in nooks where they cannot be watched with comfort or by more than one observer at a time, because the surface of a well-stocked accessible pool is so often ruffled by the wind, and because it is of little use looking at the animal out of water. To take an example, fine specimens of *Tubularia indivisa* are often found in deep gullies, and in most cases the only practicable way of realising their extraordinary beauty is to reach for a few and put them in a glass vessel with water. When time allows it will be found interesting to choose a suitable rock pool of small size and stock it for the day with

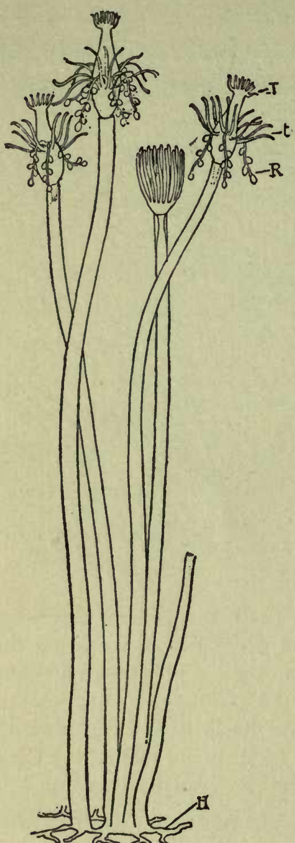


FIG. 88.—Colony of tubularian polyps (*Tubularia indivisa*). H, root-tubes uniting the members of the group; T, upper circle of short tentacles around the mouth; *t*, lower circle of long tentacles; R, pendants bearing reproductive buds.

the "catch." Unless there is a school aquarium, as there ought to be, the scholars should not be encouraged to carry home living animals. This practice usually ends in "smells" and in a disagreeable appendix to the pleasant impressions of the day. (5) It is useful to have a small collecting net and bottle on the end of a long stick for reaching things out of the sea, and a spade for digging in the sand and shingle. (6) Many of the most beautiful shore animals—sea-worms (e.g. *Nereis virens*, *Phyllodoce*), bivalves (*e.g.* spout-fish or *Solen*, *Tellina tenuis*), some sea-urchins (*e.g.* the yellow heart-urchin, *Echinocardium cordatum*), etc.—are burrowers in the sand, and the successful shore-collector must be able to dig. (7) To turn over stones is indispensable,—so many animals lurk underneath. It is very important to replace these stones in their original position, or some approximation to it. Otherwise the shore is deteriorated. If the stones are left upside down, the rich growth of seaweed which has been turned down rots and makes the surrounding sand obnoxious to many kinds of animals. The upturned under surface had also its rich growth of hydroids and the like, and these are left to die. Many good localities near large scientific centres have been spoiled by systematic careless collecting by enthusiastic but improvident students.

At High Tide.—As we have said, a shore excursion should be arranged for the time of low tide, when the conditions for discovering things are most favourable. But it is very useful also to go down to the rocks at high tide and to set the young explorers the task of finding at least a dozen animals before they have their game or their swim. Let us name a likely dozen. (1) Acorn-shells or barnacles (*Balanus balanoides*) encrusting the rocks ("A Barnacle," Huxley wrote, "may be said to be a crustacean fixed by its head, and kicking the food into its mouth with its legs"); (2) common periwinkles (*Littorina littorea*); and (3) the small yellow, red, olive and otherwise coloured small periwinkles (*Littorina rudis*); (4) the limpet (*Patella vulgata*), holding tightly to the niche its shell has grown to fit; (5) the carnivorous dog-whelk (*Purpura lapillus*; (6) young specimens of the edible mussel (*Mytilus edulis*); (7) the commonest amphipod (*Gammarus locusta*), working busily underneath the stones, tireless scavengers of the shore; (8) the sandhoppers, leaping high into the air when the tossed-up seaweed is disturbed; (9) some sea-slater, such as *Idotea tricuspidata*; (10) the common shore-crab, buried in the sand at the floor of a rock pool; (11) the commonest sea-anemone, the beadlet, *Actinia mesembryanthemum*; (12) some representatives of the primitive wingless insects (e.g. *Anurida maritima*) in the crevices of the rocks or lying like floating iron filings on the surface film of small pools.

As another very pleasant and instructive exercise we may suggest the collection of all sorts of natural shore jetsam—pieces of sponge, zoophytes, sea-pens, starfish, sea-urchins, Aristotle's lantern, moulted shells of crabs, sea-mat, bivalves and gasteropods, the egg-capsules of the buckie, mermaid's purses, and so on. These can be kept with appropriate pieces of sea-weed in clean sand in a large box. By turning this out on the table one can have, at any time, the beautiful natural disorder of the seashore.

FIG. 89.—Acorn-shell (*Balanus balanoides*), enlarged four times, showing curled feet projecting from between the (4) valves, which close the top of the external circular rampart. The latter is built up of many pieces.

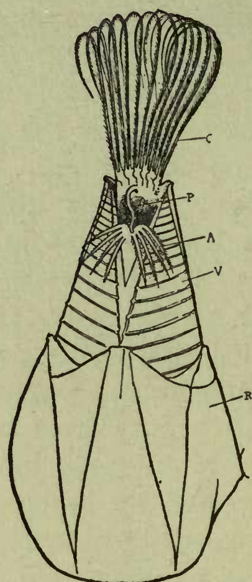


FIG. 90.—Acorn-shell much enlarged. C, six pairs of cirri or curled legs, which waft food into the mouth; P, penis; A, appendages around the mouth; V, one of the four valves; R, external rampart.

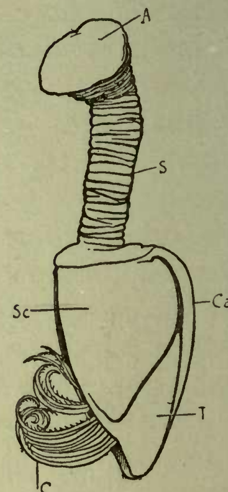


FIG. 91.—Ship barnacle for comparison with acorn-shell. A, attaching disc, representing the original tip of the head; S, stalk formed from an elongation of the front part of the head; C, cirri or thoracic legs; Sc, scutum; T, tergum; Ca, carina.

A Typical Shore Excursion. — Long experience suggests two conclusions,—a statement of which may be useful. The first is that too much should not be attempted at once. By all means let us welcome every discovery that the young explorers may make—even when it puzzles us—for the mood of inquisitive research is at the root of all science, and the shore is a stimulating incentive. At the same time, we must make sure that some things are being seen precisely and repeatedly

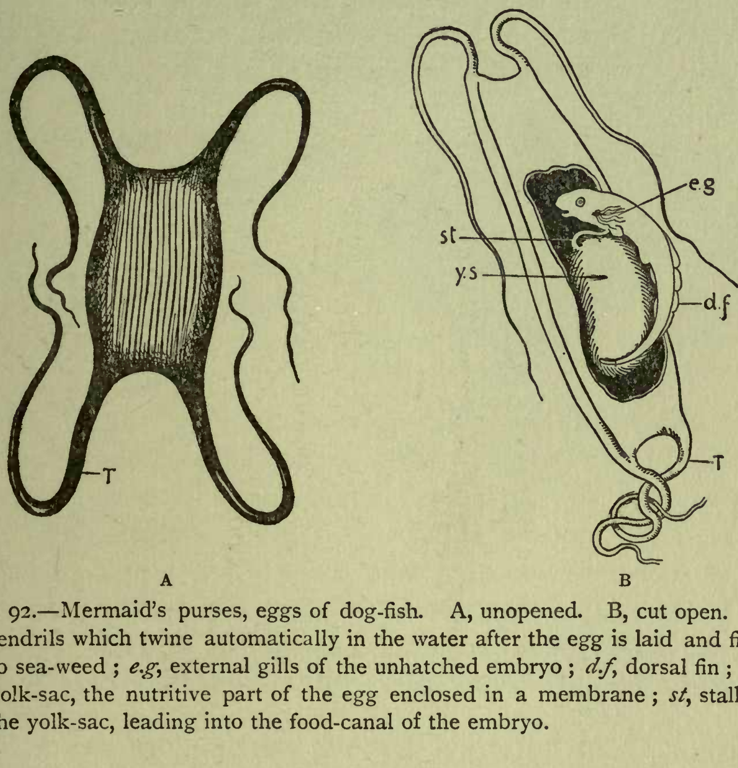


FIG. 92.—Mermaid's purses, eggs of dog-fish. A, unopened. B, cut open. T, tendrils which twine automatically in the water after the egg is laid and fix it to sea-weed ; *e.g*, external gills of the unhatched embryo ; *d.f*, dorsal fin ; *y.s*, yolk-sac, the nutritive part of the egg enclosed in a membrane ; *st*, stalk of the yolk-sac, leading into the food-canal of the embryo.

so that they enter into a more or less permanent picture of the shore and its fauna. It is well that our reach should exceed our grasp, but let us grasp something. The second is that we must make the transition from observing to interpreting. It is all very well to get to know fifty common shore animals, but this knowledge has largely failed of its purpose if we have not, in the acquiring of it, begun to form the habit of interpreting, —of inquiring into the significance of obvious facts in structure and habit and distribution.

We have referred to a few animals to be seen near the high-water mark, but let us suppose that we have got down to a more typical level. What should we look for on a first excursion ?

Coating the rocks, especially under ledges, is the crumb-of-bread sponge (*Halichondria panicea*), very varied in its thickness and vigour of growth, with numerous exhalant orifices like the craters of volcanoes. It is interesting to find a piece on a loose stone or on a detachable corner, to put this uninjured into a bowl of water, to add a little powdered carmine, and thus to *verify* the fundamental fact that the water passes in by minute pores all over the surface and passes out by the large

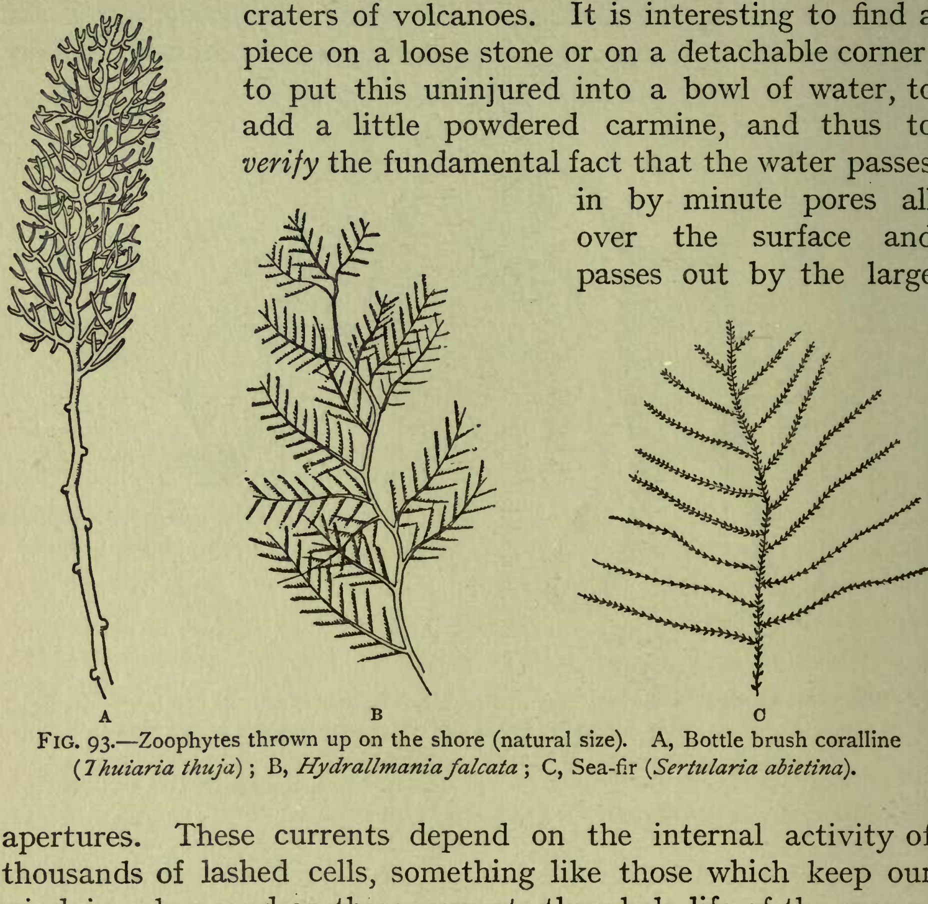


FIG. 93.—Zoophytes thrown up on the shore (natural size). A, Bottle brush coralline (*Thuiaria thuja*) ; B, *Hydrallmania falcata* ; C, Sea-fir (*Sertularia abietina*).

apertures. These currents depend on the internal activity of thousands of lashed cells, something like those which keep our windpipe clear, and on these currents the whole life of the sponge depends, for the water brings in food particles and oxygen and sweeps out waste. If the body of an animal be compared to a city, the body of a sponge may be compared to Venice. We should look for the calcareous purse sponge (*Sycon compressum*), and inquire why it can live farther up the shore than its near relative —*Sycon ciliatum*. Very common are still smaller and simpler calcareous sponges—delicate white tubes—such as *Leucosolenia* *botryoides*. But let us begin by making sure of the crumb-of-bread and the purse sponge.

From sponges we pass to zoophytes, sea-anemones, and other stinging animals (Cœlentera). We should look for some species of *Tubularia*, with its double wreath of beautiful tentacles; for the small *Coryne*, with club-shaped tentacles; for *Sertularia* and *Obelia*, growing on the sea-weed. These should be put into water to see if they are quite alive, which is plain enough when the polyps expand their heads. Sometimes a hermit-crab shows on its borrowed shell a pinkish growth of *Hydractinia echinata*, a fine instance of division of labour in a colony. From these small creatures one would pass to the polyps of higher degree—the sea-anemones, finding besides the beadlet, the wartlet (*Tealia crassicornis*) and the elegant white or salmon-coloured plumose anemone (*Actinoloba dianthus*). Far out, attached to the big Laminarians in deep pools, one may find the olive-coloured *Anthea cereus*, with non-retractile tentacles.

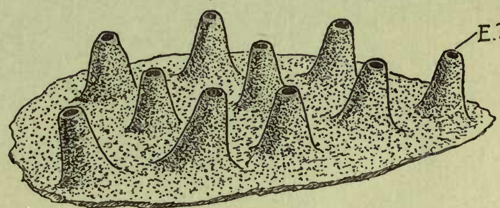


FIG. 94.—Crumb-of-bread sponge (*Halichondria panicea*). EP, exhalant pore.

Among "worms" we should look first for the living film (*Leptoplana tremellaris*), a leaf-like simple worm about half an inch long seen gliding about on the under surface of stones; for the ribbon-worms, like the purple "sea-snake" (*Lineus marinus*), often six feet long, and sometimes more than six times that, found far out at very low tide hidden under sea-weed or loosely lying flat stones; for higher bristle-footed worms burrowing in the sand, such as species of *Nereis*; for the related tube-worms such as *Pomatoceros* (often called Serpula), with a strong keeled limy tube fastened to stones; *Spirorbis*, a minute twisted limy tube very common on sea-weed; and *Terebella*, as an illustration of those with sandy tubes. Very abundant are the sea-mats (*Flustra*) and other examples of the Bryozoa or Polyzoa, often somewhat zoophyte-like, often spreading as beautiful encrustations on the stalks of the sea-weeds. The attaching bases of the larger sea-weeds often harbour a dozen different kinds of animals, and should always be carefully examined.

To illustrate Echinoderms, one looks first for the common starfish (*Asterias rubens*), a brittle star (such as *Ophiothrix fragilis*), a stray sea-urchin (such as the purple-tipped *Echinus miliaris*, often half hidden with a burden of little pebbles).

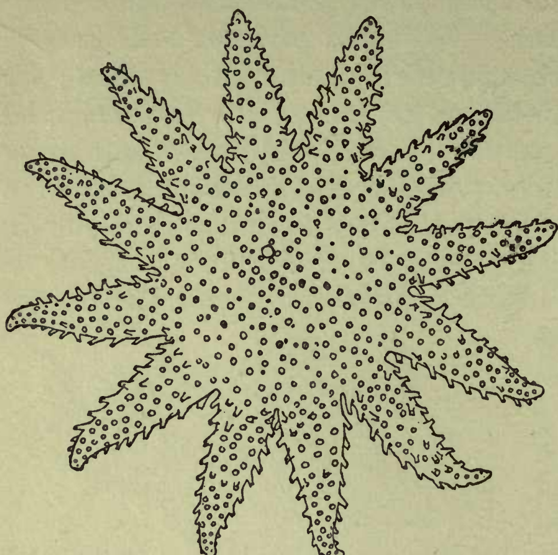


FIG. 95.—Sun-star (*Solaster papposus*).

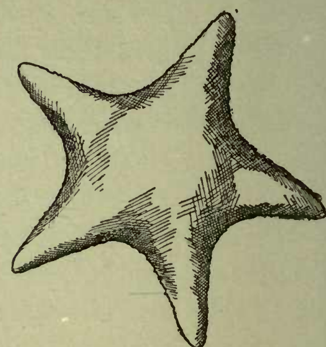


FIG. 96.—Pincushion starfish (*Porania pulvillus*).

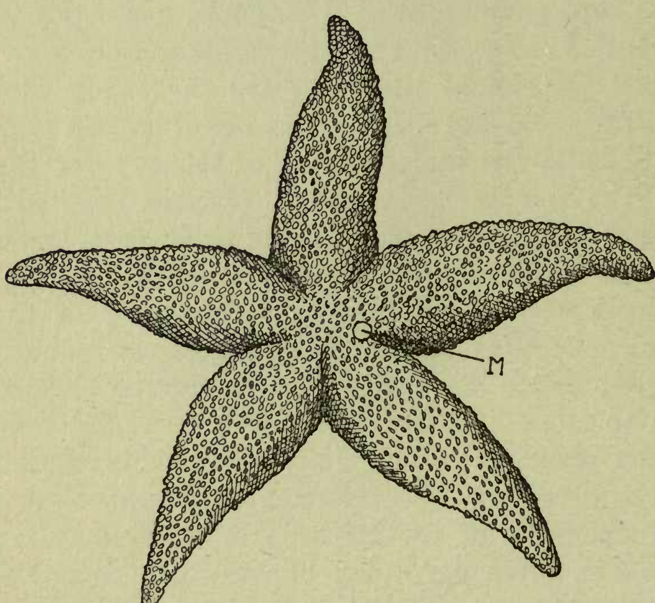


FIG. 97.—Common starfish (*Asterias rubens*). M, the madrepore, a perforated plate by which water enters the water-vascular system.

To watch these move in a basin of water is interesting. To watch with a good lens the play of tube-feet and spines and small snapping blades on the surface of a sea-urchin just covered with water is to gain an unforgettable impression.

Similarly, one of the first things to do on the shore is to find a flat stone with acorn-shells, so that the movement of the curled legs may be studied in a shallow dish; everywhere under stones there are crowds of amphipods (such as *Gammarus locusta*), scavengers of the shore; the protectively coloured shrimps must be looked for in a sandy pool; and the higher Crustacea are familiarly illustrated by the common shore-crab (*Carcinus mænas*), so variable in its coloration when it is young, by the swimming-crabs (*Portunus*), and the perennially interesting hermit-crabs.

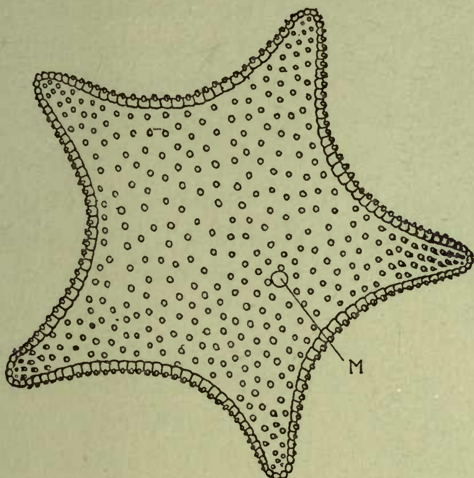


FIG. 98.—Horse starfish (*Hippasterias phrygiana*). M, the madrepore.

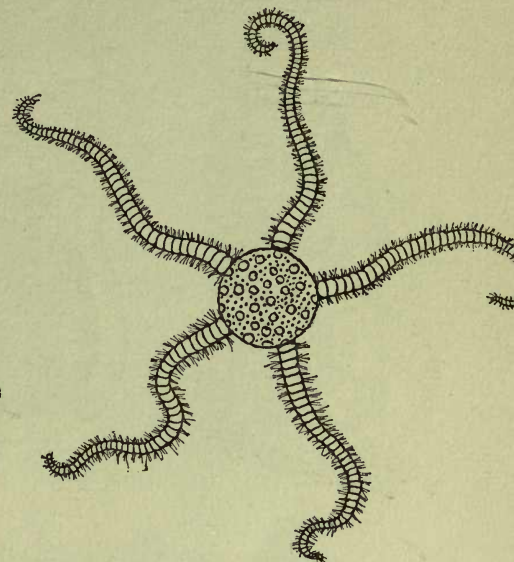


FIG. 99.—Brittle star (*Ophiopholis*).

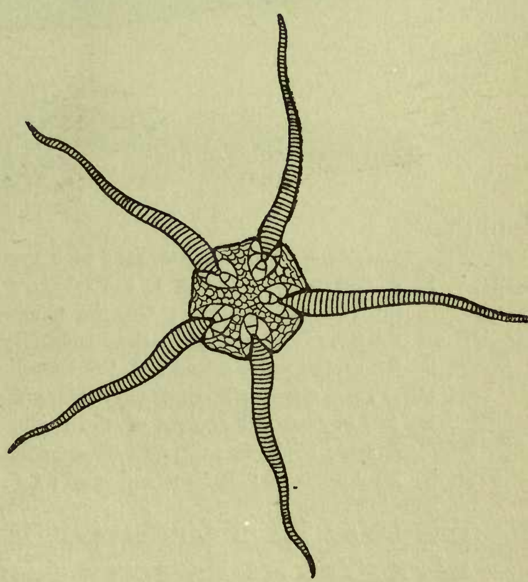


FIG. 100.—Brittle star (*Ophiura*).

To watch the action of the baler in the common crab, to search for one that has just moulted, to distinguish (by the clean-cut line of breakage) between a crab's moult and the shell of a dead crab, to look for a sand-crab (*Hyas araneus*) with a garden of sea-weed on its back, or for a shore-crab with the remarkable crustacean parasite

Sacculina protruding beneath the tail,—these are among the early exercises on Crustaceans. Nor should one forget to train the eye to find the quaint sea-spiders (such as *Pycnogonum littorale*) which crawl about among the living sea-weeds and hydroids.

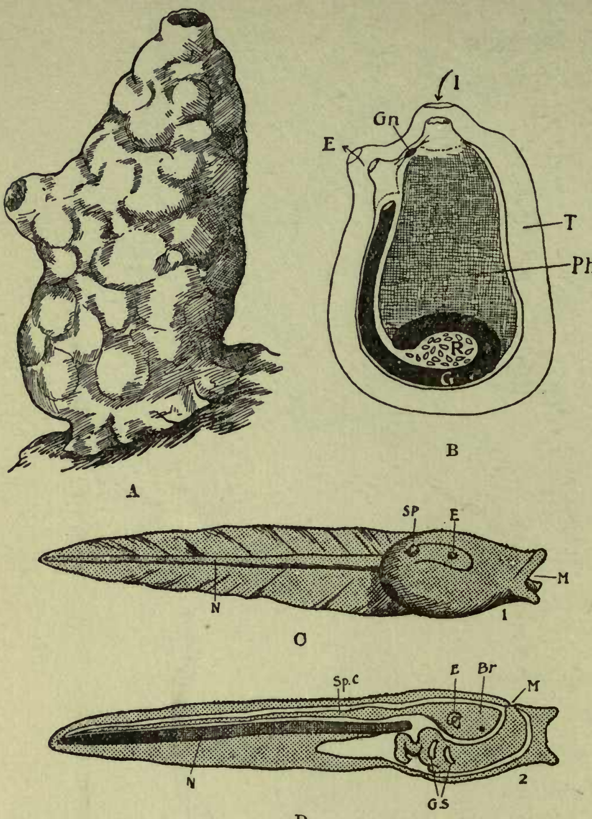


FIG. 101.—A, External appearance of a typical Ascidian. B, A dissection, showing I, the inhalant opening; E, the exhalant opening; Gn, the nerve-ganglion; T, the test of cellulose; Ph, the respiratory pharynx. R, the reproductive organ; G, the intestine.
C, 1. Free-swimming larva, greatly enlarged, external view.
D, 2. Longitudinal section of the same. M, mouth; E, eye; Br, brain; Sp, spiracle or breathing aperture; N, notochord; Sp.C, spinal cord; GS, gill-slits.

Fortunately there is an admirable guide for the exploration of the haunt we are discussing,—Dr. Marion Newbigin's *Life by the Seashore*,[1]—and with this so readily available we need not do more than emphasise our advice not to try too much at once, and to try to interpret as well as to observe.

One of the charms of this and every other area is the number of unsolved problems. The shore bristles with problems as the rocks with acorn-shells. You cannot go a step without meeting one. Even when no animals are visible, there is the problem of where they are. You lift a sandhopper, it lies stiff on your hand,—*how? why?* You see the young shore-crabs grey, green, brown, red, and other colours,—*how? why?* You find little periwinkles (*Littorina rudis*), in yellow, orange, brown, red, and other-

[1] See (Newbigin) p. 222.

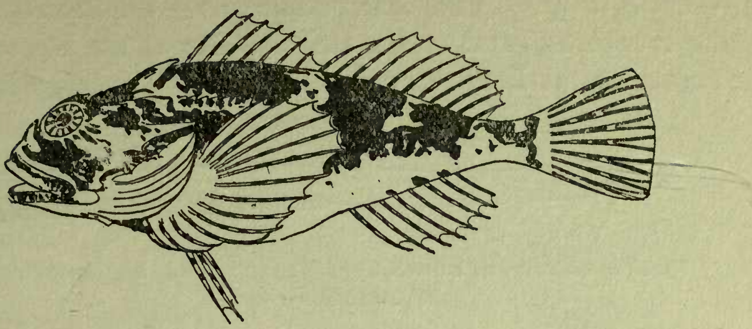


FIG. 102.—Father-lasher or bullhead (*Cottus scorpius*), a characteristic shore fish.

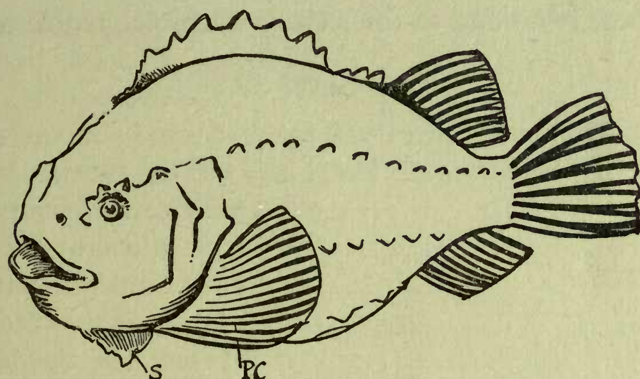


FIG. 103.—Lumpsucker (*Cyclopterus lumpus*). PC, pectoral fin ; S, sucker formed from pelvic fins.

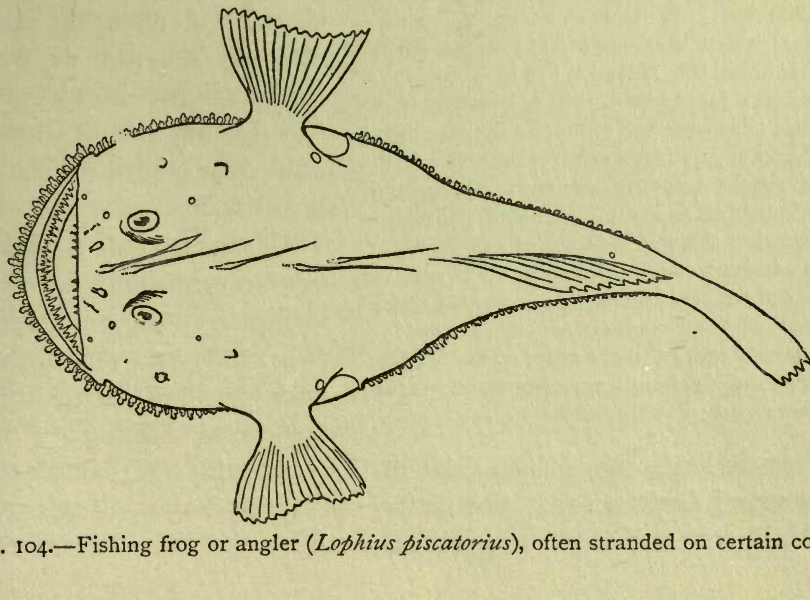


FIG. 104.—Fishing frog or angler (*Lophius piscatorius*), often stranded on certain coasts.

wise,—*how? why?* You find Ascidians—nondescript, water-bag-like creatures fixed to the stalk of one of the big sea-weeds; they began life as little tadpole-like free swimmers, with all the

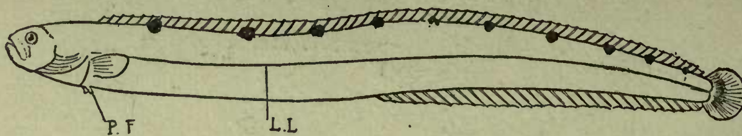


FIG. 105.—Gunnel or butterfish (*Pholis gunnellus*). LL, lateral line; PF, small pelvic fins.

essential characters of a back-boned animal (see Fig. 101)—*how* and *why* has this come about? So one might continue page after page, for there is no end to the shore's unsolved problems.

The Open Sea

The conditions of life in the open sea are sharply contrasted with those of the shore. They are on the whole very much easier. There can be no lack of room, there is abundant sunshine without risk of drought, there is an evener life throughout the day and throughout the year than is to be found elsewhere except in the abysses of the deep sea, there is an inexhaustible supply of minute unicellular Algæ, which form the basal food material.

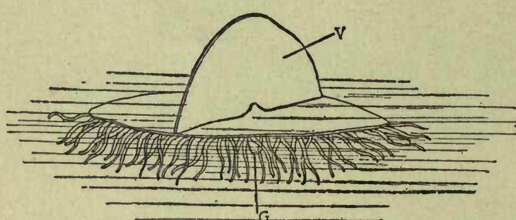


FIG. 106.—Velella, one of the Siphonophora, about natural size. It is a characteristic pelagic animal which sometimes drifts on to British coasts from the Atlantic. It is a colony of numerous individuals, with a beautiful transparent triangular sail (V) on its upper surface, and a flattened chambered float beneath. In the centre of the under surface there is a large nutritive individual or zooid (G), around the margin of the disc there is a fringe of simple, finger-like sensitive zooids; between these and the centre there are numerous reproductive zooids. Fleets of these transparent blue velellas are sometimes seen on the surface of the Mediterranean, and thousands are often found wrecked on the shore.

Many of the pelagic or open-sea animals are active swimmers, *e.g.* jelly-fishes (Fig. 108) and cuttle-fishes, and are included under the term *Nekton*; a large number do little more than drift in the currents, *e.g.* Radiolarians, many small Crustaceans, the larvæ of Echinoderms, Crustaceans, and Molluscs, and these are included under the title *Plankton.*

The pelagic fauna is very representative. It includes many Infusorians, such as the "phosphorescent" *Noctiluca*; a few genera, but many species of Foraminifera or chalk-forming Protozoa; most Radiolarians — several thousand different kinds—with which unicellular Algæ live in intimate internal partnership (*symbiosis*); jelly-fishes (*e.g.* our common *Aurelia* and *Cyanea*); swimming-bells or Medusoids, most of which are the liberated reproductive buds of zoophyte colonies; Siphonophora, like the Portuguese man-of-war (Fig. 107), and *Velella* (Fig. 106); Ctenophores, like the common *Beroë* and *Pleurobrachia*; many "worms" of diverse classes; two or three Holothurians or sea-cucumbers; a legion of Crustaceans; a few insects belonging to one family (Halobatidæ); sea-butterflies, many cuttle-fishes, and some other Molluscs; the larvæ of Ascidians and a few adult forms; many fishes, and the floating eggs of many more; a few turtles and snakes, besides such birds as the petrels and such mammals as the whales.

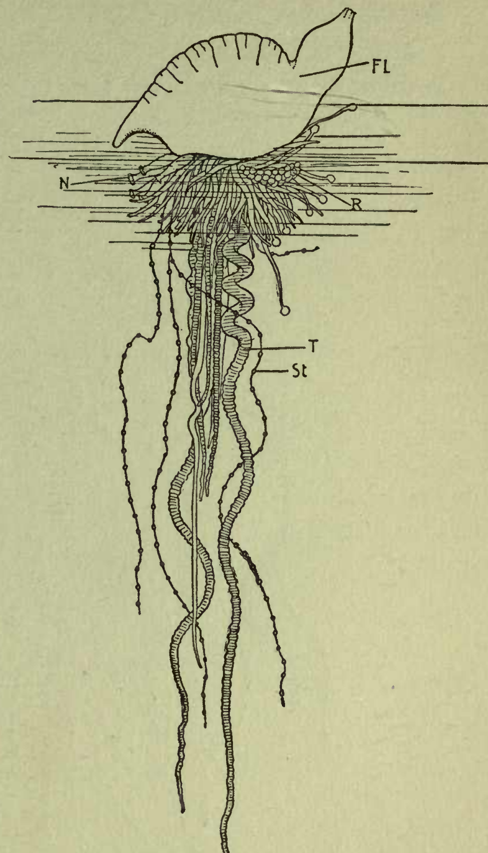


FIG. 107. — The Portuguese man-of-war (*Physalia*), one of the Siphonophora, a characteristic pelagic animal in warm seas. It is a colony of individuals or zooids, showing much division of labour. There is a large bladder or float (Fl), sometimes six inches long, and from that are suspended nutritive zooids (N), reproductive zooids (R), tentacle-like sensitive zooids (T), and long filaments bearing batteries of stinging cells (St). colour is a fine translucent blue.

Pelagic animals often occur in enormous swarms, which is doubtless indicative of relatively easy conditions. As one would expect, they tend to be lightly built, delicate, and translucent. Many of the drifting forms, *e.g.* small Crustaceans, are remarkable for the length of their appendages and outgrowths, which probably increase their power of flotation. Many, such as the Medusoids or swimming-bells, the arrow-worms (*Sagitta*), the sea-butterflies (pelagic Gasteropods), are as transparent as glass; many, such as some of the common jelly-fishes, have a beautiful blue colour; some of the Ctenophores, notably Venus's girdle,

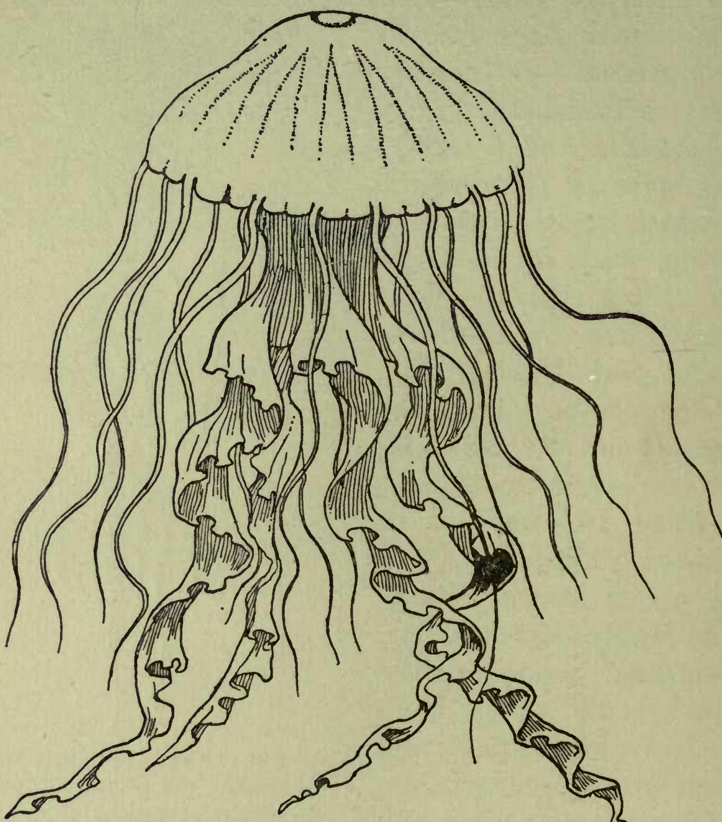
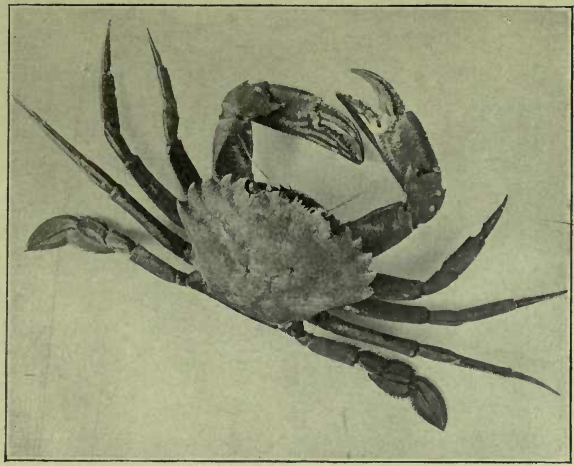


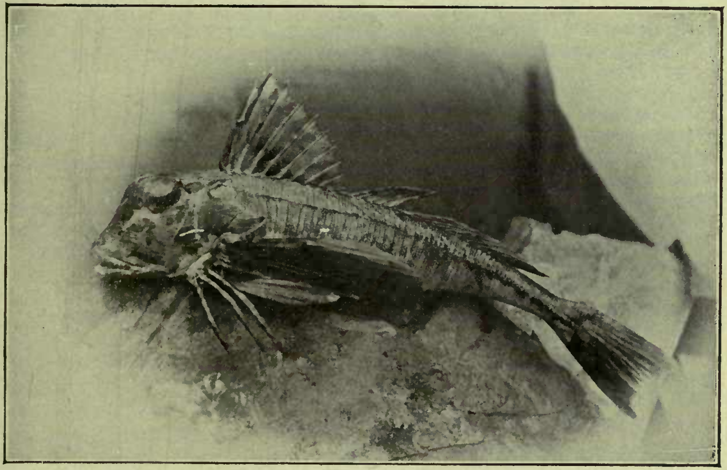
FIG. 108.—A typical jelly-fish (*Chrysaora*), occasionally found off British coasts. The mouth is in the centre below the umbrella-like disc, and is guarded by four long sinuous lips. Around the margin of the disc there are two dozen long tentacles and eight sense organs. Radial canals are seen passing outwards from the central stomach.

show a fine iridescence as they move, wafted along by the lashing of multitudinous ciliated combs; not a few, such as the compound tunicate *Pyrosoma*, are brilliantly "phosphorescent."

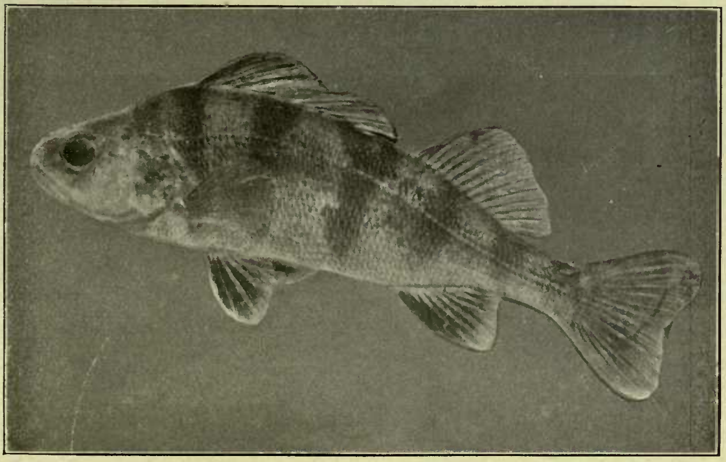
The Plankton is of great practical importance, because it forms the basal food supply of many fishes, and changes in its distribution must be followed by changes in the distribution of



VELVET FIDDLER CRAB *(Portunus puber)*



STREAKED GURNARD



PERCH *(Perca fluviatilis)*
(Photos by W. S. Berridge.)

the fishes. The eggs of all our important food fishes, except the herring, are found floating on the surface of the sea.

The Deep Sea

The fauna of the great abysses of the ocean is as interesting as that of any other region, but it is removed from the direct scope of Nature Study in school, and we shall not do more than hint at the impressiveness of that strange, silent, cold, dark, plantless world. There seems to be no depth limit to the distribution of animals; specimens have been fished up from a depth of over five miles. Representatives of most of the types from Protozoa to Fishes occur in the great depths, and the same or closely similar forms are found over very wide areas, which indicates a monotonous uniformity of physical conditions.

The deep-sea world is in darkness, except in so far as it is illumined by flashes of "phosphorescent" light; a photographic plate is not influenced below 250–500 fathoms. It is extremely cold, about the freezing-point of fresh water, for the sun's heat is virtually lost at about 150 fathoms, and there is little difference between summer and winter. The pressure is enormous, at 2500 fathoms it is about $2\frac{1}{2}$ tons per square inch; it is quite calm, for even the greatest storms are relatively shallow in their influence; there are no plants (except perhaps the resting phases of some Algæ), for typical vegetable life depends upon light; moreover, even bacteria, otherwise almost omnipresent, are not known to flourish in the great depths. The animals feed upon one another, and ultimately upon the organic debris which sinks from above.

Fresh Water

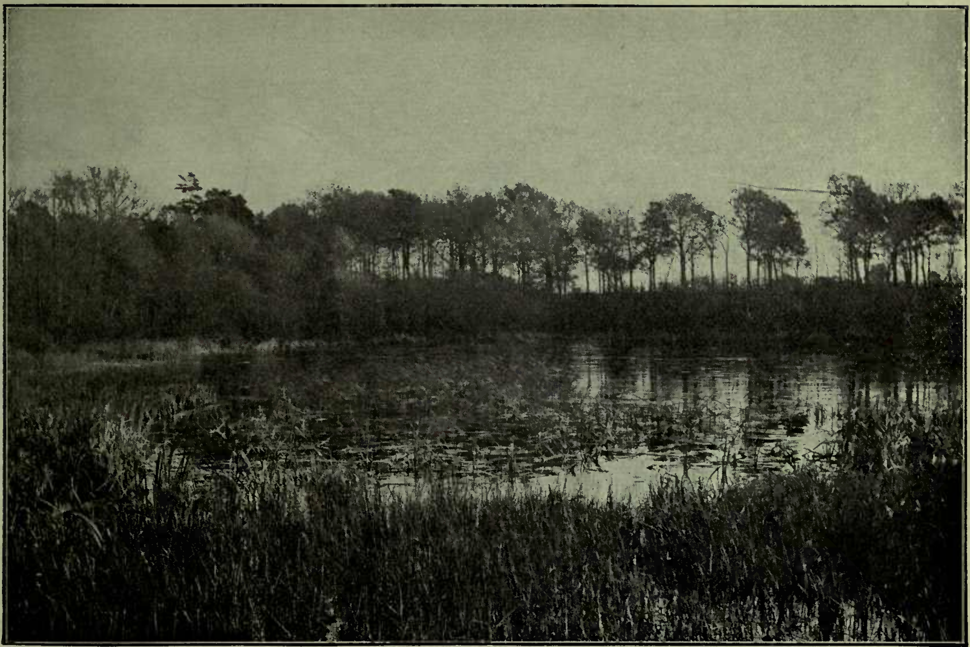
The number of different kinds of animals frequenting lakes, ponds, rivers, marshes, and the like is small in comparison with the sum of the marine list, but the fresh waters have not been so much studied as the sea. The number of individual specimens in a pond or lake is often enormous, *e.g.* in the case of water-fleas, Rotifers, and Infusorians; but the number of species is relatively small, and the number of distinct types still smaller. The same forms occur in widely separated basins and in different countries. Why is this ?

(*a*) To explain the uniformity, Darwin referred to the way in which birds and winds carry small creatures from one watershed to another, and also to the fact that slight changes of land level would often serve to bring different river systems into connection. (*b*) When we take a case like that of the sponges, which are altogether marine except one small family (Spongillidæ), we are led to infer that some of the freshwater forms must have gradually migrated (actively or passively) from the sea, through brackish water, into the fresh water. As the power of making and surviving the transition depends on the constitution of the animal, it is not surprising to find similar forms in different areas. (*c*) It seems that some lakes are dwindling remnants of ancient seas. If there was a fairly uniform pelagic fauna in these seas, *e.g.* before cretaceous times, the conversion of the seas into lakes would have similar sifting effects, hence similar survivals in different countries.

In a lake we can distinguish littoral, surface, and deep-water forms, just as in the sea. Near the shore we may find such animals as freshwater mussels and smaller bivalves, freshwater snails, numerous Crustaceans, water-beetles and other insects, leeches and distant relatives of the earthworm, planarian worms, the freshwater hydra, the freshwater sponge, and many Protozoa. The surface fauna is quite different, and has a marked analogy with the marine plankton; it includes swarms of delicately built water-fleas and Rotifers, and numerous Infusorians. The deep-water lacustrine fauna has probably been derived from the shore stocks, certain types having gradually followed the sinking food material farther and farther into the depths. In the depths of lakes we find Rhizopods related to the common Amœba, planarian worms, thread-worms, leeches, bristle-footed worms (Chætopods), numerous Crustaceans (Amphipods, Isopods, and "water-fleas"), some water-mites, some insect larvæ, various molluscs, and so on.

An account of many of the common freshwater animals will be found in the chapter on Aquaria. All that we propose to do here is to make a few suggestions in regard to possible excursions.

Ponds.—If a class excursion to a pond is to be successful



A POND WITH REEDS (Photo by Valentine.)

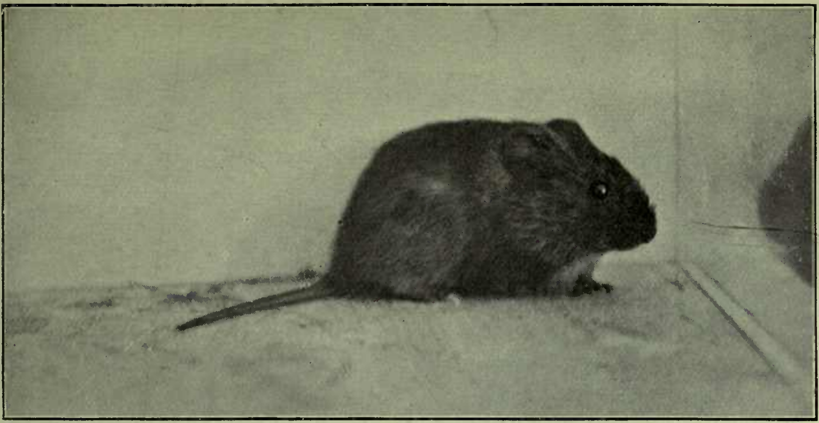
A SHORE WITH ROCKY LEDGES (Photo by Firth.)

certain conditions must be observed. (1) It is necessary to have a long stick—the longer the better—to the end of which there may be attached various kinds of net (like small butterfly nets) and collecting jar. The pupils can often do much with a tin dipper on the end of a stick, but some ponds are so dangerous that the collecting must be left to two or three careful seniors. (2) It is necessary to have two kinds of receiving vessel into which to place the animals collected, shallow vessels like soup plates to be looked down into, and tall glass vessels with flat sides to be looked through. It is almost as easy to carry half a dozen white soup plates as one, and by distributing these among the pupils careful observing with lenses may be facilitated. A large milk-basin to serve as a temporary aquarium to hold larger specimens, such as small fishes, is also useful. (3) It is necessary to take from the pond different kinds of samples—surface skimmings and mud from the bottom, water weeds of various kinds, stones from near the edge, floating pieces of wood—to put these separately into the plates, and to watch what appears in the various cases. It is important that the young observers should get into the habit of watching till what is collected settles down, and what was not at first obvious begins to appear. (4) In the case of some ponds with clear water and suitable slope it is possible to sit down or lie down on the bank and simply watch what is going on beneath the surface. But one cannot trust to this, for a little wind makes a surface-ripple that dims everything, or the water may be cloudy, or all the animals may be in hiding. (5) As in the cases of other haunts, the general advice may be given to pay the haunt a visit at different times of day and at different seasons of the year, and not to try too much at once. We restrict our hints to noting a dozen things or sets of things that should be looked for and studied on a first visit to a pond.

Water-Vole and Water-Shrew.—On the banks of the pond or mill-dam, as also of streams and canals, the water-vole (*Microtus amphibius*)—usually miscalled the water-rat—makes its long twisted burrows. It can be distinguished from the brown rat (*Mus decumanus*), which is of about the same size, and may occur in the same sort of place, by its much shorter ears (hidden among the fur), by its relatively shorter tail (about half the length of head and trunk), by having the tail covered with short hair, and by other features concerning the teeth and the like. Though it has not webbed feet, the water-vole is an adept swimmer and diver, and it often has an under-water entrance to its burrow. It is in many ways an interesting and pleasing animal. It often sits up like a squirrel, holding its food to its mouth in its paws ; the mother may carry her young to safety in her mouth as a cat carries her kitten. It feeds mainly on the roots and stems of water-plants like the iris, and, apart from breaking down the banks, does not do a great deal of harm. Much smaller, and belonging to a different order of mammals, is the water-shrew (*Crossopus fodiens*). It is an insectivore, not a rodent ; it eats small water animals not plants ; it is larger than the other British shrews (species of *Sorex*), the head and body being about $3\frac{1}{4}$ inches in length, the tail $2\frac{1}{10}$ inches. If there is doubt about a specimen, reference may be made to such books as Lydekker's,[1] where characteristic details are noted, such as the brownish red tips of the thirty teeth and the fringes of hairs on tail and feet.

Birds of the Pond.—The coot (*Fulica atra*) is a cheerful tenant of large ponds and lakes all over the country, loquacious but wary, diving incessantly after small water animals and pieces of plants, finding it a little difficult to get on the wing when startled, and in its low flight striking the water with its dangling feet. The pure white bald patch on the forehead will serve the beginner as a headmark in distinguishing coot from moor-hen, which is, moreover, much smaller. The nest is a large strong structure made of flags, raised it may be a foot above the water; the young—almost "furry" at first sight—are delightfully quaint. Nearly allied to the coot is the moor-hen (which means mire- or marsh-hen)—*Gallinula chloropus*—and to the same family (Rallidæ) the shy water-rail (*Rallus aquaticus*) belongs. With ponds and lakes we also associate swans and wild duck, sedge-warbler and reed-bunting, black-headed gulls, and many more, but perhaps the most characteristic of all is the little grebe or dab-chick (*Podicipes fluviatilis*), which is also one of the most fascinating.

[1] See (Lydekker) p. 222.



WATER VOLE

COMMON BROWN RAT

MOLE.
(Photos by W. S. Berridge and Chas. Reid.)

Freshwater Snails.—Creeping along on water plants, on stones, in the mud, or head downwards on the surface there are several different kinds of water-snails, and some of them should be collected for the aquarium. Their movements should be studied and their feeding habits. The spawn of *Limnæa* is often found as a gelatinous mass glued on to the water weeds, and it is interesting to watch the development, and to contrast the state of affairs in this genus with that in *Paludina vivipara*, which brings forth tiny miniatures of itself. Some are lung-breathers, and these have no lid (operculum) to the shell, namely, *Limnæa, Planorbis, Physa,* and *Ancylus.* Others are gill-breathers, and these have a lid to the shell, namely, *Paludina, Bythinia, Valvata, Neritina.* As there are not many altogether in Britain this group might be selected for systematic study (there are cheap books like Rimmer's[1] available). Some forms are easily known by their shells ; thus *Planorbis* has the shell coiled in a disc, in *Physa* the transparent shell is coiled to the left, *Ancylus* has a little simple shell like a nightcap, in *Paludina* the shell is large, and is usually banded.

Freshwater Bivalves.—Large freshwater mussels—species of *Anodonta* and *Unio*—are often found in ponds, as also in canals and rivers. (1) In the former the shell is thin, and the hinge is toothless ; in the latter the shell is very substantial, and the hinge is toothed. (2) They plough their way in the mud by means of their turgid, ploughshare-shaped muscular "foot," which corresponds to the flat sole on which snails creep. (3) They feed upon microscopic animals and plants, and the food canal often contains a curious transparent consolidated mass of half-digested food called "the crystalline style." This is easily seen by splitting the foot vertically with a razor after the mussel has been killed and hardened in alcohol. The food is wafted in at the posterior end by the action of millions of microscopic lashes which cover the large plate-like gills, and if a microscope is available a mussel should be sacrificed to show an unforgettable and impressive sight, the ciliary movement. It is simply necessary to cut a little piece off the gill, and put it on a slide, with a drop of water and a cover-glass. (4) There are sometimes pearls fixed to the skin or mantle lining

[1] See (Rimmer) p. 222.

the shell, which seem to be formed by the deposition of extremely delicate layers of lime around an entombed microscopic parasite —the larva of a Trematode worm. In fact, a pearl is the sepulchre of a fluke. (5) Sometimes mussels come so near the bank that they are caught by rooks, and the interesting sight has been seen of rooks letting the shells fall from a height upon stones (perhaps accidentally *to begin with*), so that the succulent mollusc became available. These five items are merely *illustrations of different ways in which one may approach animals* like these, and of course there are as many more. What better illustration could one have, for instance, of the interlinking of living creatures—of the web of life—than in the fact that the young of the freshwater mussel has to spend part of its youth as a parasite on freshwater fishes, such as the stickleback, and that a carp-like fish of Central Europe—the bitterling or *Rhodeus amarus*—lays its eggs in the mantle-cavity of pond mussels. There they are fertilised by inwafted sperms, and they develop for about a month inside the gills. "The mollusc reciprocates by throwing off its embryos on the parent fish, in the skin of which they remain encysted for some time, the period of reproduction of the fish and mussel coinciding."[1] The eggs of the freshwater mussels develop inside the outer gill-plates; the young feed there on nutritive slime; they become larvæ known as Glochidia, with strong attaching hooks on the margins of the bivalved shell, and with a long filament called the "byssus" cord. When fishes come near (or sometimes when they are absent) the mother mollusc liberates the larvæ, which are extremely sensitive to the presence of fish. Mr. Latter[2] states that the "tail of a recently killed stickleback thrust into a watch-glass containing Glochidium throws them all into the wildest agitation for a few seconds; the valves are violently closed and again opened with astonishing rapidity for fifteen to twenty-five seconds, and then the animals appear exhausted and lie placid with widely gaping shells—unless they chance to have closed upon any object in the water (*e.g.* another Glochidium), in which case the valves remain firmly closed." If no host is available the Glochidia die. We have digressed in regard to this matter partly because it illustrates the sort of natural history

[1] See (Bridge and Boulenger) p. 222. [2] See (A. H. Cooke) p. 222.

which is most wanted in school, partly because some of the facts can be readily verified, and partly because it may serve to show that a pond will supply problems enough and wonders enough to keep "Nature students" at work and in admiration for all time coming. It is not necessary to go to the tropics or the deep sea.

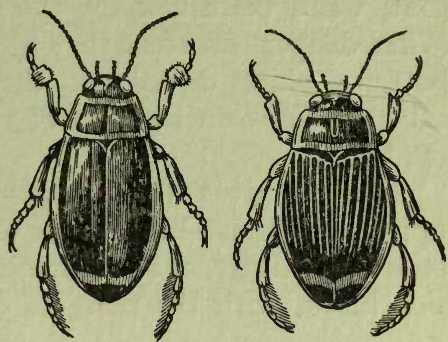


FIG. 109.—Dytiscus beetle, male and female.

The small freshwater bivalves (*Cyclas* or *Sphærium* and *Pisidium*) which are very common and differ obviously from the mussels in being very small and in having siphons, keep their young within the mother until they are fully formed.

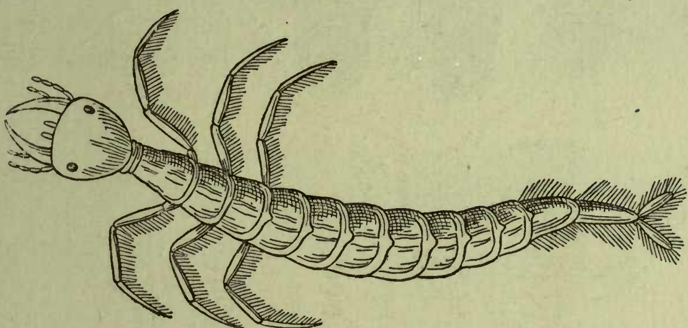


FIG. 110.—Larva of *Dytiscus marginalis*—much enlarged.

The larva of the widespread *Dreissensia* differs from that of all other freshwater bivalves in being free-swimming.

Water-Beetles.—There is fortunately available in Miall's *Aquatic Insects*[1] a very convenient aid—and an inspiring stimulus—to a study which is rich in rewards to those who will pursue it patiently. We cannot do more here than refer to a few of the commonest water insects.

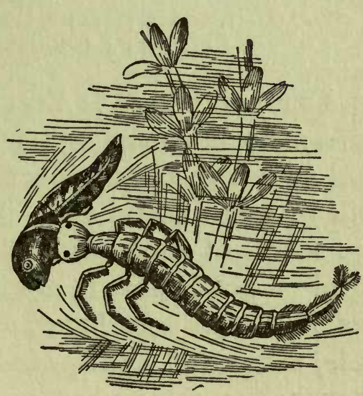


FIG. 111.—Larva of *Dytiscus marginalis* seizing a tadpole.

"One of the most abundant and common beetles throughout the kingdom" is the whirligig or steel-coat (*Gyrinus natator*), a lively little insect about a quarter of an inch long,

[1] See (Miall) p. 222.

which is familiar on the surface of slowly flowing water and of ponds. They dart about like water-sprites, " so swiftly, in fact, that, when disturbed the eye can hardly follow their motions." When danger threatens they dive among the water-weed or to the bottom, taking down with them a quicksilver-like bubble of air attached between the tips of the wing-covers and the tail-end of the body.

Fowler[1] gives the following diagnosis :—" Ovate, convex, upper side bluish-black with the sides brassy; elytra punctate, striate, the internal striæ much fainter than the external; under side black, with the margins of the elytra and the legs red or reddish, testaceous, sometimes the breast and apex of the abdomen are red. In Scotland the whirligig is usually narrower, with the sides more rounded, and the internal striæ towards the base of the wing-covers are very faint, or wanting."

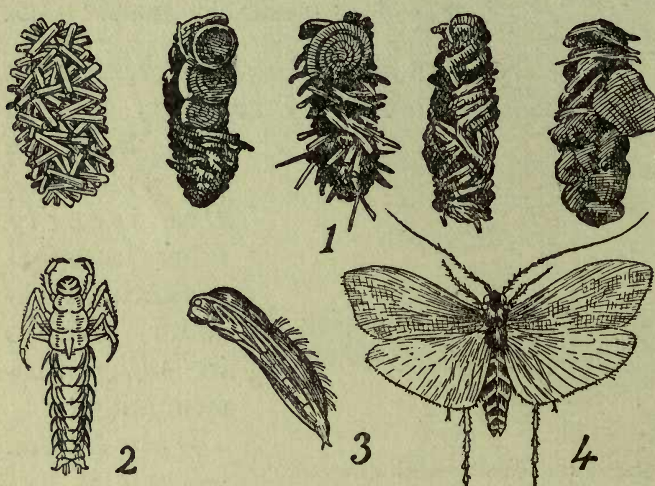
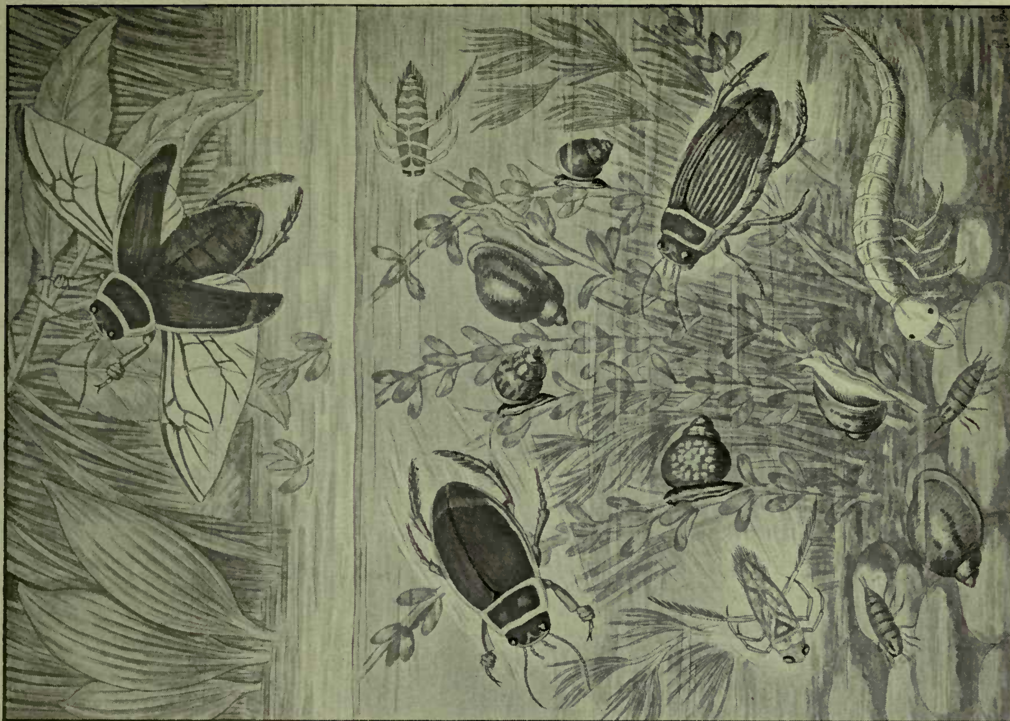


FIG. 112.—1, Caddis cases; 2, larva taken out of the cases; 3, pupa; 4, full-grown caddis-fly.

Our point here is that it will be well to make as sure of this extremely common water-beetle as one is sure of a water-hen, and to use it as an object for careful study. At this stage that will be more useful than trying to know a lot of beetles. There are scores of things to find out about Gyrinus,—how it gets from pond to pond, how it holds on below water, what happens when you hold it in your hand, what it eats. Then there is the remarkable, somewhat centipede-like larva to look for, and the cocoon it makes on the rushes, and so on.

Pond-Skaters.—Very characteristic of the surface of pools are

[1] See (Fowler) p. 222.



the pond-skaters (e.g. *Gerris*), which dart about on the surface film, or drift, or even leap. On their body and limbs there is a "velvety pile," which keeps them from being wetted. They search busily for insects which get trapped on the water. Some, such as *Velia currens*, which "loves the eddies and currents of backwaters on burns and streams, and is very abundant in Scotland," [1] are adept swimmers under water as well as skaters on the surface; but there are others, like the slender *Hydrometra stagnorum*, that moves rather slowly with long slender stilt-like legs on the surface, which cannot be submerged without great risk of drowning. No Nature Study exercise is more delightful than watching these pond-skaters or water-measurers (Hydrometridæ), and trying to understand the wonder of their movements; and after some observation of the freshwater forms it might be interesting to tell about some that walk on the sea—the species of *Halobates* in particular, that occur in open ocean hundreds of miles away from land.

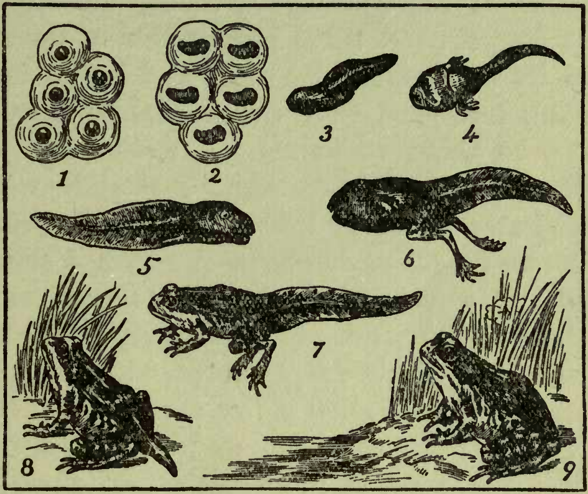


FIG. 113.—The development of the tadpole. 1, Portion of frog spawn; 2, the same after ten days; 3, a newly hatched tadpole. The remaining figures show the stages reached at successive dates—4, at one week; 5, three weeks; 6, seven weeks; 7, eleven weeks; 8, thirteen weeks; and 9, fourteen weeks after hatching.

In Professor Miall's indispensable book an account is given of many of the common aquatic insects, not merely of water-beetles (Coleoptera) and water-bugs (Rhynchota), but of dragon-flies (Odonata), may-flies (Ephemeridæ), stone-flies (Perlidæ), alder-flies (Sialidæ), caddis-flies (Trichoptera), two-winged flies (Diptera), and so on. We cannot, however, do more than refer to this interesting book, which lays special emphasis on the study of life-histories. Nothing is easier than to collect in spring the

[1] See (Sharp) p. 222.

active larvæ of, say, gnats and harlequin-flies, to put them in a deep aquarium vessel, and to watch their wonderful metamorphoses.

The River.—Many of the hints which we have given in regard to the pond will apply also to the river. It is important to choose a stretch with some variety,—here a deep slowly flowing reach with reeds and flags by the waterside, there a shallow quickly flowing reach with plenty of stones to be turned over.

As to the higher animals, there is still the possibility in some parts of the country of seeing an otter (*Lutra vulgaris*), or of finding a trout lying by the side of the stream with a great gash at its neck where the otter had begun to eat. It need hardly be said, however, that the probabilities of seeing an otter are as few as those of seeing a "water-rat" are many. But there is abundance of educational material even in these "rats,"—the first step being to learn to see with precision, to distinguish the brown rat (*Mus decumanus*), which is often about the banks, from the water-vole (*Microtus amphibius*), and thus to make it clear that we have not in Britain any animal that can be accurately called a "water-rat," except with the same licence as might be shown if one called a fox a wild dog. Precision of words is expected in our games or on board a yacht; it is not unreasonable to insist upon it in our science. Then, to return to the river, there is the beautiful water-shrew to look for.

Riverside Birds.—As we walk up the riverside in spring we startle the wary oyster-catchers (*Hæmatopus ostralegus*), which are also frequenters of the seashore, and if we are sharp-eyed we may find their protectively coloured eggs among the gravel. Its shrill *Keep-keep* is very striking, and so is the coloration of the bird—black and white plumage, orange-yellow bill, livid flesh-coloured legs and toes. The black-headed gulls (*Larus ridibundus*), called laughing-gulls because of their incessant cackling, fish for water insects in the rivers near the "gullery." Now and then we have a chance of seeing a kingfisher, like a flash of rainbow over the stream, but we are almost always sure of coots and water-hens. Very characteristic of rapid mountain streams is the water-ouzel or dipper (*Cinclus aquaticus*), a brown and white bird, often seen perched on a rock in mid-stream. It enters the water freely and fishes among the stones for small animals, now holding on with its toes, and now beating its wings. The large oval nest of moss, grass, or leaves is to be looked for in a hole in the bank or about a bridge or behind a waterfall, and it may be noted that the eggs, like many but by no means all well-hidden or inaccessible eggs, are pure white.

Freshwater Fishes.—In some of our rivers there are still lamperns (*Petromyzon fluviatilis*), but one is more likely to find the young of the sea lamprey (*Petromyzon marinus*), often called "niners," which are interesting creatures to study. Primitive vertebrates they are rather than fishes. Some reference has been made in another part of this book to the salmon and the eel, and at the proper season we should peer down from the bridge to see the female salmon dropping her eggs—each the size of a small pea—into the furrow which she has ploughed in the gravelly bed, or watch by the side of the stream to see the marvellous yearly journey of the "elvers" which make their way up stream with so much persistence. In some parts of the country children are familiar with the dramatic sight of the salmon going up the rapids and leaping a waterfall, and in the same or other rivers the spectacle of large numbers of big full-grown eels going down stream to the sea is not uncommon. To illustrate the studies which have been suggested in the chapter on Fishes, we can find abundant material in the fresh waters—with their pike, perch, trout, minnow, roach, loach, carp, miller's thumb, and stickleback.

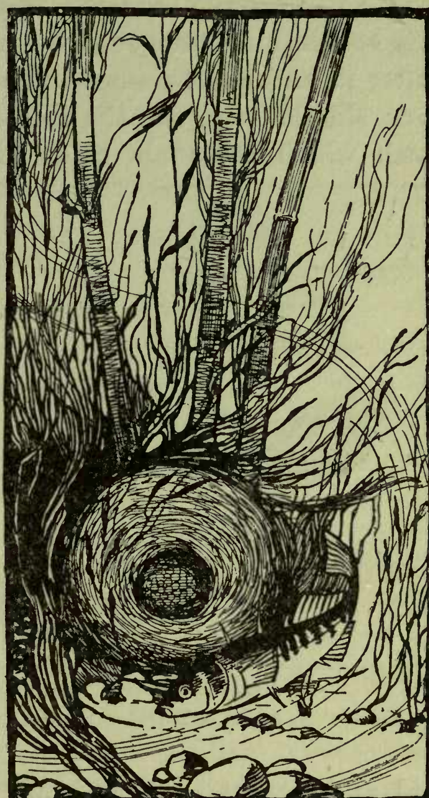


FIG. 114.—Three-spined stickleback (*Gasterosteus aculeatus*), and nest fastened to water weeds.

To the observation of the last-named (*Gastrosteus aculeatus*), which occurs in different varieties in different waters, many profitable hours may be devoted. Let us utilise the lore of the schoolboy who knows about the voracity of both sexes and the pugnacity of one, the male's change of colour from silvery white to brilliant reds and other colours at the breeding season, his building of the rough nest, and his enticing of the female to enter it, and his zealous parental care for the eggs and the young. One should look for the thin sticky threads (from the kidneys) with which the male birds bind together the materials of the nest; one should watch the development of the young fry; one should test the fact that the fishes can endure a transition to sea water. Sticklebacks are dangerous additions to a cherished aquarium, unless one wishes to study the survival of the fittest, the *relatively* fittest, but they can be kept by themselves and fed and watched. We should look for the bony shields on the sides of the body, the three depressible dorsal spines, the stout spine on the pelvic fins, the single spine in front of the unpaired ventral fin, and so on. After one has made sure of the stickleback it will be time to tackle the minnow.

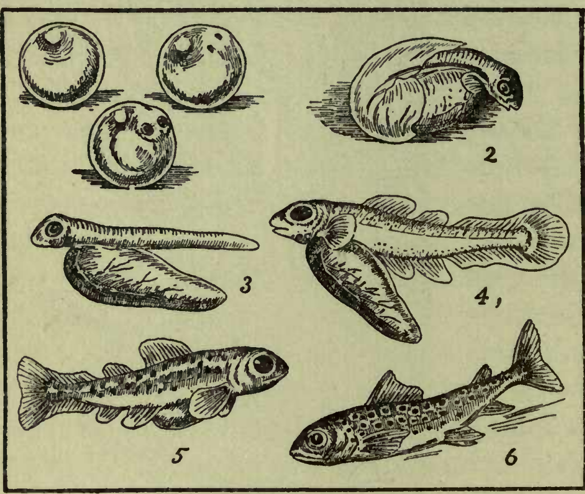


FIG. 115.—Six stages in the development of the trout. 2, shows the process of hatching; 3 and 4, show the large yolk-sac.

Another very profitable thing to do is to lift carefully out of the water the long leaves of flags and reeds and the like, placing them for examination in a basin of water. In this way we often get water-snails (*e.g.* species of *Lymnæus*); small leeches (*Nephelis octoculata*), sometimes a dozen together on one leaf; still simpler "worms" like *Planaria*; the elegant cases of some of the small caddis-flies; the freshwater *Hydra*; and bell-animalcules like

Vorticella and *Epistylis*. The base of a submerged stem is sometimes surrounded by the freshwater sponge (*Spongilla*), and splitting up the stems of the reeds usually liberates a crowd of small animals.

On the upper surface of stones often thickly covered with a growth of moss or alga one may find a wealth of small animals—such as insect larvæ, and sometimes a stone is quite covered with freshwater sponge. In such a case it is useful to mark a fine specimen and to see it decay away in autumn, the life being continued by multitudes of pinhead-like gemmules which start new sponges in spring.

One other simple observation may be alluded to. It is usually easy to find some shallow muddy bay by the riverside or in some backwater. On a quiet day, when there is no wind to ruffle the surface, that is a place to watch—to see the behaviour of the insects and molluscs and other inhabitants. Very frequently, when one's eye gets accustomed to the scene, one sees on the muddy floor hundreds of little red worms, the thickness of pins, rising an inch or so out of the mud, and swaying backwards and forwards continuously. These are bristle-bearing freshwater worms, distant relatives of the earthworm, and there are many different kinds,—*Tubifex rivulorum* being a common one. It is common where there is some contamination of the water, and thousands may be seen at once. It makes a burrow, a temporary tube in the mud, and it is interesting to see the sudden retreat of the thousands when one strikes the water with a stick. Some of the mud should be taken home and kept for a while in a pie-dish, so that Tubifex may be observed at leisure. In searching the mud with a good lens one may find in midsummer the elliptical grey cocoons out of which the young creep in September.

Terrestrial

"Worms" were probably the first backboneless animals to become thoroughly terrestrial. We find this habit in some of the planarians, nematodes, and leeches, but these usually live in very damp places, and it is perhaps to the earthworms that we should give the credit of discovering the *dry land*. The great majority of the chætopod worms are marine;

a considerable number of types—more nearly related to earthworms—e.g. *Tubifex* and *Nais*, live in fresh water; it seems probable that it was from this stock that the thoroughly terrestrial earthworms took their origin. A similar argument applies in other cases, thus the wood-lice (*Oniscus*, etc.) are "Isopod" Crustaceans, whose relatives are aquatic and for the most part marine. We can have little hesitation in supposing that the thoroughly terrestrial wood-lice, which have tubular air-passages in some of the abdominal limbs, took their origin from aquatic forms. The tropical cocoanut crab (*Birgus latro*) is practically terrestrial, except that it returns to the shore to lay its eggs; it has the upper part of its gill-chamber shut off to make a kind of lung.

"We cannot believe in any abrupt transition from the shore to *terra firma*. It has been a slow ascent, slow as the origin of dry land itself. Thus mud-inhabiting worms, dwellers in damp humus, bank-frequenting animals, those which find a safe retreat in rottenness or within bolder forms, dot the path from the shore inland. Many have lingered by the way, many have diverged into *cul-de-sacs*, many have been content to keep within hearing of the sea's lullaby, which soothed them in their cradles." [1]

The terrestrial fauna includes some Protozoa, e.g. *Amœba terricola*, which lives in moist earth; some of the Planarians, Nematodes, Leeches, Chætopods, and other "worms," a few Crustaceans like the wood-lice and the land-crabs, many insects, most of the Arachnids, a legion of shelled snails and shell-less slugs, most adult Amphibians, most Reptiles, many Birds, and most Mammals. Among vertebrates certain fishes, e.g. *Periophthalmus*, are of interest in having learned to gulp mouthfuls of air at the surface of the water, to clamber on the roots of the mangrove trees, or to lie dormant through seasons of drought. But among vertebrates, Amphibians were first to succeed in making the transition from water to dry land.

We may divide the dry land from the shore inland into (*a*) links and dunes, (*b*) meadowland, (*c*) woodland, (*d*) moorland, (*e*) mountain-side. We suppose first, though it is not strategically best, an excursion to the area nearest the seashore, namely, the links.

We mean by the links the wild area near the shore, between

[1] See (Thomson) p. 222.

the sand-hills or dunes to the sea side and the meadows to the land side. To the naturalist who can give years to exploring them, the links represent a very interesting transition area, but to the teacher, who has many other irons in the fire, an excursion to the links is apt to be disappointing. In contrast to the sea-shore, the area of the links is not very densely peopled except with insects, and although we have ourselves seen most interesting natural history scenes on the links—so often abandoned to golf, which is eliminative of life in many directions, though happily preservative of the players—we cannot pretend that it is a very promising area for a "Nature Study" excursion. In all such cases the policy is, of course, to be definite, to fix upon particular animals and particular problems. On the shore, every one may be a discoverer who looks long enough, keenly enough, and far enough, but on an excursion to the links our experience is that it is well to have some particular ends in view.

The Links and Dunes.—The rabbit is distinctive of the dunes in many parts of the country, and its distribution is of considerable interest, since the extension of its range is still going on. It is becoming common where it was rare not very many years ago, and it is, after all, a newcomer to Britain (from Spain perhaps) compared with old residenters like the red deer. In some places its prolific multiplication shows us in miniature what has happened in Australia and New Zealand. From the Nature Study point of view we may note the *protective coloration* of the rabbit when at rest, and the possible value of the conspicuous white tail as a *recognition mark* which the young ones may almost automatically follow when disturbed in the twilight. Mr. Lydekker[1] writes: "When alarmed by impending danger, the old rabbit strikes the ground forcibly with the hind-feet, thus making a sound which serves as a signal to her progeny, as well as to the rest of the colony, to follow her white tail back to the burrow with all the speed they can command." Why does the rabbit (*Lepus cuniculus*) make a burrow, while our hares (*Lepus europæus* and *Lepus timidus*) do not? Part of the answer must be that the rabbit brings forth naked and helpless young which require to be

[1] See (Lydekker) p. 222.

well hidden away, whereas those of the hares are born furred and active. This is confirmed by the fact that the peculiar hispid hare which has also naked young also makes burrows. Another obviously interesting point is that the wild rabbit is the wild stock from which all our races of domesticated rabbit have been derived.

On seashore links, separated from the sea by dunes thickly covered with bent grass and other sand binders, I once had the pleasure of seeing a whole family of stoats (*Mustela erminea*) passing swiftly inland, about ten of them nose to tail, the mother leading, at first sight curiously like a brown snake wriggling through the grass. The weasel is smaller than the stoat, it has a shorter tail without a black tip, it turns slightly paler but not white in winter (except as a great rarity). Lydekker[1] points out, that although the weasel may destroy a young bird now and then, "the benefits it confers far outweigh the injuries it inflicts; . . . it pursues in their tortuous underground runs both the field-vole and the mole; and from its relentless pursuit, both of the former and the common rat, this little carnivore ought to receive all encouragement at the hands of the farmer, more especially in districts subject to seasonal vole-plagues." Cases like this, of obvious practical interest and importance—in regard to which the pupils may be able to furnish data at firsthand, should be used, in a judicious way, to illustrate the struggle for existence.

Wheatear.—In the wilder parts of the links where the rabbits are very much at home, and on the moor where there are rabbits too, we often see a very distinctive bird, the wheatear.

Like the rabbit, it is protectively coloured when at rest, and we may hear its "chat" or "click" without seeing the bird. But the moment it gets on the wing its white rump is as conspicuous as the rabbit's "cotton-tail." "Must we conclude that the white rump of the wheatear is meant to show the young the course the parent bird has taken across the moor? . . . The wheatear reaches the Scots moors—for it is a migrant—as early as March. The apology for a nest, with its faint blue—almost white—eggs will be in many of the disused holes of his comrade the rabbit. They are easily found, because of his slovenly habit of leaving chopped pieces of bracken round the opening. As in

[1] See (Lydekker) p. 222.

the case of most of our hardier migrants, a few may remain with us all the year round."[1]

There are many other birds on the links, such as skylarks which nest in the herbage, pied wagtails, sometimes with a cuckoo on their heels, whinchats, the corn-bunting uttering his monotonous bit of song as he surveys the environment from the top wire of the fence, the meadow pipit, the curlew, and the restless solicitous lapwing. Take any one and make some study of it. Take the lapwing, and note the changes in its plumage, the annual partial migration, the apology for a nest, the "false nests" scraped out by the cock when showing off, the excited cries of the cock when the female is startled from her nest, the devices of both parents to divert attention from their young, and so on.

Meadowland.—Pursuing the plan which seems to us best in a work of this kind, we suppose a school excursion to a meadow and we suggest that, to begin with, attention will be profitably confined to a few characteristic animals.

In early summer one of the first things to strike the eye is the frothy mass so common on the stems of grasses and other low plants. It is called "cuckoo-spit" or "frog-spit," but what is it? The pupils will brush aside the bubbles and discover the young insect within which makes the (probably protective) froth. The commonest "frog-hopper," for there are several, is called *Philænus spumarius* or *Aphrophora spumaria*; it is one of the plant-bugs in the order Rhynchota, and may be spoken of as a British Cicadid. It sucks the plants and secretes abundant fluid from the hind end of the gut. In some way this assumes a frothy form, and it would be interesting to discover more precisely how the froth is made. Only the young stages of the insect live in this froth, the adult hops about from plant to plant; and it is a familar fact that the "cuckoo-spit" becomes scarcer as the summer goes on. "The frog-spit is considered by some naturalists to be a protective device; the larvæ are, however, a favourite food with certain Hymenoptera, which pick out the larvæ from the spits and carry them off to be used as stores of provision for their larvæ."[2]

[1] See (Dixon) p. 222. [2] See (Sharpe) p. 222.

Butterflies.—A gorgeous butterfly—red, orange, yellow, brown, black and blue, and how much more—comes fluttering along, and the impulse suggested by example is to rush after it and crush it inside a cap. Without having any objection to skilful butterfly hunting, we beg to suggest a more excellent way. Let us follow it or depute one of our number to follow it, watching which flowers it visits, contrasting the brilliant upper surface of the wings conspicuous in flight with the much plainer under surface seen when the butterfly rests with upfolded wings. But it also rests on the ground, on a post, on a flower, with the wings fully outspread in the sunlight. A mental photograph must be taken,—there is a triangular white mark near the outer tip of the fore-wing, then along the front margin three large dark bars separated by orange, farther back three dark spots (one large and two small) on an orange ground, and there are fine blue crescents round the outer margin of both wings. Look at it, repeat its quarterings, look at it again and make sure of the photograph. Then, when the excursion is over, its name can be discovered, and your observations corroborated, in any good butterfly book.[1] Of course, its name—since we have taken one of the very commonest—may have been known all the time—the smaller tortoise-shell (*Vanessa urticæ*), but that is not the point at all.

Humble-Bees.—On the meadow excursion one should watch the bees visiting the flowers, seeking nectar and pollen and securing unconsciously the important cross-fertilisation. One sees the hive-bees (*Apis mellifica*), who are of course half-domesticated, and many different kinds of wild bees, such as the humble-bees (*Bombus*). It should be understood (1) that there are many solitary bees, which form no community, such as the carder-bee (*Anthidium manicatum*, whose cotton-working Gilbert White described, or the burrowing bees, *e.g.* various species of *Halictus* and *Andrena* common in Britain ; (2) that the hive-bees have a society lasting as a society from year to year, and including workers markedly different in structure from the queens and drones ; and (3) that the humble-bees (*Bombus*) have societies which come to an end when the summer is over, only the queens surviving the winter. To watch how the humble-bees deal with different

[1] See (South) p. 222.

SMALL TORTOISESHELL
Resting on the Ground.

SMALL TORTOISESHELL
On Flower.

BEDEGUAR ROSE-GALL.
(Photos by H. Irving.)

kinds of plants, to find flowers like the comfrey which show little holes which the bees have bitten at the base of the corolla —an unprofitable burglary for the plant; to find the nest with its store of honey; to look for the quaint guest-bees (*Psithyrus*) that live as friendly but idle companions of the humble-bees; to try to distinguish different kinds of *Bombus*,—these are among the many exercises of observation that at once suggest themselves.

Bedeguar Galls.—The loose hedge by the side of the meadow is full of wild roses, and among these there is almost certain to be a "robin's pin-cushion" or "bedeguar gall,"—a strange growth from a leaf-bud, provoked by the grubs of *Rhodites rosæ*, one of the gall-making Hymenoptera. It is at first like a great cluster of hairs—each one well worth study with a lens,—hence another of its names, "moss-gall." But after a time the walls of the prison cells enclosing the often numerous grubs become hard and woody. Some of the galls should be cut open with a sharp knife to show the grubs within, but it would be still more interesting to rear the winged insects from the galls. When galls are opened it is sometimes found that there are other tenants besides those which have formed the galls. These are called "guests," and they have developed from eggs which have been laid in the galls formed by the true gall-makers. But the curious fact is that these guests also belong to the same family—Cympidæ. There is another species (*Rhodites eglanteriæ*), which forms brightly coloured spherical galls on the leaves of the wild rose. They are usually on the under side, and they fall off before the leaf does.

Earthworms.—Part of the meadowland is likely to afford abundant illustrations of the work of earthworms. This is discussed in another part of this book; it is enough here to notice that on the meadow excursion the pupils should examine the castings, noticing how finely ground the soil is, should look for heaps of little pebbles guarding the mouths of the burrows; should search near the rowan trees, for instance, for the midribs of the rowan's compound leaves lying like the spokes of a wheel around the entrance, the leaflets having been taken underground; should follow on the moist roadway near the meadow the tracks made by the earthworms during the night, showing, for instance, that they sometimes describe a circle; and should do half a dozen other things which can only be done on the spot. "Devouring the earth as they make their holes, which are often 4 or even 6 feet deep; bruising the particles in their gizzards, and thus liberating the minute elements of the soil, burying leaves and devouring them at leisure; preparing the way by their burrowing for plant roots and raindrops, and gradually covering the surface with their castings, worms have, in the history of the habitable earth, been most important factors in progress. Ploughers before the plough, they have made the earth fruitful."[1] Darwin showed that in garden ground there are often 53,000 in an acre, that they pass through their bodies ten tons per acre per annum, and that they bring up mould to the surface at the rate of 3 inches thickness in fifteen years.

Moles and Earthworms.—The mammals of the meadow are the moles (*Talpa europea*), and evidences of their industry are not far to seek. If one has time and a capacity for sitting quite still one may watch the approach of the mole as it moves the earth in its burrowing, one may see the "frightened" earthworms come to the surface, and the mole following them above ground and moving about quite quickly half hidden in the thick loose-set grass, and then the meal. It is interesting to think of the time when the earthworms possessed the underground world undisturbed by any moles, and could roam about till dawn without fear of any early bird. It would be valuable to find some evidence in Britain of the remarkable fact narrated by Professor Ritzema-Bos that moles store earthworms for the winter, decapitating them first so that while they remain fresh they cannot crawl away. A tap on the mole's thin skull kills it, and there is much to see on the dead body—*e.g.* the soft velvety fur with vertically set hairs; the minute rudimentary eyes; the extra sickle-bone at the wrist that helps to make the hand so effective a spade; the strong shoulder girdle, keeled breastbone, and strong pectoral muscles; the forty-four teeth, and so on. It is not difficult to get the pupils to discover the *adaptive significance* of some of these features.

But the mole is not the only mammal of the meadow. The common shrew (*Sorex vulgaris*), who also goes to the top of our highest mountains, is at home in the meadow, and its "shrill

[1] See (Thomson) p. 222.

squeaking cry" may often be heard in the summer evenings. "During the summer months these little creatures form well-marked runs among the stalks of grass of meadows; and, although they are generally found in those in which the soil is dry, they are by no means wanting in damp and marshy situations" (Lydekker).[1] They feed chiefly on insects, grubs, and worms; they are exceedingly pugnacious; and they do nothing but good. Dead shrews are common—no one knows why—in autumn, and they should be used for a careful study of external characters. Shrews sleep through the winter in safe hiding-places. A near relative of the common shrew is the lesser shrew—*Sorex minutus*—the smallest mammal

FIG. 116.—1, Frog; 2, toad; 3, frog catching a fly with its tongue.

in Britain, half an inch shorter in body than the harvest mouse (*Mus minutus*), and with teeth too small to be seen without a lens. There will also be field-voles (*Microtus agrestis*) in the meadow, and happily weasels (*Mustela vulgaris*) to keep down their numbers.

Birds of the Meadow.—We can hardly think of a meadow without seeing the swallows and martins skimming over it, without hearing the skylark and the meadow pipit. Where the cattle are feeding the graceful pied wagtails and the starlings are at their feet picking up the disturbed insects; where the long grass is being kept for hay the skulking corn-crake "proclaims his arrival by his harsh grating and monotonous cry, which may be closely imitated by drawing a knife blade smartly across the

[1] See (Lydekker) p. 222.

teeth of a stout comb." [1] Nor can the whinchat pass unrecognised. "It has a most characteristic way of perching on tall weeds in the meadow grass, and there uttering a monotonous note of *U-tac, u-tac, u-tac-tac,* flicking its rather short tail, and is rarely still for long together, restlessly flitting from one stem to another, and at intervals fluttering into the air to chase an insect." [2] We might mention many more, such as lapwing and yellow wagtail—two birds hardly to be surpassed for beauty, but the point of this article is to suggest how one may *begin to fill in* the living picture of each haunt.

There are many other creatures in the meadowland—grass-snakes and frogs, snails and slugs, spiders and beetles; but if the young explorers have made themselves well acquainted with cuckoo-spit and the small tortoise-shell, with one or more of the humble-bees, with bedeguar gall, with earthworms, moles, and shrews, and with the whinchat—they have made a good beginning with the natural history of the meadow.

Let us in leaving the meadow consider a single fact of natural history, so that we may see more clearly how an understanding of it makes demands on all the resources of our discipline. We have noted that the mole stores earthworms for use in winter—as many as a hundred being sometimes found together; and we have referred to the extraordinary fact that these stored earthworms are, in many cases at least, decapitated, so that although alive these are unable to crawl away. Round a fact like this we should let our minds play. We may begin by asking how the mole and the earthworm happen to be both underground, which is certainly not the primitive home of their respective races; we pass on to inquire how the mole catches the earthworms, and how these are often able to avoid the mole; another query raises the problem of the storing instinct; a side question leads us to consider the mole's imperfect lenses, and the peculiarity of its optic nerves; then we are bound to inquire how it is that the decapitation of the earthworm prevents its crawling away; and this brings us to consider the function of the head-ganglia as a motor centre. We know that in summer a lost head-end may be re-grown, but that this does not occur in the low temper-

[1] See (Dixon) p. 222. [2] *Ibid.*

ature of winter, a fact that raises the whole difficult problem of regeneration ; we know that the re-grown anterior part sometimes turns out to be a second tail instead of a new head, which forces us to face the fact that there are limits to the perfectness of adaptations. We cannot avoid inquiring, too, how far the mole's destruction of earthworms, which are for the most part valuable agriculturally, is compensated for by its destruction of injurious insects. And so from the unearthed store of worms in the mole's burrow we pass to problems of nerve physiology, comparative psychology, conditions of development, rural economy, and what not,—inquiries obviously far beyond the range of school "Nature Study," though inevitably suggested by it.

Woodland. — Just as there are characteristic plants which one expects in the woods—such as the pale yellow cow-wheat (*Melampyrum*) and enchanter's night-shade (*Circæa*) and the blue hyacinth (*Scilla nutans*)—so there are characteristic animals though it is not so easy to get to know them, for wood animals are peculiarly shy and evasive. In some woods during the warm part of the year it is difficult (for the thin-skinned at least) to do any Nature Study at all, because of the hosts of midges which make standing still a torture. The thin-skinned observer must perforce resort to a veil, for there is never much to be seen on a scamper.

It is advisable that the leader of a class excursion should have made the excursion or a similar one many times before, and that he should know what he is going to look for, and where. As in the case of other haunts, another piece of general advice may be given, namely, to pay the haunt a visit at different times of day and at different times of year, and not to try too much at once. We shall restrict our hints to noting a few things or sets of things that should be looked for and studied.

Squirrels.—The distinctive mammal of the woods is *Sciurus vulgaris*—" the lytil squerell full of besynesse," which ranges from Britain to Japan. The pupils probably know its hairs in the "camel's hair" brushes used in painting. To watch the animal is in itself a delight. "It is amusing," MacGillivray observed, " to watch it in its arboreal excursions, when you see it ascending the trunk and branches with surprising speed, running out even on slender twigs, always, when in motion, keeping its tail depressed, occasionally performing leaps from one branch to another, and when alarmed scampering away at such a rate that you almost expect to see it miss its footing and fall down headlong. It feeds on nuts, beech-nuts, acorns, buds, and the bark of young branches ; generally, while eating, sitting on its haunches, with its tail elevated, holding the object between its paws, and dexterously unshelling the kernel, from which it even removes the outer pellicle before munching it." [1] There are many points of interest to the "Nature student,"—*e.g.* how does the colour change with age, season, and locality ? how do the ears change with the seasons ? where is the nest made ? what does the winter store consist of ? how is it that shooting down the squirrels increases the number of wood-pigeons ?

Birds of the Woods.—When we think of the woods we hear the far-off *Coo-roo, coo-coo* of the wood-pigeon (*Columba palumbus*), the loud laughing *Pleu, pleu, pleu* of the "yaffle" or green woodpecker (*Gécinus viridis*) or the hammering of its great spotted cousin (*Dendrocopus major*), the cawing of rooks, the *Si-si-si* of the tits, and so on through the mistle-thrush's song to a climax in the nightingale's melody. There are many characteristic woodland birds, such as nuthatch, magpie, jay, gold-crest, pheasant, owls, and sparrow-hawk. Some kinds one expects in particular woods—thus the siskin, the crossbill, and the capercailzie are at home among the Scotch firs. We should try to get some definite snapshots, say, of the woodcock walking at dusk along the "cock-roads," probing the soft soil for earthworms, or of the young from which the mother has been startled lying motionless among the fallen leaves—a most striking case of protective resemblance. Very characteristic, too, is a glimpse of the tree-creeper (*Certhia familiaris*), jerking itself round the tree trunk on the search for spiders and insects.

Slugs.—In some woods—especially towards evening and after a shower—the black slug (*Arion ater*) is greatly in evidence, and it well merits study. The pupils should watch it moving, and try to find it feeding ; they should notice the two pairs of horns or

[1] See (Lydekker) p. 222.

SCENE IN A BEECH WOOD

Showing Squirrel, Black Slug, Wood Snail, Two Wood Beetles, and Toad-Stools

tentacles, and the eyes on the tips of the longest pair, and the large breathing opening on the right-hand side which leads into a "pulmonary chamber,"—formed by a dorsal fold of skin (the mantle), and bearing a network of blood-vessels on the internal surface of its roof. Some should be made to creep on a plate of glass so as to show the beautiful waves of muscular contraction passing along the so-called "foot," which is simply a flat muscular development of the ventral surface. It is profitable to collect some specimens for the vivarium, so that their characteristics may be studied at leisure,—*e.g.* their omnivorous appetite, their keen sense of smell, their fondness for bathing. The pupils may perhaps discover the slugs laying eggs, and find out something new. From another point of view it is interesting to notice that while the common snails (*Helix*) have well developed shells, and most slugs (like *Limax*) have flat vestiges hidden on their back, the species of *Arion* have lost the shells entirely, or have only a few calcareous granules on their back. From another point of view it is worth noticing that the black slug is a good example of the distinctively northern contingent of British animals.

Ant-Hills.—Among the sights of the woods are the ant-hills, which should be carefully studied In many of the pine-woods they attain huge dimensions, four feet high and ten feet in circumference, and are chiefly built of the needle-like leaves and small twigs of the Scotch fir. There are many things to be done, —to look for some of the main paths leading into the hill, to see what the workers are carrying in, to give them various kinds of things to carry, *e.g.* cow-wheat seeds which are very like ant pupæ, to put obstacles in their way and observe how they meet them, to disturb a small part of the hill to see the workers carrying the pupæ in their mouths. The white pupæ, sometimes called ants' eggs, sometimes called cocoons, should be explained; they are the stages between grubs and adults, and correspond to chrysalids. The grub is undergoing metamorphosis within the pupa-case. It should be pointed out that cocoon meant something quite different in the case of the spiders on the moor. Care must be taken to leave the general impression clear—that the ant-hill is a more or less permanent city, though it may be shifted from one place to another; that it may be older than its oldest inhabitants. The connection between ants and pheasants may be inquired into.

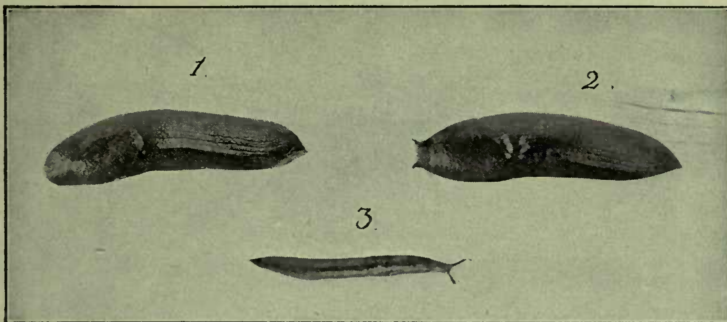
Oak - Galls.—The wood excursion should include the examination of some galls—an interesting subject from the "Nature Study" point of view, since it illustrates the interlinking of plant and animal life. In the case of the common "marble-gall"—which is a good one to start with—the gall is the result of an interaction of the living cells of the oak-bud on the one hand and of the larva of the gall-wasp on the other hand. The secretions of the larva seem to stimulate a peculiar, but most orderly growth on the part of the oak, and the result is an excrescence which affords readily available food for the larva, and is also beneficial to the plant, since it localises the injury inflicted.

The marble-gall is often about an inch in diameter, and is usually smooth, as its name suggests. It is green in summer, and then turns brown. The larva, which is found in the centre, is white, footless, and fleshy, with thirteen segments. The adult insects, which hatch out at different times, are small reddish yellow Hymenoptera (*Cynips kollari*).

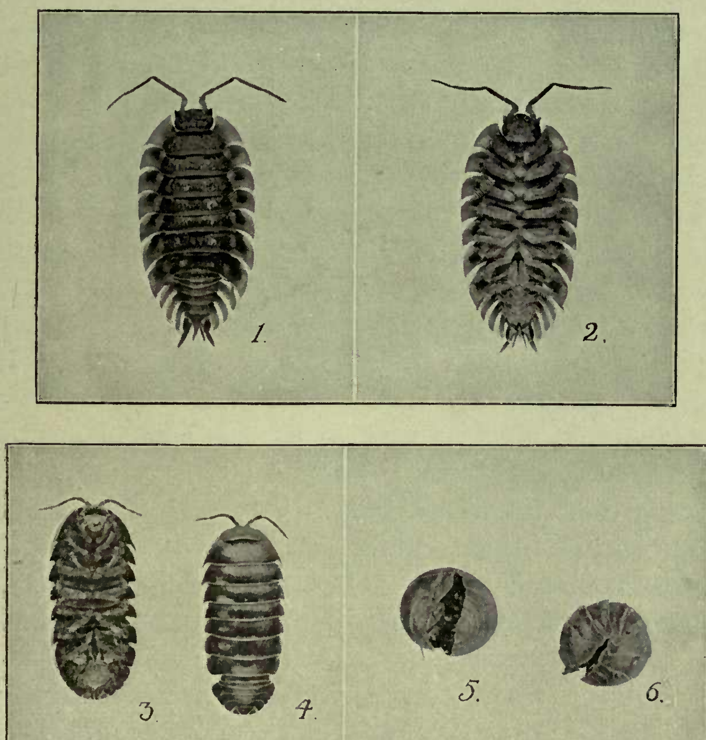
The oak-spangles (*Neuroterus*), which occur on the under side of oak leaves as small lens-like or saucer-like bodies, are due to the larvæ of a small cynipid. If the larvæ develop into adults, these form galls of another kind, so called currant-galls,—pea-shaped, glossy, green often with red spots—to which a different name (*Spathegaster*) was given before it was known that the life-history of this and many other cynipids included two different forms of gall and two different forms of adult insect. What come out of the spangle-galls on the leaf (all females) deposit eggs in the bud, and the resulting larvæ form currant-galls. What come out of the currant-galls are males and females, and the female deposit eggs in the leaf, and the resulting larvæ form spangle-galls.[1]

Wood-Lice.—Attention should be paid to the wood-lice, or "slaters," of which there are many kinds, *Porcellio scaber* one of the commonest. They are interesting in many ways, because they are terrestrial Crustaceans which have left the aquatic home of their race ; because they have a peculiar adaptation to breathing dry air, namely, tubular passages in some of their limbs ; because

[1] See (Gillanders) p. 222.



SLUG *(Limax)*
1. Resting. 2. Preparing to move. 3. In motion.



WOODLICE, magnified.
1. Dorsal. 2. Ventral. 3. Partly rolled up, ventral.
4. The same, dorsal. 5. 6. Rolled up.
(Photos by Hugh Main.)

the young are carried about before birth in spacious brood-pouches. They have nineteen pairs of limbs, just as a lobster has, and the surface of the body is often beautifully sculptured. When a large colony of *Porcellio scaber* is disturbed there is a remarkable hurry-scurry. It is easy to find young forms, pale in colour, and moulted cuticles are often seen lying about.

The Moorland. — An excursion to the moorland requires some rehearsal if it is to be a success. It is well to begin by finding a tract where one can wander without let or hindrance (which means in many cases getting definite permission from the proprietor), and it is also desirable to find as varied a corner as possible, with heathery knolls and peatbogs and tarns.

Mammals of the Moor. — Herds of red deer (*Cervus elaphus*) are still to be seen on some of the moors in the wilder parts of the Scottish Highlands and in Ireland. There are two or three wild herds in England, and there are many half-wild herds in English parks. In some parts of Scotland the children on their way to school often see the deer at a distance; it may be on the crest of a hill silhouetted against the sky. The full-grown males or stags keep to themselves for most of the year, but seek for the females or hinds in September. It is then that they bellow and fight, and are dangerous to intruders. Their well-known weapons —the antlers—drop off (and are eaten !) in early spring, and their regrowth on a larger scale every year is one of the most extraordinary facts in Natural History. The young fawn—whose beauty is fascinating—is born in May or June, and is most carefully looked after by the mother. The much smaller roe-deer (*Capreolus caprea*) is mainly a Scottish animal, and is a creature of the woods rather than of the moors ; it is not gregarious, and the two sexes keep together all the year. Intermediate in size between red-deer and roe-deer is the fallow-deer (*Cervus dama*), which, like the rabbit and the rats, was introduced into Britain (perhaps by the Romans) in comparatively recent times.

Birds of the Moor. — One would naturally start with the red grouse (*Lagopus scoticus*) in taking a survey of the birds of the moor. It is the only bird peculiar to the British Isles, and has probably been evolved from the closely allied species the willow-grouse (*Lagopus albus*), which inhabits the northern regions of Europe, Asia, and America. The warning cry of the male—*Kok, kok, kok*—is one of the most characteristic sounds of the moors. Both young and old feed on the tips of ling and heather shoots, and on the leaves and fruit of the bilberry and similar moorland plants. Among the other distinctive birds of this habitat we may note the black-cock and grey-hen (male and female of *Tetrao tetrix*), the golden plover and the peewit, the twite and the stone-chat. It goes without saying that many birds which frequent the moors in summer must be looked for elsewhere in winter. Thus the familiar curlew (*Numenius arquatus*), with its pleasing but melancholy cry and conspicuously long curved bill,

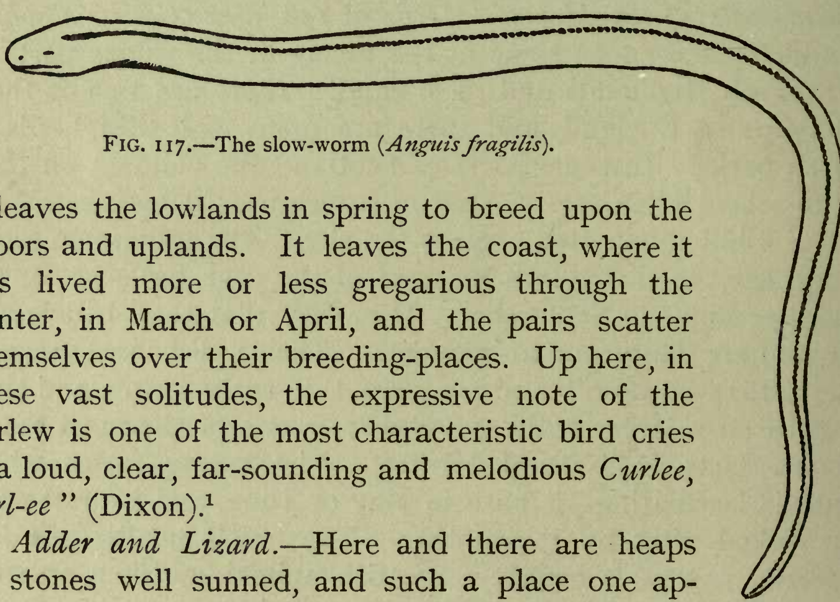
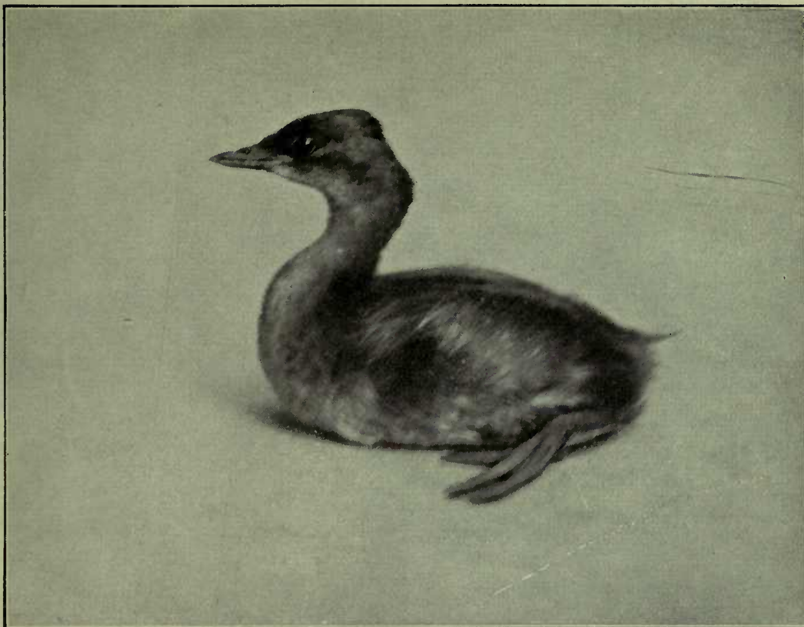


FIG. 117.—The slow-worm (*Anguis fragilis*).

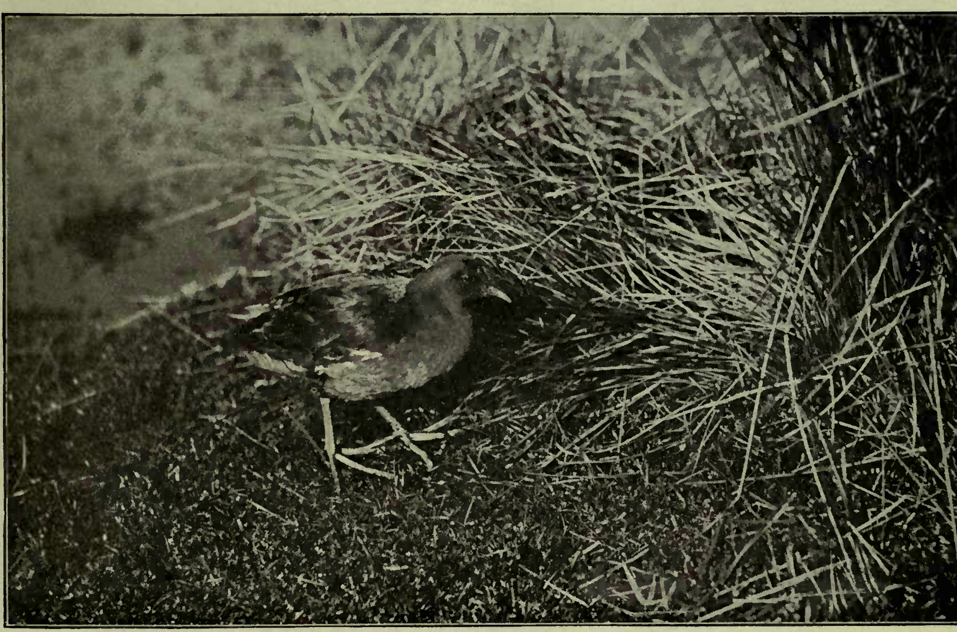
"leaves the lowlands in spring to breed upon the moors and uplands. It leaves the coast, where it has lived more or less gregarious through the winter, in March or April, and the pairs scatter themselves over their breeding-places. Up here, in these vast solitudes, the expressive note of the curlew is one of the most characteristic bird cries—a loud, clear, far-sounding and melodious *Curlee, curl-ee*" (Dixon).[1]

Adder and Lizard.—Here and there are heaps of stones well sunned, and such a place one approaches cautiously on the outlook for an adder (see Reptiles, vol. i. p. 112). Sometimes, especially when one is not looking for it, one may see the reptile basking in the sun. It is certainly not deaf, for it detects our quiet footsteps, and slips away in a moment among the stones. In similar places we should look for lizards and even slow-worms ; the grass-snake is an animal rather of the meadow than the moor. Sometimes one has the good fortune to find a snake's slough, rubbed off against the

[1] See (Dixon) p. 222.



DABCHICK. (Photo by Chas. Reid.)



MOORHEN. (Photo by W. S. Berridge.)

heather twigs, and then one may have an object lesson which justifies the whole excursion.

Spiders.—A profitable thing to do on a summer day is simply to sit down among the heather and to remain quite still, watching the busy life in the miniature jungle around us. We see the mother spiders carrying little balls of silk below the front part of the body. These are cocoons containing eggs or young spiders. If we catch one of the spiders and gently remove the silken cradle we may see the careful but very short-sighted mother searching for it. When she comes by chance within a certain short distance of it she gets the scent and soon recovers her treasure. To know the names of these moorland spiders is not an easy matter, especially since the best book (Blackwell's *British Spiders*) is large and expensive, but that is not a matter for elementary Nature Study. What is really important is to look carefully at the spiders one does see, to distinguish the four or five kinds that one sees oftenest at that place on that summer afternoon. Among the heather there are different kinds of webs to be looked at and sketched, and there are cocoons—" spiders' nests "—which are fastened to the twigs and not carried about.

Water-Spider. — In a moorland pool—which means a comparatively " wild " place—we may look for the true water-spider (*Argyroneta aquaticus*), to find which marks a red-letter day. It spins a web beneath the water, mooring it to water-weeds ; it buoys this up with air brought down from the surface entangled in its hairs ; and there it lays its eggs. In some cases it uses the empty shell of a freshwater snail for its nest, fixing it in a suitable position with threads of silk and filling it up with air as before. The water-spider will live for a while in captivity, and by watching it close at hand the pupils may convince themselves that the silvery appearance (to which it owes its name *Argyroneta*) is due to bubbles of air held among the hairs of the body.

Centipedes.—Another expedient on the moor is to turn over loosely lying stones, for instance near the half broken-down wall that separates the moorland from wood. There one may see beautiful centipedes, like *Lithobius*, pointing them out to the pupils as among the forerunners of the insects, and among the persecutors of earthworms. Their lively and graceful movements should be watched, and it may be noted that they are all carnivorous and poisonous, unlike their distant allies—the millipedes—which are vegetarian and non-poisonous. Underneath the stones one will also find slugs and earthworms, burrowing beetles and ants and other insects.

The Mountain-side.—In some parts of Britain an excursion to the top of a high hill is much more feasible than one to the seashore. The list of distinctive animals that one may hope to see in climbing the hill will vary with the altitude and with the degree of wildness. We must take a case in our own experience.

A very interesting and distinctive frequenter of the mountains is *Lepus timidus*, the variable or blue or mountain hare. A characteristically northern animal, the only hare in Scandinavia and Iceland, it lingers on mountain ranges like the Alps and the Pyrenees. In colder countries—in most of Scotland, but not in Ireland—it turns white in winter, except the tips of its ears, which are always black. At the approach of winter there is a new growth of white hairs, and the coloured hairs blanch. It seems as if it were the cold that pulls the trigger of this constitutional tendency to change, which probably has some utility, *e.g.* in making the animals less conspicuous. The mountain hare has no regular " form " like the common hare ; it hides among the rocks and heather.

Another mammal often seen on the mountains is the stoat or ermine (*Mustela erminea*), which preys upon young hares, grouse, ptarmigan, rats, voles, and so on. The mountain hare is white in winter, except the black tips of its ears ; the ermine is white except the black tip of its tail. On very high mountains the white forms may be seen all the year round, on the low ground the white form may never be seen at all. The white dress seems to be due partly to a growth of new hairs with gas bubbles where the pigment should be, and partly to a removal of pigment from hairs which were pigmented.

The other mammals that are likely to be seen on our hills are the deer, the fox (who is rather a different creature from Reynard of the plains), and the common shrew.

A northern bird seen on some of the highest Scotch mountains

STAGS ON THE CREST OF A HILL (Photo by Photochrome Co.)

GROUSE ON THE MOOR (Photo by Chas. Reid.)

WEASEL BY THE WOODSIDE (Photo by Chas. Reid.)

is the ptarmigan (*Lagopus mutus*), first cousin of the red grouse (*Lagopus scoticus*), and the willow-grouse (*Lagopus albus*). It is interesting in having a triple moult. "Both sexes not only moult after the breeding season is over into a grey suit, and then again as autumn passes away into their snowy winter clothing, but, divesting themselves of the last in spring, at that time put on each a third and most distinctive dress,—these changes, however, do not extend to the quills either of the wings or tail" (Newton).[1] It is technically called *mutus*, but that is unfortunate, since the bird has a snorting cry—startling enough in its lofty solitudes.

Among the other birds of the mountains we may note the snow-bunting, a winter visitor which has been known to nest in Scotland, though it usually retires farther north in spring. But we can only mention the eagle, peregrine falcon, raven, twite, and (in summer) abundant golden plover and a few dotterel. If we take the mountain streams and mountain tarns into account, we may add such birds as the grey wagtail and the red-throated diver (in summer).

As in other cases, it is difficult to give characteristic illustrations of the humbler life of the mountains. I have seen the viviparous lizard (*Lacerta vivipara*) and the common frog high up on the hills, and the adder is also a climber. There are snails and slugs to be looked for and interesting microscopic animals among the bog-moss. Most obvious, however, is the abundance (1) of insects (small midges, large butterflies, ground beetles), and (2) of spiders among the rocks and the heather.

Aerial

The last region to be possessed by animals was the air, and we include most insects, most birds, and the bats in the aerial fauna. The flying-fishes take enormous leaps, using their pectoral fins as parachutes, the web-footed tree-frogs jump boldly from branch to branch, the little lizard known as *Draco volans* has its skin spread out on elongated ribs and is able to swoop from tree to tree, a few arboreal Mammals have the same power.

[1] See (Newton) p. 222.

But, apart from some extinct reptiles, the only animals with the power of true flight are insects, birds, and bats. From some old tower or from a barn it may be possible to get some bats—certainly the quaintest of mammals. One should demonstrate the structure of the wing—the skin stretched between the long spider-like fingers, the backward turned knee, the sharp cusps of the cheek-teeth, and so on. As a climax of aerial life one might perhaps take the swift (*Cypselus apus*), which hardly rests in summer from dawn to nightfall in its dashing flight. If a specimen is procurable it is easy to show that the great length of the wings and the small size of the feet (with their four toes turned forwards), makes walking very difficult, and if a swallow can be got for comparison it is very well worth while spending time in showing that, in spite of some resemblance in habit and in general appearance, the two birds are not related. The swift may also be taken as a good example of a summer visitor arriving towards the end of April, and usually leaving by the end of August on its journey to African winter quarters. But it is well not to overload with information; let the pupils get a good impression of the swift in its mastery of the air. "The wild screeching note is sometimes quite startling, when uttered by a flock of birds sweeping by at lightning speed, and often in the worst of weather, for the swift seems to revel in the storm" (Howard Saunders).

Summary.—There are six great haunts of life—the shore, the open sea, the deep sea, the fresh waters, the dry land, and the air. Each of these haunts has its peculiar conditions and its characteristic fauna, and it is to some extent possible to interpret the peculiarities in the animals as adaptations to their several haunts.

More detailed Study.—Much has been done in recent years in the study of "plant associations" or "characteristic vegetations,"—the assemblages of similar plants which occur in similar areas. Wood and heath, sand-dunes and shore, moor and bog, and so on, are more or less distinctly marked, wherever they occur, by analogous plants characteristic of each environment. This is an interesting and educative kind of study, and it should be pursued in regard to animals. In the foregoing pages we have suggested a number of profitable excursions, and some—just a few—of the things one would look for, but this study of haunts must become more precise if its real value is to be discovered. It is, for instance, of much use to have vivid picturing of the difficulties of particular situations and of the varied ways in which different animals meet these. It is instructive to find the same characteristic cropping up in entirely different kinds of animals in the same sort of haunt. Thus, to take an easy example, we may picture a boreal group, in some way adapted to arctic conditions, by permanent or by seasonal whiteness; the picture is soon filled up by the polar bear, the Greenland falcon, the snowy owl, the arctic fox, the variable hare, the Hudson Bay lemming, and so on. It is often profitable to keep to one type of creature, say birds or insects, and to contrast the different kinds that are found on the shore, on the links, in the fields, in the woods, on the moor, on the mountains, and so on. This may lead on to the power of forming what one may call "impressionist pictures" of the characteristic groups of animals which may be seen on the tundra, the steppes, the desert, the forest, the mountains, and so on.

From this the survey may broaden out still more in an attempt to form mental pictures of the characteristic faunas of the great "zoological regions," corresponding more or less to the great divisions of the globe. To attempt detailed pictures would be out of place, but there seems no reason why school children should not be able to people their maps with *some* of the characteristic animals, just as they fill in *some* of the rivers and mountains. In his great work on *The Distribution of Animals*, Alfred Russel Wallace gives combined pictures of the characteristic animals of different regions, and with present-day resources these could be readily multiplied and vivified. The whole study could be made as pleasant as a game, especially if the mental pictures are built up from the dramatic sketches which abound in the works of the naturalist travellers.

Gradually it may be possible to take imaginary journeys, *e.g.* from Britain to Japan, to see that widely separated countries may have very similar faunas; from Florida to the Bahamas, from Australia to New Zealand, to see that more or less adjacent countries may have quite different faunas ; from arctic America to the Equator, to see that regions with very distinctive tenantry are often connected by transition areas. A study of the Mammals of Australia will illustrate the fact that a region may have a very sharply defined fauna, and the story of the tapirs or of the camel family will illustrate "discontinuous distribution," *i.e.* that examples of a type once widespread may survive in far separated regions though there are no living representatives in the intermediate areas. If these five sets of facts, for instance, are presented with anything like vividness, not in this condensed text-book fashion, but in narrative and picture, a grasp of some of the fundamental facts as to the distribution of animals will be secured almost unconsciously.

Very gradually and cautiously, with a few good instances to clinch each conclusion, the senior pupils may be led to see that there are many factors which co-operate to determine why some animals are here and not there, and others there and not here,—which is the main problem of the study of distribution. Why does the Great Salt Lake of Utah contain only two or three kinds of animals, instead of the dense population usually found in lakes ? Why are Amphibians absent from oceanic islands ? Why are small rodents so cosmopolitan ? Why are there no Mammals higher than Marsupials indigenous in Australia ? Why are there so many common features between the fauna of North America and the fauna of the north of Europe and Asia ? By these and a hundred similar questions the student may be led to the conclusion that six main factors have contributed to the present distribution of animals. They may be grouped in pairs,—the physical peculiarities of particular regions and the constitutional peculiarities of particular animals ; the original headquarters of the stock (often very uncertain) and the means of dispersal in each case ; the physical changes of climate, earth movements, etc. ; in particular regions and the changes brought about in the struggle for existence between the various animals tenanting these regions. Nor can man's influence be forgotten ; for although he has not lived long upon the earth compared with most other living creatures, he has been the direct cause of enormous changes in distribution ; such as the introduction of rabbits in Australia and house-sparrows in America, and the practical extermination of many animals, such as bison and beaver.

It seems to us very important that the Nature Study should merge with Geography, and we venture to illustrate the point still further. Some attempt should be made to understand the fauna of our own country,—whence it came and why it is as it is. We may indicate the first few steps in the inquiry.[1] (*a*) Of the original animal population, when Britain was simply a corner of the Eurasian continent, no traces remain, on land at least, except the fossils in the rocks. Many of these, *e.g.* some of the reptilian types, represent *lost races*, without living descendants anywhere. (*b*) In late Tertiary times, when the country had acquired many of its essential present-day features, but was still bound to Europe, there was an abundant animal population similar to that on the Continent. Britain had lions and bears, elephants and mammoths, rhinoceros and reindeer, and so on. (*c*) Then came the Ice Ages—ages of elimination—when Britain was all but covered by a huge mer-de-glace, and all the terrestrial animals probably perished. (*d*) In post-glacial times, when Britain was still bound by land bridges to the Continent, migrations occurred from north, east, and south, and the old haunts were re-peopled. To some extent it is still possible to distinguish with some probability the northern, the eastern, and the southern contingents. (*e*) Since all connection with the Continent was broken, British fauna has suffered many losses and has had but few gains.

On dull winter days, with the help of the naturalist travellers,[2] it may be possible to people the earth with some of its most interesting animals, and thus to make the world-picture more truly living. To some extent even in school it is possible to travel with Humboldt, to go on the *Beagle* voyage with Darwin, to visit the Malay Archipelago with Wallace, to explore the Amazons with Bates, to visit the Celebes with Hickson, to spend "idle days" in Patagonia with Hudson, to sail on the Indian Ocean with Alcock, or to go to the Antarctic with Bruce. But the pictures and the inquiries must not end without introducing a new consideration,—what all this complex distribution of animal life has meant and still

[1] See (Scharff) p. 22. [2] See (Brehm) p. 222.

means to man. As huntsman, shepherd, fisher, farmer, and in his manifold other practical relations with animals, as explorer and colonist, as poet and artist, physician and priest, man has been closely bound up in the bundle of life with his humbler fellow-creatures. To realise this vividly is the legitimate outcome of Nature Study.

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