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LAND AND ANIMAL ECOLOGY

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PREFACE

In order to obtain a true understanding of the life of any organism it is necessary to study it in its natural surroundings and in all its relationships with other organisms, both plant and animal, which constitute at least a considerable part of those surroundings. Yet, though the past few years have seen the production of a number of books on Elementary Biology and of a few on one branch of Ecology, so far no one has attempted to combine both Plant and Animal Ecology.

It was our previous intention to include much of this book at the end of *Fundamentals of Biology*, published recently, but the necessity of keeping the latter within a recognized maximum size compelled us to cut it out and produce this as a simple introduction to Ecology in general. Its primary object is to show, especially the more senior students in schools who have already been taught the general principles, how to extend their knowledge to field-work and how to carry biological interests beyond the laboratory. It is equally important that students at the universities should be able to do the same. No attempt at completeness has been made: not only is this impossible in a book of this size, but experience shows that when a student has once become interested in this branch of biology and has become familiar with some of the technique, he very soon fills the gaps for himself and enquires for such help as is indicated in the short bibliography in Appendix C.

We have aimed at keeping the language clear and simple, and venture to hope that this will help to make the book welcome to the many who have not had, and never will have, any formal training in biology, but yet are interested in natural history and the teeming life around them.

In conclusion, we wish to thank our wives for their help and encouragement and the various friends and publishers, mentioned after this preface, who have generously allowed us to reproduce their drawings and photographs.

J. W. S.

January 1933 L. P. W. R.

ACKNOWLEDGMENTS

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CHAPTER I

PLANT AND ANIMAL ASSOCIATIONS

Ecology.—Just as men in different walks of life live together and form communities, such as towns, in which they partly help and partly compete with each other, so various species of plants and animals together constitute what are known as **associations.** Members of a community are bound by laws and regulations and are mutually dependent in many other ways. The science which considers these inter-relationships of human beings is known as social economics; that whose province it is to discover those upon which plant and animal associations depend is **ecology.*** Human communities arise in certain places because climate, soil, etc., are favourable for the development of some particular industry. In the wake of this other businesses follow and flourish, if they are able to accommodate themselves to the prevailing conditions. As these change, new industries may arise and replace the original more or less completely; or the latter may die out through the exhaustion of the raw materials or changes in other vital factors. In other words, whether any particular business is able to thrive or not depends not only on climate and other physical factors, but also on its inter-relations with other businesses.

Plant and animal associations begin, develop, alter and die out under exactly parallel circumstances. The "site" occupied by an association and the conditions which determine the constitution of the association together form a **habitat.** The factors which determine the

* The derivations of this and of many other technical terms are given in appendix D, page 174.

nature of a habitat are (*a*) **climatic,** temperature and rainfall for example; (*b*) **edaphic,** the nature of the substratum, rocks and soil; and (*c*) **biotic,** those resulting from the activities of living organisms, including those of man.

Though plants and animals interact upon each other so much that no ecological work which ignores either of them can even pretend to be complete, plants so predominate most associations that they must be considered first. Because of their usual modes of life they, even more than animals, are dependent upon the primary

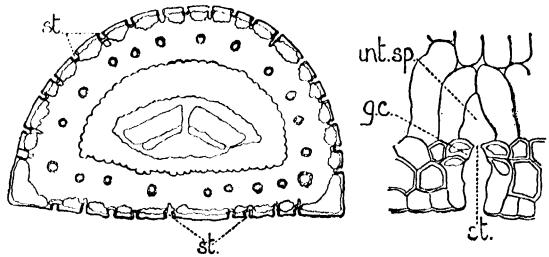


FIG. 1.—TRANSVERSE SECTION OF LEAF OF *PINUS* TO SHOW GENERAL SHAPE AND SUNKEN STOMATA.

Outline sketch of complete transverse section on left (× 20), small portion more highly magnified (× about 200) showing detail of a single stoma.

g.c., guard-cell; *int.sp.*, intercellular air-space; *st.*, stomata.

conditions (climate, soil and water) which determine the nature of a habitat. According to their adaptations in connexion with water-supply, plants are grouped as **mesophytes, xerophytes** and **hydrophytes.** The first include ordinary green plants, the second and third, as their names indicate, those which are able to put up with excessively dry and excessively wet conditions respectively.

Xerophytes cope with dryness of two very different kinds: physical, due to the absence of water, as in loose sandy places, and physiological, where, though there is plenty of water, as on seashores, in salt-marshes or in

bogs, it cannot be absorbed because of the large amount of salt or of acid which it contains. There are two principal ways in which they deal with these difficulties. They may either increase absorption by developing very long roots, which penetrate to deep available-water-containing layers in the substratum, or their aerial parts

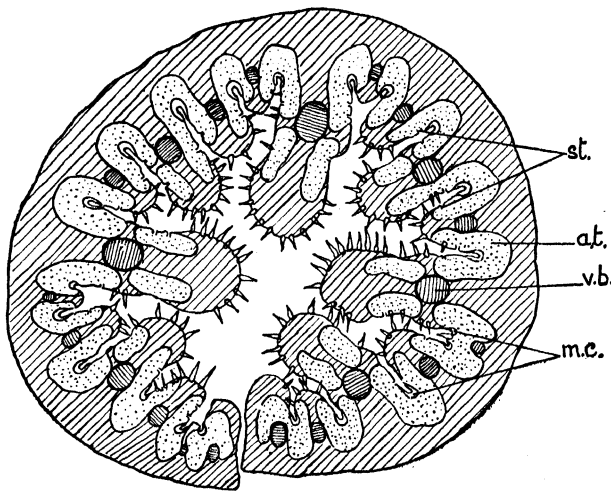


FIG. 2.—TRANSVERSE SECTION OF LEAF OF MARRAM GRASS (*PSAMMA*), ROLLED AS IN DRY WEATHER. (× ABOUT 40.)

Note the stomata situated opposite the chlorophyll-containing assimilating tissue in pits protected by hairs.

at., assimilating tissue; *m.c.*, motor cells which are sensitive to changes in the amount of water-vapour in the atmosphere and bring about the rolling and unrolling of the leaf; *st.*, stomata; *v.b.*, vascular bundle.

may be modified for reducing transpiration. The second method is by far the commoner and is effected in several ways. The whole transpiring surface or the number of stomata may be reduced; the stomata may be protected from the direct action of sun and wind by the presence of hairs; the stomata may be sunk into grooves or pits; the entire leaves may be rolled up, as in grasses (compare

figs. 1 and 2). Varieties of these adaptations are in many cases associated with the development of a thick waterproof cuticle, often covered with a layer of wax. The reduction of leaf-surface often leads to the stems assuming most of the function of photosynthesis and to the production of spines as a protection against animals. Another common feature of many xerophytes is succulence, due to the formation of special water-storage tissues. This and some of the other features are shown by many mesophytes when they grow in places, such as exposed parts along the coast, where xerophytic conditions prevail.

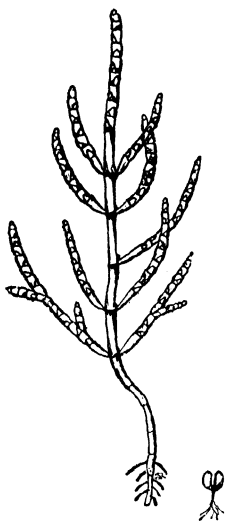


FIG. 3.—GLASSWORT (*SALICORNIA*), MATURE PLANT AND SEEDLING.

A salt-marsh xerophyte with succulent stem, reduced leaves and waxy covering.

Hydrophytes live either in tropical rain forests or floating upon or more or less submerged in water. The first are not considered here at all. The others show characteristic modifications: the reduction of roots, which when present are mainly anchors; the absence of wood and reduction of phloem, in correlation with the facts that they do not require mechanical support, that water-absorption occurs over most of their surface, and that diffusion of synthesized substances takes place readily through the soft and relatively loose tissue; the presence of chlorophyll in the epidermis, in order that the fullest advantage may be taken of the light which penetrates to submerged parts; the development of large spaces and channels as gas-reservoirs, through which exchange can take place between the leaves and the roots which are often embedded in mud devoid of oxygen (see fig. 4); the absence of ordinary stomata, except from the

upper surfaces of floating leaves ; the presence of special permanently open water-secreting stomata or hydathodes,

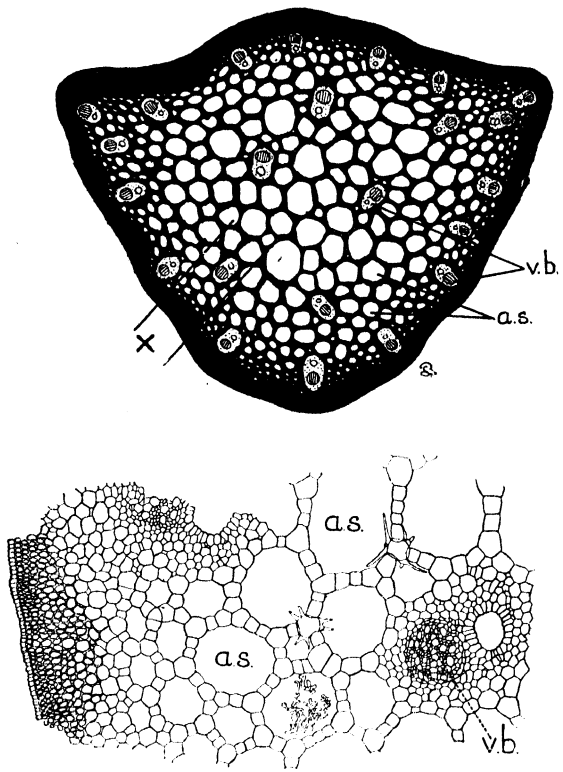


FIG. 4.—TRANSVERSE SECTION OF LEAF-STALK (PETIOLE) OF WATER-LILY (*NYMPHAEA*), SHOWING AIR-SPACES.

The lower drawing is an enlarged view (actually × about 30) of the portion labelled X in the upper drawing.

a.s., air-spaces ; *v.b.*, vascular bundles with poorly developed xylem and phloem.

which may be of use in maintaining a transpiration current and so distributing mineral salts to all the tissues ;

and the shape of the leaves. This last modification varies greatly not only between submerged and floating leaves but also between leaves of the same species, depending on whether they are growing in quiet or swiftly running water (see p. 52 and fig. 38).

Similarly, whole associations, both of plants and animals, may be classified as **marine, freshwater** or **terrestrial,** according to the prevailing water-supply of their respective habitats. Although very often these merge more or less imperceptibly into each other, yet in most cases they can be subdivided into smaller special habitats—freshwater associations, for instance, into ponds, streams and marshes.

In all associations there is competition for food and light, sometimes very severe competition, and often the general appearance of an association is due to the abundance of some plant which is so successful that it has become **dominant.** Other plants are able to thrive in its company because they are not in direct competition with it, but are able to live under less intensive light and to draw their inorganic supplies from different layers of the substratum. In some cases competition for light results in increased growth which would not otherwise have taken place. Besides being long and straggly, the plants or parts of plants in which this takes place are often of a sickly yellow colour ; in other words, they are etiolated.

Many plants are said to be **characteristic** of certain habitats, because they thrive best under the conditions determining these ; a few, found only in particular habitats, are **exclusive,** but very many are common to a number of very different environments, that is, are **indifferent.** Hence, though there are very distinctive associations, there is also a considerable tendency for both habitats and their occupants to overlap. In addition to this, changes may occur which affect the population of an area to such an extent that it alters more or less completely. These may be brought about by human activities or by some sudden edaphic phenomenon, such as subsidence, a land-slide or the bursting of a dam. Subsidence may lead to the formation of a lake, a land-

slide to the exposure of fresh rocks and soil, the bursting of a dam to the uncovering of mud rich in plant-food. On the other hand the basic changes may be slow, and due to such factors as "leaching", that is, the washing out of lime and other soluble material, the accumulation of plant remains, the failure of a dominant inhabitant, the encroaching of fresh or of salt water. In the former cases the empty areas gradually become colonized from their surroundings, first by species which are near-by and most numerous, then by those which are wind-borne from some distance, afterwards by others, until, after several series of immigrants have competed with each other, a permanent association characteristic of the finally stabilized condition is established. The same ultimate result is brought about when the edaphic changes are less sudden; outside species are given chances of which they take the utmost advantage. All such cases, in which considerable differences in population follow each other, are examples of what is known as **succession.**

In the chapters which follow the chief associations are described in a definite order, some in greater detail than others. This does not mean that it is necessary to carry out field-work in this or in any other particular order, or that some associations are of more importance than others. The general principles underlying all ecology are the same. The object of the accounts given is to show what these are and how organisms should be studied. The actual associations examined must depend upon their accessibility to any particular student.

Since plants predominate and, from the animal point of view, very largely determine the main features of any habitat, it is absolutely necessary for an ecologist to be able to recognize many of the characteristic plants in the field. It is comparatively easy to identify most flowers by means of a "flora",* which contains "keys" based on pairs of opposite characters in such a way that a flower is identified by a series of processes of elimination. The names given in keys are the Latin scientific names. There is a twofold reason for this: (*a*) scientific

* See appendix C (p. 171) Nos. 5, 28, 32 and 66 for suitable floras.

names for most organisms are the same all over the world, (*b*) popular names not only vary even within the same county, but are also often applied to entirely different plants or animals. It is important, therefore, to cultivate the habit of using the name which refers unmistakably to one definite kind of organism. For this reason both are given in this book, with the exception of those of birds and of most mammals which are not yet properly standardized. " Keys " are available for some groups of animals, but the number of different animals is so great that a general " fauna " is quite impractical. The real task of ecology, however, is not the identification of species, though this is a very important incidental, but the finding out of the inter-relations between the various organisms which constitute an association, and between the association and its habitat. Many of these inter-relations are brought out during the study of **food-cycles.** Thus, large deep-rooted trees draw their main supplies from well below the surface of the ground, the material formed by their dead leaves provides food for many humbler forms of plants and for various small animals, while their living leaves may be eaten by various insects. These in turn are often preyed upon by other insects or attacked by parasitic mites, worms, protozoans and fungi, while the predatory insects may be caught and devoured by web-spinning spiders. All these organisms eventually pass back to the soil and the air during post-mortem decomposition.

Hence it is of supreme importance during any ecological work to make careful notes on the spot concerning the physical conditions of the habitat, the relative numbers and positions of the various plants and animals, the behaviour of the animals and their relations with plants and with each other. This can be done only in the field, but identification may be (in many cases must be) left for the laboratory or the study. The time of the year is also important: what might be termed **seasonal succession** occurs in all habitats. It is well exemplified in woodland and hedgerow associations, whose spring and autumn populations differ markedly, not only from each

other but also from that of summer time when their larger members—trees—are in full leaf.

In order that the habitat may be disturbed as little as possible and no more organisms than is absolutely necessary destroyed, any stones, logs or other movable objects should always be replaced as carefully and exactly as possible. Any plant or animal recognized as being a rare species should not be taken unless for some very special reason.

Soils.—Under all ordinary conditions of climate the edaphic factors are so important in determining the main features of the vegetation that a brief consideration of the substratum, soil, is necessary. This is usually dark brown or blackish material, consisting of " weathered ", that is, broken-down, rock and of decomposing plant and animal matter. The former constitutes by far the greater bulk of the soil, and from it potassium, sodium, magnesium, calcium and other mineral salts are dissolved. The latter, known as **humus,** is responsible for the dark colour; it is the chief reservoir of nitrogen. Under natural conditions it consists mainly of dead roots and decaying leaves, masses of which form the substance called leaf-mould. It is extremely important, not only because it returns to the soil nitrogen and other elements which are essential to plants, but also because of its power of retaining water.

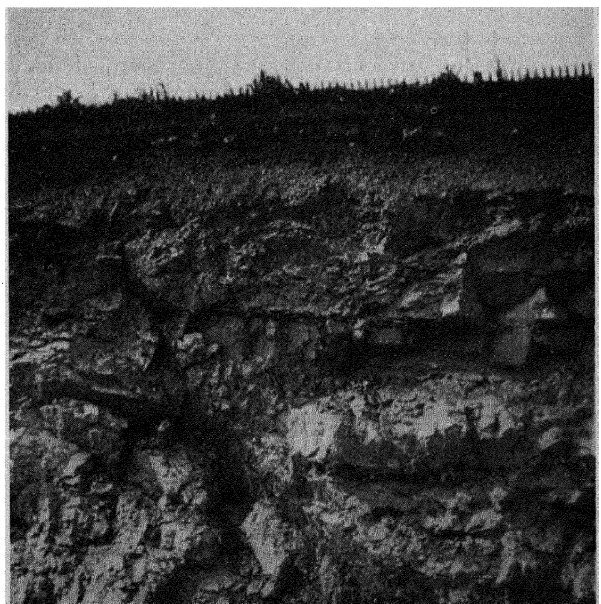
Some idea of the mechanical structure of soil may be obtained by taking a small quantity from any garden, and after removing the stones stirring it up with water in a large graduated cylinder. As soon as the stirring stops the particles of which the soil is composed begin to drop to the bottom, the largest and heaviest first. It will be some time however, in some cases days, before the water is quite clear, and even then some particles will be floating on the surface. The floating particles are **humus,** the larger heavier material at the bottom is **coarse sand,** above it is **fine sand,** above this finer material still, **silt,** and on the top very fine particles of **clay.** These form easily distinguishable layers, though there is a cer-

tain amount of merging together where they touch each other. The depth of the layers shows the proportions in which each of the different kinds of particle are present, and with a little imagination it is possible to picture them mixed together as they were in the original soil.

Though they are not spherical the particles may be regarded as balls of different sizes, carefully packed together. Small balls lie in the spaces between the big balls, smaller still between these. There is, therefore, a network of minute spaces permeating the whole mass. The particles are covered, and therefore the spaces lined, by a thin film of water in which is entangled the soil-atmosphere. The spaces are so small that they constitute a densely branched system of very narrow capillary-tubes through which water circulates as it is drawn from or added to the general mass of soil. The effective diameter of these capillary-tubes varies with the size of the particles, really with that of the spaces between them: the narrower the tube, the higher the water within it rises and the more tenaciously it clings to its walls. Further, since the surface-area of a mass of particles increases as the size of the particles decreases, fine soil holds more water than coarse. Hence, the water-content of soils and their capacity for retaining moisture are primarily dependent upon the sizes of their component particles. In addition to this, as mentioned above, the amount of humus affects the content very considerably on account of its power of holding water. (See also appendix B, p. 156.)

All soils originate from rocks which have in the first instance been subjected to the effects of water and temperature. Water trickles into cracks and expands when it freezes, thus enlarging the cracks, or splitting off larger or smaller blocks. Lichens and some kinds of algae soon obtain a foothold, and the carbon dioxide produced during their respiration forms a weak acid which dissolves out the lime present in many kinds of rock and causes them to disintegrate. Mosses, ferns and even some kinds of flowering plants then establish themselves, taking advantage of the small amount of debris washed and

blown into these cracks. They not only further this process but also split off chunks of rock by the pressure of their growing roots. As their dead remains are added to the general products of disintegration, a soil is gradually formed, and if undisturbed may eventually reach a considerable thickness. Such a soil is said to be **sedentary,**



[F. A. Lea.

FIG. 5.—CUTTING THROUGH CHALK SHOWING TRANSITION FROM ROCK INTO SUBSOIL AND SOIL (HOG'S BACK, NEAR GUILDFORD).

its primary composition depending upon the kind of rock from which it was formed and which usually underlies it. In many cases, however, the "weathered" material is blown or washed away and deposited elsewhere to form **drift** or **alluvial** soils, which have nothing to do with their underlying **substrata.** Between a sedentary soil and its

underlying rock there is a transition layer, the **subsoil,** which is continually adding to the soil above and drawing upon the rock beneath.

Soils formed from rocks containing a large amount of quartz (silica) are composed mainly of relatively large particles of **sand,** the spaces between which are so large that water drains through them rapidly, while capillary-movement is at a minimum. Sandy soils, therefore, are dry and unfertile. Limestone rocks give rise to **chalky** soils, which drain quickly because their subsoil consists of large particles and blocks of rock through which water passes rapidly (compare fig. 5). They are not, however, as dry as sandy soils because, on account of the smaller size of their particles, capillary-movement and water-retention are somewhat greater. From the breakdown of other rocks, usually called feldspars, **clay** soils result. Owing to the fineness of the particles these retain water to a remarkable extent, are very tenacious and therefore " heavy " to work, tend to become water-logged and, when trampled on, become impervious to both air and water, while on drying afterwards they crack and form extremely hard lumps.

Soils which consist of a mixture of sand, chalk, clay and humus in certain proportions are obviously the best. They contain all the necessary mineral salts, together with reserves of nitrogen, and their structure is such that, while it allows water to move freely, it has a great capacity for retaining it. Such a mixed soil is known as a **loam.** ✓

Clearly, very different plant associations will thrive on the various types of soil, and since some plants afford shelter or nesting sites for animals, others food, others both of these, the animal associations will differ too. In addition to this indirect control, edaphic factors have also a direct effect on the animal population : many of its members either burrow into suitable soil or make their nests or lairs in crevices in stones and rocks, in spaces between them, or in caves and other natural cavities.

CHAPTER II

MARINE ASSOCIATIONS

Although the seashore constitutes one large general habitat, it includes regions which differ so widely as regards both substratum and exposure to wind and sea that it must be regarded as being composed of a number of separate habitats. The substratum may consist of rocks, such as limestone, sandstone, or granite, which may be sheer, sloping, in ridges or blocks; it may form a beach of boulders, pebbles, shingle, gravel, sand or mud, or a mixture of two or more of these; it may be practically devoid of fresh water, irrigated by smaller or larger streams, or washed by a discharging river; and in any of these states it may be sheltered from or exposed to the full force of wind and waves. Above the intertidal region, but partly subjected to the effects of very high tides and exposed to sea winds, are areas of rock, sand, mud and salt-marsh whose populations must also be regarded as marine associations.

The various organisms which prevail under these very diverse conditions differ widely in both number and variety of species. Extremes of either shelter or exposure are both harmful. Very few species can withstand exposure to strong winds and heavy waves, which sweep the surface of rocks, stir up sandy and shingle beaches and hurl about large boulders. Not many can survive in mud or sand or among shingle, pebbles or boulders out of the reach of wave-action. On the other hand, regions which are subjected to moderate wave-action and the effects of flood and ebb tides support a very numerous and varied population, for the water which flows over them is thoroughly aerated besides carrying abundant food-

supplies. Habitats characterized by some of the harder rock formations naturally support the biggest associations, because, since they "weather" but slowly, they offer a suitable substratum not only to many of the larger seaweeds but also to many sessile animals. Hardly any

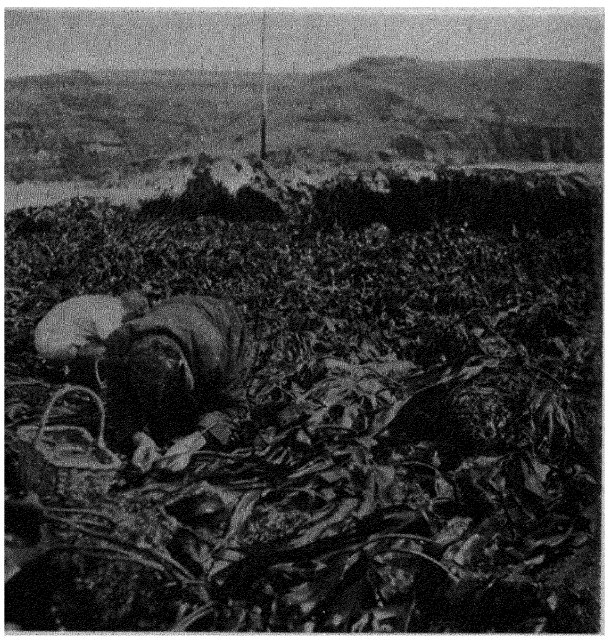


FIG. 6.—HUNTING AMONG SEAWEEDS (SALCOMBE, S. DEVON).

Note the extensive bed of oar-weeds (*Laminaria*) exposed only at low-water of spring tides; behind, ridge covered by wracks (*Fuci*) exposed at low-water of ordinary or neap tides.

plants can obtain a footing in mud or sand, though two very different species are found only in such habitats; sea-grass (*Zostera marina*), which is a flowering plant, and the very long brown alga known as "bootlaces" (*Chorda filum*). In addition, cordgrass (*Spartina*) (see fig. 33, p. 46), originally confined to mud-flats on the south and east

coasts of England, has been introduced both purposely and accidentally into other estuarine regions.

The extraordinary abundance and variety of life on the seashore is best realized during the period of low-water on the three days following the times of new and full moons. Then the tides flow to a much higher and ebb to a much lower level. They are distinguished as spring, as opposed to the ordinary neap tides. Even on the richest part of the shore, however, but few species are so obvious that they are easily seen. By far the greater majority must be looked for carefully, on or beneath the larger seaweeds, in crevices, under stones or on their under surfaces, in burrows in mud, sand or rocks, and in many other situations. It must be clearly realized that in the following account of the flora and fauna of the seashore (and other habitats) only a few of even the common organisms are mentioned. They are, however, chosen with a view to showing the student how they are adapted to the environment, and how to study others he may find.

Rock-pools often contain a very great variety of inhabitants because, while their surfaces are within ordinary inter-tidal regions, their depths may correspond with much deeper extra-tidal zones.

The Flora and Fauna of the Seashore.—Above high-water mark the rocks usually bear a remarkable collection of lichens, mostly flat encrusting forms, many of them so flat that they appear at first to be merely splashes and daubs of colour. Three of the most obvious are tufts of bluish-green *Ramalina*, crinkly-lobed growths of greyish-green *Parmelia*, and closely encrusting patches of golden-orange *Xanthoria* (*Physcia*). Where these have died and disintegrated the rock, a few cushion-like mosses find a footing, with an occasional flowering plant. From high-water mark to far below the level exposed at the lowest spring tides there is a more or less continuous covering of marine algae, the so-called seaweeds. These are arranged in belts, or zones, which, especially in the case of the " browns ", show very clearly on shores where

hard rocks furnish a continuous substratum. The top of the series is formed by the tough leathery channelled-wrack (*Pelvetia canaliculata*), usually so high up that the sea reaches it only at high-water of spring tides. It is able to withstand drying to such a degree that it is often quite hard and brittle on a hot day in summer or a cold day in winter, but becomes soft and supple when moistened. Bladder-wrack (*Fucus vesiculosus*) follows at such a distance that it is bathed at every high-tide. Especially where the slope is gentle, twisted-wrack (*F. spiralis*), very like a small kind of bladder-wrack, precedes it. Both of them remain soft and moist even after long exposure, on account of the mucus which they secrete. Bladder-wrack is so called on account of the numerous air-bladders it bears, mostly in pairs, on the upper half of its fronds. These buoy up the plants so that they spread out at flood-tide. They are, however, often absent when the seaweed is living where the depth of water covering it at high-tide is only a few inches. Growing either with it or below it are the long strap-like thalli of knotted-wrack (*Ascophyllum nodosum*), with its large ovoid air-bladders. Where the rocks are sheer

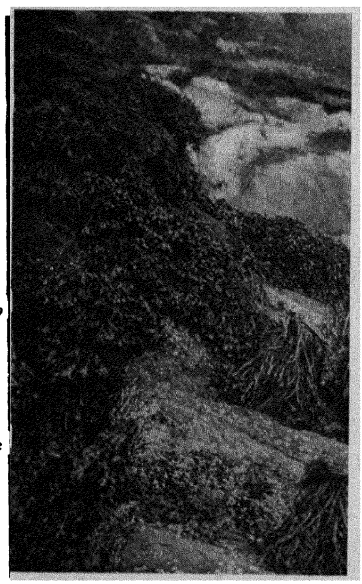
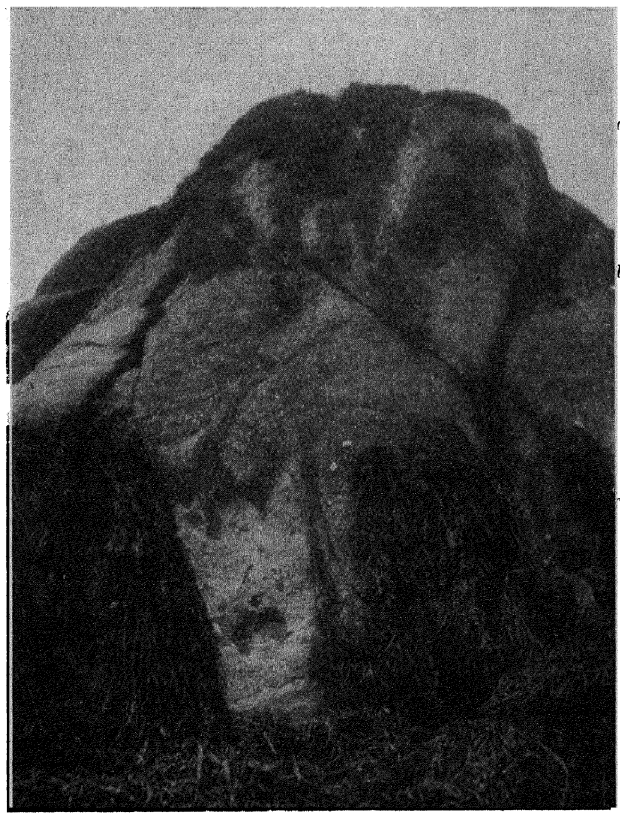


FIG. 7.—ZONING OF SEAWEEDS ON UPPER PART OF SHORE.

a, channelled-wrack (*Pelvetia canaliculata*); *b*, twisted-wrack (*Fucus spiralis*); *c*, bladder-wrack and knotted-wrack (*Fucus vesiculosus* and *Ascophyllum nodosum*) (see also fig. 9, p. 18).



[*D. A. Webb.*

FIG. 8.—ZONING OF FUCOIDS ON UPPER PART OF SHORE.

a, channelled-wrack (*Pelvetia canaliculata*); *b*, twisted-wrack (*Fucus spiralis*); *c*, bladder-wrack (*Fucus vesiculosus*); *d*. knotted-wrack (*Ascophyllum nodosum*).

Note also the numerous acorn barnacles and a few purples.

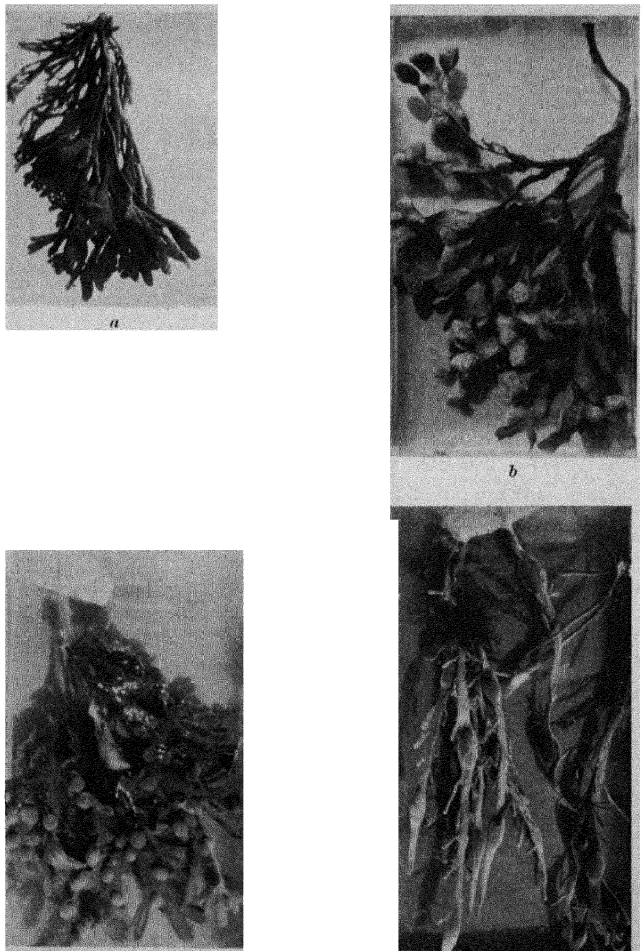


FIG. 9.—BROWN SEAWEEDS (FUCOIDS) FOUND ON THE UPPER PART OF A ROCKY SHORE.

a, channelled-wrack (*Pelvetia canaliculata*); *b*, twisted-wrack (*Fucus spiralis*); *c*, bladder-wrack (*Fucus vesiculosus*) with chalky tubes of *Spirorbis* (see p. 38) attached; *d*, knotted-wrack (*Ascophyllum nodosum*) with the red alga *Polysiphonia fastigiata* growing on part of it.

the fronds of the wrack may be many feet in length. At the extreme limit of low-water of neap tides and below it the broader toothed-wrack (*F. serratus*) flourishes, protecting itself from desiccation when exposed by a copious secretion of mucus. Beyond the fucoids and exposed only at the times of very low spring tides are the large oar-weeds or tangles, belonging to the genus *Laminaria* (see fig. 6.)

Lichens too flourish throughout the inter-tidal region, those of the genus *Lichena* looking like stunted channelled-wrack, others, such as *Lecanora*, forming dark green or blackish, more or less "slimy" smears on the surface of rocks and stones.

Where fresh water runs over the rocks or over the beach, the tubular thalli of *Enteromorpha intestinalis* form green streaks through the fucoids of the upper regions, being replaced in the deeper zones by the flat, wide fronds of sea-lettuce (*Ulva lactuca*). These and some others are able to obtain a footing even on stones embedded in sand or mud.

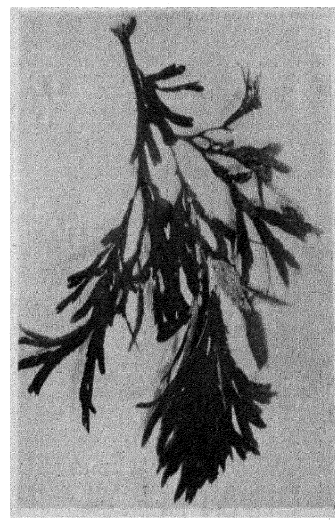


FIG. 10.—TOOTHED OR SERRATED WRACK (*FUCUS SERRATUS*).

Sea-mats (Polyzoans) can be seen growing on the seaweed as epizootics (see p. 128).

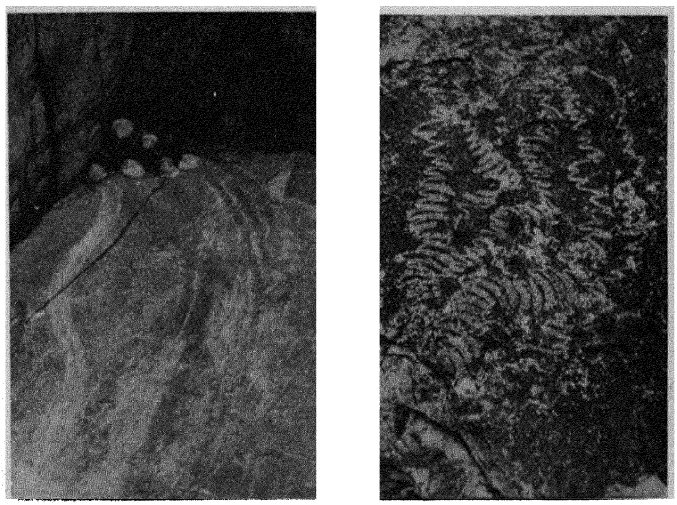
In pools among the rocks still other species thrive, all of them providing food, shelter and support for a host of animals. Such pools are often lined by pink coral-like encrustations, which also cover many stones and even limpet shells. These have no connexion with corals, which are animals closely related to sea-anemones, but belong to a group of seaweeds characterized by a pro-

tective covering of lime. Though some are found in the lower inter-tidal associations, most of them are deep-water forms living beyond the large oar-weeds, and their presence in rock-pools is clear evidence that the conditions prevailing in the deeper parts of these closely approximate to those which occur in lower and usually extra-tidal regions.

Different though these many forms of algae are, they all resemble each other in a few fundamental characters. None of them have any waterproof epidermal covering, the whole of their surface being able to absorb water. They are all fixed to a solid substratum, in the larger forms by a holdfast which is not a root but merely an organ of attachment. They are without any strengthening tissue comparable to the wood of land plants; this they do not require since when covered by the sea they are also supported by it, whilst when uncovered at low-water it is an advantage that they should "collapse" and lie in heaps, and thus avoid exposing a large surface to the air. In addition, they all produce motile or floating reproductive cells. In other words, they are admirably adapted to an aquatic existence.

As explained above, most shore animals shelter beneath seaweeds, boulders, stones and so on, or burrow into sand or mud while the tide is down, but some do frequent bare rocks and stones, limpets, young mussels and barnacles being familiar examples. The common rock-limpet (*Patella vulgata*) is easily recognized by its strong conical shell and its extraordinary power of adherence. So strongly does it grip with its foot and the edge of its shell, which often fits tightly into a slight depression made by it in the rock, that when once it is aware of the presence of an enemy there is very little chance of removing it entire. At other times it does not grip so tightly and may then be dislodged by a smart blow. Obviously, such an animal is well able to retain sufficient moisture for respiratory purposes during the period of low-water. It feeds when the tide is in on the minute algae which form thin coverings on rocks, rasping them off with its file-like tongue or radula (see fig. 11).

Another gastropod mollusc* which often exposes itself is the purple or dog-winkle (*Nucella* (*Purpura*) *lapillus*), so-called because it produces a colourless secretion which changes to purple on exposure to light. This fluid, not so much from the purple itself as from its allies, was used in the making of the famous Tyrian dye. The animal is something like a small whelk in appearance, but its spiral shell is much thicker, usually white or



[*O. H. Latter.*

FIG. 11.—LIMPETS.

On the left, tracks made by limpets; on the right, marks made by their radulae in the slimy covering of algae on rocks.

cream in colour though sometimes slaty-blue and occasionally banded with reddish-brown. During spawning-time numbers of individuals congregate together and deposit clusters of egg-capsules in sheltered situations. Each of these is shaped like a deep wine-glass almost

* **Appendix A contains** brief classifications of the plant and animal kingdoms, together with short definitions of the various groups.

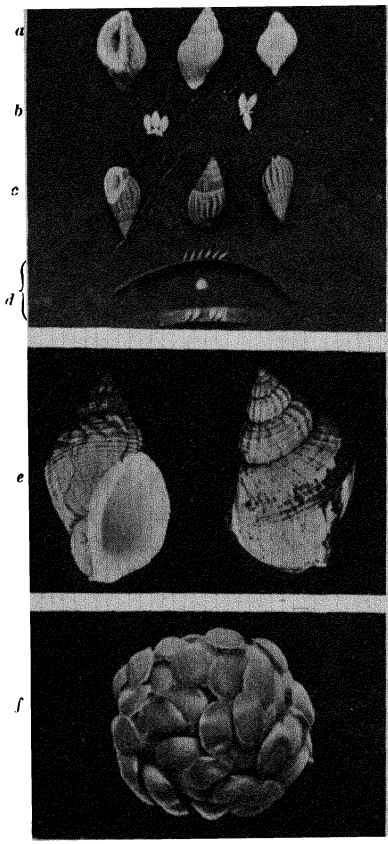


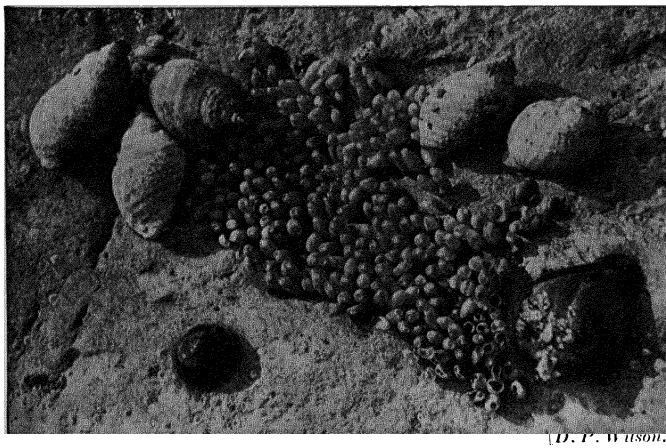
FIG. 12.—CARNIVOROUS GASTROPODS. [× ABOUT ⅓.]

a, purples (*Nucella* (*Purpura*) *lapillus*); *b*, egg-capsules of a purple; *c*, dogwhelks (*Nassarius* (*Nassa*) *reticulatus*); *d*, egg-capsules of a dogwhelk on sea-grass (*Zostera*); *e*, common whelks (*Buccinum undatum*); *f*, egg-capsules of whelk.

closed at the top and contains a number of ova, only one of which, however, develops, the others providing it with food. Thus, even in its earliest infancy this creature begins to indulge in the predatory habits which characterize it throughout its life. When adult it bores holes through the shells of other molluscs and then sucks out the contents by means of its extensile mouth-tube or proboscis. In correlation with this method of feeding a respiratory siphon is developed, so that though it may have its head in its food it is able to keep up free communication between the water and its respiratory organs. The common whelk (*Buccinum undatum*), whose large empty egg-cases are often washed up on the shore, and the dogwhelk (*Nassarius* (*Nassa*) *reticulatus*) also feed in this way, the latter often doing considerable damage

in oyster-beds, and sometimes even attacking the toes of unwary waders, as one of the authors knows to his cost. The shells of all these carnivorous gastropods are distinguished by a distinct notch or groove in their lips; it is through this that the siphon is extended.

The common edible periwinkle (*Littorina littorea*) is perhaps more familiar than any of the above, and certainly far more abundant on many shores, especially on stony mud-flats where there is a freshwater influence.



[*D. P. Wilson.*

FIG. 13.—PURPLES (*NUCELLA* (*PURPURA*) *LAPILLUS*) DEPOSITING EGG-CAPSULES.

On rocky shores it is exposed only at low-tide. It has a thick, sharply pointed shell which is usually blackish, but occasionally deep orange-red, sometimes spirally banded, and, especially when young, creamy in colour (see fig. 14). When disturbed winkles living on rocks readily release their hold and fall. (Purples do so too, but not quite so readily.) They rely for protection partly on the thickness of their shells, the mouths of which can be tightly closed by a tough horny "door", the operculum, attached to the hinder part of the foot, and partly on their re-

semblances to the mud or to the stones among which they are likely to fall. In feeding habits periwinkles resemble limpets and not the carnivorous gastropods.

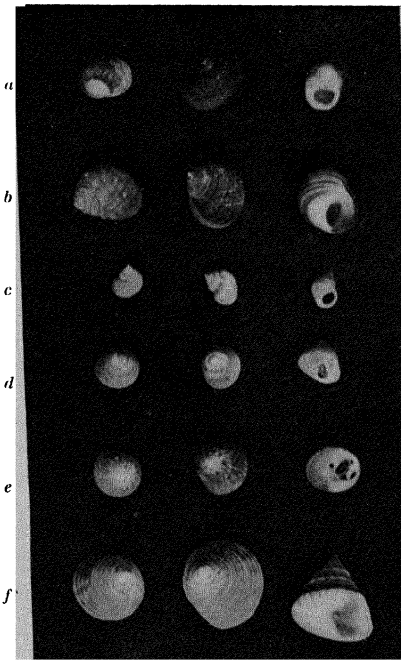


FIG. 14.—WINKLES AND TOPS. (× ABOUT ⅓.)

a, smooth-winkles (*Littorina littoralis* (*obtusata*)); *b*, common periwinkles (*L. littorea*); *c*, rough-winkles (*L. rudis*); *d*, grey tops (*Gibbula* (*Trochus*) *cineraria*); *e*, flat tops (*G.* (*T.*) *umbilicalis*); *f*, painted tops (*Calliostoma* (*Trochus*) *zizyphinum*).

Closely related species, the smooth-winkle and the rough-winkle (*L. littoralis* (*obtusata*) and *L. rudis* respectively) are found higher up the shore. The former abounds on bladder-wrack. It is much smaller than its pointed relative, and further differs from it by having a smooth, rounded shell. In colour it varies from dark cream through yellow, to deep olive-green and black, shape and colour both combining to render it extremely like the air-bladders of the wrack upon which it feeds. The rough-winkle lives still nearer high-water mark and is exposed for the greater part of the day. Because of this its respiratory organs are slightly modified, the eggs develop within the parent and the young are born complete with shells. In general shape this winkle resembles

the larger *L. littorea*; its colour is usually of a yellowish hue. (See fig. 14.)

On many rocky shores and boulder-beaches the common or edible mussel (*Mytilus edulis*) occurs in great numbers. This is one of the lamellibranch or bivalve molluscs, so-called because they have plate-like gills, and are protected by a shell consisting of two valves joined together by a hinge. Masses of very small mussels often form blackish streaks in crevices about high-water mark, larger specimens being sometimes found lower down on a rocky shore. The largest of all, however, occur partially hidden in the stony mud of estuaries, where they may be up to four inches in length. In the first of these habitats their small size is due not only to their being crowded together, but also to the fact that they receive a more scanty food-supply. In this condition they are sometimes known as "seed" mussels. Whether large or small they are very dark blue in colour and of the same general shape, rather like a bean which is bluntly pointed at one end, broad and rounded at the other. The pointed end is anterior. The hinge is an elastic ligament along the dorsal surface, which causes the valves to gape open when the closing muscles attached to them, known as the adductors, are relaxed. Mussels are firmly fixed to stones and rocks by means of a tuft of strong silk-like threads constituting the byssus. When the valves gape a double brown frill projects slightly from the posterior end. This is formed by the edge of the mantle, a flap of tissue which envelops the whole of the rest of the animal and which secretes the shell. Careful observation reveals the fact that the frills form two short tubes, a dorsal exhalant and a ventral inhalant siphon. Through the latter of these water currents are drawn by means of cilia on the mantle and other organs, to be passed out through the former after circulating over and around the body. These currents carry in supplies of oxygen and small solid particles of food, and bring out carbon dioxide and all other waste products. The byssus is made one strand at a time by special glands in the foot, which is

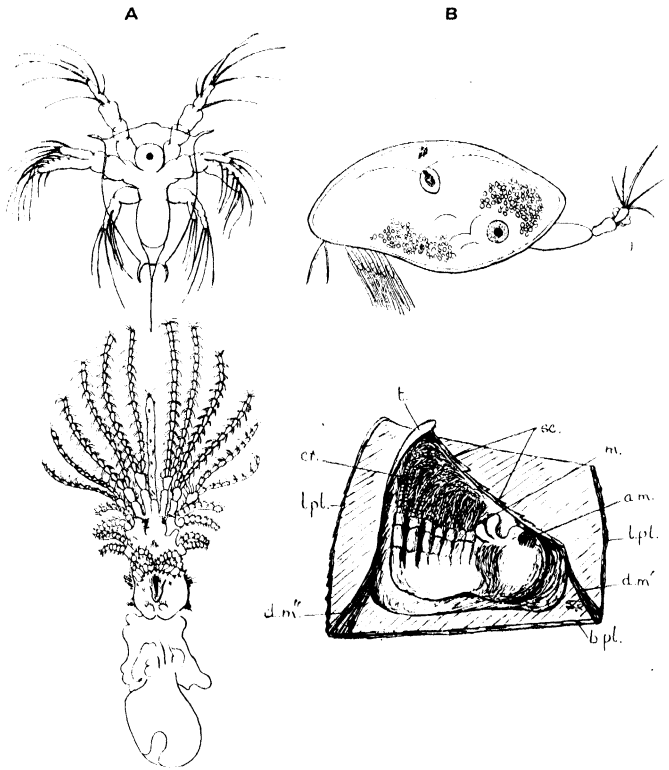


FIG. 15.—ACORN BARNACLE (*BALANUS BALANOIDES*).

A, nauplius of *Balanus*, the first larval stage; B, cypris larva, a later stage; C, cast "skin" of a barnacle (a common object in marine plankton) (see p. 70); D, diagrammatic sectional view of an adult *Balanus* to show its general anatomy (B and C have been copied from drawings made by J. Vaughan Thomson in 1833.)

a.m., adductor muscle; *b.pl.*, basal plate; *cr.*, cirri (= thoracic legs); *d.m'.*, depressor muscle of scutum; *d.m''.*, depressor muscle of tergum; *l.pl.*, lateral plates of "shell" in section; *m.*, entrance to mouth; *sc.*, scutal plate; *t.*, tergal plate. (These last two plates form one side of the operculum which when closed protects the soft parts of the animal; during feeding the two halves of the operculum move apart and the legs protrude.)

it is no longer an organ of vigorous locomotion. Slow movement from place to place, however, can be effected by the foot stretching out, forming a new byssus and breaking away from the original.

The common rock or acorn barnacles (*Balanus balanoides*) are familiar to everyone. They are often so abundant throughout the whole inter-tidal zone that a greyish colour is imparted to the rocks to which they are attached. Although they are permanently fixed and enclosed within valves, which are very shell-like in texture, these animals begin life as actively swimming larvae whose structure and moulting processes prove them to be crustaceans. (See fig. 15.) Adult barnacles feed by means of their legs, which are thrust out and withdrawn between the pair of roofing valves. The bristles with which the legs are beset cross each other, so that the whole tuft acts as a sweeping-net, catching minute particles and taking them to the mouth. When the valves are tightly shut the soft parts of the creature are kept moist and protected from danger as efficiently as are those of a limpet.



FIG. 16.—*GAMMARUS*, A TYPICAL AMPHIPOD, MALE ABOVE AND FEMALE BELOW, AS SEEN IN SIDE VIEW. (× ABOUT 1½.)

Many other crustaceans of very different habits from those of the barnacle may be found in all kinds of places from high-water mark down into deep water, provided there is shelter. Beneath almost any stone on the damper part of a shore, amphipods, *Gammarus marinus* and *G. locusta*, closely allied to the freshwater shrimp (*Gammarus pulex*—see p. 62) will be seen swimming about on their sides, the larger male often "embracing" the female. Belonging to the same group of Crustacea, but with their hind-legs modified for jumping, are the well-known sand-hoppers, of which there are two common species, *Talitrus saltator* and *Orchestia gammarella*. They live at about high-water mark of spring tides, the former especially

on sandy, the latter on stonier beaches; they are usually abundant under decaying seaweeds and other rubbish washed up by the tide. Upon this they feed and thus act as scavengers. The sea-slater (*Ligia oceanica*) is another frequenter of this part of the shore, but only when there are rocks and crevices within which it may hide. Resembling a giant wood-louse in appearance but often reaching over an inch in length, it is a typical isopod, being depressed or dorso-ventrally flattened in contrast to the amphipods which are flattened from side to side.

Perhaps the best known of all shore crustaceans is the green shore-crab (*Carcinus maenas*). Individuals of all

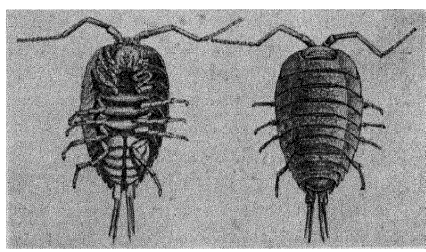


FIG. 17.—THE SEA-SLATER (*LIGIA OCEANICA*), VENTRAL AND DORSAL VIEWS. (× ABOUT ¾.)

sizes may be found from minute creatures less than a quarter of an inch in diameter to full-grown forms quite four inches across. These crabs are abundant everywhere in shallow water and especially where the water is contaminated with organic matter, as in harbours and estuaries. They do not appear to object to brackish water, and their feeding habits rightly give them first place amongst the scavengers of the shore. Being but little wider than they are long and narrowing somewhat posteriorly, they are very different in shape from the reddish edible-crab of fishmongers (*Cancer pagurus*). Only small specimens of this latter are found between tide marks; they are never as fierce either in appearance or in habits as their green relatives, nearly always

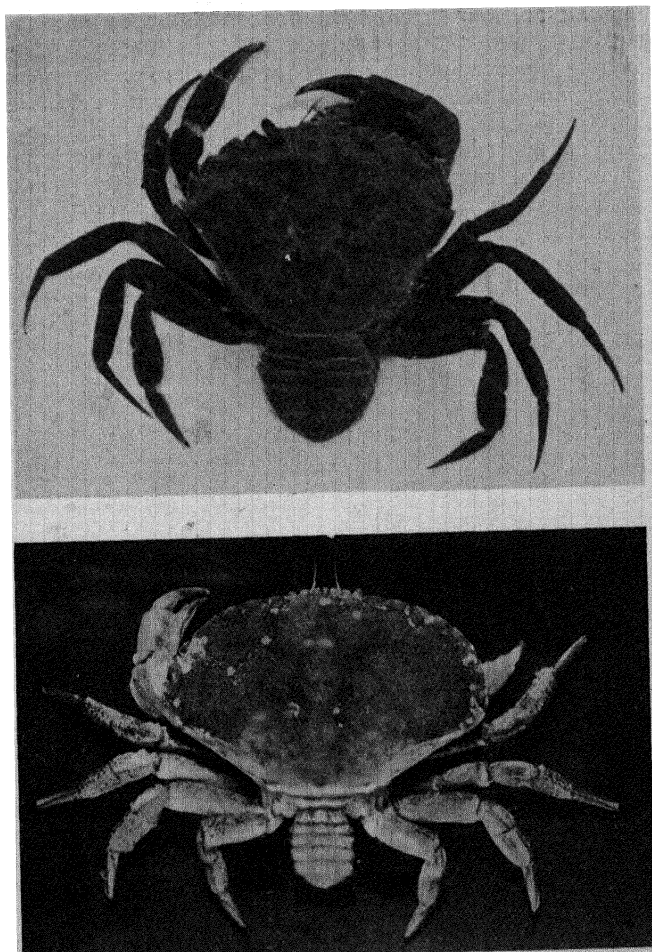


FIG. 18.—CRABS.

Above, green shore-crab (*Carcinus maenas*); below, edible crab (*Cancer pagurus*). (Both specimens have abdomen pulled out from its natural position, while the edible crab has a regenerated right cheliped.)

tucking up their legs and claws when disturbed instead of holding them out aggressively at right angles to their body. On account of its wedge-like shape a shore-crab (*Carcinus*) is able to squeeze into very narrow crannies. It is also able, with the help of its flattened hindmost pair of legs, which with the fringe of long bristles round their distal segments form weak paddles, to "sink"

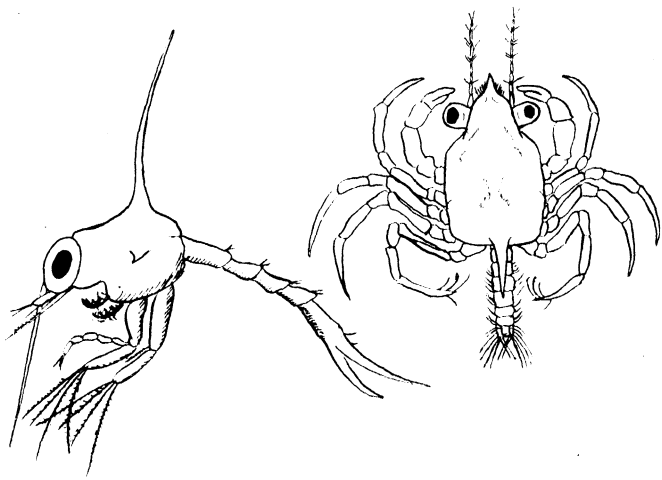


FIG. 19.—LARVAL STAGES OF CRAB (*CANCER*). (AFTER M. LEBOUR.)
a, first zoea stage (× about 22); *b*, megalopa from last zoea (× about 8).
(It is seen from the magnifications that *b* is really nearly three times as large as *a*.)

backwards into sand remarkably quickly at the approach of danger, there to remain with very little more than its eyes, antennae and mouth uncovered. Its colour varies partly with size, partly with situation. Very small specimens, found among shingle and under and amongst stones on sand, are either densely spotted grey and brown, or blotched with light spots, some of which have a pearly lustre. Larger specimens vary from pale to very dark

olive-green, while mature individuals in deep water are ochreous with reddish decorations. Thus at each stage protective coloration is exhibited. The body-proper is relatively small, the greater part of the sides being respiratory chambers in which the gills are sheltered. As in most crabs, males are easily distinguishable from females, because their abdomens are narrower and devoid of all but the genital appendages, whereas the broader abdomens of the females bear well-developed swimmerets to which the fertilized ova are attached. Here they are retained, not only well protected but continually waved to and fro by the movements of the swimmerets and thus bathed by an ever-changing current of oxygen-containing water. From them free-swimming larvae, known as zoeae, hatch out, which after a short period in the surface waters gradually metamorphose into adult crabs.



FIG. 20.—ON THE LEFT THE COMMON SHRIMP (*CRANGON VULGARIS*), ON THE RIGHT THE COMMON PRAWN (*LEANDER SERRATUS*). (× ABOUT ½.)

Pools left by the tide receding from a sandy shore often contain shrimps. In many cases this title is used to include two related but really very strikingly different crustaceans, true shrimps (*Crangon vulgaris*) and "cup shrimps" which are young prawns (*Leander serratus* and *L. squilla*). When shrimps are at rest on a sandy bottom they are very difficult to see on account of their colour pattern so exactly resembling the mottled background; when alarmed, they bury themselves in the sand with the aid of their shovel-like second antennae. Prawns possess neither of these adaptations, since, strictly speaking, they are deeper-water forms, but often they are so transparent that they are almost invisible, whilst they

are also able to alter their coloration to match the background. Perhaps the easiest way to distinguish prawns from shrimps is to examine their heads: in the former the dorsal shield or carapace is drawn out into a long serrated beak or rostrum, while in the latter this process is very short. Like lobsters both these animals change colour when boiled, prawns assuming a bright pink colour and shrimps a pinkish-brown.

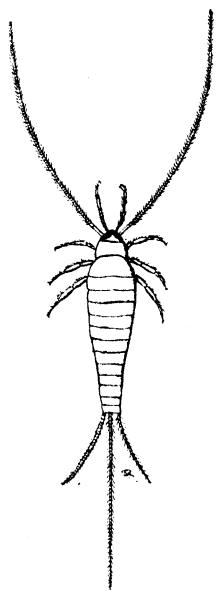


FIG. 21.—SEASHORE BRISTLE-TAIL (*PETROBIUS (MACHILIS) MARINUS*) (× ABOUT 6.)

Insects, various species of flies and beetles especially, abound on the higher regions of the shore where the debris washed up by the tide provides an ample food-supply. On stony and rocky shores, frequently in the same retreats as are occupied by the sea-slater (see p. 28), the common bristle-tail (*Petrobius* (*Machilis*) *marinus*) is often the outstanding insect. This is especially so during summer when it is remarkably active both in running and jumping and may be present in enormous numbers.

Sea-anemones, such as the beadlet (*Actinia equina*), attached to rocks or stones, the opelet or snake-locks (*Anemonia sulcata*) to stones embedded in mud, to sea-grass (*Zostera*) and to seaweeds, and the daisy (*Cereus pedunculatus* = *Sagartia bellis*) to stones and shells embedded in mud, are common on nearly all shores throughout the lower half of the inter-tidal regions; many species are abundant in rock-pools (see figs. 22 and 23). They are coelenterate animals whose general structure resembles that of *Hydra*, but is rather more complex; they are closely related to the corals. The apparent florets are contractile tentacles armed with cnidoblast cells. In many cases the stinging threads or nematocysts dis-

charged by these are remarkably strong; this can be realized if a finger be thrust among the tentacles of an opelet. The tiny barbs will then be felt sticking to the skin and the whole animal may sometimes be lifted right up, so powerfully do they hold. By means of the tentacles food, including prawns and small fish, is seized and conveyed to the expansile mouth. When disturbed or left exposed by the receding tide the whole body contracts and most anemones withdraw their tentacles completely. In the fully contracted condition

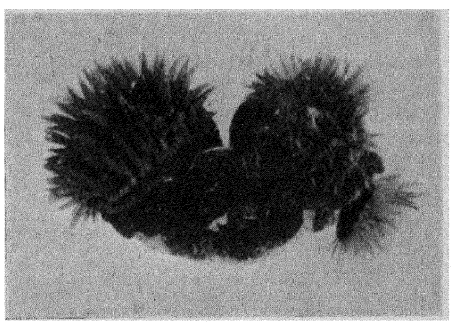


FIG. 22.—BEADLET ANEMONES (*ACTINIA EQUINA*).

(Note the beadlets at the bases of the tentacles of the anemone on the left.)

some of them, the beadlet, for example, have the appearance of little masses of tough jelly of various hues. In these there is no attempt at concealment, but some, such as the dahlia (*Tealia felina*), cover themselves with particles of shingle and other material.

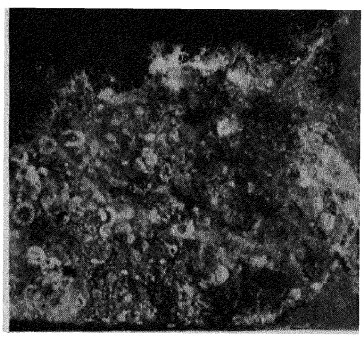
Some sponges, especially small specimens of the bread-crumb sponge *Halichondria panicea*), which is so common on many rocks, may at first sight be mistaken for contracted anemones (see fig. 24). Close examination, however, establishes the fact that their walls are not smooth, as in the beadlet, but rough and perforated by countless minute pores. Currents of water continually pass inwards

a, two opelet or snake-lock anemones (*Anemonia sulcata*) attached to a rock; the one on the left is just about to release its hold. The rest of the rock is covered by encrusting sponges and on the left the small openings of the chalky tubes of the keeled tube worm (*Pomatoceros triqueter*) may also be seen.

b, stone with various small anemones (mostly *Sagartia* spp.), sea-firs (hydroid coelenterates), sea-mats (polyzoans), sponges, barnacles and worm-tubes.

c, stone with daisy anemones, jewel anemones (*Corynactis viridis*) whose tentacles are each tipped with a tiny globule, worm-tubes, sponges, mussels and a small queen scallop (*Aequipecten opercularis*) on the left.





b



FIG. 23.—SEA-ANEMONES.

through the pores, to be eventually discharged through large openings called oscula. These currents carry in both dissolved oxygen and minute food-particles, the latter of which are ingested by peculiar flagellated collar-cells; such cells are found only in sponges and one group of flagellated protozoans.

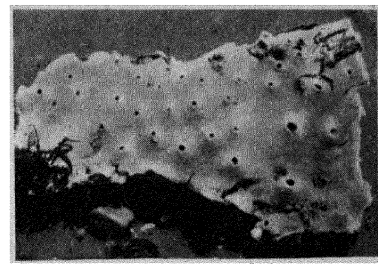
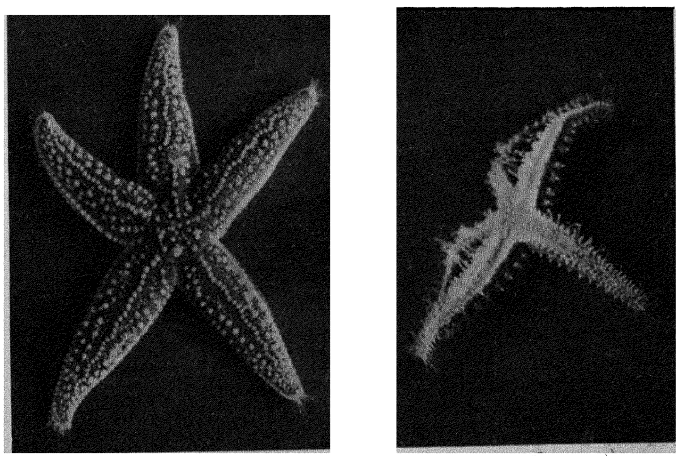


FIG. 24. — BREAD-CRUMB SPONGE (*HALICHONDRIA PANICEA*) SHOWING OSCULA.

Various kinds of echinoderms frequent the lower regions of rocks and the under-surface of boulders, small specimens of the common starfish (*Asterias rubens*)



a *b*

FIG. 25. — ON THE LEFT, THE COMMON STARFISH (*ASTERIAS RUBENS*), UPPER OR ABORAL SURFACE; ON THE RIGHT, THE SPINY STARFISH (*ASTERIAS GLACIALIS*) IN THE ACT OF TURNING OVER FROM ORAL TO ABORAL SURFACE.

Note in both the tube-feet, chalky plates and spines.

being perhaps the most abundant. These are typical members of their phylum, exhibiting characteristic structures and movements. Along the under-surface of each muscular ray or arm is an ambulacral groove, so-called because it contains a large number of extensible tube-feet. Each of these is an ultimate branch of a system of water-containing tubes, and ends in a small circular disc. Extension of the tube-feet is brought about when water is passed into them from the main vessels, and, by means of the terminal discs, a very strong grip of any solid body can be obtained. Since both the arms and the tube-feet contain muscle fibres, the two together enable the animals to perform complex locomotor and other movements. Starfish are all armed with strong spines, but they do not sting, as is often popularly imagined. They feed on molluscs, engulfing gastropods entire with their eversible stomachs, pulling apart the valves of lamellibranchs by means of their tube-feet and arms and sucking out their unfortunate makers. To many people starfish are known only from sandy beaches. But little observation is required to show that they do not belong there, but have really been washed ashore through the effects of storms from deeper water.

Worms, segmented and unsegmented, are to be found in great numbers all over the shore. Species of ragworms, belonging to the genus *Nereis* and popularly known as red-rags, live amongst rocks, boulders and stones, others, including *Nephthys*, the so-called white-cat, are burrowers and therefore show degeneration of some of their organs. These form a link with lugworms (*Arenicola marina*) which spend practically the whole of their lives burrowing in muddy-sand. The latter are so completely adapted to such an existence that they feed in the same way as do earthworms, passing through their alimentary canals the material in which they are burrowing. Parapodia and chaetae are all but absent, and respiration is helped by tufts of simple tubular gills borne by some of the segments; these are able to take advantage of the relatively small amount of oxygen available. Many of the burrowing worms form definite tubes in which they live,

Those of the sand-mason worm (*Lanice conchilega*), which are built from particles of sand and broken shells plastered together with mucus, stick up above the surface for an

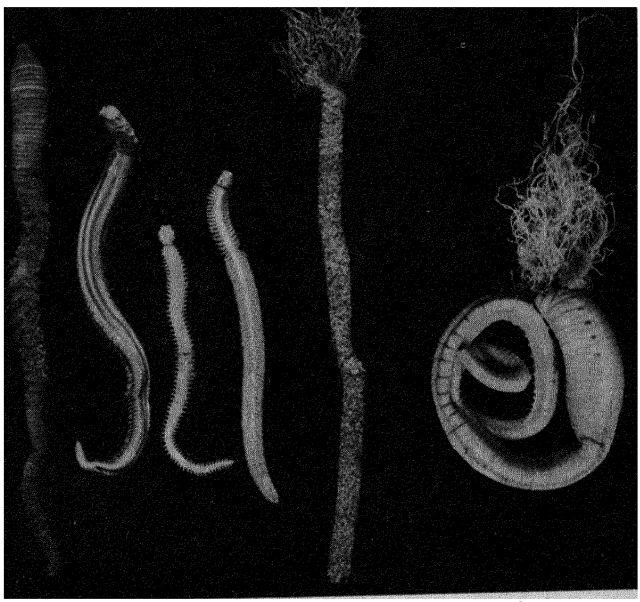


FIG. 26.—MARINE WORMS (ANNELIDS).

a, common lugworm (*Arenicola marina*); white-cat (*Nephthys*); *c*, common ragworm (*Nereis*); *d*, sexual form of ragworm (heteronereid form) in which the posterior part of the animal is modified for swimming and contains ripe sex cells; *e*, tube of the sand-mason worm (*Lanice conchilega*); *f*, *Amphitrite*, a terebellid worm allied to *Lanice* and found in muddy sand at low-water mark. (× ⅓.)

inch or more; they are often very noticeable on sandy shores. The worms quit their tubes and sink down deeper into the sand when disturbed; only rapid digging will reward the collector with anything but an

empty tube. Serpulid worms abound on many shores: the white chalky tubes of *Pomatoceros triqueter*, the keeled-tube worm, for example, are common on many stones about low-water mark. The actual worms, which are very beautifully coloured creatures about an inch or an inch and a half in length, are able to close the mouth of their tube with a "stopper" or operculum somewhat the same as do periwinkles and so prevent desiccation should they be uncovered. Coiled tubes of still smaller worms are numerous on many seaweeds, especially on fucoids (see fig. 9, p. 18). They are often mistaken for tiny sea-snails, but when they are quietly watched under water the delicately branched gills and the "stopper" which are protruded clearly reveal the nature of the tube-maker. From the shape of the tube these worms are named *Spirorbis*.

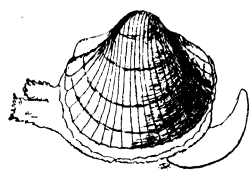


FIG. 27.—COMMON COCKLE (*CARDIUM EDULE*) WITH SIPHONS AND FOOT EXTENDED. (× ABOUT ⅔.)

Burrowers in sand and mud include many bivalves. Some of these, such as the common cockle (*Cardium edule*) and the carpet shells (*Paphia* (*Tapes*) *pullastra* and *P. decussata*), whose siphons are short, inhabit the upper layers, spending most of the low-water period, when they are liable to exposure, with their valves tightly shut. Their large muscular and protrusible foot, shaped more or less like a ploughshare, enables them to furrow their way through the sand, and by suddenly straightening this organ a cockle is able to leap a considerable distance. The so-called razor-shells or spout-fish (*Ensis* (*Solen*) *siliqua* and *E. ensis*) live at a deeper level and are definitely modified in correlation with their habits. Their shells are long and narrow, their feet strong muscular organs by means of which they are able to burrow rapidly and to hold firmly to the walls of their burrows. The latter are open at the top, a small funnel-like depression in the sand revealing their presence, so that, though their siphons are very short, they are able to obtain fresh supplies of

water without coming to the surface. Other more normally shaped forms, gapers (*Mya*), for example, have extremely long extensile siphons which can reach the surface, often several inches above the rest of the animal. Their openings are often hidden by tufts of algae.

Several kinds of fish, such as gobies (*Gobius*), suckers (*Lepadogaster*) and blennies (*Blennius*), find their homes among stones and boulders on the shore (see fig. 29.) They

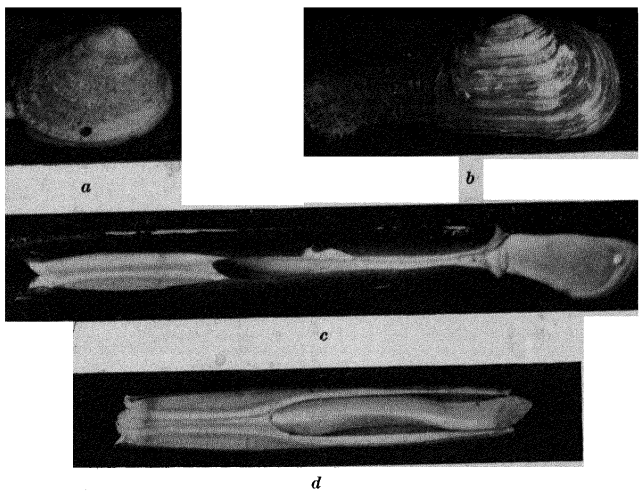


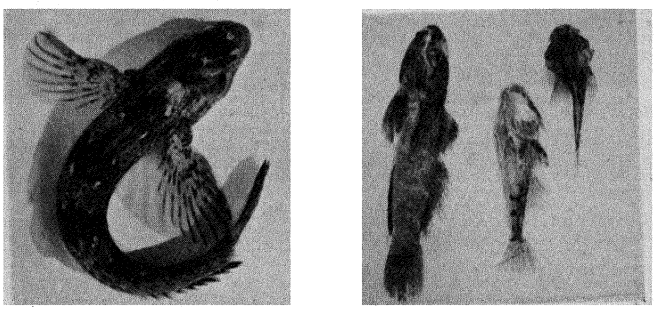
FIG. 28.—SOME BIVALVE MOLLUSCS WHICH BURROW IN SAND (× ABOUT ⅔.)

a, a carpet (*Paphia* (*Tapes*) *pullastra*) ; *b*, a gaper (*Mya truncata*) ; *c* and *d*, two views of a razor-shell or spout-fish (*Ensis siliqua*).

are all relatively feeble swimmers and are able to scramble over or wriggle among stones. Gobies, and especially suckers, have modified fins which enable them to attach themselves to solid objects. All of them have the power of changing colour very considerably according to their surroundings. Sand-eels (*Ammodytes*) are often extremely abundant in shallow water along sandy shores. Where they are present they form much of the food of sea-gulls,

as well as of other fish. Their lower jaws can be used as scoops or shovels, so that when alarmed or left behind by the receding tide they can rapidly burrow into loose sand.

Very many birds are found along our coast-line. Some, like the rock-pipit, do not show any special adaptations for this particular habitat, but the majority are either waders or swimmers. The legs and toes of the former are long, thus enabling them to walk in shallow water and over soft sand and mud. Those of the latter, how-



a *b* *c* *d*

FIG. 29.—SEASHORE FISHES.

a, common blenny (*Blennius pholis*); *b*, a goby (*Gobius*), in slightly ventral view showing the characteristic sucking disc formed by the union of the two pelvic fins; *c* and *d*, a bullhead (*Cottus*) in ventral and in dorsal view, the latter showing the characteristic shape of the head and the spines.

ever, are usually short and set far back, while the toes are webbed. Of the waders there is none more familiar than the ringed plover, which, though not necessarily remaining in the same locality all the year, is present around our coasts during both summer and winter. Its plumage renders it difficult to see on a pebbly beach, though it is very conspicuous on mud or grass. Its beak is not as long as that of most waders, but it is strong enough to enable it to feed on small crustaceans, worms and molluscs. The oyster-catcher is an example

of a typical wader. It digs its long and stout orange-coloured beak into the sand and in some way extracts worms, crabs and other crustaceans, cockles and carpets; in the case of the last two it catches its victims before

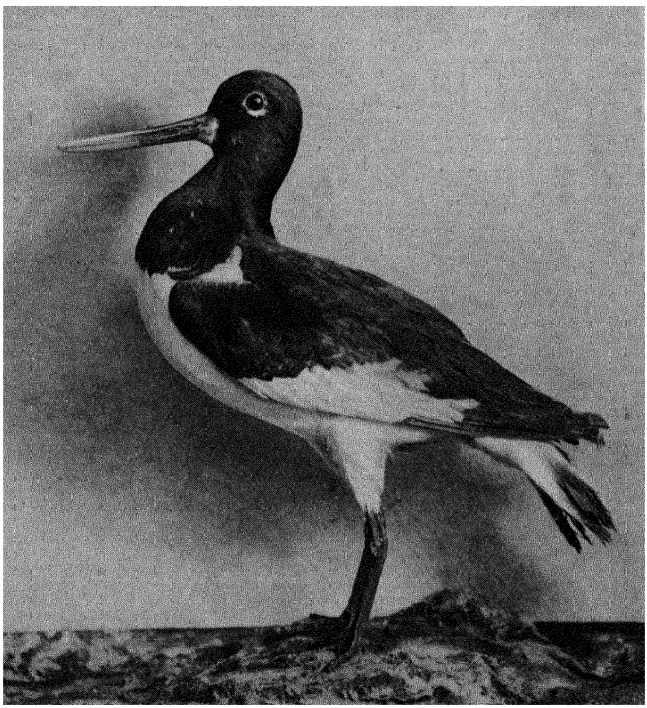
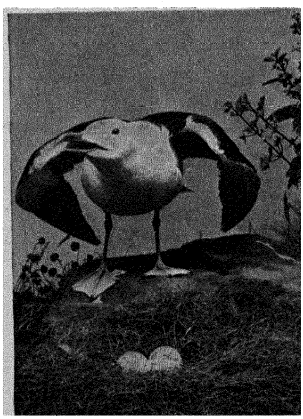


FIG. 30.—OYSTER-CATCHER. (× ABOUT ⅓.)
Note the long powerful bill and the long toes.

they are able to close their valves. With equally rapid blows it can dislodge unsuspecting limpets. Hence it is able to obtain satisfying meals from very different types of shore. Turnstones, as their name implies, feed

rather differently, foraging among pebbles or on sandy beaches among the washed-up weed.

The swimmers include terns, gulls, guillemots, and cormorants. Their beaks are generally broad, strong, and often slightly hooked, and are therefore well adapted to catching fish. Cormorants and gulls construct quite considerable nests of sticks, seaweed and grass. Most marine birds, however, do not make real nests but lay their eggs in slight hollows in the ground amongst stones, in clefts in high rocks, or on the surface of high rocky ledges. Terns and oyster-catchers are examples of the first, razorbills of the second, guillemots of the third. During the breeding season the last-named congregate in vast numbers, and each lays its single large egg on a rocky ledge without any attempt at a nest. It is often said that its shape prevents the egg from being dislodged. It is quite true that when touched or exposed to the wind it spins round and round instead of rolling about, but many observers believe that the efficiency of this adaptation has been considerably exaggerated. Nearly all sea-birds' eggs are coloured to match their surroundings, while the newly-hatched young are usually well advanced and in most cases covered with a mottled down which renders them all but invisible against most backgrounds. Even the first plumage of many of them, gulls for example, shows this protective mottling.



[*Birmingham Museum.*

FIG. 31.—GREAT BLACK-BACKED GULL. (× ABOUT $\frac{1}{16}$.) Note the webbed feet and hooked beak.

Vegetation of Other Marine Habitats.—In order to thrive either on or close to the seashore, flowering plants

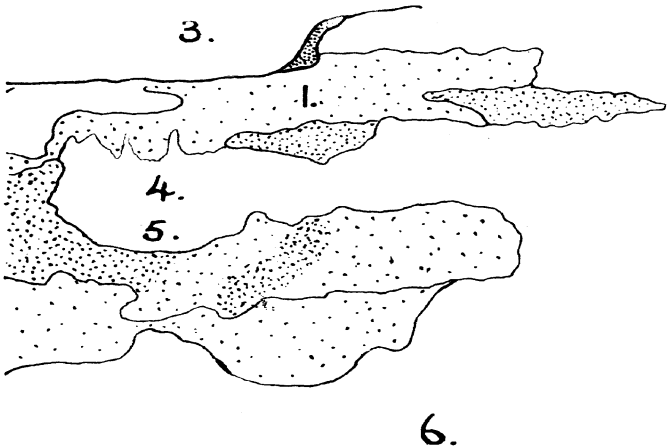
must be able to withstand a number of adverse conditions, such as lack of water, an excessive amount of salt in the water, exposure to keen wind and strong sunlight. In other words, only xerophytes can flourish and, because both air and water are heavily charged with salt, such xerophytes are known as halophytes.

Salt-marshes which are flooded periodically by seawater often support dwarf wracks and other algae in addition to characteristic flowering plants, such as sea-aster (*Aster tripolium*), sea-lavender (*Statice limonium*), glasswort (*Salicornia herbacea*), seablite (*Suaeda maritima*), seaside spurry (*Spergularia salina*), sea-purslane (*Atriplex portulacoides*), sea-rush (*Juncus maritimus*), sea-arrowgrass (*Triglochin maritimum*), sea-milkwort (*Glaux maritima*), sea-beet (*Beta maritima*), and scurvy-grasses (*Cochlearia officinalis*, *C. danica* and *C. anglica*). (See photograph and plan of key of typical salt-marsh vegetation on pages 44 and 45.)

Most of the typical plants of **rocks, pebble** and **shingle beaches** have long penetrating roots, especially those which, like samphire (*Crithmum maritimum*), sea-pink or thrift (*Armeria maritima*), seaside and buckshorn plantains (*Plantago maritima* and *P. coronopus*, respectively) and sea-spurry (*Spergularia rupestris*), are able to flourish on rocks by growing down between very narrow chinks. Common dock (*Rumex crispus*), too, sometimes obtains a footing here, though it is more often found among pebbles and shingle together with scurvy-grass (*Cochlearia anglica*), oraches (*Atriplex hastata* and other species), yellow horned-poppy (*Glaucium luteum*), sea-campion (*Silene maritima*), scentless mayweed (*Matricaria inodora*) and other plants with shallower and more spreading roots. In all of them, except the dock, the leaves are succulent; in most they are also long and needle-shaped. Those of scurvy-grass, orache, horned-poppy and sea-campion which are flat, are either extremely succulent and smooth or covered with a "mealy" coating of wax.

Photo supplied by The British Mosquito Control Institute.] [*See plan of key on page opposite.*

FIG. 32.—TYPICAL SALT-MARSH VEGETATION, HAYLING ISLAND, HANTS (AUGUST).





1, Mud on which the dominant alga is *Vaucheria* sp., while there are also circular patches of *Enteromorpha* and *Chaetomorpha*; 2, sea-aster (*Aster tripolium*); 3, sea-sedge (*Scirpus maritimus*); 4, cordgrass (*Spartina*—see p. 14); 5, sea-meadow-grass (*Poa maritima*); 6, glasswort (*Salicornia herbacea*); 7, region of *Poa maritima* with seablite (*Sueda maritima*), sea-arrowgrass (*Triglochin maritimum*), sea-purslane (*Atriplex portulacoides*), and sea-plantain (*Plantago maritima*).

Plan of Key to Fig. 32 opposite.

Sandy shores furnish typical desert features, namely, an unstable soil which is liable to be blown about and to cover vegetation, a water-supply which is deep down below the surface if present at all, and full exposure to wind and sun and to reflected heat. Nearest the sea the sand may be more or less consolidated and subject to periodic flooding. It is therefore able to support halophytes, such as saltwort (*Salsola kali*), oraches (*Atriplex patula* and other species), goosefoots (*Chenopodium rubrum*



FIG. 33.—DUNES FORMED AS THE RESULT OF COLONIZATION BY GRASSES, SUCH AS A MARRAM (*PSAMMA ARENARIA*), WHICH ACT AS "WIND-SCREENS." (ST. ANNE'S, LANCS.)

and *C. album*), sea-rocket (*Cakile maritima*) and perennial sea-purslane (*Arenaria peploides*). Where the sand is loose, sea couch-grass (*Agropyrum, junceum*) and sea-sedge (*Carex arenaria*), both with creeping rhizomes, may grow and hold up the sand. These may be colonized by marram-grass (*Psamma arenaria*), which is much more robust and by binding the sand is responsible for the formation of typical **dunes** (see fig. 33.) On these the vegetation includes in addition to sea-purslane, sea-rocket, oraches and xerophytic forms of many inland plants, such as lady's-fingers (*Anthyllus vulneraria*),

bird's-foot trefoil (*Lotus corniculatus*), rest-harrow (*Ononis arvensis*) and various thistles, also lyme-grass (*Elymus arenarius*), sea-convolvulus (*Convolvulus soldanella*), horned-poppy, sea-holly (*Eryngium maritimum*), sea-spurge (*Euphorbia paralias*) and other species. Horned-poppy and sea-holly differ from the others in having broad leaves, whose transpiration is reduced to a minimum by means of a covering of wax which causes them to appear bluish in colour. All these are halophytes because they are able to thrive under conditions whose outstanding feature is excess of salt.

CHAPTER III

FRESHWATER ASSOCIATIONS

Streams, ponds and **marshes** are all characterized by the same main feature, a preponderance of fresh water. Because of this the associations have a number of features in common. Their plants are either typical hydrophytes (see p. 4) or are able to withstand very moist conditions. Their animals show modifications, particularly in connexion with respiration and locomotion. The conditions prevailing in streams (including rivers), ponds (including lakes), marshes and their boundaries form graded series between swiftly flowing water and dry land on the one hand, and between deep water under considerable pressure and free air on the other. The adaptations developed by their inhabitants are therefore extremely diverse.

Flora.—In large bodies of water, unless the depth is very moderate and more or less uniform, distinct zoning occurs. A great variety of less prominent forms, however, including many filamentous algae such as *Spirogyra*, is often intermixed with the dominant. Thus, from the edge towards the deeper regions the following plants may be found succeeding each other :—floating persicaria (*Polygonum amphibium*) and floating meadow-grass (*Glyceria fluitans*) with narrow leaves ; water-plantain (*Alisma plantago*) and arrowhead (*Sagittaria sagittifolia*) with aerial lanceolate and arrow-shaped leaves respectively, both borne on long petioles which rise from bulbous rhizomes rooted in the mud and sand ; water-crowfoots (*Ranunculus aquatalis* and varieties) with finely divided submerged and flat, roundish floating leaves ; white and

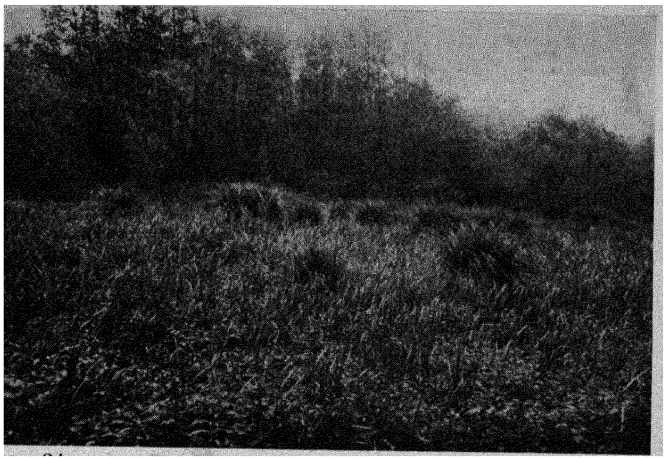


FIG. 34.—TYPICAL MARSH VEGETATION IN JUNE (WEY VALLEY, NEAR GODALMING, SURREY.)

In the foreground reeds, sedges, irises and meadow-sweet are dominant; behind alders are in the centre and willows at each side.



FIG. 35.—THE VEGETATION OF A SHALLOW POND IN JUNE. (NEAR ELSTEAD, SURREY.)

Arising out of the water in the foreground are the long leaves of water-plantain (*Alisma plantago*); behind these the tall inflorescences of great reedmace ("bulrush") (*Typha latifolia*) can be seen; further back still there are masses of common rush (*Juncus*

yellow water-lilies (*Castalia* (*Nymphaea*) *alba* and *Nymphaea* (*Nuphar*) *lutea*, respectively) with large floating leaves on long tubular petioles rooted by strong rhizomes ; pond-weed (*Potamogeton*), of which there are many species and varieties, and water-milfoil (various species of *Myriophyllum*) with very fine leaves ; Canadian water-weed (*Elodea canadensis*) sometimes loosely rooted but usually free ; and stoneworts (large green algae belonging to the genera *Nitella* and *Chara*). Floating species include duckweeds (*Lemna*), frogbit (*Hydrocharis morsusranae*), hornwort (*Ceratophyllum demersum*) and bladderwort (*Utricularia*). Of these, the first two have flat leaves which float on the surface, while duckweeds have tufts of hanging roots which probably serve merely to help them float the right way up. Hornwort and bladderwort are both totally submerged and their leaves are finely divided. Some of the leaflets of bladderwort (see fig. 56, p. 78) are in the form of little chambers or bladders which trap and digest " water-fleas ".

The most frequent plants along the banks of streams and ponds and in marshy places generally include alder

FIG. 36.—GRASSES, RUSHES AND SEDGES.

a, Wall-barley (*Hordeum murinum*), a grass belonging to the Gramineae ; *b*, a rush (*Juncus*) ; *c*, a wood-rush (*Luzula*), belonging like *b* to Juncaceae ; *d*, a sedge (*Carex*) ; *e*, cotton-grass (*Eriophorum*), also belonging to the sedge family (*Cyperaceae*) ; *f*, true bulrush (*Scirpus*), another member of the Cyperaceae.

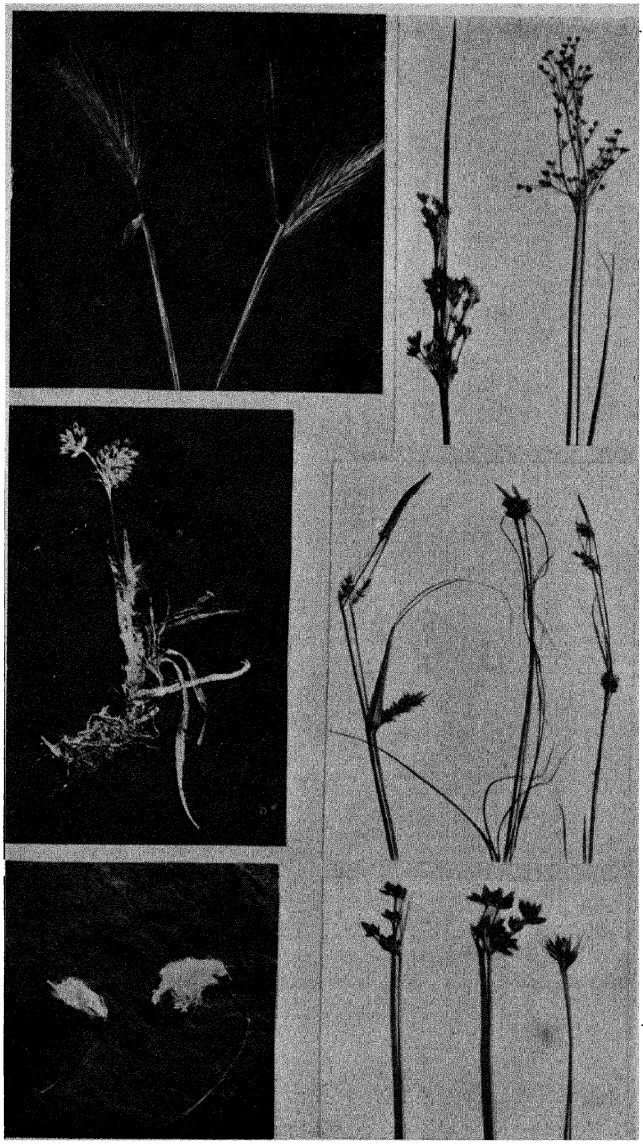
Some characters of these families :

Gramineae.—Stem cylindrical, hollow and jointed ; leaves alternate, flat with split sheaths ; inflorescence a spikelet of one or more florets, each enclosed by one pair of glumes.

Juncaceae.—In *Juncus* the leaves are hollow and cylindrical, at least at their tips, very rarely flat ; in *Luzula* (the only other genus) they are flat and hairy ; florets in terminal or (apparently) lateral clusters or panicles.

Cyperaceae.—Stem almost solid, usually triangular ; very slender leaves with entire sheaths ; inflorescence of spikelets, each in axil of single glume. In *Eriophorum* the bristles of the ripe fruit are very long.

(Some characters of the Typhaceae, the reedmace family, are given on p. 52., fig. 37.)


a
b
c
d
e
f

(*Alnus glutinosa*), willows (*Salix* of various species and varieties), great reedmace (*Typha latifolia*), often, but erroneously, called bulrush, rushes (*Juncus*) with their smooth cylindrical stems, sedges (*Carex*) with their solid, often triangular stems, grasses, such as reed canary-grass (*Phalaris arundinacea*), yellow iris or flag (*Iris pseudacorus*), great bur-reed (*Sparganium ramosum*), marsh-marigold (*Caltha palustris*), mint (*Mentha aquatica*), loose-strife (*Lythrum salicaria*), true forget-me-not (*Myosotis palustris*), marsh-penny-wort (*Hydrocotyle vulgaris*), ragged-robin (*Lychnis flos-cuculi*), lady's-smock or cuckoo-flower (*Cardamine pratense*) and meadow-sweet (*Ulmaria campestris*), their distribution from wet to less wet situations being roughly in the order in which they are mentioned. Some species, of which floating meadow-grass and water-crowfoot are excellent examples, may be found in all situations, from very swiftly flowing water to almost dry mud. So very different are they under the two extremes, that many botanists consider some of the forms of *R. aquatilis* to be distinct species. In swiftly running water the leaves of floating meadow-grass and the leaflets of crowfoot are very long and narrow, while on mud both are short, crowfoot often developing only flat "floating" leaves which are absent in the other situation (compare fig. 38). In addition, many of the other species mentioned above are not wholly confined to streams, ponds or marshes. Some of them occur in meadows and pastures where the

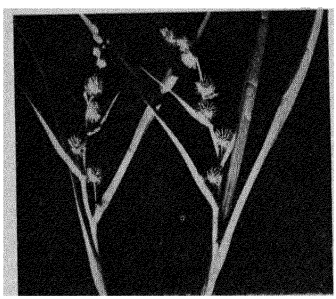


FIG. 37.—BUR-REED (*SPARGANIUM*).

Sparganium and *Typha* are the only two members of the Typhaceae. In both genera the leaves are flat, rigid and with sheathing bases; in *Sparganium* the stems are branched or slender and the flowers are in globular heads; in *Typha* the stems are stiff and reed-like and the flowers are in cylindrical spikes.

drainage is not as good as it might be ; some of them occur also on moorlands and in bogs, the transition between these and marshes being a gradual one. Typical bogs, however, differ from marshes (see p. 76) : their water is derived either from rain or from regions poor in soluble salts and

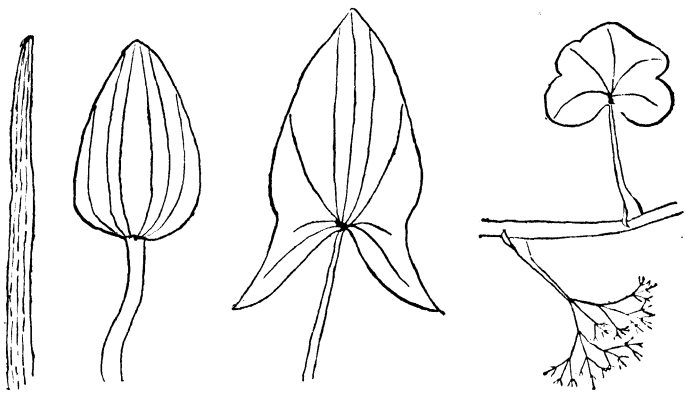


FIG. 38.

Left : three leaves of arrowhead (*Sagittaria sagittifolia*) ; left, portion of submerged leaf ; middle, a floating leaf ; right, an aerial leaf. Right : two leaves of water-crowfoot (*Ranunculus aquatilis*) ; above, a floating leaf ; below, a submerged leaf.

lies " stagnant " over thick masses of decomposing vegetation, being often deep brown in colour from dissolved peat. It is therefore distinctly acid in reaction (see appendix B, pp. 167–170), and the habitat is physiologically dry. Typical bog plants, then, are xerophytes of particular kinds.

Fauna.—Ponds and lakes contain a more varied fauna than do streams and rivers proper. This is because only actively swimming species or those which can secure themselves to some stationary object, such as a stone or rock, can hold their own against currents.

The tension between the water and the air above it, which produces the phenomenon known as the surface-film, constitutes an extremely important factor in the

life of many aquatic animals, insects in particular. In both ponds and lakes, along the sides of rivers and streams and in quiet reaches and pools where the current is reduced, many species hang downwards from the surface-film, whilst others glide about upon the upper surface entirely in the air. Occasionally, some forms may be seen gliding along the under surface, small grey or blackish flatworms, resembling simple leaves in general shape, being familiar examples. These are planarians, free-living relatives of the parasitic liverflukes and tapeworms. Their usual habitats, however, are the under surface of stones and aquatic plants. The freshwater coelenterate *Hydra* may also sometimes use the surface-film, leaving its stone or leaf and hanging downwards from its basal disc. The green *Hydra viridis* may be carried to the surface buoyed up by a little bubble of oxygen liberated during photosynthesis by the *Zoochlorella* cells to which the animal owes its colour.

A large number of insects and insect larvae and pupae obtain their supplies of oxygen through the surface-film. In most of them there is free communication between one or more spiracles and the air, while the rest of the body hangs submerged. Mosquito larvae and pupae form some of the best-known examples. The eggs are deposited on the surface of still or relatively still water, those of most species singly, but in the case of the common *Culex pipiens* in batches of 200–300 which form floating egg-rafts. The larvae, often known as " wrigglers ", hang head downwards when undisturbed, taking in air through two spiracles situated at the apex of the respiratory siphon. At the same time they are catching small organisms by means of the feeding-brushes which fringe the mouth. The pupa, though it does not feed, is nevertheless active, and its air-trumpets also pierce the surface-film. When disturbed both larvae and pupae close their spiracles by means of valves and wriggle down into the water. Just before the imago emerges gas is secreted into the pupal covering, the dorsal part of which then protrudes through the surface of the water so that emergence is into the air.

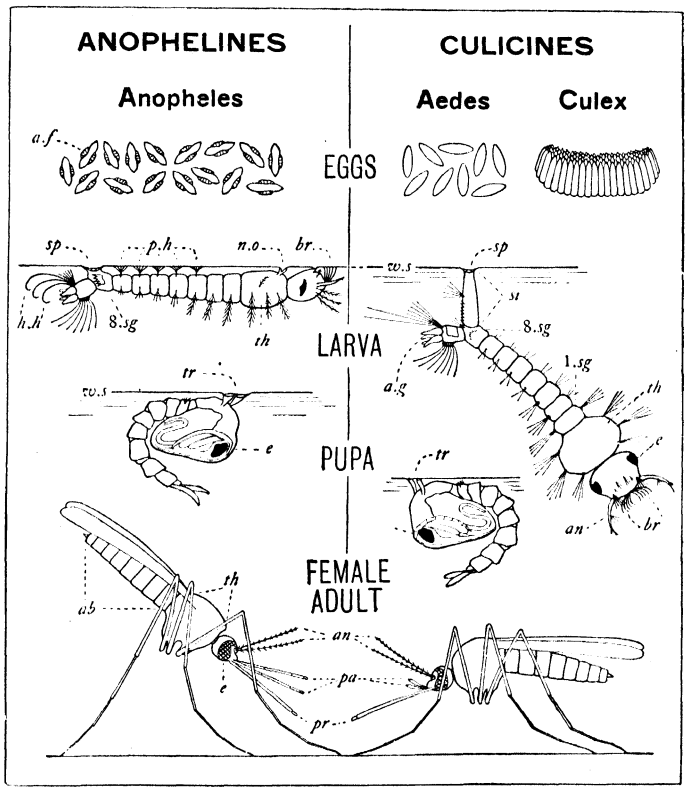


FIG. 39.—CHIEF DISTINGUISHING FEATURES OF ANOPHELINE AND CULICINE MOSQUITOES. (AFTER MARSHALL.)

ab, abdomen; *a.f*, air-floats; *a.g*, apical plates or anal gills; *an*, antenna; *br*, "feeding brushes"; *e*, eye; *h.h*, hooked hairs; *n.o.*, notched organ; *pa*, maxillary palp; *p.h*, palmate hairs; *pr*, proboscis; 1.*sg*, 1st abdominal segment; 8.*sg*, 8th abdominal segment; *si*, respiratory siphon; *sp*, spiracles; *th*, thorax; *tr*, respiratory trumpets; *w.s*, water surface.

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Many midges, which at first sight resemble mosquitoes though they never feed on blood, also breed in ponds, ditches and streams. Sometimes, as in the case of most species of harlequin-flies (*Chironomus*), their larvae are very abundant and conspicuous. They are known as " blood-worms ", because of their bright red colour, due to haemoglobin, whose occurrence is rare in insects. Its presence here is possibly correlated with the fact that these larvae inhabit situations where the amount of oxygen is small. They live in tubes which they make of mud, sand or green slime on the bottom of a ditch or pond ; they often abound in drinking-troughs. Small oligochaete worms belonging to the genus *Tubifex* are so similar in colour and habitats to the *Chironomus* larvae that the two may, at first sight, be mistaken for each other. Unfortunately, the name " blood-worm " is often applied to both.

The most conspicuous of the segmented worms inhabiting ponds and streams are some of the Hirudinea or leeches. They are easily recognized by their two suckers, the anterior bordering the mouth, the posterior forming a disc-like attaching organ. These creatures swim with an undulating motion or travel over solid objects with a " looping " movement. During the latter, the body is alternately elongated and shortened and the anterior and posterior suckers are similarly attached and released. Leeches live by eating worms or by sucking blood from fish, frogs and other vertebrates through a triangular hole cut in the victim's skin by means of three semi-circular chitinous jaws. A single full meal may suffice for several months.

Not the least remarkable of the insect larvae living in fresh water are those of dragonflies. These, although sometimes called nymphs, are usually ugly, slow-moving creatures living in the mud at the bottom of ponds, their colour varying considerably with the surroundings. Most of them are exceedingly predaceous, stalking other animals and capturing them by means of a much modified labium. This, the so-called " mask ", is a jointed structure folded back below and behind the mouth, and

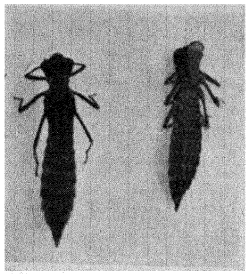


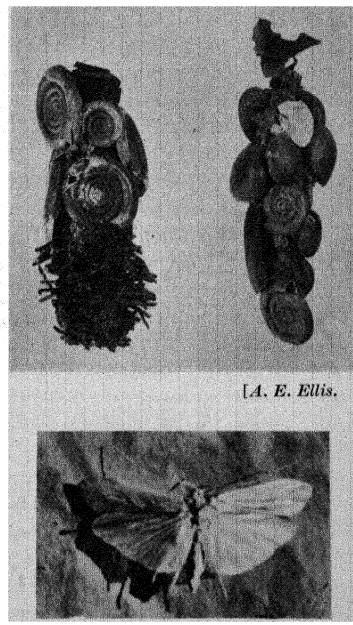
FIG. 40. — DRAGONFLY NYMPHS.

Dorsal view on left, ventral view showing "mask" on right. (× about ½.)

bearing distally a pair of curved pointed jaws. When prey has been approached to within "striking" distance the mask is suddenly extended so that it projects well beyond the head and the unsuspecting victim is grabbed by the jaws. Some of these larvae respire by means of leaf-like gills borne on the hinder end of the body and containing tracheae.

Others pump water into and out of the enlarged rectum in whose walls there are tracheae, but older larvae all have, in addition, functional thoracic spiracles and are able to use atmospheric oxygen when the fore-part of the body is raised out of the water just before metamorphosis. The ordinary method of locomotion is by means of the strong legs, but those forms which carry on rectal respiration can also propel themselves by discharging water forcibly from the anus.

Little cases composed of fine gravel, small



[*A. E. Ellis.*

FIG. 41. — CADDIS-FLIES.

Above, cases made by the larvae and found in freshwater streams; below, an adult caddis-fly.

stones, shells or fragments of vegetation are abundant in most of these habitats. They are made by caddis-worms, the larvae of the four-winged caddis-flies (see fig. 41). Each larva is a soft white grub, with a hard head, strong legs and usually a terminal pair of chitinous hooks by means of which it clings tightly to the tube lining the case. The latter is formed of silk, secreted through a spinneret below the mouth. Though many species walk about actively, dragging their cases with them, most of those which inhabit streams fasten them securely to the under surface of stones and rocks.

Other insects, notably some beetles and bugs, spend practically the whole of their lives in or upon water. Of the beetles, one of the most abundant is the little whirligig (*Gyrinus natator*) which may be seen flitting about on the surface of ponds and streams and the margins of rivers where the current is "dead", diving below and vanishing rapidly if disturbed. The silvery "streaks" which they cause are due to the large air-bubble which each of them carries between the end of the abdomen and the tips of the wing-covers. They are most plentiful during the autumn, many of them dying off at the approach of winter and the rest burying themselves in mud until the following summer. Though this beetle is only about one-third of an inch long (see fig. 42 *d*) a glance at it when it is out of the water is sufficient to show that it is admirably designed for an aquatic existence. Its general outline is oval, with the dorsal surface smoothly convex and the ventral flat. The second and third pairs of legs, the latter in particular, are wonderfully modified for swimming, being very much flattened and fringed with hairs. The various regions are so articulated that while their full surface is opposed to the water during back-strokes, they fold under each other and present only a narrow edge during the return. Respiration is effected by means of the air-bubble to which the conspicuousness of the swimming beetle is due and which is in contact with the spiracles. Its renewal is effected during the rapid protrusion of the tips of the abdomen and of the elytra through the surface of the water.

One of the largest of our aquatic insects is the water-beetle *Dytiscus** *marginalis*. It grows to a length of an inch and a half, and spends practically its whole time in water. Its contour closely resembles that of the whirligig, and its hind-legs are powerful swimming organs. The main air-supply is obtained in the same way, but is larger and stored between the elytra and a felt-like covering of hairs on the abdomen. In addition,

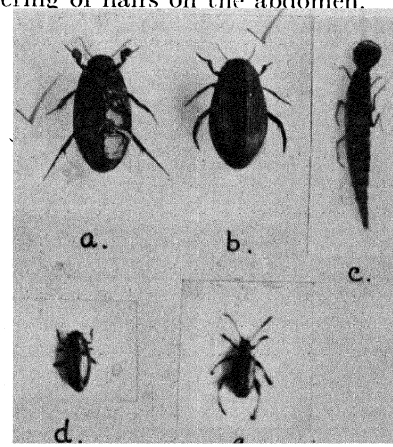


FIG. 42.—WATER-BEETLES.

a, ventral view of male *Dytiscus*; *b*, dorsal view of female *Dytiscus*; *c*, larva of *Dytiscus*; *d*, whirligig beetle (*Gyrinus*); *e*, leaf-eating beetle (*Donacia*). (*a–c* × about ½, *d* and *e* natural size.)

the posterior spiracles are very large and take in air directly when the beetle hangs undisturbed from the surface. The two sexes can be distinguished by an examination of the first pair of tarsi, the three basal joints in the male forming a disc of attachment, covered with extraordinary adhesive hairs. Eggs are laid singly in slits made in rushes or other water-plants and give rise to larvae which grow rapidly if the food-supply is good. These grubs are active and carnivorous like the adults.

* The older spelling, *Dyticus*, is really the correct one.

They have strong legs fringed with long hairs, and both these and the end of the abdomen are effective swimming-organs, the latter being similarly hairy and bearing a pair of small processes on the last segment. The larva is lighter than water and rises to the surface unless it clings to some submerged object. It takes in a supply of air while hanging from the surface through a pair of spiracles on the terminal processes. When fully fed it

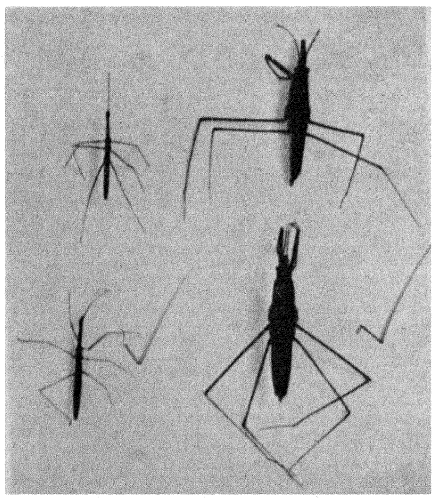


FIG. 43.—AQUATIC BUGS.
Left, water-measurers (*Hydrometra*); right, pond-skaters (*Gerris*).

burrows into the soil, makes a chamber and pupates. Early larvae complete their life-histories during the summer, but late ones pass the winter in the soil.

The larva of another small water-beetle, *Donacia crassipes* (fig. 42 *e*), which feeds upon the roots of water-lilies, appears at first sight to be quite unadapted to an aquatic life. Careful examination, however, shows that the posterior spiracles, which open into the longitudinal air-tubes, are associated with a pair of sharp curved spines.

Observation has proved that these are used to pierce the roots of water-lilies and thus to tap the supply of air contained within them (see p. 4).

Aquatic bugs form a corresponding series to the water-beetles. A few, like pond-skaters (*Gerris*) and water-measurers (*Hydrometra*) with long slender bodies and long legs, skim over the surface of the water, but most of them swim actively in the water itself. The majority of the latter belong to the genus *Corixa*. The most prominent, however, is the water-boatman (*Notonecta glauca*). The film of air which covers its hairy body is responsible for its silvery-white appearance under water and for its characteristic movements. So buoyant is it that it literally bobs up to the surface when it releases its grasp on anything submerged. A considerable amount of its time is spent hanging from the surface, through which just the tip of the abdomen protrudes, air being all the time passed forwards to large thoracic spiracles through wide passages along the ventral surface of the abdomen. These passages are formed by long hairs fringing each side of a median keel and joining those of corresponding lateral fringes. On account of the large amount of air which they hold, the ventral surface is uppermost when the insect is fully submerged. To this fact the generic name, *Notonecta*, is due. Actual swimming is effected by means of the hind legs, which are hairy, very long and considerably flattened.

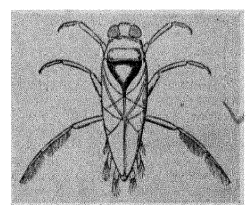


FIG. 44.—WATER-BOATMAN (*NOTONECTA GLAUCA*). (× ABOUT ½.) (AFTER MIALL.)

The largest species of bug in British waters, the water-scorpion (*Nepa cinerea*) differs from all its relatives in being so completely compressed that its shape and dull blackish coloration cause it to resemble a dead leaf in general appearance. It frequents mud on the bottom of ponds and backwaters, preying upon other insects, but makes periodical visits to the surface for supplies of air. Sometimes it hangs from the surface-film by

means of its respiratory tube which projects backwards like a long slender tail. Though both its shape and colour cause this insect to appear anything but attractive in its usual habitat, the converse is the case when its wings are expanded for flight. Then not only is its general outline very beautiful, but the orange or pinkish hue, the venation of its hind-wings and the orange-red colour of its abdomen are all very striking.

It will be clear from the examination of the above-mentioned aquatic insects that practically all of them have well-developed wings. Flight, however, is seldom seen for the simple reason that it usually takes place at night. It occurs when a particular habitat has become over-populated, unsuitable for breeding purposes or exhausted of food.



FIG. 45.—WATER-SCORPION (*NEPA CINEREA*). (× ABOUT ½.)

Many arachnids are aquatic, but only one of them, the common water-spider (*Argyroneta aquatica*) is of any considerable size. Though it may often be seen darting about over the surface of ponds and sluggish streams or through the vegetation at their margins, this spider must be kept in a small aquarium to be properly appreciated. Here, under suitable conditions, it will construct a dome-shaped nest, anchored well below the surface to aquatic plants, fill it with air which it carries bubble by bubble from the surface, and finally deposit its egg-mass within it. Part of its time it spends below the surface, part upon it hunting for prey (see fig. 46).

Minute crustaceans known as "water-fleas" are often abundant in ponds and lakes; they are referred to at the end of this chapter. In rivers and streams two other crustaceans are also found: the so-called freshwater shrimp (*Gammarus pulex*) and the crayfish (*Astacus fluviatilis*). Large specimens of the latter may be six inches long by an inch wide. They frequent the banks, hiding in holes during the day but coming out at night

in search of food, both living and dead. *Gammarus*, which is much smaller, only about half-an-inch long, lives under stones and amongst debris, feeding, like its marine relatives (fig. 16, p. 27) on practically any organic matter that comes its way. Both these creatures, therefore, are scavengers.

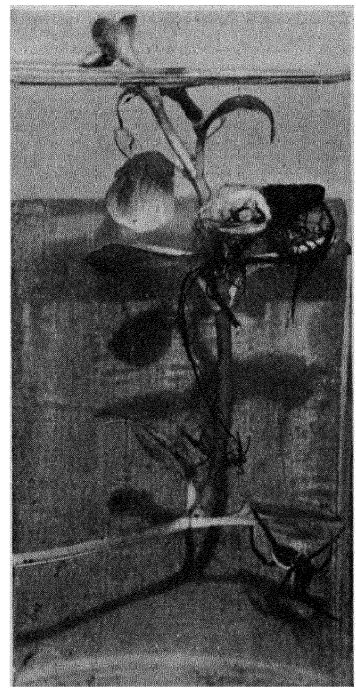


FIG. 46.—THE COMMON WATER-SPIDER (*ARGYRONETA AQUATICA*) SHOWING ONE INDIVIDUAL WITHIN NEST AND ONE BELOW COVERED WITH AIR-FILM.

Species of both gastropod and lamellibranch molluscs are found in fresh water. Some of the commonest of the former belong to the genus ***Limnaea***, the wandering snail (***L. pereger***) being the most abundant, the great pond-snail (***L. stagnalis***) the largest, sometimes as much as 2″ in length, the dwarf pond-snail (***L. truncatula***) perhaps the most important, because it is often responsible for the spread of liverflukes, which cause so much loss to sheep farmers and which pass essential parts of their life-histories within it (see p. 134). In ***Limnaea*** the shell resembles that of an ordinary snail in having its first whorl or turn at the tip. In the great ram's-horn snail (*Planorbis corneus*) and its relatives, however, the initial whorl is central, the later ones growing round it so that the adult shell is flat and coiled like a watch-spring (see fig. 47.) The under surfaces of stones in a stream often harbour some very small forms,

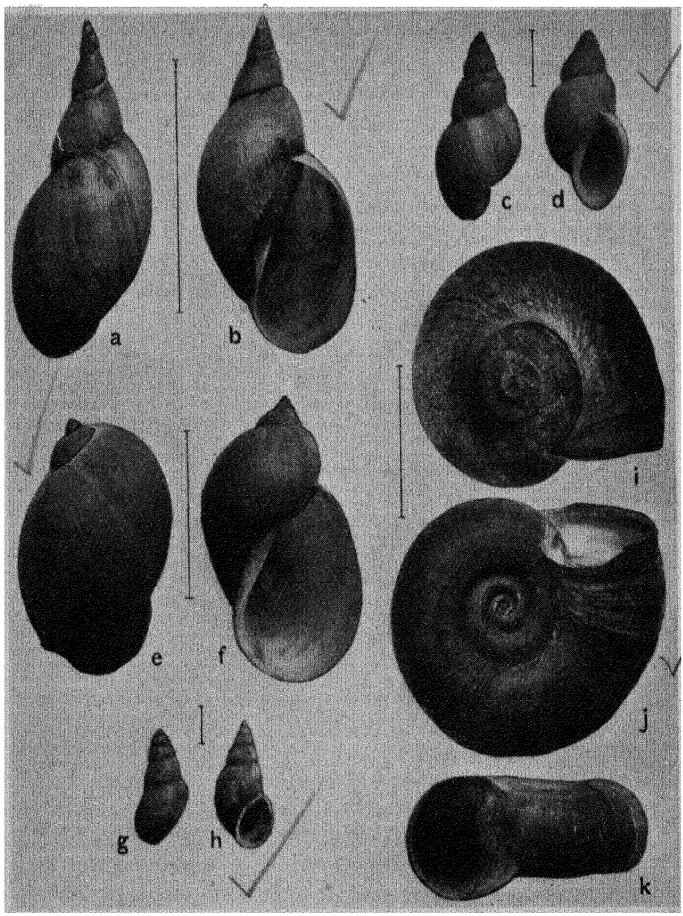


FIG. 47.—FRESHWATER SNAILS.

a and *b*, great pond-snail (*Limnaea stagnalis*); *c* and *d*, dwarf pond-snail (*Limnaea truncatula*); *e* and *f*, wandering snail (*Limnaea pereger*); *g* and *h*, spire-shell (*Hydrobia ventrosa*); *i*, *j*, and *k*, ram's-horn snail (*Planorbis planorbis*).

notably small snail-like species, known as spire-shells (*Hydrobia*) and freshwater limpets (*Ancylus*).

The largest freshwater mollusc is the pond-mussel (*Anodonta cygnea*), which may attain a length of six, sometimes of eight inches. It is a typical bivalve, differing from the marine edible mussel (*Mytilus edulis*—see p. 25) in being devoid of any byssus-gland, and in possessing a really strong muscular foot. It thrives best in relatively large shallow ponds and lakes where there is rich mud in which it can all but bury itself and through which it can "plough" its way by means of its large foot. Its eggs develop within the outer gills into small bivalved larvae, each valve of which is triangular and

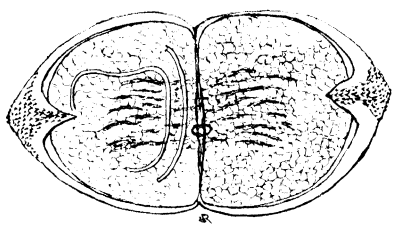


FIG. 48.—GLOCHIDIUM LARVA OF THE POND-MUSSEL (*ANODONTA CYGNEA*), VENTRAL VIEW SHOWING HOOKS AND HOOKLETS AT APICES OF VALVES, ADDUCTOR MUSCLE THROUGH THE MANTLE AND PART OF BYSSUS THREAD. (× ABOUT 85.)

bears sharp teeth on its ventral point. When fully formed these glochidia, as they are called, develop a byssus thread and by it maintain their attachment to the parent. They are discharged into the water during early spring through the exhalant siphon. Though unable to swim, or to exist independently for any length of time, they flap their valves together whenever a fish, such as a stickleback, is in the vicinity. If the fish be near enough the sticky byssus is thus brought into contact with it, and the snapping of the valves may secure a firm attachment. The glochidia live parasitically on the fish and undergo further development protected by the tissues of their host which grow round them in the form

of a cyst. After three or four months metamorphosis is complete and a young mussel is set free.

The habits and preferences of freshwater fish differ widely, but very few, like char (*Salvelinus*) and pollan (*Coregonus*), are confined to lakes and ponds. Many, such as carp (*Cyprinus carpio*), perch (*Perca fluviatilis*), tench (*Tinca vulgaris*), loach (*Nemachilus barbatulus*), pike (*Esox lucius*), three- and two-spined sticklebacks (*Gasterosteus aculeatus* and *G. pungitius*) and minnow (*Phoxinus aphya*) are found in ponds and very slowly flowing water; others, dace (*Leuciscus leuciscus*), chub (*L. cephalus*), gudgeon (*Gobio fluviatilis*) and brook-lamprey (*Lampetra planeri*) prefer more swiftly flowing streams and rivers; while others still, eel (*Anguilla vulgaris*), trout (*Salmo trutta*), salmon (*S. salar*), river-lamprey (*Lampetra fluviatilis*) and sea-lamprey (*Petromyzon marinus*) divide their time between the sea and fresh water. Of the last group eels breed in the sea, the others in fresh water.

Many fish form abundant proof that an organism can be extremely interesting and, at the same time, so abundant as to be known by everyone. Sticklebacks, for instance, though ordinarily inhabitants of fresh or brackish water, can continue to thrive if transferred directly from fresh to sea water or vice versa, and their breeding habits are truly remarkable. The male or cock develops a brilliant coloration during the mating season and constructs a nest of twigs and plants bound together with a secretion from his kidneys. To this he escorts the female or hen, and over it he mounts a very jealous guard until the young fish hatch out. He not only repels predaceous enemies, but also keeps the eggs aerated by directing water-currents through the nest with his pectoral fins. Meanwhile, the hen, after she has deposited her eggs, swims away entirely relieved of any "household responsibilities". This common little fish is also one of the few members of its class which is able to make a "noise"; this is accomplished by means of a stridulating organ, consisting of a spine in the anterior dorsal fin which rubs against a dorsal spinous process.

There are so many accounts of frogs and their fish-like tadpole larvae that anything beyond a mere mention of them here would be superfluous. Other amphibians, which lay their eggs and undergo metamorphosis in ponds, are toads (*Bufo vulgaris*) and newts. Of the latter there are three species, the common (*Molge vulgaris*), the great crested or great warty (*Triton cristatus*) and the palmate or webbed (*Molge palmata*). The spawn of toads consists of chains of large eggs resembling those of frogs, but newts lay their eggs singly and wrap them up in small leaves of living plants.

In addition to many species of ducks and swans, whose legs are so placed that their feet can act as stern-propellers, many different kinds of birds frequent aquatic habitats.



[*A. E. Ellis.*

FIG. 49.—GREAT CRESTED NEWT (*TRITON CRISTATUS*) (FEMALE).

Kingfishers, the most brilliantly coloured of all our birds, have favourite perches on branches overhanging streams and rivers into which they dive after fish, crustaceans, etc. Their nesting sites, however, are long burrows in sandy banks above the water. Reed, marsh and sedge warblers and reed buntings prefer the vegetation at the water's edge. Here they live and build their nests well above the level of the water. The larger nests of water-rail, moorhen and coot are also found in similar places, but are always nearer the surface of the water, that of the last named being built up if this rises, until its thickness may be very considerable. Grebes construct large floating nests which they sometimes paddle about (see fig. 50). All these last four birds swim well, their long toes being flanged and the shanks of their legs flattened in all except

the rail. The narrow build and very long toes of this last, which enable it to move rapidly through thick vegetation and over soft marshy places, are useful also as adaptations for swimming. Black and white streaks in its plumage help to conceal it among reeds and other vegetation, their effectiveness being increased by the bird



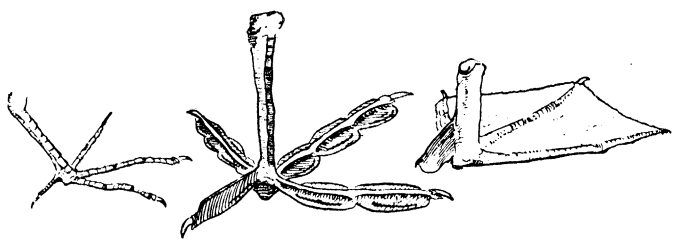
FIG. 50.—FLOATING NEST OF GREAT CRESTED GREBE.

"freezing" when alarmed. The other three dive and swim under water when disturbed.

Wading birds, too, often frequent fresh water, one of the commonest being the heron. This bird spends a great deal of its time wading "up to its knees" at the edge of ponds and rivers, awaiting the approach of fish and other aquatic animals. Though essentially water-birds so far as feeding is concerned, herons rarely nest

in any other places than the tops of trees, usually numbers together so that heronries are formed, looking like small rookeries but with fewer and larger nests (see fig. 52).

Three species of native mammal are to be met with in fresh water. Of these the smallest is the water-shrew. It resembles its smaller terrestrial relations in general features, but differs from them in having larger feet, with digits fringed with long hairs, and in being provided with a keel-like series of stiff hairs along the mid-ventral line of its tail, whose usefulness as a rudder is thereby increased. The commonest mammal is the water-vole, often mistaken for a rat, but easily distin-



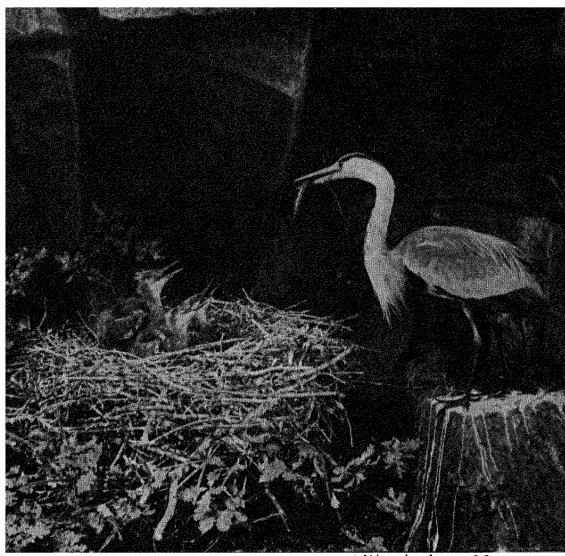
a *b* *c*

FIG. 51.—FEET OF WATER-BIRDS.
a, water-rail; *b*, coot; *c*, duck.

guishable on account of its head being shorter and broader and its tail much shorter and hairy (compare fig. 63, p. 88). It feeds principally on plant-material but occasionally takes other food. Though without any special modifications, it is an expert at swimming and diving. By far the largest mammal is the otter, a carnivorous form, which feeds almost entirely on fish. Its modifications for an aquatic life consist in the reduction in size of the external ears, the flattening of the head, body and tail, the closeness of the short fur and the development of a web between the digits (see frontispiece). All these mammals live in burrows in the banks of rivers and streams, but the otter breeds in a specially chosen retreat some distance from the water. It is an interesting

fact that otters when born are without any instinct for water and have to be "forced" into it, but yet are naturally adept at diving and swimming.

During the last few years a fourth species of aquatic mammal has established itself in various centres in Great Britain. This is the musk rat or musquash, a North



Birmingham Museum.

FIG. 52. A HERON.

Note the long legs and toes, typical of a wading bird, and the long, powerful fish-catching bill.

American rodent, which was first imported into this country during 1927, when several "farms" were established for the production of musquash furs. Animals which have escaped from some of these have found suitable conditions for breeding, so that Great Britain is now threatened with the same trouble as has overtaken a very large area of the mainland of Europe through the

importation into Bohemia of five musk rats during the autumn of 1905. So rapid was the increase that it was estimated that, in spite of international action to control them, there were some 100,000,000 in 1926. Since then this species has considerably increased both its



[*John Ritchie.*

FIG. 53.—MUSK RAT ABOUT TO ENTER THE WATER. Note especially the tail and the feet.

range and numbers. The musquash resembles the water-vole (to which it is related) in general form but is much larger, being up to thirteen inches in length with a nine-inch tail in addition. Its hind-limbs and tail also are considerably modified. The latter is naked, scaly, strongly compressed and acts as an efficient rudder, while the

large webbed hind-feet are powerful swimming organs. The dense fur is dark reddish-brown or black.

These animals inhabit streams, canals, ponds and ditches, burrowing extensively into their banks which collapse in consequence. The entrance to a burrow is usually under water and always marked by masses of scooped-out earth on the bottom of the waterway. The inhabitants are active only at night, and therefore they may be well established before their presence is realized. On account of their vegetarian feeding-habits they may cause a great deal of damage to agricultural crops, but occasionally they also attack small live-stock, freshwater fish and molluscs. During the autumn winter quarters are constructed in marshy places. These are in the form of large mounds standing three or four feet above the water and consist of rushes, leaves and other vegetable matter including shoots of aquatic plants. Here there is not only shelter but also abundant food, a single mound often providing both for a family of forty or more.

Plankton.—Ponds and lakes are essentially bodies of still water, streams and rivers of rapidly flowing water. Upon this fact all the main differences between their various associations depend. Not only are streams and rivers denuded of their contents by currents, but they also offer much smaller areas of easily accessible substrata. For this reason, ponds and lakes provide a greater supply of organic food, much more cover and very much quieter physical conditions. Hence the number both of species and individuals is much smaller in streams and rivers, except along the muddy banks of sluggish rivers where the conditions often approximate to those in a pond. Only very strong swimmers, or such forms as can anchor themselves firmly without exposing much surface, can live in any rapidly flowing water. In the still, or relatively still water of ponds and lakes, on the other hand, even the most delicate organisms can flourish without injury. It is here, therefore, that small "floating" forms are often abundant. Many of these do not merely float passively, but have well-developed

organs of locomotion. Even the most powerful, however, are too frail to resist the weakest of currents or eddies. All of them collectively form the **plankton,** the plants phyto-plankton, the animals zoo-plankton.

So abundant are some species of unicellular or fine filamentous algae that their countless millions often form green sheets or scums on the surface of ponds and puddles. In addition to these, many kinds of other small plants and of animals often abound, *Volvox* amongst borderline organisms, hordes of minute crustaceans, usually alluded to as " water-fleas " because of their intermittent jerky movements of locomotion, and mites in great numbers. Water-fleas belong to three main groups, the commonest genera being *Cyclops*, *Daphnia* and *Cypris* (fig. 54). The first is something like a half-pear in general shape, swims by means of its first antennae, and the female carries her eggs in a pair of sacs, one on each side of the narrow posterior end of the abdomen. Daphnids row themselves about with their large second antennae, and the eggs are carried in a brood-pouch between the dorsal surface of the body-proper and a large hood which completely covers the whole body except along part of the mid-ventral line. Under favourable conditions many generations of females may be produced without any males, but when males occur the eggs which they fertilize are furnished with a protective covering; these afford a means of tiding over bad times, such as drought or lack of food-supply. Cyprids are extremely like minute mussels in general shape, the body being enclosed within two shell-like valves between whose gaping ventral edges the swimming legs slightly protrude, while a brood-pouch is formed as in the daphnids. Here males are entirely unknown. The eggs of *Daphnia* develop directly, but those of *Cyclops* and *Cypris* give rise to free-swimming nauplius larvae which undergo metamorphosis.

These larger members of the zoo-plankton feed on smaller and on microscopic plants, as has been seen above in the case of midge and mosquito larvae, and in turn constitute favourite articles of diet for many fish. Plankton therefore provides some of the first links in

the food-chains of ponds and lakes, as it does in those of the sea. Marine plankton is much richer than that of fresh water, partly because of the greater numbers of

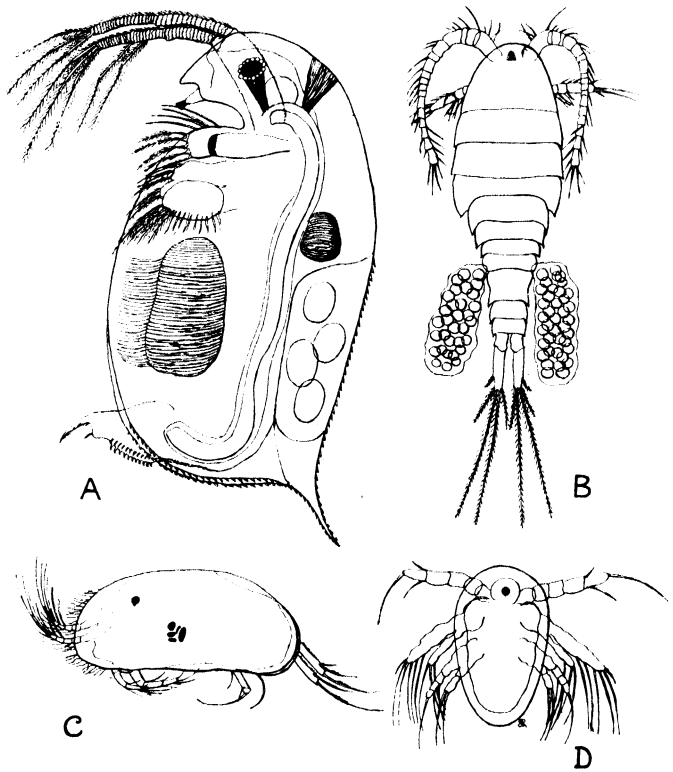


FIG. 54.—"WATER-FLEAS."

A, *Daphnia* (a branchiopod), female with eggs in brood-pouch; B, *Cyclops* (a copepod), female carrying egg-sacs; C, *Cypris* (an ostracod); D, nauplius larva of *Cyclops*.

microscopic plants, and partly because the vast majority of marine animals produce planktonic larvae. The suppression of the latter under the influence of currents

furnishes the most striking differences between typical marine and typical freshwater life-histories.

It is abundantly clear, therefore, that, although the aeration in streams and rivers, resulting from the rapid movement of the water, is far in excess of that produced by the photosynthesis of submerged plants in ponds, this advantage is more than counterbalanced by the lack of food and the general physical effects of currents.

CHAPTER IV

TERRESTRIAL ASSOCIATIONS

Bogs, Moorlands and Heaths.—The prevailing conditions in all these habitats are xerophytic in nature. Bogs and moorlands are both due to the accumulation of plant remains during long periods under conditions unfavourable to complete decomposition. The compressed material which results is known as peat. It contains many carbon and nitrogen compounds, the most important of which, from the ecological point of view, are humic acids. In bogs these acids are dissolved by the water present. Bogs, therefore, are physiologically dry. Moorlands consist mainly of deep layers of dry peat and are therefore dry both physiologically and physically, while heaths are physically dry because their sandy or gravelly substratum has an extremely low water-content. In correlation with these conditions trees are very infrequent or entirely absent, so that there is very little, if any, shelter from the strong winds to which moors especially are often exposed. Bog and moorland are very closely related and readily pass into each other under conditions which decrease water-content on the one hand and increase it on the other. Bogs may be formed also on heaths : in the absence of lime plant remains decompose slowly, and therefore tend to accumulate, retain water and become acid.

Many bogs are covered with a deep layer of bog-moss (*Sphagnum*), a type of moss which has special water-storage cells in its leaves, and whose apex continues to grow while its base dies and forms peat. Associated with it are bog-asphodel (*Narthecium ossifragum*) and various reeds and sedges, including the so-called cotton-

grasses (*Eriophorum*), all with long narrow leaves, sundews (*Drosera rotundifolia* and, less frequently, *D. longifolia*) and butterwort (*Pinguicula vulgaris*), whose leaves bear glandular hairs by means of which they are able to catch and digest flies and other small insects from which they obtain their supplies of nitrogen (see fig. 56,) sweet gale (*Myrica gale*), creeping or dwarf willow (*Salix*

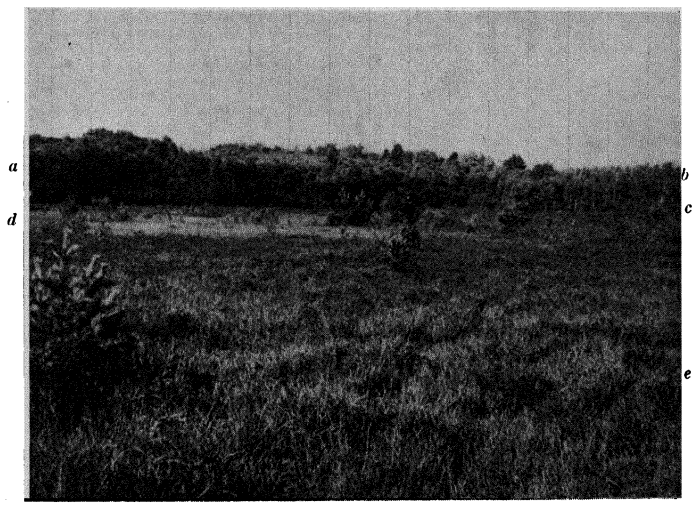


FIG. 55.—TRANSITION FROM BOG TO HEATH AND COLONIZATION OF THE LATTER BY BIRCH AND PINE (NEAR GODALMING, SURREY) (SEPTEMBER).

a, pinewood; *b*, birchwood; *c*, heath being invaded by trees; *d*, bog dominated by bog-moss (*Sphagnum*) and sundew (*Drosera*); *e*, reeds, sedges and heaths.

repens) and cross-leaved heath (*Erica tetralix*) rooted in the peat wet below, bog-pimpernel (*Anagallis tenella*) and marsh-pennywort (*Hydrocotyle vulgaris*) with low creeping stems, and bog-bean (*Menyanthes trifoliata*) in very wet places.

The vegetations of a typical dry moor and a heath resemble each other closely: they are both physically dry. Ling (*Calluna vulgaris*), cross-leaved heath, the

latter only in damp situations, bell-heather (*Erica cinerea*), furze or gorse (*Ulex europaeus*) and bilberry (*Vaccinium myrtillus*), all with small resistant leaves and tough stems,

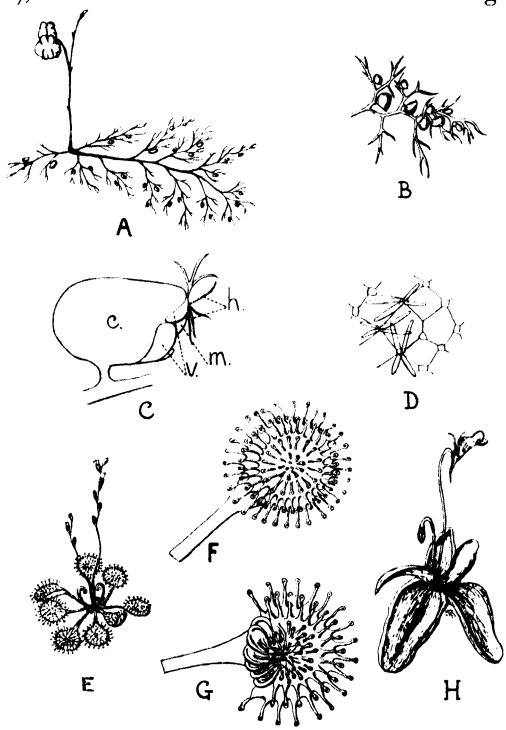


FIG. 56.—INSECTIVOROUS PLANTS.

A–D, common bladderwort (*Utricularia vulgaris*). A, a whole plant; B, a small portion enlarged; C, a bladder seen as a transparent object—*c.*, cavity of bladder, *h.*, hairs guarding the mouth, *m.*, mouth, *v.*, valves; D, a small portion of the inner wall of the bladder more highly magnified, showing stalked and branched absorptive cells.

E–G, round-leaved sundew (*Drosera rotundifolia*). E, a whole plant in flower; F and G, leaves with glandular hairs enlarged—in F, the hairs are all stretched out waiting for "prey", in G some of them are bending over a small insect.

H, butterwort (*Pinguicula vulgaris*).

constitute the larger plants of a heath community besides being present on many typical moors. Both birch (*Betula alba*) and Scots pine (*Pinus sylvestris*) are often found on the dry sandy southern heaths, and if the latter becomes at all dominant it will, in course of time, change the character of the whole community (see fig. 55 and pine woods in chapter V). On the other hand, the ling-association can often maintain itself between the trees of a birch wood which does not cast heavy shade. Where it is well established little else can grow, for the plants cover the ground closely and any space around them is kept very dry. Grasses, such as matgrass (*Nardus stricta*), sheep's fescue (*Festuca ovina*), waved hairgrass (*Deschampsia* (*Aira*) *flexuosa*) and bent-grass (*Agrostis vulgaris*) occur where there are gaps, with tormentil (*Potentilla tormentilla*), wild thyme (*Thymus serpyllum*), heath - bedstraw (*Galium saxatile*), wild sage (*Teucrium scorodonia*), sheep-sorrel (*Rumex acetosella*) and bracken (*Pteris aquilina*). Many of these, together with such semi-parasites as louse-wort (*Pedicularis sylvatica*) and eyebright (*Euphrasia officinalis*) which send suckers into the roots of grasses, the dominant species of which is usually purple moorgrass (*Molinia caerulea*), are found more plentifully on moors.

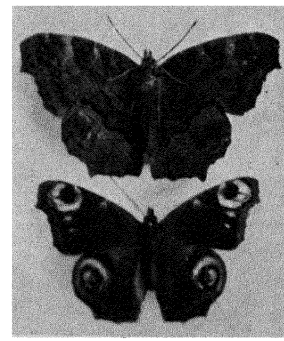
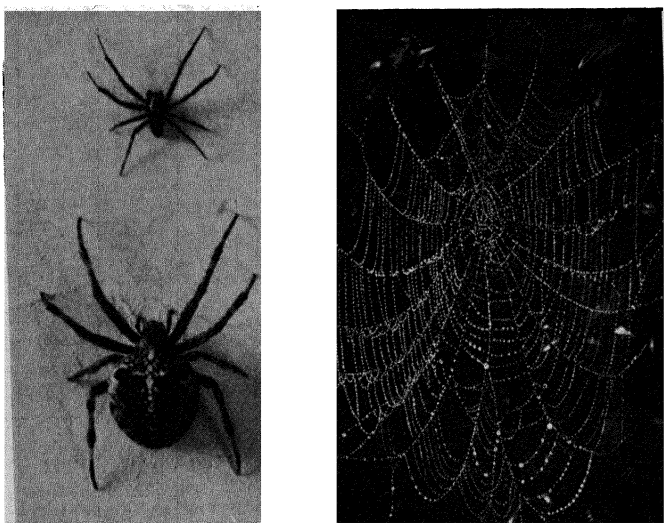


FIG. 57.—PEACOCK BUTTERFLY (*VANESSO IO*). (× ½.)
Note dorsal surface (below) showing "dazzle" coloration, ventral surface (above) showing resemblance to a dead leaf.

The bushes and longer grasses provide cover and nesting sites for birds, many of which, snipe, curlew and grouse for example, show protective coloration. Others, such as the noisy little stonechat, furnish examples of brightly coloured animals which rely on contrast as a safeguard. This phenomenon, often known as "dazzle", is most easily observed in insects. Butterflies, for ex-

ample, though usually brilliantly coloured, are very difficult to follow on account of their jerky movements. When they suddenly come to rest they often seem to vanish completely. This is because the under surfaces of their wings, which are then exposed, are often dull and usually so coloured and patterned that they harmonize with the background. (Compare fig. 57.)



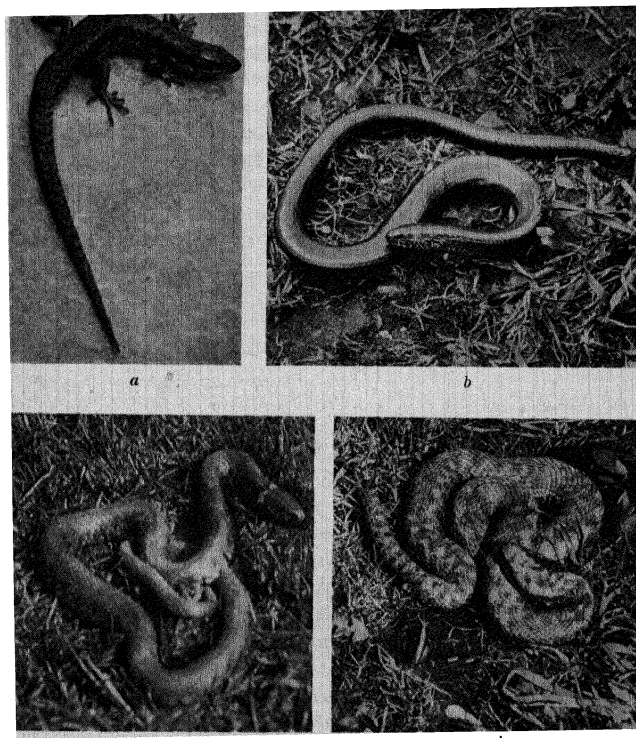
[*Rev. R. A. Ellis.*

FIG. 58.—SPIDERS.

On the left, male (top) and female (below) (*Aranea* (*Epeira*) *diadema*); on the right, a web covered with dew.

Insects of all kinds abound in the vegetation, among them being such characteristic moths as the emperor (*Saturnia pavonia*) and the oak-eggar (*Lasiocampa quercus*). Hunting spiders (*Lycosa* and others) may be seen carrying their egg-sacs with them, while the orb-spinners, such as the cross-spinner (*Aranea* (*Epeira*) *diadema*), hang their wonderful traps between the bushes during late summer.

Moorlands and heaths are the habitats of all the British reptiles. The viviparous lizard (*Lacerta vivipara*) whose



[*A. E. Ellis.*

FIG. 59.—REPTILES.

a, common lizard (*Lacerta vivipara*); *b*, slow or blind worm (*Anguis fragilis*); *c*, grass-snake (*Tropidonotus natrix*); *d*, adder or viper (*Pelias berus*).

young hatch from the eggs as they are being laid, its relative, the so-called slow-worm or blind-worm (*Anguis fragilis*), the grass-snake (*Tropidonotus natrix*) and the

adder or viper (*Pelias berus*) all find conditions to suit them. The last is our only poisonous native species. It is usually under two feet in length and marked with a dark zigzag along its dorsal surface, whereas the grass-snake often exceeds a yard in length and generally has an orange or yellow V-shaped patch just behind the head. Though lizards and slow-worms are without any active means of defence they have a protective device in their tails. These snap off at special breaking-joints when the animals are alarmed. The broken-off portion continues to wriggle and the erstwhile owner often makes good its escape while the attention of the enemy is focused on the detached member. The lost extremity is gradually replaced but the substitute differs somewhat from the original.

Chalk-Downs and Limestone Pastures.—Water drains through chalk very rapidly so that these habitats are usually dry. At the same time the water which is retained contains a high percentage of calcium bicarbonate as the result of the solvent action of carbon dioxide. Hence, such soil supports two distinct types of plants, those indifferent to lime and which can survive in dry soil and are therefore also found in other dry situations, and calciphils which require or prefer a large amount of lime in their substratum. A negative character of the flora is the absence of certain plants, notably furze or gorse (*Ulex europaeus*), broom (*Cytisus scoparius*), foxglove (*Digitalis purpurea*), ling (*Calluna vulgaris*), heathers (*Erica cinerea* and *E. tetralix*), sundew (*Drosera*), waved hair-grass (*Deschampsia* (*Aira*) *flexuosa*), matgrass (*Nardus stricta*), bracken (*Pteris aquilina*) and bog-moss (*Sphagnum*) which are quite intolerant of lime. All these plants are alluded to as calcifuges, a group which also includes such non-native cultivated shrubs as rhododendrons and azaleas.

Limestone soils poor in humus support typical ash-wood and in the Cotswolds also beechwood. The latter, especially in the south-east of England, is common on chalk. Both these associations are described in the next

chapter. In some places chalk-downs bear a characteristic " scrub " of whitebeam (*Pyrus aria*), wayfaring tree (*Viburnum montana*), yew (*Taxus baccata*), juniper (*Juniperus communis*), and hawthorn (*Crataegus oxyacantha*), the first four of which are chalk-loving trees. Traveller's-joy or old man's beard (*Clematis vitalba*) is often found in these situations, climbing round hawthorn and other shrubs by means of its twisted petioles. On pastures the dominant grasses are quaking grass (*Briza media*), sheep's fescue (*Festuca ovina*), crested kocleria (*Koeleria cristata*) and smooth meadow-grass (*Poa pratensis*), while crested



FIG. 60.—TYPICAL CHALK-SCRUB VEGETATION ON HOG'S BACK, NEAR GUILDFORD (SEPTEMBER).

In the photograph can be seen yew, whitebeam, wayfaring tree, juniper and hawthorn.

dog's-tail (*Cynosurus cristatus*), spiked heath-brome-grass (*Brachypodium pinnatum*) and fine bent-grass (*Agrostis vulgaris*) are common. Other flowering plants include horse-shoe vetch (*Hippocrepis comosa*) found only on calcareous soils, lady's-finger (*Anthyllus vulneraria*), clustered bell-flower (*Campanula glomerata*) and box (*Buxus sempervirens*) rarely found away from chalky soils, rock-rose (*Helianthemum vulgare*), milkwort (*Polygala vulgaris*), flaxes (*Linum* spp.), salad burnet (*Poterium sanguisorba*), pasque-flower (*Anemone pulsatilla*), small scabious (*Scabiosa columbaria*), great mullein (*Verbascum thapsus*), wild

mignonette and dyer's weed (*Reseda lutea* and *R. luteola*), hoary plantain (*Plantago media*), various orchids which prefer a calcareous soil, and such plants of dry soils as silver-weed (*Potentilla anserina*), common speedwell (*Veronica chamaedrys*) and eyebright (*Euphrasia officinalis*).

Pastures and Meadows.—Both of these may be described as grass-moors on fertile ground, meadows more usually on lower and richer ground than pastures. The main differences between them are the result of usage, a pasture being grazed and a meadow mown and sometimes grazed afterwards. In the former case the plants are kept permanently short, whereas in the latter they are allowed to grow, many of them to flower before they are cut. Both associations are typically devoid of trees; this is because any seedlings which may appear are destroyed before they become properly established.

Good meadow contains clovers (*Trifolium* spp.), and grasses which grow rapidly and have the power of recovering an erect position after being trampled upon or blown down. These include perennial rye-grass (*Lolium perenne*), sweet vernal-grass (*Anthoxanthum odoratum*), cock's-foot (*Dactylus glomerata*), meadow-grasses (*Poa pratensis* and *P. trivialis*), fox-tail (*Alopecurus pratensis*), Timothy-grass (*Phleum pratensis*), white bent-grass (*Agrostis alba*), Yorkshire-fog (*Holcus lanatus*), crested dog's-tail (*Cynosurus cristatus*), and fescues (*Festuca pratensis* and *F. ovina*). The weeds which grow among them vary with the soil, its treatment and its water-content, damp "water-meadows", for example, containing many marsh plants (see p. 52). Common weeds in well-drained meadows are creeping and bulbous buttercups (*Ranunculus repens* and *R. bulbosus*), ribwort plantain (*Plantago lanceolata*), dock (*Rumex crispus*), sorrel (*Rumex acetosa*), marsh-thistle (*Carduus palustris*), ox-eye daisy (*Chrysanthemum leucanthemum*), groundsel (*Senecio vulgaris*), ragwort (*Senecio jacobaea*), yellow meadow-vetchling (*Lathyrus pratensis*) and cuckoo-flower or lady's smock (*Cardamine pratensis*).

On pastures the chief grasses are fine bent-grass (*Agrostis vulgaris*), sheep's fescue (*F. ovina*), sweet vernal-grass, waved hair-grass (*Deschampsia* (*Aira*) *flexuosa*), smooth meadow-grass (*Poa pratensis*) and heath-grass (*Triodia decumbens*). Many of the weeds, such as creeping buttercup, heath-bedstraw (*Galium saxatile*) and wild



[*D. A. Webb.*

FIG. 61.—A TYPICAL ROSETTE PLANT FROM A CLOSE-GRAZED PASTURE —GREATER PLANTAIN (*PLANTAGO MAJOR*).

thyme (*Thymus serpyllium*) have prostrate stems, while others have only radicle leaves which spread out close to the ground and arise from a very short stem known as a root-stock. These are "rosette" plants, dandelion (*Taraxacum officinalis*), mouse-ear hawkweed (*Hieracium pilosum*), yarrow (*Achillea millefolium*), sheep's fescue, and

carline thistle (*Carduus vulgaris*) being among the commonest. Their flower-buds are near the centre, which is often hollowed, with the result that the apex of a bud is no higher than the leaves surrounding it. They have deep tap-roots which are usually contractile, so that the plant is pulled down as it grows and thus prevented from attaining any height. Under the effects of grazing other plants often assume a rosette form, a good example being ribwort plantain. On the other hand, typical rosette plants living among the taller growth in a meadow increase in height by producing large leaves which grow upwards in their struggle for light. Dandelions are among the most familiar and striking examples.

Bright green patches of vegetation sometimes appear on pastures and meadows, more especially on the former. These are usually due to the fact that dung from grazing animals has been allowed to lie, instead of being spread. Decomposition follows and, as a result of the vigorous growth caused by the increased nitrogen-content of the soil, either a dense mat of fine grass or a tall tuft of coarse grass is produced, according to the species present. In other cases such bright patches are within " fairy-rings ", which consist of a central green part surrounded by alternate rings of barren and green circles. There are usually three or four of these, and " fruiting " bodies of various agaric fungi (mushrooms and toadstools) appear at certain times of the year in the outermost. It is to their activity that the rings are due. Grasses are unable to grow in the region they drain of food-material and so a barren patch appears. The first mycelium, as the network of fine threads which constitute the main vegetative part of the fungus is called, dies after " fruiting ", but its branches have in the meantime formed a vigorously-growing ring. The process is then repeated and a further ring is formed. By this time the dead remains of the older mycelia have decomposed and grasses have grown in the now fertile soil. Fairy-rings are found not only in meadows and pastures, but also on moorlands.

Characteristic birds include the corncrake in meadows, the skylark in pastures, though both of these may be

found in other grassy places, the former in longer, the latter in shorter grass and vegetation. Though the corncrake is well known from the call to which it owes the latter half of its name, it flies so little, except during migration, that it is seldom seen. Its coloration is protective, mainly buff and brown with many lighter and darker streaks and patches. On the other hand, the sky-

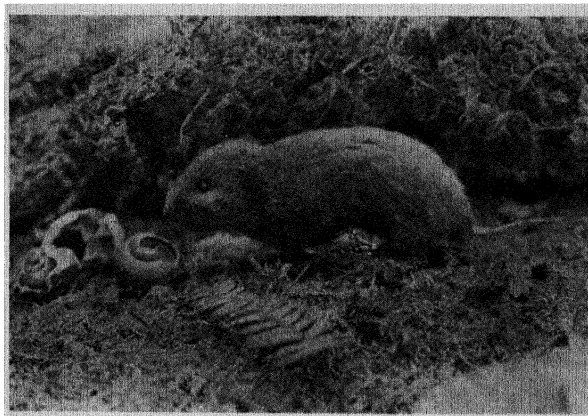


[*The late E. Step.*

FIG. 62.—FAIRY-RING OF ST. GEORGE'S MUSHROOM (*TRICHOLOMA GAMBOSUM*).

lark is familiar to everyone, its penetrating song drawing attention to it when soaring high in the air or perching on a wall or fence. It wears the same type of livery as the corncrake, and is not at all obvious when at rest on the ground. It is, however, of darker general hue in correlation with its habit of nesting in small depressions in the ground, whereas the corncrake nests amongst tall grasses.

In addition to voles, field-mice and shrews, pastures in particular often harbour moles, small mammals which



[*John Ritchie.*

FIG. 63.—A FIELD-VOLE AT ITS LARDER.

are most wonderfully adapted to a subterranean life. A mole is six inches or so in length by about two in width

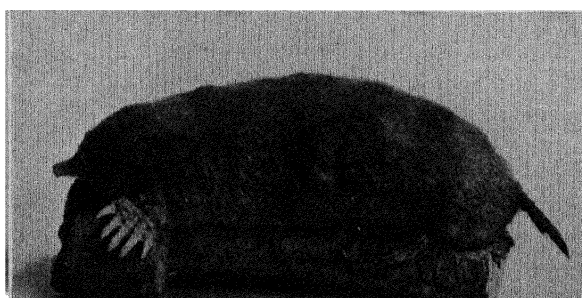


FIG. 64.—A MOLE. (× ABOUT ½.)

and roughly circular in cross section. Its rigid body has an unbroken outline and is covered by a very dense velvety fur, which lies flat in whichever direction it be

rubbed. The tapering head, with a long flexible snout, is devoid of external ears, and the eyes are sunk and protected by long hairs. The fore-limbs are level with the neck, the hind-limbs almost ventral in position, so that neither of them protrude laterally. The hand is much enlarged and turned outwards to form a very effective scooping spade, the bones of the fore-limbs, pectoral girdle and sternum being much modified to afford attachments for the large muscles employed during digging. The burrows made are very complex, and consist of main tunnels, branches nearer the surface,

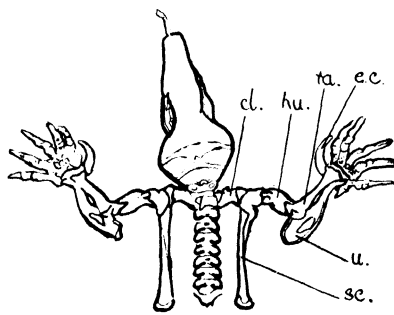


FIG. 65.—FORE-PART OF SKELETON OF MOLE. (× ⅔.)
cl., clavicle; *e.c.*, extra carpal bone; *hu.* humerus; *ra.* radius; *sc.*, scapula; *u.*, ulna,

ventilating shafts, bolt holes, living chambers, and nursery, but the very complicated "fortress" pictured in so many books does not really exist. The more superficial tunnels are made while the animals are searching for food, which consists mainly of earthworms, cockchafer grubs, wireworms, leather-jackets and slugs. (The habits of these agricultural pests are described in the section on gardens in chapter V.) Clearly then, in spite of the inconvenience often caused by the mounds of loose soil which mark the positions of living and nesting chambers, these little creatures are definitely friends of the cultivator.

CHAPTER V

TERRESTRIAL ASSOCIATIONS (*continued*)

Trees assume such an important rôle in the associations briefly described in this chapter that some consideration of them is necessary before accounts of the associations themselves are given. **Woods** are essentially tree associations; **hedgerows** usually consist of one or more kinds of smaller trees among which an occasional large one is prominent; **gardens** often contain many kinds of trees and shrubs.

How to Study Trees.—In order to obtain a true idea of any tree it is necessary to consider the shape and chief features of one of its kind living in a position where its growth is not affected by neighbouring trees or buildings. Even then a proper knowledge can only be obtained if the same examination be repeated at different times of the year: all trees, evergreens included, undergo seasonal changes. During the spring and summer flowers and leaves are usually prominent, during summer and autumn leaves and fruits, throughout the winter and early spring bark and buds and in some cases, undeveloped flowers.

A student should study a tree with a view to answering the following questions:—

What is its general outline when viewed from some little distance?

What relations do its branches bear to the trunk? Do they come off at right angles, or at some other angle? Are they crowded together or well spaced? Do the twigs turn up or down, or in neither direction?

What colour is the bark? What is its texture? Is thick or thin? Does it scale off?

Are lenticels clearly visible on the young twigs ? Are they scarce or numerous, large or small ? Have they a constant and characteristic shape ?

How are the buds arranged round the twigs ? What colour are they ? Are they smooth, rough, hairy or sticky ? What shape and size are they, and how many bud-scales do they appear to have ? At what time of the year do the buds burst ?

How dense is the foliage ? Does it form a closed canopy through which little light penetrates, or an open one which allows a considerable amount to pass ? What is its general colour ?

Are the leaves simple or compound ? What is their shape, their colour, and their texture ? Are they smooth or hairy, and are the upper and lower surfaces alike ? Are their edges toothed, notched or entire ? At what times of the year do they unfold and fall ?

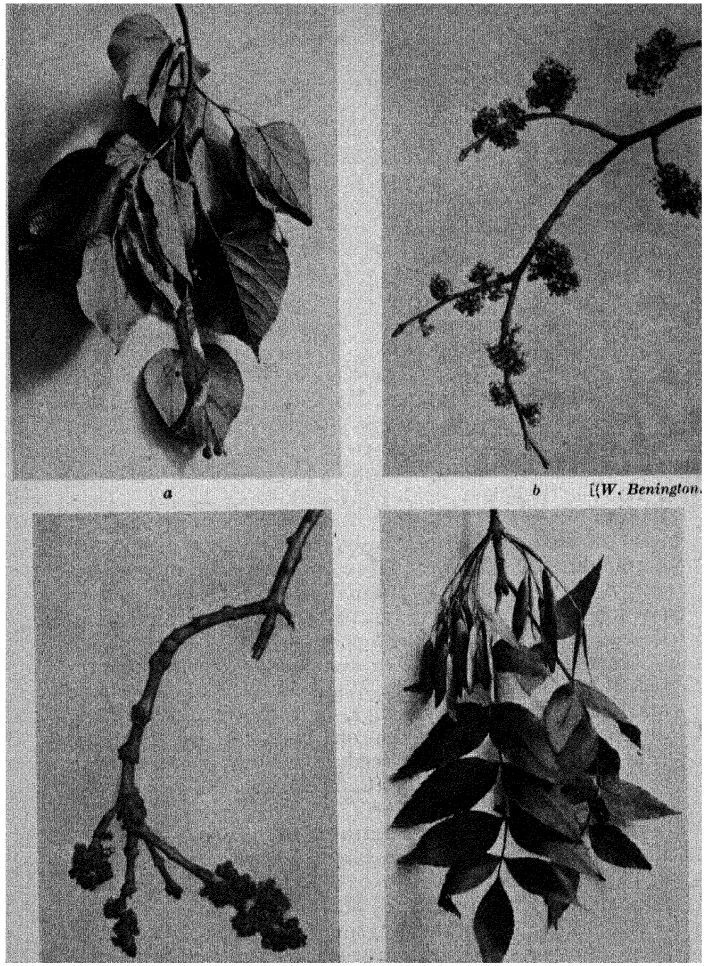
Are the trees monoecious or dioecious ? How are their flowers arranged ? Do they form catkins or some other kind of inflorescence, or are they solitary ? Are they hermaphrodite or unisexual, conspicuous or inconspicuous, anemophilous (= wind-pollinated) or entomophilous (= insect-pollinated) ? When do they open and when do they fade ? (Compare figs. 66–69.)

Are their fruits simple or compound, exposed or protected, succulent or dry ? What is their colour, shape and size ? Have they wings, or any other supporting device ? Do they persist on the tree through the winter ? What are their seeds like ? At what time of the year are they ripe ? (Compare figs. 66, 68 and 69.)

Some of the Main Features of Trees.*—Most of the common trees found in Great Britain can be identified by means of (*a*) their buds ; (*b*) their bark ; (*c*) their flowers and fruits ; and (*d*) their leaves.

Buds differ in their arrangement, shape, colour and in the character of their scales. They may be arranged alternately, spirally, or in opposite pairs ; they may be

* More information may be obtained from various books on trees, some of which are mentioned in appendix C, Nos. 29 and 59.



[(*W. Benington.*

FIG. 66.

a, Lime (*Tilia europaea*) showing leaves and fruits (September).
b, Common Elm (*Ulmus campestris*) in flower (Spring).
c, Ash (*Fraxinus excelsior*) in flower (Spring).
d, Ash showing leaves and fruits (September).

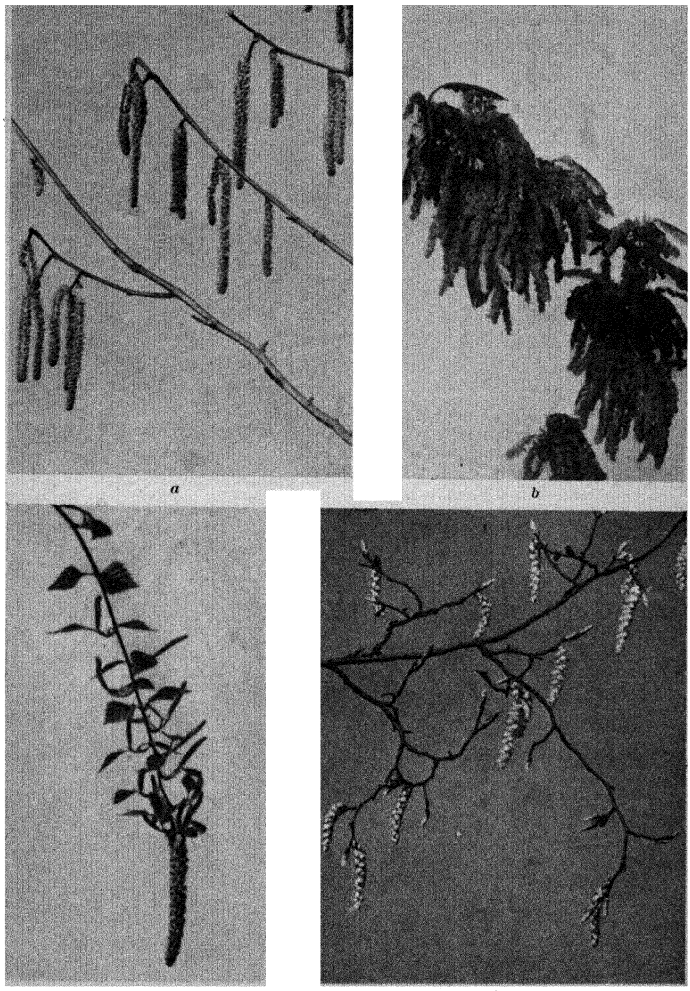
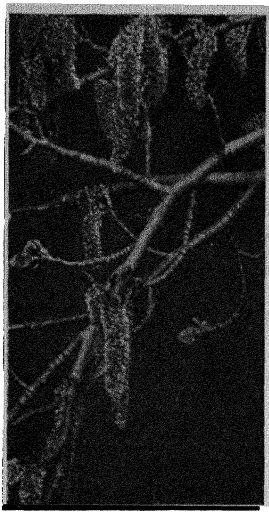


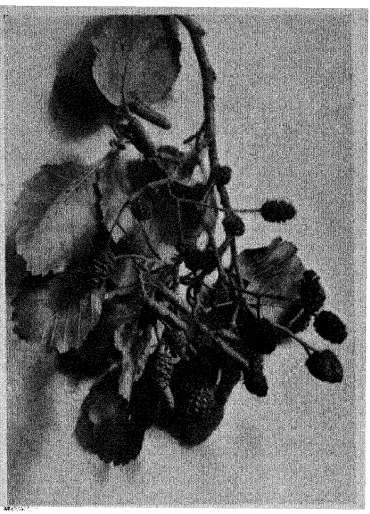
FIG. 67.

a, Hazel (*Corylus avellana*) showing male catkins (Early Spring).
b, Oak (*Quercus*) showing male catkins and young leaves (Spring).
c, Birch (*Betula alba*) showing a male catkin and young leaves (Spring).
d, Hornbeam (*Carpinus betula*) showing drooping male catkins and young female catkins at the ends of the branches (Spring).

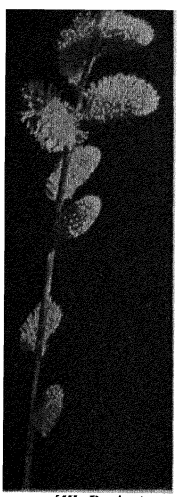
Photos: W. Benington.



a [*W. Benington.*



b



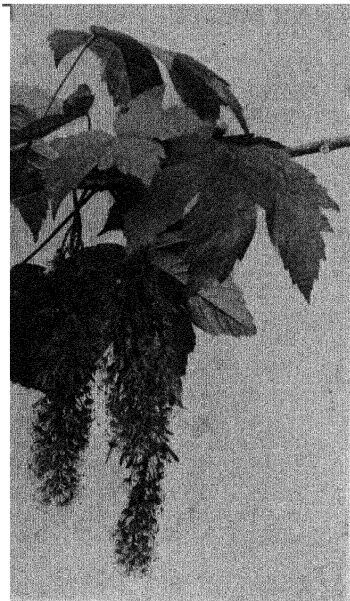
[*W. Benington.*
c



[*W. Benington.*
d

FIG. 68.

a, Poplar (*Populus*) showing male catkins (Early Spring).
b, Alder (*Alnus glutinosa*) showing leaves, fruiting catkins with hard, woody scales, and developing catkins which will open next spring (September).
c, Willow (Aspen) (*Salix*) showing male catkins—"palm" (Early Spring).
d, Plane (*Platanus*) showing leaves and fruits (September).



a [*W. Benington.*



c



b

FIG. 69.

a, Sycamore (*Acer pseudoplatanus*) showing leaves and flowers (Spring).

b, Sycamore showing leaves and fruits (September).

c, Maple (*Acer campestris*) showing leaves and fruits (September).

various shades of red, brown, or green, and show one, two, or several scales which may be smooth or hairy; in shape, they may be short and squat, long and narrow, ovoid, or more or less spherical.

Bark may be thick or thin, quite smooth or with lines, scaly, furrowed more or less deeply, rough or crumpled. In colour, it may be grey, green, brown, or reddish.

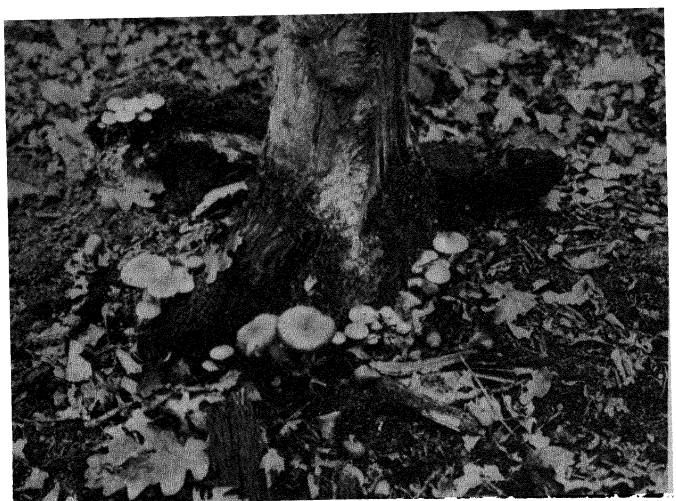
The flowers of most trees are more or less inconspicuous and unisexual. In a few cases male and female are borne on different trees. They may appear before or after the leaves. In the former case they are usually wind-pollinated and at least the male flowers form pendulous catkins. The fruits which result from fertilization are exceedingly varied and adapted for dispersal by very different agencies, the chief of which are wind and animals.

Leaves may be simple or compound, their edges entire or indented, their surfaces smooth or hairy, their petioles short or long. Their arrangement on the twig varies considerably, so that they form characteristic mosaics.

Types of Woods and their Flora.—Most soils in the British Isles which are neither water-logged nor acid and which are at an altitude not exceeding about 1,500 feet are capable of supporting the associations of trees and other plants to which the name "wood" is given. Soil and altitude, however, play important parts in determining the dominance of certain trees. Thus, beech (*Fagus sylvatica*) and ash (*Fraxinus excelsior*) are favoured by a chalky or limy soil, pedunculated oaks (*Quercus pedunculata*) require a deep soil with a plentiful water-supply, though sessile oaks thrive in a shallow and much drier soil at a higher altitude, between 500 and 1,000 feet. Above this birch (*Betula alba*) and evergreens, such as Scots pines (*Pinus sylvestris*), are able to flourish, the former up to 1,500, the latter to 2,000 feet.

The kind of undergrowth, that is, the shrubs and other smaller plants, present is determined partly by soil and altitude, partly by the nature of the dominant trees. The latter are responsible both for the density of the shade and, to a large extent, for the amount of humus

present. Beech, common elm (*Ulmus campestris*) and sycamore (*Acer pseudoplatanus*) all produce very dense canopies of leaves, and therefore when they are dominant the undergrowth is scanty through lack of light. In addition to this, tough leaves, such as those of beech, undergo decomposition so slowly that only a very few plants can persist. In the case of the needle-like leaves of pines decomposition is even slower, especially since



[*The late E. Step.*

FIG. 70.—TOADSTOOLS.

where these trees flourish the amount of moisture present is very small. In most woods, however, there is a rich undergrowth, the general temperature being more constant than in the open, while the ground temperature also has a much smaller range of variation. The latter condition is on account of the covering of dead leaves which, in addition to providing an endless source of nitrogen for the soil, very considerably reduces evaporation. The time of the year is also an important factor.

During the autumn, before the general temperature has fallen and while the surface temperature is high on account of rapid decomposition, many kinds of mushrooms and toadstools are to be found living upon dead leaves, twigs and branches (compare fig. 70). Mosses, liverworts and lichens are often best developed during the winter; they may be on living trees, trunks, branches, or exposed upper parts of roots, on fallen timber or as partial saprophytes

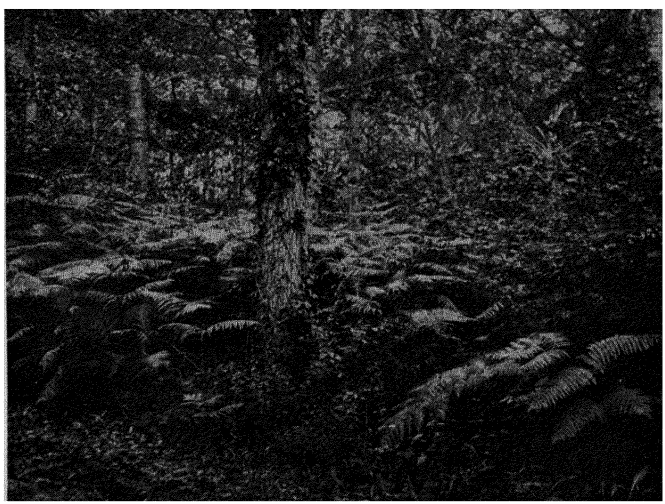


FIG. 71.—TYPICAL OAK WOOD WITH DENSE UNDERGROWTH (JULY). (NEAR NORTH CHAPEL, SUSSEX.)

on the humus in the soil. This sombre carpet, however, is variegated during the spring with plants which flower before the shrubs and trees produce their leaves.

An **oakwood** association contains the greatest number of plant species. In the first place, oaks are seldom the only trees present, ash, birch, beech, hornbeam (*Carpinus betula*), sweet chestnut (*Castanea sativa*), sycamore, lime (*Tilia europaea*), hazel (*Corylus arellana*) and elm often occurring in varying numbers. Then the undergrowth

itself may be dominated by elm-suckers, shrubby hazels, blackthorn or sloe (*Prunus spinosa*) and holly (*Ilex aquifolium*); with these many climbers and scramblers, such as ivy (*Hedera helix*), honeysuckle (*Lonicera periclymenum*) and bramble (*Rubus fruticosa*), may be associated. The smaller herbaceous plants include lesser celandine (*Ranunculus ficaria*), wood-anemone (*Anemone nemorosa*), wood-sorrel (*Oxalis acetosella*), wild hyacinth or bluebell (*Scilla nutans*), dog's-mercury (*Mercurialis perennis*), primrose (*Primula vulgaris*), all flowering in the spring. Later on, others become more evident, such as dog-violet (*Viola canina*), ground-ivy (*Nepeta glechoma*) and foxglove (*Digitalis purpurea*). Grasses are represented by false-brome (*Brachypodium sylvaticum*) and wood-millet (*Milium effusum*), to mention only two. Bracken (*Pteris aquilina*) may be the only fern if the situation is dry, but quite a number of others, such as polypody (*Polypodium vulgare*), flourish in damp woods.

Much of the characteristic flora of oakwood disappears in **birchwood** which occurs on drier soils and often at a higher altitude. Other plants which are found in this association include juniper (*J. communis*), alder-buckthorn (*Rhamnus frangula*), ling (*Calluna vulgaris*), common furze or gorse (*Ulex europaeus*), bilberry (*Vaccinium myrtillus*), heath-bedstraw (*Galium saxatile*) and many grasses.

Ashwood exists on chalky soils poor in humus. Plenty of light penetrates and for this reason there is a varied undergrowth. The wych-elm (*Ulmus montana*), wayfaring-tree (*Viburnum lantana*), spindle-tree (*Euonymus europaeus*), whitebeam (*Pyrus alba*), yew (*Taxus baccata*) with hawthorn (*Crataegus oxyacantha*), privet (*Ligustrum vulgare*), maple (*Acer campestris*) and sloe are among the trees and shrubs. Herb-paris (*Paris quadrifolia*), autumnal crocus (*Colchicum autumnale*), small scabious (*Scabiosa columbaria*), marjoram (*Origanum vulgare*) and other lime-loving species (see also pp. 82–84) are among the herbs.

In **beechwood** associations, also on chalk but usually at a lower altitude than ashwood, the shade is so dense that but few plants are able to survive. Chief among

them are mosses, yew, spurge-laurel (*Daphne laureola*), dog's-mercury, ivy, wood-sanicle (*Sanicula europaea*), broad-leaved helleborine (*Epipactis latifolia*), bird's-nest orchid (*Neottia nidusavis*) and yellow bird's-nest (*Monotropa hypopitys*). The last two are without proper leaves: they are saprophytes living on humus. Where the shade is less dense holly may obtain a footing, while at the edges both this and other shrubs found in ashwood flourish.



[*W. B. Crump.*

FIG. 72.—A BEECH HANGER IN WINTER WITH CARPET OF FALLEN LEAVES. (NEAR ARUNDEL, SUSSEX.)

Pinewood flourishes on all dry soils provided the roots of the dominant trees, pines, can obtain a permanent hold. The dryness may be physical, as in deep sandy soils, or physiological, as in partially drained bogs. With the Scots pine, larch (*Larix europaea*) and the two non-native conifers, spruce (*Picea excelsa*) and Douglas fir (*Abies Douglasii*), are sometimes planted, besides being often grown in separate plantations. The shade under closely-planted pines is so dense that all their own lower branches die off except at the edges of the wood. Prac-

tically the only plants to be found under them are a few mosses and the yellow bird's-nest, while in open places, bracken, a few birch and mountain-ash (*Pyrus aucuparia*), with a little ling, bilberry and bramble, and herbs, such as tormentil (*Potentilla tormentilla*), heath-bedstraw and wood-sorrel may occur.

Most of the trees and shrubs to be found in woods are wind-pollinated and produce their inconspicuous flowers



FIG. 73.—PINE WOOD NEAR GODALMING, SURREY (MAY).

before their leaves unfold, the most outstanding exception being lime, which is pollinated by bees. Where several kinds of trees and shrubs flourish together, oak with hazel for instance, the roots are at different levels; the same is also true of the underground parts of herbs, all of which are nearer the surface than the roots of trees and shrubs. Thus, the rhizomes of grasses are very near the surface, those of bracken are deeper down, and the bulbs of hyacinths, owing to the action of their contractile roots, deeper still.

The Fauna of Woods.

(*a*) **Birds.**—The abundant cover provided by woods shelters animals of all kinds, except those which are peculiar to water. The most outstanding are birds, from large birds of prey, such as the sparrow-hawk, to the diminutive little goldcrest. The former makes a large nest of sticks near the top of a tall tree, usually a pine, and feeds upon small mammals, insects and smaller birds and their eggs. Most of its food it catches while on the wing, grasping and carrying it in its long toes armed with sharp curved talons and tearing it to pieces with its powerful hooked beak. The latter constructs a beautiful, little and almost spherical nest of moss, lichen, hair and cobwebs hidden and nearly always suspended in a yew, holly or some other low shrub, and its food consists of small insects caught with its very small beak. Between these two extremes is a long series showing wonderful diversity in nesting habits, in structure and in feeding. The wood-pigeon is well known by its clattering heavy flight and from its raids on newly-set peas, young cabbage-plants and corn "in the ear". It lays only two almost spherical white eggs in a nest of sticks placed high up in a tree, but the small number is balanced by the fact that three broods may be reared in a period extending from March to November. Two gaily-plumed members of the crow family, the magpie and the jay, which also build large nests, are often persecuted because they do a certain amount of harm to young domesticated birds and fruit. Though the former is usually said to be black and white it is really a very handsome bird, for brilliant prismatic greens, blues and purples glitter through the black. The jay is even more beautiful: not only does it possess an erectile head-crest of black and white, but the reddish-brown background of the rest of its plumage is interspersed with bright blue and white. Both of them are, however, eclipsed by the green woodpecker with its red crown and bright green and yellow wings. In many places this bird is called the "yaffle" and is better known from its call, resem-

bling a rather hoarse laugh, than from its appearance. Both it and its two smaller relatives, the great-spotted and lesser-spotted woodpeckers, are essentially tree-dwellers and all owe their popular name to the fact that a wood often resounds to the noise made by their powerful beaks when they are busy hammering holes into diseased timber. This they literally riddle in their search for insects, while in other timber which, though hard on the outside, is rotten within, they make their nesting-holes. A good deal of the tapping noise is due to their habit of testing the trunks of trees before they begin to

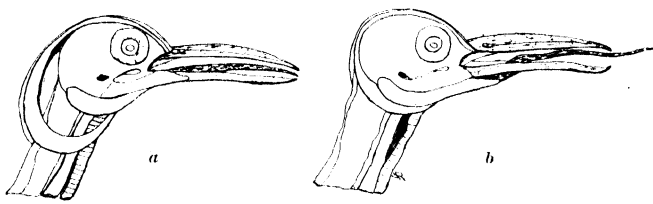


FIG. 74.—THE TONGUE OF THE GREEN WOODPECKER.
a showing tongue retracted, *b* tongue protracted. (× about ½.)
(*From preparations in the British Museum* (*Natural History*).)

peck into them, the sound emitted enabling them to judge whether a particular place is likely to be suitable or not. At other times the tapping or "drumming", especially in the case of the two spotted woodpeckers, is a definite sex-call, and it is possible that for this they locate hollow boughs which will make the best sounding-boards. They are all able to climb actively about a tree trunk, using both feet and tail. The toes are arranged in opposed pairs and are armed with sharp re-curved claws, the tail quill-feathers are rigid and end in stiff points which stick into the bark. The tongue is one of the most remarkable known, for not only is it long and pointed and with a hard tip beset with backwardly-pointed spines, but some of its skeletal structures arch right over the cranium into the base of the beak and thus allow of very rapid protrusion (see fig. 74). With

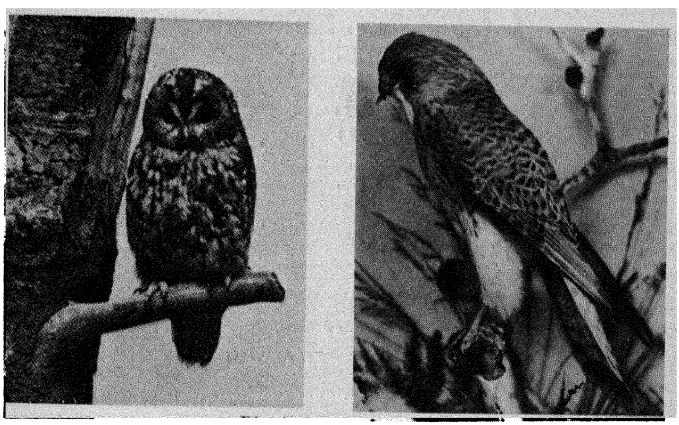
this extraordinary weapon woodpeckers are able to transfix and withdraw insects from their retreats deep down in crevices and burrows. The nuthatch and the tree-creeper are two other birds which are able to climb about the bark of trees in search of minute insects, though the former as its name implies, is also fond of nuts and seeds. The long-tailed, coal, marsh, and blue tits may often be seen hanging upside down on the same insect-hunting errand.

Of the birds which live to a very large extent on the ground, the woodcock, though not entirely confined to woods, is one of the most striking, but being both a late migrant and nocturnal in habit it is not so well-known as many other birds. It has a long probe-like beak with an extremely sensitive tip. The whole beak is often plunged as far as its base into soft spongy ground in search of worms and other inhabitants; in correlation with this the eyes are relatively far back and thus "out of the way," and the ears very far forward and therefore in a good position for hearing any sounds made by burrowers when the head is near the ground. The nightjar is another shy nocturnal bird, but unlike the woodcock it feeds entirely on moths and other night-flying insects which it catches on the wing; for this purpose its mouth has a very wide gape fringed with long hair-like feathers. Both these birds build their nests in bracken-covered retreats where not only their own mottled-brown plumage but also the colours of their eggs harmonize so completely that it is extremely difficult to see them. The nightjar's plumage is duller than that of the woodcock, and this bird has a habit of crouching flat and quite motionless along a fallen tree-trunk and may therefore be overlooked completely.

Birds of prey include not only the sparrow-hawk and sometimes the kestrel, both of which are diurnal, but also the nocturnal long-eared and tawny owls. These nest in hollow trunks and similar places but, except when sitting, spend most of the day sleeping on a branch where their mottled plumage helps to hide them against the patches of light and shade produced by the foliage.

Their toes are even more prehensile than those of the hawks, since the outer is reversible and the usual position during perching is two in front and two behind. Their food occasionally includes small birds, but consists principally of rats, mice, voles and other small mammals, many of which are extremely harmful, so that they are really among the very best friends of the human race.

No account of even a few birds whose main habitat is a wood could be considered complete without some



a *Birmingham Museum.* *b*

FIG. 75.

a, tawny or brown owl (× about $\frac{1}{8}$); *b*, kestrel (× about $\frac{1}{6}$). Note the position of the toes of each.

mention of the wood-warbler or wood-wren and the chiffchaff. Both are summer visitors, though in mild winters the latter may remain in the south-west of England and in Ireland. The wood-wren is found chiefly in open woodlands where oaks and beeches predominate, but the chiffchaff also inhabits thicker woods and gardens, though, except in very cold weather, it sings mostly from the tree-tops. Both feed on insects and build domed nests, the wood-wren in depressions in the ground, the chiffchaff just above the ground.

(*b*) **Mammals.**—Most mammals which find shelter in woods are so wary that but few people know any of them by sight except the fox, the red squirrel (the grey squirrel is an importation from Russia), and in a few places where they are preserved the roe-deer, the fallow-deer and the red-deer. Other carnivorous forms besides the fox are the stoat, the weasel, which is more commonly found in hedgerows, and their larger relatives the pine-marten and the polecat, the former now very rare, the latter extremely local. The stoat is larger than the weasel, its tail about half as long as the rest of the animal and with a black

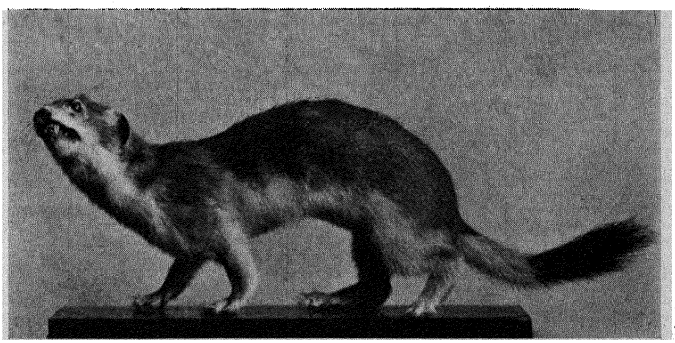


FIG. 76.—STOAT. (ABOUT $\frac{1}{3}$.)

tip, whereas that of the weasel is not more than a quarter the length of the head and body and its colour is uniform. Both do a great deal of good by destroying mice and other harmful small mammals, but they also prey upon rabbits, hares and birds, including an occasional one from a farm or preserve. During winter in places where conditions are really severe, such as in the extreme north of the British Isles, stoats assume a white pelage tipped with black and are then known as "ermines". Related to them is the badger which makes large burrows, often among the roots of trees, usually not alone but in company with others so that an "earth" may be of considerable extent. From this nocturnal journeys are made

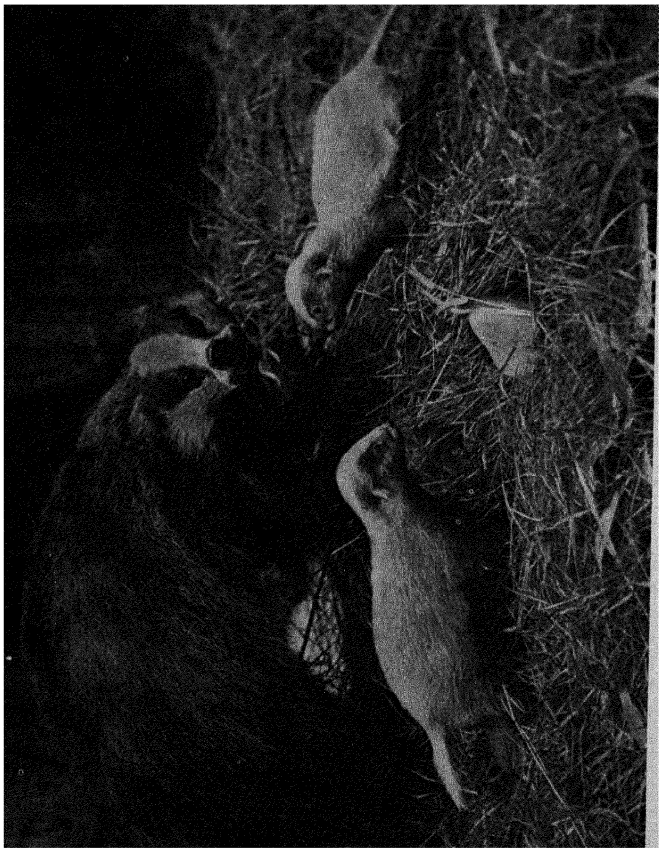


FIG. 77.—BADGER AND YOUNG.

in search of food, which varies from hyacinth or bluebell bulbs to fruit, young rats, mice, wasp grubs and other insects, and occasionally a bird, the diet varying with the food most easily obtained provided this is not too near the " earth ". Squirrels differ from all other rodents or gnawing mammals included in the British fauna by making their nests, very closely resembling those of some birds, in trees. Like their smaller relatives the wood or long-tailed field-mouse and the field-vole (see fig. 63, p. 88), which are both also common in fields, they store food during the autumn and hibernate, that is, pass the winter in a state of torpor. They differ, however, from these other two rodents by waking up occasionally on very bright days, resorting to their stores and returning to " sleep ". Many other small mammals hoard food during the autumn, not so much to provide winter supplies but for use during early spring before new " stocks " are to be found.

(*c*) **Other Animals.**—Invertebrates of literally thousands of different kinds flourish in woods : nematodes or threadworms among the decaying humus, some also attacking living plants ; slugs and snails of various kinds, prominent among them the black slug (*Arion ater*) which is not only a carnivore but often a cannibal ; earthworms of many kinds, some of them beneath the bark of decaying branches and tree trunks ; centipedes and millepedes, spiders and mites, woodlice, all in great variety, and, more numerous than all the others put together, insects of every order. Many of them feed on the decomposing plant remains, others prey upon these, but many attack the living plants themselves and are in turn hunted by others. Some larvae, notably those of the goat-moth (*Cossus ligniperda*), of the longicorn beetles, so-called because they have very long antennae, and of the wood-wasp (*Sirex gigas*) feed by eating their way through the wood of various trees, while other beetles are known as " bark-beetles " because their grubs tunnel in the bark and outer living tissues. Still others, such as the cockchafer (*Melolontha vulgaris*), whose larva is referred to on page 115, devour the foliage of many

trees and sometimes cause serious trouble in timber-growing districts. The larvae of many Lepidoptera, too, feed on the foliage of various trees. During May and June that of oak and other trees is sometimes seriously damaged by the attacks of caterpillars of the oak-moth (*Tortrix viridana*). These are green with black spots, while the moths when at rest on a twig may well be overlooked, since their green fore-wings conceal the somewhat glassy hind-wings, which are of a pale smoky hue.

In many woods, especially those in which there are

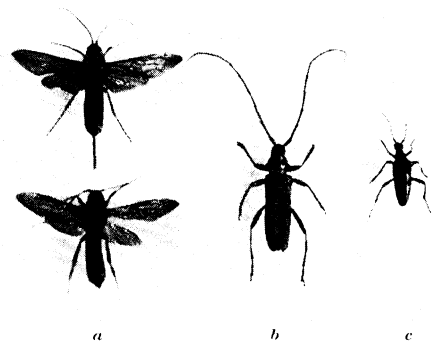


FIG. 78.

a, giant wood-wasp (*Sirex gigas*), female above, male below; *b* and *c*, longicorn beetles (*b* is *Aromia moschata*, *c*, *Rhagium difasciatum*). (× ⅔.)

pines, large heaps of leaves and small twigs are abundant; though these may be as much as four feet in height and eight in length they are the work of quite small insects, the red or wood-ant (*Formica rufa*). Further accounts of many other animals present in woods are given in the section on gardens (pp. 112–120).

Hedgerows.—Hedgerows harbour plants of almost every type and provide a series of very instructive associations. In many cases a large number of very different conditions is found within a relatively small area.

The aspect, the nature of the substratum, both of the hedge itself and of the land adjoining it, and the trees and shrubs, which are the dominant members, all vary greatly.

The aspect is of very great importance : it determines the exposure to sun and prevalent winds. Naturally a hedge association extending north and south, that is, with east and west aspects, is much richer than one at right angles to this direction. The sub-associations on the two sides also differ, but more so in the case of those with north and south aspects. The smaller members are in competition with each other for two interdependent necessities, light and support, and for this reason climbing and shade-loving species are numerous. The hedge may be kept cut so as to maintain a more or less uniform height ; where this occurs some plants are not allowed to grow to their full stature. The substratum may be the same as, and level with that of the neighbouring associations, or the hedge may be " built " on a bank standing well above the adjoining ground on one or both sides ; it may be edged by a water-containing ditch, a dry road, moorland, heath or cultivated ground ; quite often it forms the boundary to a wood and then resembles that association in many respects.

From the above it should be obvious that the conditions under which hedgerow plants thrive vary enormously, and when studying the association it is of the utmost importance that notes of all these factors be made on the spot.

The hedgerow-proper may consist of only one kind of tree or shrub, or it may contain several kinds. Oak, elm, ash, willow, lime, poplar, and crab-apple (*Pyrus malus*) are the usual trees. Hawthorn (*Crataegus oxyacantha*), elder (*Sambucus nigra*), hazel, blackthorn or sloe (*Prunus spinosa*), holly (*Ilex aquifolium*), furze or gorse (*Ulex europaeus*) in certain parts of the country, privet (*Ligustrum vulgare*) and pollarded maple (*Acer campestris*), beech and oak constitute the commonest hedge shrubs. Climbers and scramblers growing through these on their way to the light include honeysuckle (*Lonicera periclymenum*), bindweeds (*Convolvulus arvensis,* the field-

bindweed and *C. sepium*, the larger great bindweed) and hop (*Humulus lupulinus*), all with twining stems ; traveller's-joy or old man's-beard (*Clematis vitalba*) with twining petioles, bush-vetch and tufted-vetch (*Vicia sepium* and *V. cracca*) with typical leaf-tendrils, white bryony (*Bryonia dioica*) with large spring-like tendrils, and ivy



FIG. 79.—PART OF A LOW HEDGEROW SHOWING CLIMBERS (AUGUST)
a, great bindweed (*Convolvulus sepium*) ; *b*, cleavers (*Galium aparine*) ; *c*, bush-vetch (*Vicia sepium*), half-way up the plate.

(*Hedera helix*) with climbing roots ; dog-rose (*Rosa canina*), brambles (*Rubus fruticosus*) and cleavers or goose-grass (*Galium aparine*) which scramble by means of thorns and hooks.

Many of the non-climbing flowering plants which live within the shade have either long and narrow or much divided leaves : they are thus able to make the

most of the narrow shafts of light which penetrate the upper foliage. Others present are definitely shade-loving species, such as dog-violet (*Viola canina*), primrose (*Primula vulgaris*), ground-ivy (*Nepeta glechoma*) and cuckoo-pint (*Arum maculatum*). Where the shade atmosphere is moist, ferns are prominent, hart's-tongue (*Phyllitis scolopendrum*) being often very conspicuous. In many cases one particular species dominates the others : wild beaked-parsley (*Anthriscus sylvestris*), garlic-mustard or Jack-by-the-hedge (*Alliaria officinalis*) and stinging nettle (*Urtica dioica*) are three common examples of such flowering plants.

All hedges harbour animals of many kinds, those with a southern aspect being favourite nesting-sites for birds. Insects are numerous everywhere, slugs and snails prefer damp shade, while the bottom of the hedge and the bank may be literally alive with small mammals, such as field-mice, dormice, voles, shrews and hedgehogs. The last two of these are insectivorous, feeding on worms and insects, but the others are mainly, some of them entirely, herbivorous and often do a considerable amount of damage to growing plants, including trees. Rabbits, too, inhabit hedge-banks when these consist of relatively dry and loose soil, tunnelling into and under them and making their nests of dry grass at the ends of the tunnels.

Gardens.—Although general conditions in a garden are artificial they result in a very characteristic flora and fauna. The weeds of the more intensely cultivated parts are chiefly annuals, many of them sprouting, flowering and producing seeds within a very short time, so that a number of generations arise during one summer. Groundsel (*Senecio vulgaris*), common chickweed (*Stellaria media*), mouse-ear chickweed (*Cerastium vulgatum*), shepherd's-purse (*Capsella bursa-pastoris*), germander speedwell (*Veronica chamaedrys*), scarlet-pimpernel (*Anagallis arvensis*), common sow-thistle (*Sonchus oleraceus*) and annual meadow-grass (*Poa annua*) which may also behave as a perennial, are a few of the commonest of these ephemerals. Perennial weeds are represented by such

plants as buttercups, both creeping and bulbous, lesser celandine (*Ranunculus ficaria*), gout-weed (*Aegopodium podagraria*), dandelion (*Taraxacum vulgare*) and both the field-bindweed and larger great-bindweed (*Convolvulus arvensis* and *C. sepium*), the latter twining round gooseberry or other bushes and not only strangling them but exhausting the soil with its roots, the former being very common on light soils either trailing on the ground or climbing up short plants, including gooseberry bushes.

The fauna includes both vegetarian and carnivorous feeders. The former are enemies to gardeners, but the latter prey upon some of them and are therefore regarded as beneficial; unfortunately, however, there are many more of the former. Earthworms are usually present in countless numbers. They are of the utmost importance, as was first shown by Charles Darwin.* While burrowing they not only open up channels for both water and air but also help in the formation of more soil. They bring material from the deeper layers to the surface, and leaves and other matter from the surface into the general mass. During feeding they ingest both soil and organic matter and void the indigestible remains in the form of the extremely fine material which constitutes the well-known casts. Harmful animals include snails, especially the garden-snail (*Helix aspersa*), and their relatives devoid of an outside shell, such as the field-slug (*Agriolimax agrestis*). Both these are active only during damp and relatively warm periods, being busiest on summer nights, and leaving behind them their trails of slime. During the winter slugs often bury themselves, while snails resort to such places as hollows and crannies in rockeries and close their shells with a " door " of hardened mucus.

Arthropods are represented by woodlice among the crustaceans, centipedes and millepedes, numerous insects and spiders. *Oniscus asellus* is an example of a woodlouse which, though mainly a scavenger, sometimes does considerable damage to plants, especially to greenhouse-plants. Myriapods provide excellent illustrations to the

* *Vegetable Mould and Earthworms* (1881).

general rule that a dangerous-looking arthropod is a friend, a harmless-looking an enemy to the tiller of the

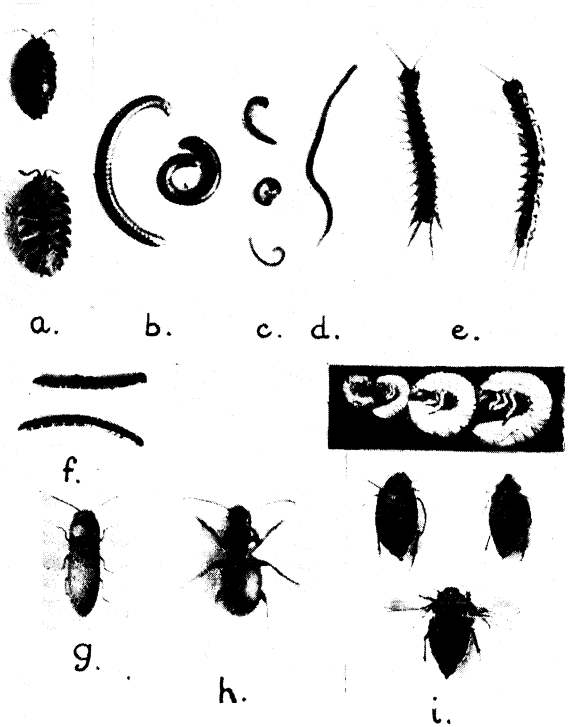


FIG. 80.—GARDEN ARTHROPODS.

a, woodlice (*Oniscus asellus*); *b* and *c*, millepedes (*b*, *Julus*, *c*, (above), *Polydesmus* (below) *Blanjulus*); *d* and *e*, centipedes (*d*, *Geophilus*, *e*, *Lithobius*); *f*, wireworms, larvae of click-beetles; *g*, adult click-beetle (*Agriotes*); *h*, adult ground or carabid beetle; *i*, cockchafer (*Melolontha vulgaris*); above, larvae at different stages of growth; below, adults; top left, male; top right, female. (*a–f* natural size; *g* × 2; *h* × about 1½; *i* × ½.)

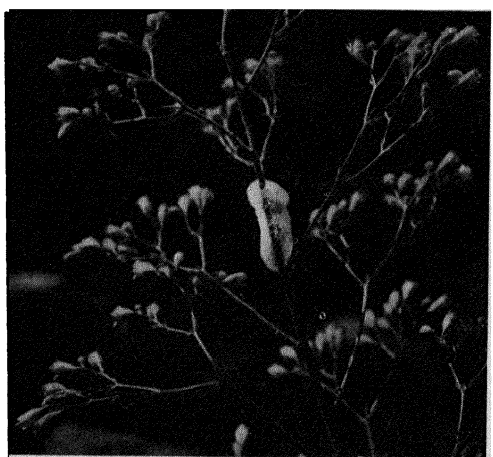
soil. Centipedes are useful because they are carnivores preying upon other species many of which are vegetarians.

Since they are predaceous they have well-developed heads with strong jaws, large eyes and antennae, a pair of strong legs to each segment of the flattened body, strong terga and sterna. In addition, the first pair of legs is modified to function as poison-jaws. The whole appearance is fierce and formidable. Millepedes, on the other hand, have small heads with small antennae and relatively small jaws, the segments of their bodies are much more numerous, almost circular in section and each bears two pairs of very small legs. When disturbed they curl up and rely upon the thickness of their exoskeleton to protect them. Their appearance is anything but formidable. They are, however, among the worst enemies of the cultivator; they feed chiefly on the roots and other underground parts of plants including potato tubers, in the latter of which they even breed. The common centipede (*Lithobius forficatus*) is deep chestnut-brown, the common millepede (*Julus terrestris*) blackish in colour. The former lives under stones and beneath the bark of dead wood; the latter may be found in this last situation, but its usual habitat is in the ground.

Many insects and their larvae afford the same kind of contrast. Leather-jackets and wireworms, for instance, both look harmless but do incalculable harm, especially in lawns, by eating off young roots. The former, the larvae of the daddy-long-legs (*Tipula oleracea*), are dull greyish, worm-like grubs. The latter, the larvae of click-beetles, such as *Agriotes lineatus*, are orange-brown in general colour but with a darker head; they have a stiff body with three pairs of absurd little legs. Other beetle larvae haunting the same places have white bodies with brown terga and sterna; their strong heads bear well-developed eyes, antennae and formidable jaws, whilst the thoroughly armoured thorax carries three pairs of stout legs. These give rise to active carabid beetles, most of which continue the predaceous habits of the larvae. The cockchafer (*Melolontha vulgaris*), on the other hand, is an example of a beetle which not only does damage by its vegetarian habits during its adult stage, but has a large ugly larva which attacks the roots

of plants. It lives for three years in the larval state feeding upon rootlets, and by the end of this time has attained a length of about two inches. Its natural enemies are moles, field-mice and certain carnivorous beetles.

Caterpillars of many Lepidoptera and of various Hymenoptera are often so abundant that they constitute serious pests. Among the most frequent are those of the currant moth (*Abraxas grossulariata*), the cabbage



[*D. A. Webb.*

FIG. 81.—"CUCKOO-SPIT."

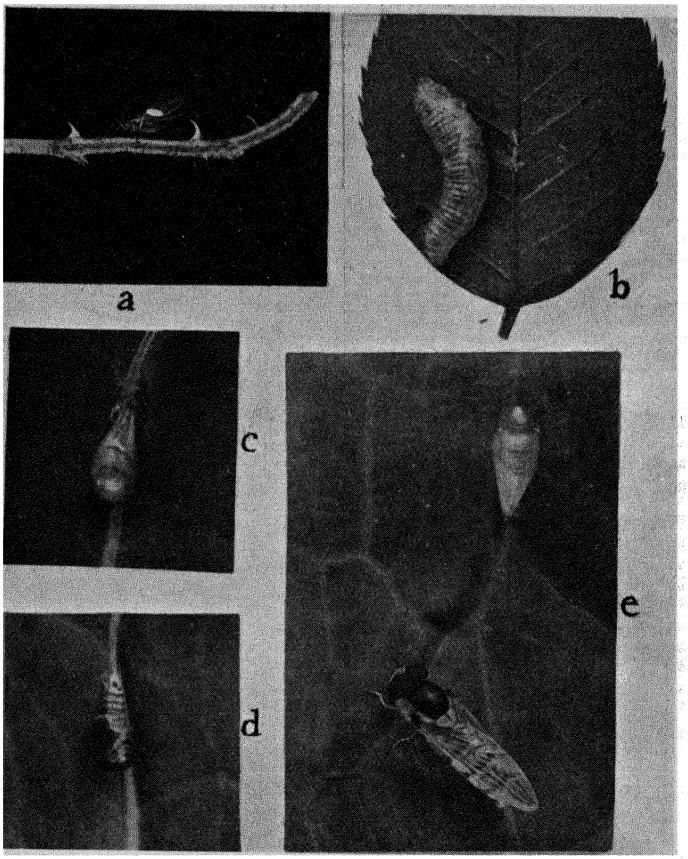
moth (*Mamestra brassicae*), the cabbage white butterflies (*Pieris brassicae* and *P. napi*) and the currant sawfly (*Nematus ribesii*). Their presence, like that of many other insects, such as various aphids, is due to abundance of the respective food-plants. These aphids or plant-lice include green-flies, black-flies and American blight. They all produce numerous generations of females from unfertilized eggs during the summer and then in the autumn males appear. Fertilized eggs are usually deposited in sheltered places, such as crevices in the bark

of trees, and the young emerge in the following spring. "Cuckoo-spit insects", which are the larvae of other plant-lice, frog-hoppers, are often abundant on many plants, not only in gardens but in many other situations also. They feed on sap, which they obtain through punctures made by their piercing and sucking mouth-parts. The "spit" itself is formed by whipping the surplus fluid and air from the anus with the hind-part of their bodies; it provides them with both food and protection during their younger stages. The froth begins to appear at about the same time as the call of the cuckoo is first heard, and the adults, which are expert jumpers, resemble very miniature frogs in general appearance—hence their names. One of the commonest is *Philaenus spumarius*.



FIG. 82.—ICHNEUMON-FLIES, FEMALE ABOVE, MALE BELOW. (× ABOUT 1.)

All these harmful insects in turn attract others which prey upon them. Chief of these are the usually very small ichneumon-flies, which lay their eggs in caterpillars and other larvae, or even in the eggs of Lepidoptera. The resultant grubs feed on their "hosts" without killing them until they themselves are ready to pupate. The little chrysalides attached to the skin of a dead caterpillar and usually covered by a cocoon of golden silk are often referred to as "caterpillars' eggs". Aphids, too, have a number of enemies amongst insects. These include the larvae of hover-flies, true flies which closely resemble bees and wasps, of lacewing-flies which are more nearly related to dragonflies, and of the little red or orange beetles with black spots, generally known as "ladybirds". The first are small maggots whose appearance is very slug-like, the second are small hairy semi-transparent larvae with strong legs and large protruding mandibles, whilst the last are small angular multi-coloured creatures with rather less well-developed legs and jaws.



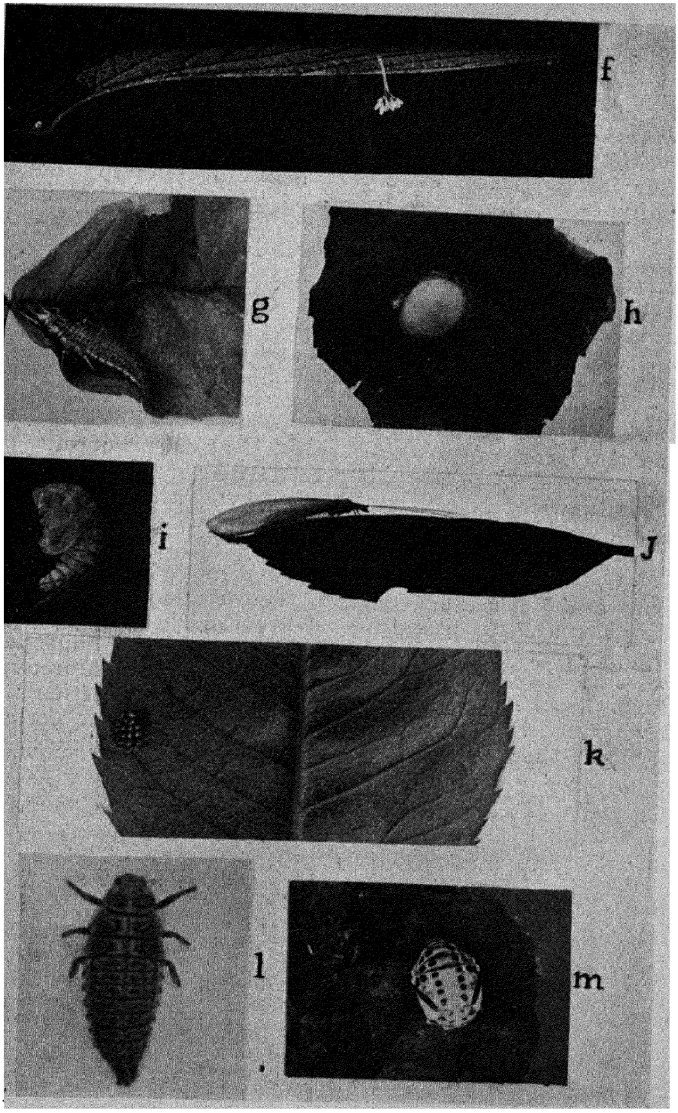
[*Hugh Main, Esq.*

FIG. 83.—BENEFICIAL INSECTS.

a–e, hover-fly (*Syrphus*); *f–j*, lacewing-fly (*Chrysops*); *k–m*, ladybird.

a, eggs on wing of aphid; *b*, larva; *c*, fresh puparium; *d*, mature puparium; *e*, imago just emerged.

f, eggs (× 3); *g*, larva; *h*, cocoon; *i*, pupa (× 3); *j*, imago (× 1). *k*, cluster of eggs; *l*, larva (*Adalia*) (× 5); *m*, pupa (*Anatis*). (*The photographs are twice natural size except where otherwise stated.*)



[*Hugh Main, Esq.*

Many insects which are harmful during some periods of their life-history are beneficial during others. Lepidoptera offer some of the most outstanding examples, for, though their larvae feed on various parts of plants, their imagines are essential agents in effecting cross-pollination. Many flowers are so constructed that their nectar can be reached and their stigmata and stamens rubbed only by insects with long, narrow "tongues". At the other extreme are small flies and beetles which carry pollen from stamen to stigma when walking about an inflorescence, such as that of a composite. A number of these deposit their eggs in holes made through the epidermis, and the grubs which hatch out burrow into the food-supply with which they are surrounded.

Wasps, though hated for the damage they do to fruit and the consternation they cause if at all numerous, do a great deal of good: they feed their larvae on many other kinds of insects and their larvae, the majority of which are harmful from the gardeners' standpoint. Ants also do an incalculable amount of good, for, in addition to effecting cross-pollination as they move about flowers, they are general scavengers. Unfortunately, however, they are able to make use of practically every kind of organic material and may therefore become household pests if they once find their way indoors. Moreover, during some years when conditions are particularly favourable, they may be so numerous during the periods of flight that they become an intolerable nuisance.

CHAPTER VI

HUMAN HABITATIONS AS THE ENVIRONMENT

Inhabited houses, stores and warehouses, as well as many boats, both cargo and passenger, all provide the same general environmental conditions as each other, namely, protection, warmth and plentiful and usually very varied food-supplies. They therefore include extremely favourable habitats for various kinds of organisms, chiefly animals. Indeed, many organisms have become so closely associated with human abodes that they are practically, in a few cases completely, unknown away from them.

Some are brought in with, or attracted by supplies, especially of dried foods, some by wood and other furnishings which provide them with food and shelter, others by the debris which is plentiful in even the most scrupulously kept houses, still others by man himself. Many others, mainly birds and rats in temperate countries, find nesting and resting sites both on and within our buildings, and from these small unwelcome invaders sometimes enter.

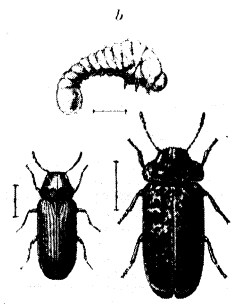
Though by no means the most domesticated, the brown or Hanoverian rat is the most important of our uninvited guests. It does damage both by burrowing through and gnawing away structures of practically every kind of material, not excepting even lead and concrete, and by eating and soiling food and other stored materials. The so-called old English, or black rat is still found on some ships, in ports and in a few places where it has not been exterminated by the larger and more recent invader from the East. It is somewhat smaller in size, but with larger ears and a longer tail than its now more abundant rela-

tive. It is also an expert climber and has a milder temper (white and piebald tame rats are varieties of this species), for which reason its territory has been rapidly, but not completely, taken over by the brown rat since the latter's first advent into Britain about 1730. The house-mouse is far more numerous, especially in houses, but probably not so numerous as it is sometimes thought to be, since field-mice, voles and shrews, which invade our domiciles on the approach of winter, are often mistaken for it. In general habits rats and mice resemble each other, though the brown rat is much more cunning than any of its relatives.

Cockroaches, the common cockroach (*Blatta orientalis*) and the smaller so-called German cockroach (*Blatella germanica*), still often called black-beetles though they are brown in colour and orthopterans not beetles (Coleoptera), are sometimes unpleasantly numerous in houses. They too are invaders which have gradually ousted previous tenants, in this case other orthopterans, house-crickets (*Gryllus domesticus*). The common cockroach has spread more or less throughout Great Britain since the end of the sixteenth century, while the German has become firmly established in many districts since about 1850. With very loosely built and exceedingly depressed bodies and powerful legs, these insects are able to squeeze through remarkably narrow chinks. They are fond of damp and warm places in the dark, and are able to feed not only on ordinary food materials but even on hair, leather, paper and plaster. They therefore flourish in such places as basements, kitchens and bakehouses, especially about ranges, behind and beneath radiators, hot-water pipes, behind skirting boards and in similar places. They come out to feed during periods of darkness. A much larger species, the American cockroach (*Periplaneta americana*), is found on board ship, in breweries, in many stores, in cages in zoological gardens and sometimes in houses. It is lighter in colour and both sexes are fully winged, whereas in the other two the wings of the female are represented by very incomplete elytra.

Though cockroaches do an immense amount of harm, especially by tainting food with their foetid secretions, they have two points in their favour. They act as scavengers and they search out and devour bed-bugs (see p. 125). In some places their relation, the house-cricket, which is still more closely related to grasshoppers and locusts, still holds its own. Though less catholic in its tastes, this creature closely resembles cockroaches in its general habits. The "chirping" sound it makes by rubbing special parts of its elytra against each other, which has been immortalized by Dickens, is the feature by which it is best known.

In some cases, beetles—ground-beetles, devil's coach-horses and the so-called cellar beetles—are also to be found in kitchens and basements. The first two are carnivorous, while the last appear to live on plaster and fine debris. The timber of floors and other structures, the wooden parts of furniture, stored food and other dry materials, provide other beetles with food and shelter during most of their lives. Timber pests include the death-watch beetle (*Xestobium rufovillosum*) and the common furniture beetle (*Anobium punctatum*). In habits all these small beetles resemble each other very closely. Eggs laid in crevices or borings give rise to small white grubs which eat their way through the wood, passing back into the burrows the indigestible remains of their food. This takes the form of frass or fine powder, small heaps of which outside affected wood often afford the first recognized indications of the presence of the marauder. When fully fed the larvae pupate, usually just within the wood, and finally the imagines appear on the surface, where they pair after having bitten their way out.

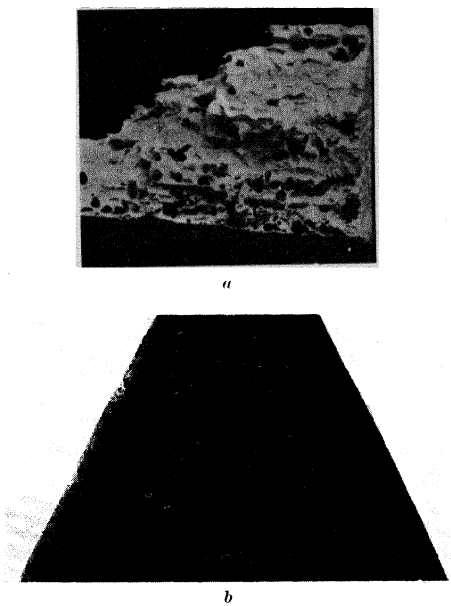


[*British Museum*.

FIG. 84.—FURNITURE BEETLES.

a, common furniture beetle (*Anobium punctatum*); *b*, larva of *Anobium*; *c*, death-watch beetle (*Xestobium rufovillosum*).

The small " shot " holes in timber and furniture attacked by the " worm ", as the grubs are usually called, are in most cases exits of this kind. The " ticking " of some of these beetles, notably of *Xestobium*, is a sex-call made by knocking the front of the head against the surface



a

b

FIG. 85.—WOOD SHOWING DAMAGE BY THE DEATH-WATCH BEETLE (*XESTOBIUM RUFOVILLOSUM*.)

a, interior of a piece of wood, showing damage done by the grubs ($\times \frac{3}{4}$); *b*, surface view of a piece of wood showing exit holes caused by the young imagines ($\times$ about $\frac{1}{2}$).

on which the insect is standing. Responses have been obtained to " calls " made by tapping with a pencil.

Dry food, especially ships' biscuits and cattle cake and meal, are favourite breeding-places for other beetles. Of

these *Anobium paniceum*, the so-called biscuit weevil,* is the best known. It is all but omnivorous and thrives equally well on a diet of ginger, pepper, opium, paper or almost any other organic matter. It is run very close by *Ptinus tectus*, first brought to this country some twenty years ago in cargoes of Argentine maize, and now spreading throughout Great Britain and Ireland. The only material which this species has refused to eat during a great many experiments is billiard-table cloth.

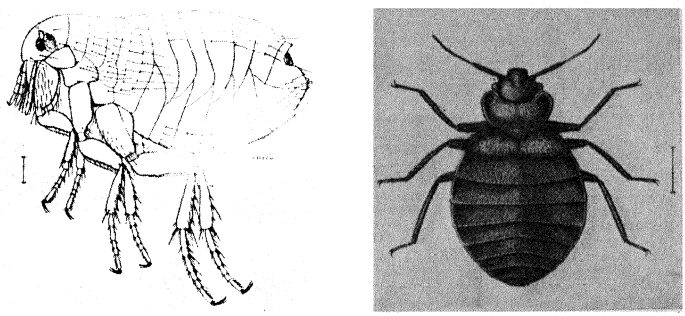
Conditions favourable to such beetles also suit many kinds of moths. The European flour or biscuit-moth, *Ephestia kühniella*, is frequent in flour-mills and biscuit factories, and the fig-moth, *E. cautelli*, in figs, apricots and other kinds of dried fruit. Cheese, flour and raw-sugar often harbour myriads of extremely small mites, of which the best known is *Tyroglyphus siro*, the cheese-mite. All these may find their way into our larders and pantries with groceries. Clothes-moths, however, principally *Tinea pellionella*, are better known to the housewife. These breed among furs, in clothes, carpets and other articles containing wool. The larvae are readily distinguished by the fact that they cover themselves with a tubular case formed from faecal pellets containing undigested wool-remains.

More intimately connected with man himself are the common flea (*Pulex irritans*) and the bed-bug (*Cimex lectularius*), both of which are suckers of human blood (see fig. 86). *Pulex* lays its eggs and undergoes a complete metamorphosis in the dust between floor-boards, in upholstery and similar places. *Cimex*, on the other hand, congregates behind picture-rails, wainscoting and in other dark places, from which it makes nocturnal excursions on its long legs against unwary sleepers. The eggs are laid in their hiding-places and are cemented down by their bases; the larvae which emerge from them are very like miniature adults and undergo a very incomplete

* The name weevil is properly restricted to curculionid beetles, all of which are characterized by having the front of the head prolonged into a " beak " from the sides of which the elbowed antennae project.

metamorphosis. Whereas fleas are the only laterally compressed parasites, bed-bugs are among the most completely depressed.

The abundance of organic matter, both food for human consumption and the waste products resulting from human activity, not even excluding faeces, attract a great many different kinds of flies. Of these one of the most abundant is the common housefly, *Musca domestica*, which, though it does very little visible damage, is of



a *b* [*British Museum.*

FIG. 86.—*a*, THE HUMAN FLEA (FEMALE) (*PULEX IRRITANS*), SIDE VIEW (× ABOUT 12); *b*, THE COMMON BED-BUG (FEMALE) (*CIMEX LECTULARIUS*), DORSAL VIEW (× ABOUT 5.)

extreme importance as a carrier of harmful bacteria from faeces and other decomposing matter to food.

Stored products which are not absolutely dry, including bread, jam, meat, leather, paper and fruit, especially when kept in dark and damp places, provide ideal conditions for many bacteria, and moulds, such as *Mucor* and *Penicillium* of various species, whilst floors, wainscoting and window-frames made of incompletely seasoned timber, unless they are very thoroughly ventilated, encourage the fungi of dry-rot, *Merulius lacrymans* for example.

In addition to harbouring these and many other small organisms, our buildings provide shelter and nesting sites

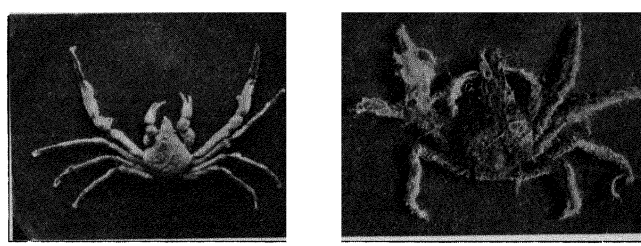
to such birds as house-sparrows, starlings, house-martins, swallows, jackdaws and barn-owls, and to the common, long-eared and other bats. From these and their nests various kinds of fleas, lice, bugs and mites sometimes make invasions.

CHAPTER VII

THE ORGANISM ITSELF AS THE ENVIRONMENT

From what has been said in previous chapters, especially the last, it is obvious that organisms themselves play a very considerable part in determining the conditions in any particular habitat. It is clear also that in many cases they are the determining factor upon which the presence or absence of other organisms depends.

Epiphytes and Epizootics.—In some cases one kind of organism settles on and becomes fixed to another kind



a *b*

FIG. 87.—EPIPHYTES AND EPIZOOTICS.

a, sponges covering spider-crab (*Inachus*); *b*, seaweeds masking spider-crab (*Hyas*).

which it uses merely as a mechanical substratum. Smaller seaweeds attached to larger, sessile animals, such as sea-firs, sea-mats, sea-squirts and many kinds of barnacles growing upon seaweeds, mollusc-shells, crabs, etc., are examples. Plants with this habit are known as epiphytes, animals as epizootics. Lichens, mosses and many ferns

which grow on trees are generally called epiphytes, though they usually obtain a certain amount of their food-supplies from material, such as dead leaves, which accumulate on the bark.

Commensalism.—Under this term, which means literally "feeding at the same table", are included many



FIG. 88.—HERMIT CRABS WITH COMMENSALS.

a, The little hermit (*Eupagurus prideauxi*) and the cloaklet anemone (*Adamsia palliata*).

1, dorsal view showing enveloping base of anemone; 2, ventral view showing tentacles of anemone and crab enclosed within the base of the anemone.

b, The hairy hermit (*Eupagurus cuanensis*) and the fig-sponge (*Ficulina ficus*).

1, ventral view showing entrance to home of crab, and a small portion of sponge removed from region which originally contained shell; 2, Dorsal view showing osculum of sponge.

kinds of partnership between different animals. In what may be called real commensalism both partners are definitely benefited, but in many cases, so far as can be seen, only one derives any advantage; from this stage it is but a step to parasitism. Anemones and hermit-crabs afford some of the best examples. The little hermit (*Eupagurus prideauxi*) usually has associated with it the anemone *Adamsia palliata*, called the cloaklet because as it grows it not only extends beyond the limits of the shell but also gradually dissolves it away and finally surrounds the crab. The anemone thus saves the crab from the perils of periodic change of residence and, being armed with long lines of stinging-cells, wards off enemies from both itself and its partner. In return it is carried from place to place and, since its mouth is placed just below that of the crab, obtains fragments of food when the latter feeds. Somewhat similar relations exists between the large hermit (*E. bernhardus*) and another anemone, *Calliactis* (*Sagartia*) *parasitica*. In this case there is often a ragworm, *Nereis fucata*, sharing the same house as the crab. It is obviously protected by both its associates and derives the same advantage as the anemone, but what does it do in return? The same problem is provided by small fish which take refuge within jellyfishes and the cloacae of sea-cucumbers.

On the other hand, quite a different kind of partnership exists between crocodiles and the bird *Pluvianus aegyptius*, between rhinoceroses and the oxpecker (*Buphaga africana*), and between starlings and cattle and sheep. In all these there appears to be a more definite mutual advantage: the crocodile-bird is allowed to hop about the widely opened mouth, removing and devouring leeches and probably particles of food lodged between the teeth, the oxpecker and starlings both pick off and eat ticks and other parasites while "riding" on the backs of the bigger animals.

Symbiosis.—This term is often used loosely to mean the same as commensalism, sometimes even to include parasitism. From its meaning "living together with"

this might seem correct, but the word was originally coined by the botanist A. de Bary for the association of algae and fungi in lichens, where the relationship is physiological, each partner benefiting from the metabolism of the other.

There are many other similar associations between algal cells and various animals. One of the most familiar is seen in the case of the green hydra (*H. viridis*), which owes its colour to the presence in its endoderm cells of chloroplast-like bodies. These carry on photosynthesis but do not store starch : the carbohydrates formed are utilized by the animal, which also benefits by the oxygen liberated while the alga is active. On the other hand, the alga is provided with carbon dioxide and other products which result from katabolic processes in the animal. In other words, the relationship is extremely like that between the algal and fungal components of a lichen. In the same way algal cells live with certain protozoans, such as *Amoeba viridis* and others, with sponges, with many sea-anemones and other animals, including a flatworm known as *Convoluta*. When the alga is green it is called *Zoochlorella*, when yellowish *Zooxanthella*. This leads directly to parasitism, *Convoluta*, for example, becoming after a time entirely dependent on *Zoochlorella*.

Certain bacteria and leguminous plants also live together. The bacteria invade the rootlets on which they form small nodules, and benefit the plant through their power of fixing free nitrogen. They in turn receive elaborated compounds. In some cases, however, the bigger partner becomes tired of the bargain and disintegrates and absorbs the bacteria. It is probable that the reverse is the case as regards at least some mycorrhiza—associations between fungi and the roots and sometimes other organs of certain flowering plants, such as heaths, rhododendrons and many forest trees. The fungus may cease to be of any service and become parasitic on the flowering plant.

Parasitism.—In this condition one partner in an association derives benefit to the detriment of the other,

which is known as the "host". The association may be between two animals, two plants, or a plant and an animal, and the parasites may be grouped as ectoparasites, living outside the bodies of their hosts, and endoparasites living within. Some, however, especially fungi, flowering plants, and amongst animals, parasitic barnacles, of which *Sacculina* of the shore crab is the best known, have absorbing organs in the tissues of their hosts but the rest of their bodies on the surfaces.

Many ectoparasites, most blood-sucking flies for example, which visit their hosts merely in order to obtain a rapid meal, are without any special adaptations apart from those shown by their alimentary organs. Others,

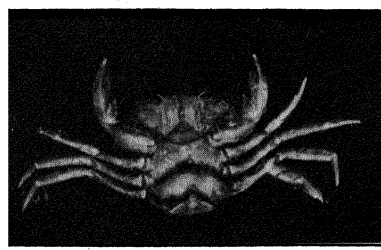
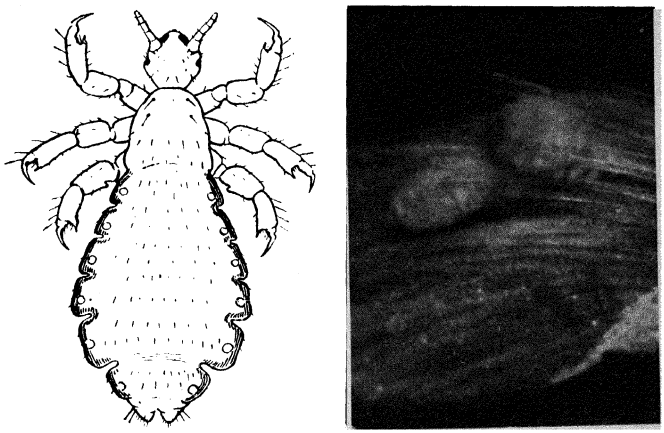


FIG. 89.—SHORE CRAB (*CARCINUS*) PARASITIZED BY *SACCULINA*. (× ½.)

which take prolonged meals, either develop organs of attachment, such as the oral and posterior suckers of leeches, or are flattened dorso-ventrally and thus run but little risk of being rubbed off. The majority of ectoparasitic insects and mites which remain more or less permanently on their hosts, as well as many crustacean parasites of fish and other aquatic animals, are extremely depressed. Fleas alone are compressed or laterally flattened; this is in correlation with their methods of locomotion. Further, many ectoparasites develop attaching devices in the form of suckers, anchors or grasping organs. The first two are to be seen in the so-called fish-lice, such as *Argulus* and *Caligus*, the latter are well exemplified in lice such as *Pediculus* and *Phthirius*. Though the

majority of ectoparasites live by sucking blood and other body-fluids, some, the Mallophaga or biting-lice, such as *Lipuris* and many other bird-lice, and *Trichodectes*, various species of which live on different mammals, feed on feathers, hairs and other epidermal structures.

Endoparasites are often long in proportion to their breadth and therefore able to pass through narrow pas-



a [*British Museum.* *b* [*John Ritchie.*

FIG. 90.—LICE.

a, The human head-louse (*Pediculus*), female. Dorsal view (× about 17); *b*, Lice in situ amongst hairs of mammal.

sages, even along blood-vessels in some cases, or are flattened and thus adapted for adhering to an internal surface. In addition they often bear suckers or hooks. The larger forms include roundworms, flukes and tape-worms, the first and last being common in the intestines of vertebrates. Living in darkness they are without pigment, and, as they feed chiefly on the soluble products resulting from the digestive activities of their hosts, their

alimentary systems are at best but poorly developed. Tapeworms are completely devoid of any digestive tract and absorb their food through the general surface of the body. All either have a thick cuticle or secrete anti-enzymes which prevent them from being digested by their hosts. As they are not exposed to danger and do not require to go in search of their food both nervous and muscular systems are simple. On the other hand they have to get rid of their own waste products, so their excretory systems are well-developed, whilst in correlation with the fact that they are exposed to great risks when passing from one host to another their reproductive organs predominate and give rise to enormous numbers of offspring. In many cases, including most flukes and tapeworms, the life-history is complex and involves at least two kinds of hosts. That of the common liverfluke (*Fasciola* (*Distomum*) *hepatica*), which may in one year cause millions of pounds loss to sheep farmers, is described in detail in most textbooks of zoology. Here, therefore, there is no need to give more than a summary to show how complex it really is. An ovum passes down the bile duct into the intestine of the sheep and to the exterior in the faeces. If passed into water it hatches and liberates a miracidium larva, which, after swimming for a time, burrows into the "lung" of *Limnaea truncatula* and becomes a sporocyst. This develops numerous rediae which make their way to the digestive gland of the snail and there produce other bodies like themselves. These may in turn produce still others. The cercariae to which the rediae finally give rise make their way to the exterior where they swim about in search of herbage. Here

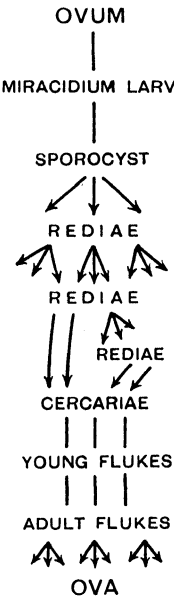


FIG. 91. — LIFE-CYCLE OF THE LIVERFLUKE *FASCIOLA (DISTOMUM) HEPATICA*

they encyst, and if they be ingested by sheep or young cattle the cyst wall is dissolved and the young flukes make their way up the bile duct to become mature in the liver. Then each produces up to 500,000 eggs. Each kind of host of which a parasite is able to make use provides a separate environment and thus assists in dissemination. It is an advantage, therefore, for organisms which can afford to produce their reproductive elements so plentifully as to " neutralize " the risks which they have to face in order to reach a new host to be able to pass different stages of their lives in different kinds of hosts.

In contrast to this, the common roundworms belonging to the genus *Ascaris* have one of the simplest life-histories. The eggs are laid in the intestine and pass out in the faeces. If they are later taken in at the mouth, in water or with food, the egg-shells are dissolved by the digestive enzymes and the larvae liberated. These burrow through the gut wall, carry out a complex migration through the body during which they undergo a sort of metamorphosis, and eventually find their way back to the intestine, where they become mature.

APPENDIX A

CLASSIFICATION

The following brief classifications make no pretence at being complete. They are given in order to enable the student both to obtain a general perspective of the plant and animal kingdoms and to place in their relative positions the majority of organisms which he is likely to find during ordinary ecological work. Genera within brackets have not been mentioned in the text.

I. THE PLANT KINGDOM

Thallophyta— A descriptive term employed for plants of simple structure, without any differentiation into root, stem and leaf and usually without any definite alternation of generations.

Algae— Thallophytes containing chlorophyll; life-history usually includes sexual phases.

Chlorophyceae— Contain chlorophyll only; form extremely varied, from unicellular and simple filamentous to complex branching thalli; the green algae: e.g. (*Euglena*) (*Chlamydomonas*), *Volvox*, *Zoochlorella*, *Spirogyra*, *Vaucheria* (desmids), *Enteromorpha*, *Chaetomorpha*, *Ulva*, *Chara*, *Nitella*.

Phaeophyceae— A brownish pigment, fucoxanthin, present in addition to chlorophyll; brown algae, including many medium-sized and large as well as many unicellular forms: e.g. (*Ectocarpus*), *Laminaria*, *Fucus*, *Ascophyllum*, (*Himanthalia*), *Chorda*.

Diatoms, unicellular brown algae distinguished by a bivalved siliceous test and occurring chiefly in marine plankton, may also be included in this group.

Rhodophyceae— Chlorophyll masked by an intense red pigment, phycoerythrin; chiefly marine and of relatively small size; thallus, with very few exceptions, consists of branched filaments: e.g. (*Chondrus*), (*Porphyra*), *Polysiphonia*, (*Corallina*).

Myxophyceae (Cyanophyceae)—Unicellular, colonial or filamentous forms characterized by a mucilaginous secretion which forms a sheath and by a bluish pigment, phycocyanin; reproduction only by fission; the so-called blue-green algae: e.g. (*Nostoc*), (*Rivularia*).

Bacteria— Unicellular forms without chlorophyll, which reproduce only by fission.

Fungi— Thallophyta which are entirely devoid of chlorophyll; reproduction mainly by spores, but a sexual phase also occurs during most life-histories.

Phycomycetes— With non-septate hyphae and well-developed sexual organs: e.g. (*Pythium*), *Mucor*.

Ascomycetes— Hyphae septate; spores formed in chains or produced within definite fruit-bodies known as asci: e.g. *Penicillium*, (*Claviceps*), (*Saccharomyces* = yeast).

Basidiomycetes— Hyphae septate; sexual organs absent; usually with definite fruit-bodies in which spores are borne generally in groups of four, each group on a special swollen end of a

hypha, known as a basidium : e.g. (*Puccinia*), (*Agaricus*), *Tricholoma, Merulius.*

Lichenes— Thallus composed of an association of fungal hyphae and unicellular or filamentous algae : e.g. *Ramalina, Parmelia, Xanthoria, Physcia, Lecanora, Lichena.*

Myxomycetes— The same as Mycetozoa of zoologists (see classification II, p. 142).

Bryophyta— At best only imperfectly differentiated into stem and leaves and never with roots ; distinct alternation of generations, the gametophyte being conspicuous and bearing the sporophyte.

Hepaticae— Usually more or less flat and sessile and never with any approach to vascular tissue ; liverworts : e.g. (*Pellia*), (*Marchantia*), (*Lunularia*).

Musci— Stem and simple leaves with water-conducting stands of elongated cells ; mosses : e.g. (*Funaria*), (*Polytrichum*), *Sphagnum.*

Pteridophyta— With distinct alternation of generations, the sporophyte being the more conspicuous and independent, though at first parasitic upon the small gametophyte ; sporophyte completely differentiated into root, stem and leaf and with complete vascular systems.

Filicales— With large leaves bearing numerous sporangia on their lower surfaces ; ferns : e.g. *Pteris*, (*Aspidium*), *Polypodium, Phyllitis.*

Lycopodiales— Of low, usually creeping habit, with small numerous sessile leaves, those bearing the sporangia in

cone-like groups; club-mosses: e.g. (*Lycopodium*), (*Selaginella*), (*Isoetes*).

Equisetales— Stems green, erect, hollow and distinctly jointed; joints surrounded by whorls of small scale-like leaves: sometimes also with whorls of branches: sporangia borne on umbrella-like sporophylls which form terminal cones; horsetails: e.g. (*Equisetum*).

Spermatophyta— Gametophyte generation extremely reduced and never free from the sporophyte which is completely differentiated into root, stem and leaf; seed-bearing plants.

Gymnospermae— Seeds produced on open sporophylls grouped together to form cones; conifers: e.g. *Pinus*, *Picea*, *Abies*, *Larix*, *Juniperus*, *Taxus*.

Angiospermae— Seeds produced in a closed chamber or chambers, the carpel or carpels; ordinary flowering plants.

Dicotyledoneae*— With two seed leaves or cotyledons; foliage leaves usually broad with reticulate venation: e.g. *Ranunculus*.

Monocotyledoneae*— With one seed-leaf or cotyledon; foliage leaves usually long and narrow with parallel venation: e.g. *Zostera Scilla*, *Poa*.

* Definitions of orders and families of these will be found in any of the floras mentioned in appendix C, Nos. 5, 28, 32 and 66.

Phylum **Protozoa**— Chiefly microscopic unicellular forms but occasionally consisting of a number of similar cells.

Class

Mastigophora (Flagellata)—With one or more long, whip-like locomotor organs known as flagella ; the class includes such forms as (*Euglena*), (*Polytoma*), (*Chlamydomonas*), *Volvox*, (dinoflagellates), (*Trypanosoma*).

Rhizopoda (Sarcodina)—Without any restraining pellicle and with pseudopodia (that is, are amoeboid) during their principal phase.

Order

Lobosa—Pseudopodia usually short and blunt : e.g. *Amoeba*, (*Difflugia*), (*Arcella*).

Foraminifera — Pseudopodia thread-like and anastomosing ; usually with a perforate, chambered, calcareous shell ; nearly all marine : e.g. (*Gromia*), (*Polystomella*), (*Globigerina*).

Radiolaria—Pseudopodia simple and thread-like ; with a capsule usually within an outer skeleton of siliceous spicules ; sometimes form colonies ; occur in marine plankton : e.g. (*Acanthochiasma*).

Heliozoa—Pseudopodia fine, radiating and simple ; without any mineral skeleton ; occur chiefly in freshwater plankton : e.g. (*Actinophrys*), (*Actinosphaerium*).

Mycetozoa—Resemble compound *Amoebae* during part of their life-cycle, most of them producing sporangium-like bodies at other times; live in damp terrestrial places; often referred to as "slime-fungi"; e.g. (*Badhamia*), (*Plasmodiophora*).

Class — Ciliata—With numerous short, hair-like locomotor organs known as cilia.

Order — Holotricha—Cilia evenly distributed over the surface of the body: e.g. (*Paramecium*), (*Opalina*).

Heterotricha — Cilia usually evenly distributed over the surface of the body except for a special band round the mouth: e.g. (*Spirostomum*), (*Stentor*), (*Balantidium*).

Hypotricha—Cilia of varying length, often in groups and mainly on the under surface of the body: e.g. (*Stylonychia*), (*Kerona*, ectoparasitic on *Hydra*).

Peritricha—Cilia restricted to oral region with the exception of a posterior ring in free-swimming forms: e.g. (*Vorticella*), (*Carchesium*), (*Trichodina* ectoparasitic on *Hydra* and other animals).

Suctoria—Cilia replaced in adult stage by suctorial tentacles: e.g. (*Acineta*).

Class — Sporozoa—Parasitic forms without any locomotory organs when adult: almost always intracellular: spores occupy a conspicuous position in life-history: e.g. (*Monocystis*), (*Plasmodium*).

Phylum **Porifera**— Multicellular animals with one or more large exhalant orifices and

very numerous minute pores; with a loose skeleton; internal layer composed mainly of collar cells; chiefly marine; sponges.

Class — Calcarea—Skeleton of calcareous spicules: e.g. (*Leucosolenia*), (*Grantia*).

Hexactinellida—Skeleton of six-rayed siliceous spicules; found only in deep water.

Demospongia—Skeleton of simple siliceous spicules and fibres of spongin, of spongin fibres only, or absent: e.g. (*Spongilla*—freshwater), *Ficulina*, *Halichondria*, (*Euspongia*, the bath sponge).

Phylum **Coelenterata**— Metazoa whose body-wall bounds the enteron, and consists of but two cellular layers between which is a non-cellular jelly, the mesogloea.

Sub-phylum — Cnidaria—Polyp and medusoid forms with nematocysts.

Class — Hydrozoa—In all the more common forms the mesogloea is thin and the polyp individuals are conspicuous; almost all marine: e.g. *Hydra*—freshwater, (*Obelia*), (*Tubularia*), (*Velella*).

Scyphomedusae—Always with a conspicuous medusoid stage in which the mesogloea is thick, sometimes alternating with an inconspicuous polyp stage: e.g. (*Haliclystus*), (*Aurelia*, a typical jellyfish).

Actinozoa—Sessile forms consisting of solitary or colonial polyps of complex structure.

Order — Alcyonaria—Colonial forms whose polyps always bear eight pinnate tentacles: e.g. (*Alcyonium*).

Zoantharia—British forms mainly solitary with numerous

simple tentacles usually in multiples of five or six : e.g. *Actinia*, *Anemonia*, *Tealia*, *Adamsia*, *Calliactis*, *Cereus*, *Sagartia*, *Corynactis*, (*Caryophyllia* and other hard corals).

Sub-phylum Ctenophora—Free swimming with locomotor organs in the form of combs of cilia ; without nematocysts ; occur in marine plankton ; sea-gooseberries : e.g. (*Pleurobrachia*).

Phylum **Platyhelminthes**—Unsegmented, flat, worm-like creatures, the majority with a complex life-history involving two or more hosts.

Class Turbellaria—Relatively small and simple leaf-like forms ; free-living in both fresh and salt water : e.g. *Convoluta*, *Planaria*, (*Leptoplana*).

Trematoda—More or less leaf-like parasitic forms, whose life-history usually involves two hosts, one at least of which is a vertebrate : e.g. (*Polystomum*), *Fasciola* = *Distomum*.

Cestoda—Tapeworms, living during the adult stage in the intestine of vertebrates ; each " tape " consisting of an attaching scolex and a chain of proglottides ; bladder-worm stage in second host, usually but not always, a vertebrate : e.g. (*Taenia*, the tapeworm, and *Cysticercus*, the bladder-worm stage.)

Phylum **Nemertini**— Usually long, more or less depressed unsegmented worms of various colours ; with remarkable powers of contraction and expansion ; surface covered with cilia ; with a protrusible proboscis usually not connected with the mouth ; mainly marine : e.g. (*Lineus*, the " bootlace " worm).

Phylum **Rotifera**— Microscopic but multicellular aquatic forms with anterior bands of locomotor and feeding cilia which in movement give the impression of two minute rotating wheels.

Phylum **Annelida**— Elongated segmented worms.

Class — Chaetopoda — With segmentally arranged chitinous bristles (chaetae) which assist in locomotion.

Order — Polychaeta—Each segment with numerous chaetae, usually borne on lateral projections called parapodia; all marine: e.g. *Nereis, Nephthys, Arenicola, Lanice, Amphitrite, Pomatoceros, Spirorbis.*

Oligochaeta—Each segment with only a few segmental chaetae and without lateral projections: e.g. *Lumbricus* and other earthworms, *Tubifex*.

Class — Hirudinea—Segmented worms with an anterior oral and a posterior adhesive sucker; with one exception devoid of chaetae: e.g. (*Haemopsis*, the common freshwater horse-leech.)

Phylum **Gephyrea**— Aberrant burrowing coelomate worms with little or no trace of segmentation: e.g. (*Thalassema*), (*Phascolosoma*).

Phylum **Arthropoda**— Segmented animals with a jointed exoskeleton of chitin.

Sub-phylum — Crustacea—Arthropoda with two pairs of antennae and with a deposit of calcium salts in the chitin of the exoskeleton; respiration usually by means of gills; mainly marine but with some freshwater and terrestrial species.

Class

Branchiopoda—Chiefly small, fresh and brackish water forms; anterior appendages leaf-like, abdominal appendages absent; with or without a carapace: e.g. *Daphnia*.

Ostracoda—With a bivalved carapace which completely encloses the indistinctly segmented body: e.g. *Cypris*.

Copepoda—Body elongated and distinctly segmented, usually with five pairs of anterior appendages, in addition to large antennae; ripe females nearly always carry conspicuous egg-sacs; actively swimming freshwater and marine forms and parasitic fish-lice: e.g. (*Calanus*), *Cyclops*, *Caligus*, *Argulus*.

Cirripedia—Sessile, sometimes parasitic, forms whose segmentation is very incomplete; often enclosed within calcareous plates in the adult stage: e.g. *Balanus*, (*Lepas*), *Sacculina*.

Malacostraca—Distinctly segmented and made up of head, thorax (8 segments) and abdomen (6, in one case only 7, segments) with a posterior telson; thoracic and abdominal appendages quite distinct from each other; many orders of which only some are given below.

Order

Mysidaceae—Carapace fused with not more than the first three segments; thoracic appendages biramous; mainly small planktonic organisms, mostly marine: e.g. (*Mysis*).

Isopoda—Usually dorso-ventrally compressed; no carapace, but first and sometimes second segment fused with head; eyes not on movable stalks; abdominal appendages all alike; some parasitic forms extremely modified: e.g. *Oniscus*,(*Asellus*), *Ligia*, (*Idotea*.).

Amphipoda—No carapace ; eyes sessile ; abdominal appendages in two different sets ; laterally compressed : e.g. *Gammarus, Orchestia, Talitrus*, (*Caprella*).

Decapoda—With a cephalothorax covering branchiae ; eyes on movable stalks ; the first three pairs of thoracic appendages modified as maxillipedes : e.g. *Leander, Crangon, . Astacus*, (*Homarus*), (*Palinurus*), (*Galathea*), (*Porcellana*), *Eupagurus*, (*Portunus*), *Carcinus, Cancer, Inachus*, (*Macropodia* = *Stenorhynchus*), *Hyas*.

Sub-phylum — Myriapoda—Arthropoda with a single pair of antennae ; respiration by means of tracheae ; with numerous pairs of similar legs.

Order — Diplopoda—usually more or less cylindrical ; each apparent segment with two pairs of small legs : e.g. *Julus, Blanjulus, Polydesmus* and other millepedes.

Chilopoda—usually depressed ; each segment with a single pair of legs, the first pair modified as poison jaws : e.g. *Lithobius, Geophilus* and other centipedes.

Sub-phylum — Insecta—Arthropoda composed of distinct head, thorax and abdomen ; head with one pair of antennae and mouth-appendages, thorax with three pairs of legs and usually two pairs of wings, abdomen without locomotor appendages ; respiration by means of tracheae.

Class — Apterygota—Completely wingless ; ametabolous, that is, without a metamorphosis.

Order — Thysanura—Antennae many-jointed; eyes compound; abdomen of eleven segments; bristle-tails: e.g. *Petrobius* = *Machilis*, (*Lepisma*).

Collembola—Antennae with four joints; no compound eyes; abdomen of six segments, often with a springing device; springtails: e.g. (*Anurida* = *Podura*),(*Lipura*).

Class — Pterygota—Nearly always winged and undergoing a metamorphosis.

Sub-class — Exopterygota—Hemimetabolous, that is, metamorphosis gradual or incomplete.

Order — Orthoptera—Usually two pairs of wings, the anterior leathery; biting mouth-appendages; cockroaches, crickets, locusts, and grasshoppers: e.g. *Blatta*, *Blattella*, *Periplaneta*, *Gryllus*.

Dermaptera—Fore-wings leathery and very short; biting mouth-appendages; anal cerci forming forceps; earwigs: e.g. (*Forficula*).

Plecoptera—Wings membranous; biting mouth-appendages; antennae and cerci long; early stages aquatic; stoneflies: e.g. (*Perla*).

Psocoptera—Book-lice, all very small insects.

Odonata—Wings large and membranous; biting mouth-appendages; thoracic segments so inclined that the legs are thrown forward; early stages aquatic, including characteristic nymph; dragonflies: e.g. (*Agrion*), (*Libellula*).

Hemiptera — Typically two pairs of wings; mouth-parts piercing and sucking; bugs: e.g. *Aphis*,

	Philaenus, Nepa, Corixa, Notonecta, Gerris, Hydrometra, Cimex.
	Ephemeroptera—Wings membranous, hinder pair much the smaller; long posterior processes; mouth-parts vestigial; early stages aquatic; mayflies: e.g. (*Ephemera*), (*Baetis*).
	Mallophaga — Wingless ecto-parasites of birds and mammals with biting mouth-parts; biting lice: e.g. *Lipuris* of birds, *Trichodectes* of mammals.
	Anopleura — Wingless ecto-parasites of mammals with piercing and sucking mouth-parts; sucking lice: e.g. *Pediculus, Phthirius.*
	Thysanoptera—Minute; wings similar, fringed with long hairs; mouth-parts piercing and sucking, asymmetrical; e.g. (*Thrips*).
Sub-class	Endopterygota—Holometabolous, that is, metamorphosis complete.
Order	Neuroptera—Wings alike and membranous; biting mouth-appendages; early stages often aquatic; alder and lacewing-flies: e.g. *Chrysops*, (*Sialus*).
	Mecoptera—Wings alike, membranous and with few veins; mouth-parts biting; abdomen of male turned up; larvae like caterpillars with numerous ocelli and prolegs; scorpion-flies, e.g. (*Panorpa*).
	Trichoptera—Wings and body completely covered with hairs; larvae with a pair of posterior hooked prolegs, aquatic and usually living in cases; caddis-flies: e.g. (*Phryganea*).

Lepidoptera — Usually two pairs of large wings ; body and wings covered with coloured scales ; long sucking mouth-parts ; larvae are caterpillars with not more than five pairs of prolegs ; butterflies and moths : e.g. *Pieris*, *Mamaestra*, *Saturnia*, *Vanesso*, *Lasiocampa*, *Cossus*, *Ephestia*, *Tinea*, *Abraxas*, *Tortrix*.

Coleoptera—Usually two pairs of wings, the first pair being hard and stiff elytra ; mouth-appendages biting ; beetles : e.g. *Dytiscus*, *Donacia*, *Gyrinus*, *Aromia*, *Rhagium*, (*Carabus*), (*Coccinella*), *Adalia*, *Anatis*, *Agriotes*, *Melolontha*, *Ptinus*, *Xestobium*, *Anobium*.

Hymenoptera—Two pairs of membranous wings with an interlocking device ; mouth-parts biting and licking ; often social ; ants, bees, wasps, ichneumon-flies, gall-flies, sawflies : e.g. *Formica*, (*Apis*), (*Vespa*), *Sirex*, *Nematus*.

Diptera—Anterior wings only, hinder represented by a small pair of halteres ; mouth-parts modified for sucking up surface fluids or for piercing and sucking ; true flies : e.g. *Musca*, *Culex*, *Anopheles*, *Aedes*, *Chironomus*, *Tipula*, *Syrphus*.

Aphaniptera—Parasitic wingless forms ; laterally compressed ; hind-legs modified for jumping ; piercing and sucking mouth-appendages ; fleas : e.g. *Pulex*.

Sub-phylum Arachnida—Arthropoda without antennae, but with chelicerae and usu-

ally leg-like pedipalps ; adults with four pairs of walking-legs ; mouth-parts usually adapted for piercing and sucking ; include scorpions and king-crabs besides the following classes.

Class — Phalangida—Composed of a cephalothorax and an abdomen of six segments ; chelicerae chelate ; pedipalps leg-like ; without spinning gland ; tracheal respiration ; harvesters.

Araneida—Composed of a cephalothorax and an unsegmented abdomen ; chelicerae with poison-glands ; several pairs of spinning glands ; respiration by means of lung-books or lung-books and tracheae : spiders : e.g. *Aranea* = *Epeira*, *Lycosa*, *Argyroneta*.

Acarida—Body not divided into regions : mouth-appendages either biting or piercing or sucking ; respiration tracheal or cutaneous ; mites : e.g. *Tyroglyphus*, (*Atax*).

Phylum **Nematoda**— Roundworms and threadworms ; body long and cylindrical, usually pointed at both ends ; some free-living, some internal parasites of plants or animals : e.g. *Ascaris*, (*Tylenchus*).

Phylum **Chaetognatha**— Small marine planktonic worms with lateral and caudal fins and oral bristles : e.g. (*Sagitta*).

Phylum **Mollusca**— Unsegmented, soft-bodied forms usually protected by a limy shell which is secreted by a characteristic organ, the mantle.

Class — Pelecypoda or Lamellibranchiata—Bivalves, that is, with shell composed of right and left

valves, and, in most cases, capable of entirely enclosing all the soft parts; mainly marine: e.g. *Anodonta*, *Mytilus*, *Aequipecten*, *Paphia* = *Tapes*, *Mya*, *Cardium*, *Ensis* = *Solen*.

Amphineura—Symmetrical forms whose shell consists of eight overlapping dorsal valves; marine; chitons or mail-shells.

Gastropoda—Asymmetrical forms, often with a superficial symmetry; usually with a single spiral shell (univalves); always with a well-developed ventral muscular foot and a distinct head region with eyes and tentacles.

Order Prosobranchiata (Streptoneura)—Twisted forms with a well-developed shell, breathing by means of comb-like gills (ctenidia) enclosed within the mantle cavity: e.g. *Patella*, *Gibbula* = *Trochus*, *Calliostoma*, *Littorina*, *Buccinum*, *Nucella* = *Purpura*, *Nassarius* = *Nassa*.

Opisthobranchiata — Shell and mantle cavity reduced or absent: respiration by means of a single external ctenidium or by means of secondarily developed organs on the surface: e.g. (sea-slugs, such as *Aplysia*, colids and dorids).

Pulmonata—Shell usually spiral, sometimes reduced or absent; respiration aerial, mantle cavity functioning as a lung; terrestrial and freshwater: e.g. *Ancylus*, *Limnaea*, *Hydrobia*, *Planorbis*, *Helix*, *Arion*, *Agriolimax*.

Class Cephalopoda (Siphonopoda)—Shell internal or absent; foot produced into eight or ten arms bearing adhesive discs and surrounding the mouth; octopuses and cuttlefish: e.g. (*Eledone*), (*Sepia*).

Phylum **Polyzoa**— Mainly marine colonial forms, many of which encrust seaweeds, stones and shells, whilst other at first sight resemble Hydrozoa. From these they are distinguished by the zoids, which are not polyps but possess a distinct U-shaped alimentary canal : e.g. (*Membranipora*), (*Bugula*), (*Lophopus*).

Phylum **Echinodermata**— Radially symmetrical animals with an exoskeleton of calcareous plates and spines and a characteristic water - vascular system ; all marine.

Class

Crinoidea—With five biramous pinnate arms, and with aboral whorls of cirri by means of which the animals are able to fix themselves temporarily ; e.g. (*Antedon*).

Asteroidea — Usually with five, sometimes with seven or thirteen broad arms ; always with well-developed tube-feet projecting from ambulacral grooves along their aboral surfaces ; starfish ; e.g. *Asterias*, (*Asterina*).

Ophiuroidea—With five long narrow arms radiating from a distinct central disc and without ambulacral grooves ; tube-feet reduced ; brittle-stars : e.g. (*Ophiothrix*), (*Ophiura*).

Echinoidea—Calcareous plates fused together to form a globular or heart-shaped test ; tube-feet well developed ; sea-urchins : e.g. (*Echinus*), (*Echinocardium*).

Holothuroidea—Usually more or less sausage-shaped, mouth and anus at opposite ends ; leathery test with at most only scattered calcareous plates ; sea-cucumbers : e.g. (*Cucumaria*).

Phylum **Chordata**— Animals in which during at least part of their life there are pharyngeal clefts and a supporting rod-like notochord.

Sub-phylum Enteropneusta (Hemichordata) — e.g. (*Balanoglossus*).

Tunicata (Urochordata)—Chordata in which the notochord is present only in the posterior region, and usually only during the larval stage ; adults mainly sessile, often colonial, and enclosed in a test composed mainly of a cellulose-like substance, tunicin ; ascidians : e.g. (*Oikopleura*), (*Ascidiella*), (*Botryllus*).

Cephalochordata—e.g. (*Amphioxus*).

Vertebrata — Bilaterally symmetrical, segmented chordates in which the notochord is in the adult surrounded and usually completely replaced by a segmented skeleton in the form of cartilage or bone.

Class Cyclostomata—Worm-like "fishes" without scales and paired fins ; skeleton cartilaginous ; do not possess jaws like all other vertebrates but have a suctorial mouth : e.g. *Lampetra, Petromyzon*.

Pisces—Aquatic vertebrata with pharyngeal gills ; typically with two pairs of fin-like appendages which are never of the arm and leg type ; true fishes.

Order Elasmobranchii—Marine fish with placoid scales, cartilaginous skeleton, ventral mouth and heterocercal tail : e.g. (*Scyllium*), (*Raia*).

Teleostei—Marine and freshwater fish usually with flat bony scales and always a bony

skeleton : e.g. *Blennius*, *Gasterosteus*.

Class Amphibia—Vertebrates with pentadactyl limbs and a moist naked skin ; fish-like larval stages.

Order Urodela—Amphibia with a tail and two pairs of almost equal limbs : e.g. *Molge*, *Triton*.

Anura—Without tails when adult; hind-limbs much larger than the fore : e.g. *Rana*, *Bufo*.

Class Reptilia—Limbs when present of the pentadactyl type ; dry skin covered with flat, overlapping horny scales ; British orders include Lacertilia (lizards, e.g. *Lacerta* and *Anguis*) and Ophidia (snakes, e.g. *Tropidonotus* and *Pelias*).

Aves—Birds ; vertebrates with few dermal glands and a characteristic covering of feathers, but with horny scales on the feet ; fore-limbs modified as wings.

Mammalia—Mainly terrestrial vertebrates characterized by a covering of hairs and abundant dermal glands ; some aquatic but still air-breathing forms (e.g. whales and porpoises) possess only a few bristles and even these are often lost during foetal life.

APPENDIX B

HINTS ON COLLECTING, KEEPING ALIVE AND PRESERVING VARIOUS ORGANISMS

This appendix is written for the beginner, not for the professional collector. Further hints may be obtained from many naturalists, especially in connexion with special groups of organisms. Many books also deal with this subject, one of the most generally useful and compact being the *Handbook of Instructions for Collectors* (4th edition, 1921), published by the British Museum (Natural History), S.W.7.

Soil.—For accurate analyses, either mechanical or chemical, samples should be taken which include not only the surface soil but also that to a depth of at least 6″. In some cases, however, subsoil or even rock may be reached at less than 6″ from the surface. Samples of soil which is not too dry or too stony may be taken with an auger, something like a large "cheese-tester", with an internal diameter of 1½″–2″. This is forced into the ground with a twisting motion. Another method is to dig round the sides of a 6″ or 9″ cube of earth which is lifted on a spade. Or better still, a strong iron frame, 12″ square by 6″ deep, with the under edges bevelled for cutting in, is hammered down until flush with the surface; the surrounding soil is then dug out, an iron plate forced under, and the whole lot lifted.

If a rough mechanical analysis to determine the proportions of the particles of different sizes is to be carried out, the soil is washed through sieves with meshes of different definite diameters. The standards used are as follows:

Above	2 mm.	stones
2	to 0·2 mm.	coarse sand
0·2	to 0·02 mm.	fine sand
0·02	to 0·002 mm.	silt
below	0·002 mm.	clay

If the soil is being collected to determine the water-content, it is important that the sample be taken from the layer which contains the actual absorbing organs of the plants. The water-content can be obtained quite simply by weighing before and after air-drying and then heating to 100° C. and weighing again. An approximate estimate of the humus-content can be made by first drying to 100° C. and then weighing before and after heating to redness.

A full chemical analysis is a lengthy and complex process and before attempting this reference should be made to some of the more advanced books on soil (see appendix D). Nevertheless, a very rough idea of the amount of calcium carbonate present may be gained by adding a few drops of dilute hydrochloric acid to a small quantity of soil in a test-tube and noting the amount of effervescence: if this be marked the soil contains at least 1% of carbonates; if slight ½–1%, while a mere crackling within the tube indicates less than ½%. The calcium carbonate content is important to bear in mind when dealing with the "acidity" or "alkalinity" ("reaction" or hydrogen-ion concentration) of the soil. This latter is referred to on page 168, and the method employed in determining it on page 169.

Collecting.—The most important piece of apparatus for field work is a note-book with pencil. Small pieces of paper which can be attached to specimens should also be carried.

Ordinary **flowering plants** can usually be "plucked" by hand, though some must be cut with a knife (or saw), others removed with a trowel. Most of these are best carried in a metal vasculum, slung from a shoulder-strap. Specimens from the same habitat may be bound together with a rubber band over a strip of paper bearing an identification mark; single specimens can be labelled by passing them through the paper.

Mosses and liverworts are best wrapped separately (old envelopes are useful for this), or carried in small tins or tubes; those from the same habitat may be put together in a sponge bag. Moist tissue paper is often useful for packing those obtained from wet situations.

Many **algae** may be treated in the same way as mosses and liverworts, but fine filamentous species should be carried in tubes of water. Aquatic plants beyond the ordinary reach can often be torn up by means of a small grapple firmly attached to a stout cord, or be severed with a cutting hook attached to a long stick.

Fungi and lichens should always be kept separate from other plants and from each other; this is because many of them are easily damaged and their spores are likely to get mixed.

Terrestrial insects.—Butterflies, moths and other kinds of actively flying insects may be caught in nets of muslin. These should be wide and deep in order to provide a large "mouth" and to prevent the insects from immediately flying out again. Insects on the wing or resting on freely exposed vegetation are taken by means of strong, bold sweeps followed by a rapid twisting of the wrist so that the mouth of the net is shut. From the net they are transferred to a laurel or cyanide killing bottle (see p. 166), or if females

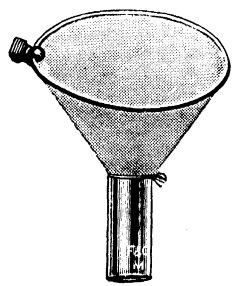


FIG. 92.—SMALL TOW-NET FOR COLLECTING AQUATIC ORGANISMS, SUCH AS MOSQUITO LARVAE AND PUPAE.

An extending walking stick may be obtained for fixing on to the frame of the net.

required for breeding purposes to a chip box or other small receptacle.

Insects, spiders, etc., frequenting dense vegetation are more easily caught with an umbrella sweeping-net, while larvae and adults of many species which live on trees and shrubs may be shaken on to sheets of paper or shallow trays.

Aquatic organisms.—For small freshwater fish, large water-beetles and other organisms of moderate size small canvas hand-nets are useful. It is often profitable to pass these over the bottom of ponds and in amongst the vegetation. For smaller forms, many aquatic insects and their larvae for example, small nets with bottles or tubes tied into them are best (see fig. 92). These are sometimes referred to as tow-nets, but tow-nets proper are much larger nets made of bolting silk of definite mesh and used to collect the mainly

microscopic plants and animals which constitute the plankton of both fresh and sea water. Ordinarily, such a net is towed behind a boat which is propelled very slowly: in this way minute organisms are filtered off and collect in the jar at the end. It is, however, sometimes possible to take advantage of water running through a sluice, down a weir, or past a pier by fixing a tow-net so that the water passes through it.

For collecting marine specimens many types of net are used. These vary from small hand-nets for investigating rock-pools, and dredges which are towed along the bottom of the sea from a boat, to huge trawls 120 feet across the mouth. For shore work it is essential to carry suitable containers for bringing back specimens. Some of these must be large enough to harbour crabs, others small enough to prevent subsequent loss of such animals as small chitons and planarians. For the former, tins with handles or stout baskets with bottles to fit are most suitable, and for the latter small tubes. To these must be added a hammer and chisel for splitting rocks and a crowbar for turning boulders which are too large for hands alone, while a fork (or a spade) is essential for work on a sandy or muddy shore. It is best to transport many forms without water, so long as they are kept damp. They must of course be put into water as soon as possible after arrival at the laboratory.

Living Specimens

(1) **Aquaria.**—Many aquatic animals, both freshwater and marine, may be kept for a short time, some of them for a considerable time, in such vessels as finger-bowls, pie-dishes and wide-mouthed glasses. For more or less permanent aquaria, however, larger "tanks" are necessary, and when setting them up some of the chief factors bearing upon life in natural waters must be kept in mind. Light enters from the top, not from the sides; animals require supplies of oxygen and of organic food-material; plants need carbon dioxide and mineral salts; marine organisms thrive only in water containing certain salts in definite proportions and amounts; most plants need "anchorage"; many animals, especially marine species, require either "retreats", or a solid substratum to which they may attach themselves.

Large bowls, such as those used in dairies, and shallow porcelain sinks have the advantage of letting in light only from the top, and at the same time exposing a large surface

of water to the air. Actually, rectangular tanks, preferably built of slate with glass fronts, enable observations to be made more easily. If all-glass tanks, such as old accumulator-jars, be used, their "backs", and if possible their "ends" too should be darkened. Many accumulator-jars are too short and narrow to allow a sufficient area of water to be exposed to the air, in addition to being so deep that they are difficult to clean.

All aquaria should be placed in such a position that the maximum illumination falls on them from above. They should, if possible, be lighted from the north, so that direct sun-rays do not overheat the water, and green scums, which tend to cover the sides of all aquaria, do not grow too vigorously.

All vessels should be well washed before being used. Old accumulator-jars or built-up tanks must be soaked thoroughly in order to remove all traces of chemical and other deleterious substances. Many aquatic organisms are extremely sensitive to the salts of lead and other soft metals. The latter, therefore, must never be used for supply-pipes, frame-work, or other structures likely to come into contact with aquarium-water.

The bottom is best covered with fine gravel, and this in turn with sand, both thoroughly washed. Freshwater plants may be set in the sand and gravel with stones over their roots, or in pots embedded in the sand; sea-weeds should be growing on stones or pieces of rock before they are introduced. Arches and rockeries should be built up to provide shelter and retreat. All this should be done while the aquarium is dry. Water must be introduced gradually through a tube reaching to the bottom, and the plants should be given time to settle properly before any animals are put in. With regard to the latter several points must be kept in mind. Their number must be below that which will exhaust the oxygen supply or raise the carbon dioxide content to a dangerous percentage. Predaceous species must not be included with others which it is intended to keep. Most aquatic insects can fly, so that perforated covers are required for vessels containing them. Similar protection must be afforded simple aquaria in which mosquitoes and other insects which lay their eggs on or in water are being reared.

Artificial aeration is highly desirable. It can be effected in several ways by means of either running water or compressed air. Tap-water is sometimes unsuitable, either because it has been treated or has certain harmful substances

dissolved in it. When this is the case clean water from streams, ponds and rain-water butts can be used. The water is best supplied by gravity from containers placed higher up than the aquaria, to which it is passed through tubes, each discharging by a very fine orifice at an angle to the surface of the water in the aquaria. A constant level is easily kept by means of siphon-tubes regulated with burette-clips. If it is desired to provide marine aquaria with flood and ebb-tides, this can be done very simply by having two siphons whose openings are at different heights. The simplest form of compressed-air machine consists of a stout tin with a delivery tube controlled by a stop-cock and an inlet tube fitted with a valve through which air can be introduced with a bicycle pump. The end of the delivery tube should open at the bottom of the tank, so that the air-bubbles pass upwards through the water. More elaborate but continually working devices are water-driven aerators, of which the Kindel air-pump and the apparatus figured on page 162 are examples. Both of these are operated by a tap-supply, and therefore require a drain to carry off the driving-water.

With an ample air-supply many animals will thrive in the absence of green plants, and since but few marine algae do well in aquaria, marine aquaria usually contain animals only. In all cases feeding must be properly attended to. All "left-over" food or dead organisms must be removed at once with a dipping-tube, a net or wooden forceps. Should real "trouble" occur, all surviving organisms, both plant and animal, must be well washed before either being transferred to another aquarium or returned to their former home after that has been thoroughly cleaned. (A further note on the management of marine aquaria will be found in the last paragraph of this appendix (p. 170).)

(2) **Vivaria.**—Slugs and snails, insects and various other arthropods may be reared and their habits and life-histories studied if they be kept in simple "cages".* The essential requirements are suitable food-plants, a moderately moist atmosphere, good ventilation, damp soil and fragments of flower-pot or something of the kind for "cover". When collecting winged imagines from a cage advantage may often be taken of the fact that all winged insects tend to "rise" before starting flight. (This habit should be remembered also when collecting under natural conditions.)

* See also appendix C, No. 46, p. 172

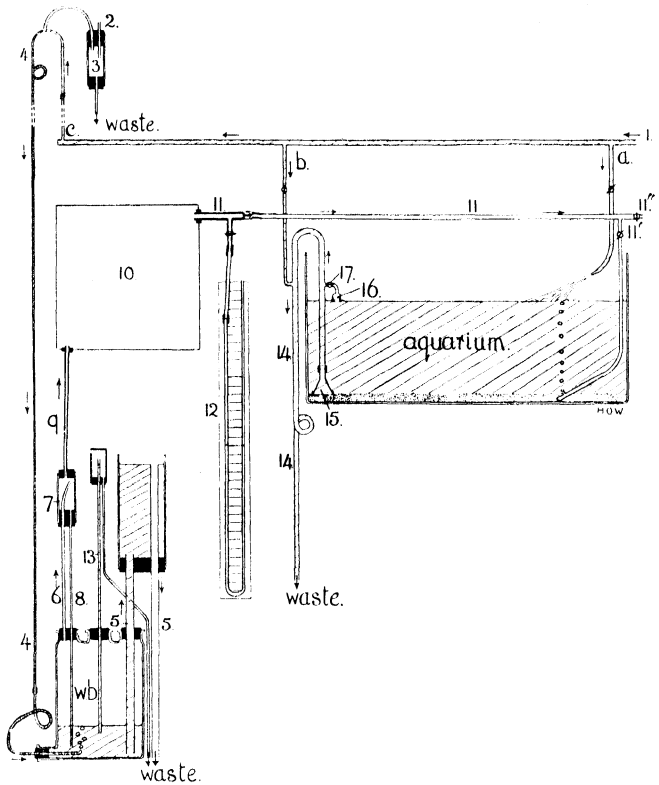


FIG. 93.—DIAGRAM OF AQUARIUM WITH AERATING AND SIPHONING APPARATUS.

1, water-supply branching to *a*, aquarium (if freshwater), *b*, siphon and *c*, air-pump ; 2, point at which air enters the pump ; 3, overflow tube ; 4, tube down which air is dragged by water into the Woulff's bottle (*w.b.*) ; 5, overflow for water which collects at the bottom of the bottle ; 6, tube through which air leaves the Woulff's bottle ; 7, trap for any water which may pass up 6, and 8 a tube for returning it to the Woulff's bottle ; 9, tube conveying air from 7 to air-reservoir 10 ; 11, air-distributing tube to aquaria, 11′ being the branch to the aquarium shown and 11″ tube leading to other tanks ; 12, air-pressure gauge ; 13, " exhaust " tube from the Woulff's bottle for excess air accumulating above

Amphibians and reptiles require larger vivaria containing "ponds". The supply of suitable food for many of these is often somewhat troublesome. If flies are required in any quantity it is always best to breed them. Eggs are most easily obtained by collecting them from dead organic matter, such as meat or fresh manure and other putrefying substances, especially those which have been exposed to the sun. The eggs or the mass of material containing them should be placed on soil in the cage out of the sun. Grubs will soon hatch out and, as the food-material into which they burrow very soon becomes offensively smelly, care should be taken when assigning a place for the rearing-cages. The position of the vivaria containing reptiles is also important: these animals enjoy plenty of heat, so warm sunny places should be chosen.

Preserving

(1) **Botanical.**—The aerial and thinner subterranean parts of most flowering plants, pteridophytes and many bryophytes are dried, and then mounted on single or between double sheets of stiff paper. With special drying paper the colours of flowers tend to keep better, but excellent results can be obtained with newspaper. Specimens must be spread out between the drying paper, separated by several folded newspapers or sheets of cotton wool and subjected to pressure for 6 to 12 hours. They should then be carefully arranged between fresh paper and pressed for 24 hours, re-arranged and pressed again for several days. Most species will then be ready for mounting. They may be fixed in position by narrow bands of paper gummed at each end. Labels should be attached to the sheets of mounting paper.

The majority of algae may be treated in the same way, but are mounted in fresh water. Most marine species should be washed in fresh water before they are mounted. This method of mounting is accomplished by immersing a thick paper or thin card and floating the alga on to it. The latter

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the pressure to which the apparatus is set and which prevents water from splashing out from overflow 5; 14, siphoning apparatus kept working by water-supply 1*b*; 15, inverted filter-funnel covered with muslin for completely emptying the tank; 16, thistle-funnel similarly covered for normal use. The last maintains a constant level of water in the aquarium when tap 17 is kept open; when the tap is closed water leaves the aquarium through 15.

(In order to obtain the best results tube 4 should be as long as possible, at least 8 ft.)

is then arranged with a soft brush. When this is satisfactorily completed the mount is carefully lifted out, drained, and placed between drying papers (or newspaper). Before it is covered with the upper paper thin muslin must be spread over in order to prevent sticking.

Plant material which will not dry satisfactorily may be preserved in a 3% solution of formaldehyde (see page 166).

(2) **Zoological.**—All zoological material may be preserved in formaldehyde of from 2½% to 10%, 5% being the most useful general solution (see also p. 166). For worms, however, 75% and for sponges 90% alcohol should be used.

In order to obtain the best results with aquatic organisms these should be brought in alive, allowed to expand in water, and then carefully narcotized. For most species menthol crystals are recommended, but for the majority of coelenterates and polyzoans magnesium sulphate (Epsom salts) gives the best results. Menthol is sprinkled on the surface, but magnesium sulphate falls to the bottom. Both act slowly, and more and more of the latter should be added at intervals; care, however, must be taken that the crystals do not touch the specimens. In order to test the state of anaesthesia an expanded part may be touched very gently with a glass rod. Completely anaesthetized specimens should be removed carefully but rapidly and plunged into the preservative. In many cases it is best to plunge them into corrosive sublimate (see p. 167) or much stronger formaldehyde than that in which they are to be finally preserved; they may be transferred almost immediately to the latter. Very few worms can be completely anaesthetized. In many cases it is best to arrange these individually on strips of glass, to cover them with other strips and then flood suddenly with strong alcohol, holding down the covering slip meanwhile.

Most insects and terrestrial arthropods are best killed with laurel or cyanide (see p. 166), "set" on special boards or cards with their wings and appendages carefully arranged, and kept in store boxes. They are fixed with thin, non-rusting entomological pins, which also hold down small labels. The details of treatment vary somewhat for different orders of insects.

Notes on Certain Useful Chemical Reagents, etc.

Alcohol.—When this is used as a preservative more care is required than with formaldehyde, for example (see below), 70% is the best strength for storage purposes, stronger than

this tends to cause shrinkage. Remember that the water contained in plant and animal tissues makes a great difference to the final strength of the alcohol; the latter, therefore, should be changed once or twice before the jars are finally sealed up. Sponges are best plunged into strong alcohol which should be replaced by a 90% solution after 24 hours.

Bouin's Fluid.—

Picric acid (saturated aqueous solution) .	75 c.c.
Formaldehyde (full strength). . .	25 c.c.
Acetic acid (glacial)	5 c.c.

This is a good general fixative for all zoological material intended for later sectioning. The material should not be left too long in the fluid, otherwise it becomes very hard. It should be washed and stored in 70% alcohol. As it colours the specimens yellow it is of little use for external features, and being acid slowly dissolves away calcareous structures.

Carbon Dioxide.—Soda-water made in a sparklet siphon is a supersaturated solution of this gas. If carefully run down the side of a vessel containing water it forms a layer which cuts off the air and gradually narcotizes animals in the water. It is especially useful for whelks and other molluses. It also causes small animals to come out of their retreats in sea-weeds.

Chloral Hydrate.—A 0·1% or weaker solution is quite a good narcotic for *Balanus*, ascidians and sponges.

Chrom-Acetic Acid.—This is an excellent fixative for plant material intended for microscopical preparations. For other general purposes it is unsuitable as by the time the solution has penetrated, the plant is very brittle. Various formulae are available, probably the best are :—

General formula :

Chromic anhydride ("acid") .	0·3 gramme
Acetic acid (glacial) . . .	0·7 c.c.
Water	99·0 c.c.

Marine formula (for sea-weeds)

Chromic anhydride ("acid") .	1 gramme
Acetic acid (glacial) . . .	0·4 c.c.
Sea-water	400 c.c.

Cut up the material to the smallest suitable size, fix for about 24 hours in plenty of the fixative (50 volumes of solution to one of plant), wash thoroughly in fresh (or sea) water, and transfer to weak alcohol, gradually increasing the strength to 70%.

Formaldehyde.—Formalin is a 40% aqueous solution of the gas formaldehyde. It may be diluted to any proportion, but 40% is as much as water can dissolve. As sold, formalin, often called formaldehyde, is usually 37–38%. (In making up solutions of the strength mentioned on p. 164 it is treated as 100%.) The normal dilution is 1 in 10, giving a 3·8% solution; this is sufficiently strong for most purposes.

Formalin, especially when it is exposed to light, tends to become oxidized and results in an acid solution. It may then be neutralized with finely powdered chalk or borax. It is not economical to keep strong formalin in bulk for any length of time, but the white solid (various polymers) which appears may be removed by filtration.

All specimens tend to absorb the preservative from the solution; this, coupled with the oxidation process, may make the solution very weak. It should always be replaced once or twice before any museum jars are sealed off.

(N.B.—Always ask for formaldehyde when buying. "Formalin" is a proprietary name applied to a solution of formaldehyde in sealed containers, sometimes sold at an enhanced price.)

Glycerine.—This is a good final preservative for crustaceans. They tend to keep their colour in it for a longer time than in most other preservatives. It is used practically pure, but specimens should be "graded up" beforehand. The greatest care must be taken in sealing up museum jars, etc., containing specimens in glycerine, since it is extremely hygroscopic and therefore absorbs water from the atmosphere.

Killing-Bottles for terrestrial arthropods.—These are ordinarily charged with potassium cyanide. Any wide-mouthed bottle with an air-tight bung is suitable, but the most convenient size is an 8 or 10 oz. For this 1 oz. of potassium cyanide is required. The poison is broken up, put into the bottle and covered with plaster of Paris mixed with water to make a paste which is just thick enough to pour out of the container in which it is mixed, and to run between the chunks of cyanide. Sufficient paste to fill the bottle to a height of $1\frac{1}{2}$″–2″ should be poured in. If properly mixed this very soon sets hard and dry.

For killing most aerial arthropods, except large beetles and humble bees, laurel leaves may be used in either a bottle or a tin. They should be cut into narrow strips, packed fairly tightly and covered with muslin to prevent the victims from becoming mixed up with them. Animals killed with

laurel do not stiffen as do those killed with cyanide, until some time after they have been removed from the laurel chamber. In many cases chopped laurel leaves are actually used for relaxing those killed by cyanide.

Magnesium Sulphate (Epsom Salts).—See page 164.

Menthol.—See page 164.

Mercuric Chloride (Corrosive Sublimate).—A very good rapid fixative, especially for hydroids, for use before carmine stains. Hot or cold aqueous or alcoholic solutions may be used. The water solubility is about 4% and the alcoholic about 60%. The latter is really the more rapid, as a large volume of water can be saturated almost immediately. Always remember that this substance is extremely poisonous, and that material treated with it must be thoroughly washed, as in time the action becomes corrosive.

Perényi's Fluid.—A good preservative for spawn of amphibians. If the material be left in the fluid for a few weeks all the jelly gradually dissolves, rendering examination of the egg or embryo easier.

The fluid is made up as follows:—

Nitric acid (60%) . . .	4 c.c.
Alcohol (90%)	18 c.c.
Chromic anhydride . . .	0·09 grammes
Water	38 c.c.

Determination of Hydrogen-Ion Concentration

According to the theory of electrolytic dissociation, pure water (H_2O = HOH) dissociates into an equal number of positively charged hydrogen ($H^{\cdot}$) ions and negatively charged hydroxyl (OH') ions. The amount of water not ionized is practically negligible. The dissociation constant (K_w), or degree of ionization, of water may therefore be written merely as $H \times OH'$, instead of in full as $\frac{H^{\cdot} \times OH'}{HOH}$. This constant for one litre of pure water has been found by methods of electrical conductivity to be $1 \times 10^{-14 \cdot 14}$ grammes, usually taken as 1×10^{-14}, at 18° C. This means that one litre contains only 1×10^{-7} (= 0·0000001) grammes of ionized hydrogen and a similar weight of hydroxyl ions.

These free hydrogen ions are the active agents in the chemical effects of acids, and therefore any aqueous solution in which they are in excess of the hydroxyl ions present is acid. Conversely, when the hydroxyl ions predominate a

solution is alkaline. When, as in pure water, both kinds of ions are present in equal concentration (1×10^{-7}) a solution is said to be neutral. Since $H^{\cdot} \times OH'$ is a constant it follows that it is only necessary to consider the concentration of one kind of ion; in actual practice it is that of the hydrogen ions. If, therefore, the concentration of hydroxyl ions increase to 1×10^{-6}, then that of the hydrogen ions will decrease to 1×10^{-8}.

These are awkward figures for practical purposes and the symbol pH is employed. This indicates what negative power of 10 is to be used. The hydrogen-ion concentration of pure water at 18° C., being really 1×10^{-7} is therefore written as pH 7. In an acid solution in which the hydrogen-ion concentration increases to, say, 10^{-6}, the pH value then decreases to 6. If in an alkaline solution the number of hydroxyl ions increase to 10^{-6}, there will be only 10^{-8} hydrogen ions, and the pH value will be 8. The pH value, therefore, increases above 7 with alkalinity and decreases with acidity—exactly the converse of the way in which the real hydrogen-ion concentration varies.

The protoplasm of most living organisms is extremely sensitive to changes in the hydrogen-ion concentration. Some organisms are naturally more sensitive than others and there are different optima for different organisms. Plants living in a peat bog, for example, may be subjected to soil-water as acid as pH 4, those on a chalk-down to a solution as alkaline as pH 8 (see p. 76 and p. 82). In ponds photosynthesis, by causing a diminution of carbon dioxide, may correspondingly alter the pH value, while it is very important that decaying food etc. may not be allowed to decrease the pH value in either freshwater or marine aquaria, especially in the latter from which green plants are usually absent. (See also p. 170.)

Acids and bases are termed " strong " or " weak " according to their degree of ionization. Hydrochloric acid, for example, having a high dissociation constant, $\frac{(H^{\cdot} \times Cl')}{HCl}$, is strong, while acetic, phosphoric and the many humic acids being but little ionized in water are designated as weak. This means that a small addition of hydrochloric would very greatly affect the pH value, but a considerable quantity of weak acid would have to be added to bring about the same result. These so-called strong acids and bases (caustic soda, for instance) play very little part in nature, but those in

which much of the compounds remains unionized are extremely important. There may be great quantities of the latter present and yet the hydrogen-ion concentration does not alter appreciably. The salts of these weak acids or bases are known as " buffers ". Soils are usually heavily buffered through the presence of various silicates, humates, and phosphates, all salts of weak acids. If a strong acid were added the dissociated hydrogen ions would at once unite to form molecules of a weak and relatively undissociated acid; consequently the pH value would hardly alter. Similarly, some of these buffers may also be salts of weak bases, and in practice it sometimes happens that the application of lime—a relatively strong base—does not have the desired effect of reducing the actual acidity. In this case the hydroxyl ions become united to form weakly dissociated bases.

The hydrogen-ion concentration, or pH value, of any liquid is determined by one of two methods. The first is electrical and is by far the better; it requires, however, very complicated apparatus and is therefore seldom used except in research laboratories. The second, known as the colorimetric method, is carried out by means of coloured dyes or indicators. The first of these dyes to be used was litmus, red in acid solution, purple at absolute neutrality and blue in alkaline solutions. But litmus is only a rough guide, the colour changes being much too indefinite. Other indicators are used to-day, most of them having a relatively small range of pH within which there are definite intermediate colours. Thus, bromo-thymol blue is yellow at pH 6 and below, blue at pH 7·5 and above, passing through definite intermediate stages of greenish yellow and green; phenol red is yellow at pH 6·8 and below, then yellow-orange, orange, orange-red and finally red at pH 8·5 and above. In practice a certain definite amount of indicator is added to the liquid to be tested in a tube of uniform diameter and its colour compared with that of a series of tubes containing the same amount of indicator added to a buffer solution of known pH value.

All these indicators may be obtained from such chemical firms as the British Drug Houses, Ltd. This particular company also supplies a very useful mixed indicator, known as the B.D.H. Universal Indicator, which has a wide range (pH 3 to 10·5) with a large variety of colours; it is useful for rapidly obtaining an approximate value of the pH of any fluid.

If the liquid whose pH is to be determined be slightly

coloured or opaque compensation is made by viewing the buffer tubes through the same thickness of the liquid under examination. This is done in a comparator which consists of a frame to hold six tubes in the position as shown in ground plan in fig. 94. The object of having six and not four tubes is that the sample can then be compared with that on both its right and its left.

In the determination of the pH of soil, samples are first

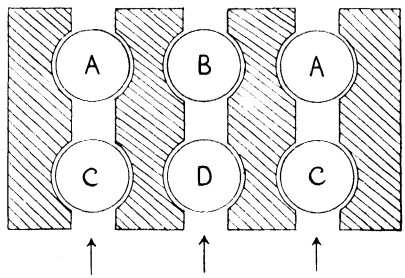


FIG. 94.—GROUND-PLANT OF A COMPARATOR.

The six tubes contain the following: A, sample whose pH is to be determined; B, sample plus indicator; C, standard buffer solution; D, distilled water. The colours are viewed in the direction of the arrows.

mixed thoroughly with distilled water, allowed to settle and the more or less clear liquid then pipetted off and tested with an indicator. For rapid determinations in the field the B.D.H. Soil Indicator Set is useful and compact, full instructions being enclosed. For more accurate determinations reference should be made to more advanced books.

It is important to maintain the correct hydrogen-ion concentration in marine aquaria. In many cases an efficient aerating system (compare fig. 93) is sufficient, but if the tanks contain predaceous animals, such as fish and crabs, the pH valve may fall considerably and trouble will ensue. It is then necessary to test the tanks occasionally and aim at keeping the pH between 7·8 and 8·2; cresol red is a useful indicator. If the pH falls below the correct figure clear lime-water should be added until the indicator gives the required tint. In hot weather it may be necessary to add this fairly often. Care should be taken, however, to use a saturated solution of lime-water so that the specific gravity of the sea water is not lowered.

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APPENDIX D

GLOSSARY OF DERIVATIONS

A.S. = Anglo-Saxon.
Fr. = French.
Ger. = German.
Goth. = Gothic.
Gk. = Greek.
Icc. = Icelandic.
L. = Latin.
M.E. = Middle English.
O.E. = Old English.
O.F. = Old French.
O.L. = Obsolete Latin.
W. = Welsh.

adductor, L. adducere, to bring to
alluvial, L. alluere, to wash to or on
ambulacral, L. ambulare, to walk
ametabolic, Gk., negative prefix, metabolē, change
anastomosing, Gk., anastoman, to open (of one sea into another)
anemophilous, Gk., anemos, wind ; philos, dear, fond
antenna, L., an insect's horn
articulated, L. articulare, to furnish with joints
association, L. associare, ad and socius, sharing

bacterium, Gk., baktērion, a little stick
basidium, diminutive from Gk., basis, a base, pedestal
biotic, Gk., bios, life
biramous, L. bis, twice ; ramus, a branch
bog, Gael. bog, soft
branchia, Gk., brangchia, the gills of fishes
byssus, Gk., bussos, a fine yellowish flax

calcifuge, L. calx, chalk; fugere, to flee
calciphil, L. calx, chalk ; Gk., philos, dear, fond
canal, L. canalis, a water-pipe
capillary, L. capillaris from capillus, hair
carnivorous, L. caro, carnis, flesh ; vorus, devouring
centipede, L. centum, a hundred ; pes, pedis, foot
cercaria, Gk., karkos, a tail
chela, Gk., chēlē, hoof, claw
chelicera, Gk., chēlē, hoof, claw ; keras, horn
chitin, Fr. chitine ; Gk., chiton, a tunic, covering
chloroplast, Gk., chlōros, green ; plassein, to mould, shape

chrysalis, Gk., chrusallis from chrusos, gold, because of the metallic colours it often exhibits
cloaca, L., a drain
cnidoblast, Gk., knīdē, a nettle ; blastein, to sprout, bud
coelomate, Gk., koilōma, a hollow
commensalism, L. cum, together ; mensa, table
ctenidium, Gk., ktenidion, diminutive of kteis, ktenos, comb
cuticle, L. cuticula, diminutive of cutis, skin
cyst, Gk., kustis, a bag

denude, L. denudare, to make naked
dermal, Gk., derma, skin
desert, O.F.-L. deserere, to unbind, because of the looseness of the sand
dioecious, Gk., dis, double ; oikos, house
down, A.S. dún, a hill
dune, A.S. dún, a hill

ecology, Gk., oikos, house ; logos, discourse,
economics, Gk., oikonomia, household management, government
ecto-, Gk., ektos, outside
edaphic, Gk., edaphos, the ground
elytron, Gk., elutron, cover, sheath
endo-, Gk., endon, within
endoderm, Gk., endon, within ; derma, skin
epi, Gk., epi, upon
epidermis, Gk., epi, upon ; derma, skin
estuarine, L. aestuarium from aestus, tide
etiolated, Fr. étioler, to become pale
exhalant, Fr. exhaler ; L. exhalare, to breathe out

foetal, O.L. feuēre, to bring forth

gametophyte, Gk., gamein, to marry ; phuton, plant
habitat, L. habitare, to live in
halophyte, Gk., hals, halos, salt ; phuton, plant
hanger, wood on side of steep hill from O.E. hangra
hastate, L. hastatus from hasta, a spear
heath, A.S. hǽð ; Ger. heide ; Goth. haithi, a waste
hermaphrodite, Gk., Hermaphroditos, son of Hermes and Aphrodite, who grew into one person with a sea nymph whilst bathing
holometabolic, Gk., holos, whole ; metabolē, change
humus, L., the ground
hydathode, Gk., hudatōdēs, full of water
hydrophyte, Gk., hudroeis, fond of water ; phuton, plant
hypha, Gk., huphē, a web

inhalant, L. inhalare, to breathe in

katabolic, Gk., katabolē, a throwing down

lair, A.S. leger, a couch
lanceolate, L. lanceola, diminutive of lancea, a lance head
larva, L. a mask, spectre
leaching, A.S. leccan, to moisten

maggot, W. magiaid, worms
mandible, L. mandibula, a jaw
marsh, A.S. mersc, full of meres; mere, a pool
maxilla, L., jawbone
maxillepede, L. maxilla, jawbone; pes, pedis, foot
meadow, A.S. mæd from máwan, to mow
mesogloea, Gk., mesos, middle; gloia, glue
mesophyte, Gk., mesos, middle; phuton, plant
metabolism, Gk., metabolē, change
metamorphosis, Gk., a transformation
millepede, L. mille, a thousand; pes, pedis, foot
monoecious, Gk., monos, alone; oikos, house
moor, Ice, mór, peat
mycelium, Gk., mucēs, mushroom; hēlos, nail, wart
myriapod, Gk., murios, countless; pous, podos, foot

nauplius, Gk., a son of Poseidon; naus, a ship; plein, to sail
nematocyst, Gk., nēma, nēmatos, thread; kustis, bladder
notochord, Gk., nōton, back; chordē, a string of gut

ocellus, L. diminutive of oculus, eye
osculum, L., a little mouth

parapodium, Gk., parapodios, on the ground
parasite, Gk., parasitein, to live at another's table
pasture, L. pastura, pascere, to feed
peat, for beat—M.E. beten, to mend a fire
pectoral, L. pectoralis, pectus, pectoris, the breast
pedipalps, L. pes, pedis, foot; palpus, palpare, to stroke
pelage, Fr.-L. pellis, skin
pellicle, L. pellis, skin
pentadactyle, Gk., penta, five; dactulos, finger
permeate, L. per, through; meare, to pass.
petiole, Fr.-L. petiolus, a little foot
phylum, Gk., phulon, stock, race
pinnate, L. pinna, a feather
plankton, Gk., plagktos, wandering
polyp, Gk., polupous, many-footed
pond, from A.S. pyndan, to shut in
predaceous, L. praedari, to plunder
predatory, L. praedari, to plunder
proboscis, Gk., an elephant's trunk
proglottis, Gk., proglossis, the tip of the tongue

pseudopodium, Gk., pseudos, false, foot
pupa, L., a doll

saprophyte, Gk., sapros, rotten ; phuton, plant
scolex, Gk., skolex, a worm
septate, L. sepire, to enclose
spawn, F. espandre, to shed
spermatophyte, Gk., sperma, seed ; phuton, plant
spiracle, L. spiraculum, from spirare, to breathe
sporocyst, Gk., sporos, seed ; kustis, a bag
sporogonium, Gk., sporos, seed ; goneucin, to produce
sporophyll, Gk., sporos, seed ; phullon, leaf
sporophyte, Gk., sporos, seed ; phuton, plant
stamen, L. from stare, to stand
sternum, Gk., sternon, the chest
stigma, Gk., stigma, a prick, spot
stoma, Gk., the mouth
stridulating, L. stridēre, to creak
succulence, L. succulentus, juicy
symbiosis, Gk., living with, companionship
synthesize, Gk., sunthesis, a putting together

tarsus, Gk., tarsos, the flat part of the foot
telson, Gk., the limit or end
test, L. testa, an earthen pot
trachea, L. trachia, the windpipe
tuber, L., a swelling

undulating, Low. L. undulare, to wave

valve, Fr. from L. valva, a sliding door
vernal, L. vernalis, belonging to the spring
vestigial, L. vestigium, a trace

whorl=whirl. M.E. whirlen, to whirl, turn round and round

xerophyte, Gk., xeros, dry ; phuton, plant

zoea, Gk., zoe, zoia, life
zone, Gk., zōnē, a belt

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