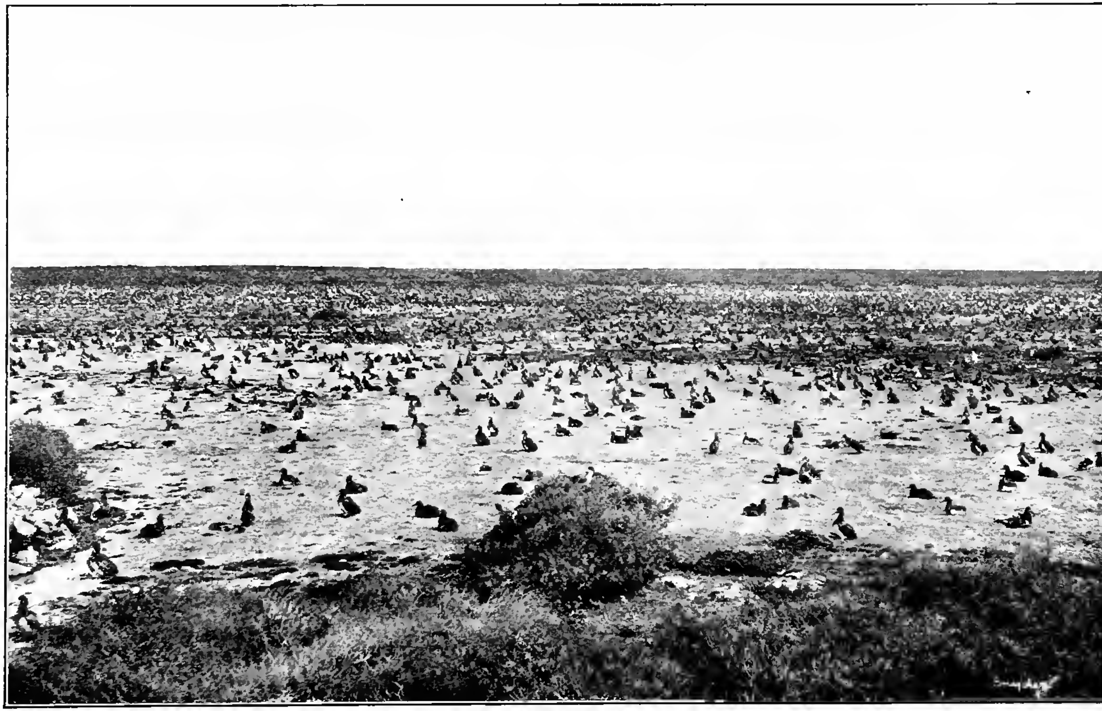

Nesting-grounds of the albatross, king of ocean birds. (A photograph made by Prof. J. O. Snyder of Stanford University, when the U. S. Fish Commission steamer "Albatross" visited Laysan Island—a small uninhabited island in the Pacific Ocean—in the summer of 1902. These thousands of albatrosses, young and old, are all of the one species, *Diomedia immutabilis.*)

FIRST LESSONS

IN

ZOOLOGY

BY

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PREFACE

This book, an introduction to the study of animals and their life, is intended for use in grammar schools and in those high schools which are not equipped with laboratories or which do not care to undertake the study of zoology by having the pupil dissect a series of types or examples. For high schools prepared to take up this college method of zoological study the author's Elementary Zoology is intended. In preparing a text-book for the guidance of teachers and pupils in high schools without laboratory equipment and in grammar schools and classes of younger pupils, the author has believed it better to write a new book, rather than to shorten and "simplify" the text intended for larger high schools and older pupils. He has believed it better to make the life-history and habits of familiar animals the basis for a beginning study of zoology by young pupils rather than to make the study of structure and classification such a basis. But this is not a reading book, or nature-study story book. It is a guide and outline for constant, specific personal work in observation, and answering questions by means of this observation, on the part of the pupils, and only such telling of facts is included as seems necessary to make significant and coherent and related the self-made discoveries of the pupils.

The actual method of use of the book will be obvious to any teacher into whose hands it may fall. The succession of chapters is one that seems natural and useful to the author; for any teacher it will be, of course, a simple matter to modify and rearrange the course of work as outlined. In fact the opportunities for obtaining material for study offered by the situation of the school, as, for example, whether on the seashore or in the interior near a lake or river, or on the dry plains, and the relation of the school terms to the seasons of the year, and other special and varying conditions, will dictate in large measure the teacher's actual procedure. The numbered parts of the book indicate the classification of the study of animals into particular phases or kinds of study rather than a definite linear arrangement or sequence of this study. The lessons or subjects of Part IV, for example, should be interpolated wherever the teacher finds fittest opportunity in connection with the study of special animals or groups of animals. Chapters VI, VII, and VIII of Part II have to do with that part of the study of animals which, as usually treated, demands the facilities of equipped laboratories. As here treated no laboratory work is required, but these chapters have been arranged to call for the continuous and thoughtful "seeing why" of facts mostly already familiar to the pupil. In this way the author believes that what little knowledge of the internal anatomy of animals young people can get will have a maximum of worth.

The author wishes to express his special obligations to Dr. O. P. Jenkins, professor of physiology in Stanford University, for the first draft of Chapters VI, VII, and VIII of Part II, and to thank Mrs. D. S. Jordan and Miss Isabel McCracken for their critical reading of the MS. and proof-sheets, respectively, of the book. For aid and courtesy in the matter of illustrations the author's thanks are due Miss Mary Wellman, who made all the drawings for figures whose origin is not elsewhere specifically indicated, and to Professors M. V. Slingerland of Cornell University and L. L. Dyche of Kansas State University, Dr. L. O. Howard, U. S. Entomologist, Mr. Geo. O. Mitchell of San Francisco, Mrs. Elizabeth Grinnell of Pasadena, California, Mr. J. O. Snyder, Stanford University, Mr. Frank Chapman, editor of "Bird-Lore," Mr. G. O. Shields, editor of "Recreation," Mr. Geo. A. Clark, secretary U. S. Fur Seal Commission, the American Society of Civil Engineers, Cassell & Co., the Out West Publishing Co., Camera Craft, "The Condor," and the Whitaker and Ray Co. of San Francisco. The illustrations got from these various sources are all specifically indicated in connection with their special use.

VERNON LYMAN KELLOGG.

STANFORD UNIVERSITY, May, 1903.

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PART I

THE LIFE-HISTORY OF ANIMALS

CHAPTER I

MOSQUITOES, SILKWORMS, AND DRAGON-FLIES

Animals not fully developed at birth.—It is familiar knowledge of us all that any animal when just born differs from its parents more or less. The downy little chick, just from the egg, is very different from the old hen or crowing rooster; a kitten with its unopened eyes and helpless little legs differs plainly from the strong, large mother cat. These differences are due to the fact that the chick and the kitten are not fully developed, or, as we say, not full grown. And such differences are even greater in some other animals, as, for example, butterflies and frogs. Butterflies' eggs hatch, not into butterflies, but into worm-like caterpillars, while newly hatched frogs are not frog-like at all, but are the little, long-tailed, fish-like creatures we call tadpoles. But the caterpillar will develop into, or grow up to be, a butterfly, just like the splendid one which laid the egg from which it hatched, and each tadpole will grow to be a frog. What is true of cats and chickens, frogs and butterflies, is true of all other animals; that is, every animal has to go through more or less growth and development in order to become like its parent. The story of an animal's birth, its growth and gradual change or development into a mature or adult individual, is called its life-story or *life-history*.

In the following studies of insect life-histories the growth and development of the insects from hatching to maturity can be readily observed in the schoolroom. The particular insects chosen are selected because they can be easily obtained and reared indoors, and because they present especially interesting changes in their development. But other insect life-histories may be observed, either completely or in part, if it is so desired. Various caterpillars and chrysalids can be kept alive and watched as they develop into moths or butterflies, and various grubs that live in the ground can be kept until they become beetles. Flesh-flies may be allowed to lay their eggs on decaying meat, and the hatching of the maggots, their change into brown seed-like pupæ, and the final emergence from these of the blue and green flies all carefully noted.

MOSQUITOES

The eggs and hatching.—Mosquitoes' eggs are usually laid in small blackish masses, which float on the surface of water. (In the case of some species the eggs are laid in groups of only a few, or even deposited singly.) These sooty egg-masses are composed of a single layer of slender elongate eggs standing on end and loosely fastened together to form a narrow, irregular, little raft, slightly concave on the upper surface, and wholly unsinkable. They are to be found on small pools of standing water, or in watering-troughs or exposed barrels—wherever indeed there is quiet or stagnant water. These egg-masses should be brought into the schoolroom and kept in glass tumblers, with some of the water on which they are found floating (fig. 1). Examine an egg-mass with a hand lens to note the arrangement and appearance of the eggs. How many are there in the mass?

The eggs should be kept under pretty constant obser-

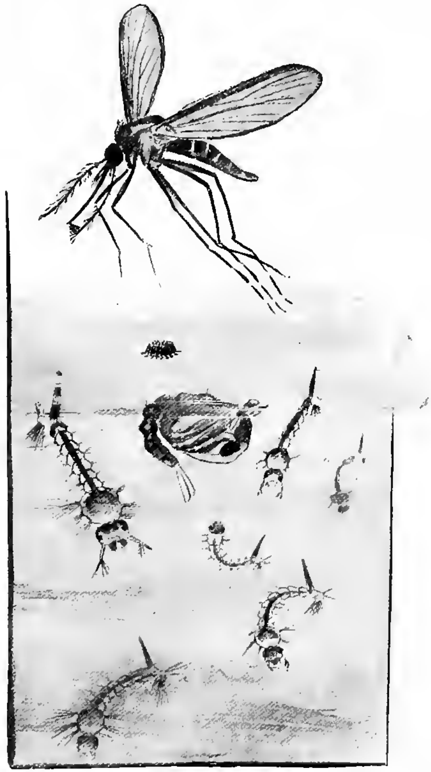


FIG. 1.—The mosquito, *Culex* sp.; showing eggs (on surface of water), larvæ (long and slender, in water), pupa (large-headed, at surface), and adult (in air). (From living specimens.)

vation, for hatching is likely to take place soon after they are brought into the schoolroom. Ordinarily they hatch in from twelve to twenty-four hours after they are laid. They may, of course, hatch at night. But if the hatching occurs during the day it can be easily observed.

From which end of the egg does the young mosquito emerge? It may not be easy to find the egg-masses on the pools; in that case the wrigglers or larvæ (described in the next paragraph) should be sought for and brought into the schoolroom in tumblers or jars containing water taken from the pool in which they are found. The life-history can be studied from this point on. The tumblers must not be kept in places too cool or dark, or the young mosquitoes will develop abnormally slowly.

The "wrigglers" or larvæ.—The newly hatched mosquito bears no resemblance to the familiar winged fly which we call by that name. In this first stage of its life, or second stage, if we call the egg stage the first, it is familiarly known as a "wriggler," but is called *larva* by naturalists. The active young stage of any insect which differs markedly from the fully developed or mature one is called the *larval stage*.

The larvæ swim actively about. By what means do they swim? If they cease swimming do they sink deeper in the water or rise to the surface? Is the body of the larva more or less dense than the water? that is, is it heavier or lighter than water? Note that some of them hang quietly from the surface, and that each one comes occasionally to the surface and rests there for a while to breathe. Every animal has to breathe; that is, to take up oxygen from the air and to give off from its body carbon dioxide (CO_2). There is always some air mixed with or dissolved in water, and some aquatic animals—fishes for example—have special structures called gills which enable them to take up this dissolved oxygen, and thus to breathe under water. But the mosquito larva has no gills, and therefore has to come occasionally to the surface to breathe.

Examine with a hand lens one of the larvæ in a watch-glass of water. Distinguish the head end of the body;

note the eyes (two small black spots), the feelers, or antennæ, and a pair of tufts or brushes of hair on the head which vibrate rapidly and constantly. These brushes by their vibration create currents in the water setting toward the mouth, which lies between them, and thus bring food to it. This food consists of any tiny animalcules and microscopic bits of organic matter in the water. Are there any legs or wings? Examine the posterior end of the body and note its division into two parts—one the end of the hind body or abdomen, the other a breathing-tube projecting from the next to last body-ring. Make a drawing of the larva, showing and naming all these parts.

Observe again the larvæ in the jar. When they hang from the surface note that only the tip of the breathing-tube reaches it. Note the vibration of the mouth-brushes. The larvæ feed busily for most of the time. If they sink in the water when they stop "wriggling," i.e., swimming, how is it that they can rest quietly at the surface? For this reason: the tip of the stem-like breathing-tube projects slightly above the surface when the wriggler comes up to breathe, so that the expanded edges of its mouth are caught by the tense surface film and the wriggler's body being but slightly heavier than water, is thus supported or suspended by the film. It is easier to prove the existence of this film than to explain it. If you carefully lay a clean needle on the surface of the water it will not sink, although much denser, i.e., heavier than water, but will be supported by the surface film. If you fill a tumbler to its brim you can still add more water carefully and so heap it up above the level of the brim. This is because the surface film extending over the water from edge to edge holds it in place. If you dip your finger in and then lift it up the water does not all run off, but a large drop will remain hanging to your finger.

The tense surface film holds the little mass together in the form of a drop. The mosquito larva takes advantage of the surface film and is able to keep itself at the surface when breathing by hanging from it. Water-striders and the numerous little flies which run quickly and safely about on the surface of the water are supported by the film. Their feet make little dents or depressions on the water's surface, but do not break through.

It is probable that the movements of the feeding-brushes also help to keep the wriggler at the surface, as the wrigglers seem to be able to balance themselves, i.e., keep from sinking, in the water by these movements.

Observing the larvæ or "wrigglers" from day to day it will be noted that they increase in size, that is, are growing. They breathe and feed and swim and grow. And some keenly observant pupil may see that they occasionally cast their skin, or moult. That the larvæ do moult one or more times is certain; how many times, however, has not yet been found out.

The pupæ.—After several days—just how many each pupil should determine for himself—the long slender larvæ enter upon another stage in the mosquito's life called the *pupal stage*, and the young mosquitoes are now called *pupæ*. In this stage the head end is large and bulbous, the hind body is usually curled underneath the head, and the creature spends most of its time floating at the surface. It can swim, and does so when disturbed, by a peculiar straightening and folding of its body. When it stops swimming what happens to it? In what way must the pupa differ from the larva in its relation to the density of water?

Examine with a hand lens one of the pupæ in a watch-glass of water. Note the two tubes or horns which project upwards from the back or dorsal part of the bulbous head end of the body, and the pair of flaps at its posterior tip. What are the dorsal tubes for? With what do they correspond in the larvæ? The pupa takes no food at all, and usually floats quietly at the surface. Why then does it swim at all? What is the use of the flaps at the end of the body? Note the indications of legs and wings folded on the under side of the head end. Make a drawing showing and naming these parts.

In two or three days the pupa suddenly changes into the full-fledged winged mosquito. That is, the cuticle or outer skin wall of the body splits along the middle line of the back, and the winged mosquito emerges through this opening. What part of the body appears first? What parts next? While the mosquito is emerging the pupal skin serves as a raft upon which the soft-bodied damp insect is partly supported until its wings and legs are unfolded and dried and hardened, and it is ready to fly away. Sometimes the body rests simply on the surface of the water, being supported by the surface film. This transformation of pupa into fully developed mosquito can be readily observed, and each pupil should see it.

The winged or imago stage.—The mosquito is now full-grown and fully developed; and in this fully developed stage it is called an *imago*, to distinguish it from larva and pupa. It is of course the same insect, a mosquito all the time, but we commonly apply that name only to the winged stage or imago. A few of the winged mosquitoes should be killed in a "killing-bottle" (see page 335), and examined under a hand lens. Two kinds may be distinguished; one with many long hairs on their feelers or antennæ, the other with fewer and much shorter hairs; the latter are females, the ones with bushy antennæ males. These antennæ are the mosquito's organs of hearing. How many wings has the mosquito? How many pairs of legs? Can you find behind the wings a pair of delicate little knobbed processes projecting from the body? These are called balancers and they aid the mosquito in directing its flight. Note the long, piercing and sucking beak (fig. 2) by means of which the mosquito gets its food, which is either the blood of animals or the sap of plants. The male mosquitoes never (or very rarely) suck blood. On each side of the beak, and arising at its base, is a pair of feelers or palpi, presumably organs for smelling and tasting, or which at least aid in determining the character of the food. These palpi are as long as the beak in the males, but less than half as long in the females. What are the large black spots on the head? Make a drawing of a mosquito, showing and naming these parts.

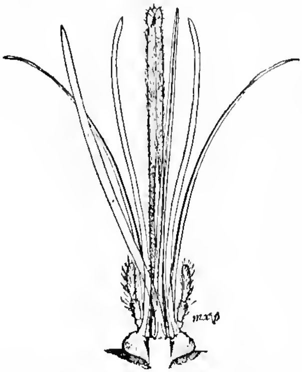


FIG. 2.—Beak of female mosquito dissected to show the piercing needle-like parts, and their sheath; *mx.p*, the maxillary palpi, or feelers of the mouth.

If some of the mosquitoes are kept alive in jars filled with water and covered with netting the females may perhaps lay eggs on the surface of the water. But it is not at all certain that they will; indeed, they seem to lay eggs only rarely when thus kept in confinement. If a slice of banana be put in the jar the mosquitoes may be seen to suck the sap from it, and they may be kept alive for many days if given fresh banana every three or four days. If the egg-laying occurs, the life-history of our mosquitoes is completed. A new cycle is about to begin.

Distribution of mosquitoes.—Mosquitoes are distributed all over the world, being found in enormous numbers in arctic regions and on high mountain ranges as well as in the tropics, and in swamps and marshy valleys. About three hundred and fifty species, or different kinds, of mosquitoes are known, nearly fifty of which are found in North America. Besides the irritation caused by their "bite," i.e., piercing with the sucking beak, it has been proved that mosquitoes are the conveyers and distributors of the germ of malarial fever. Only certain kinds of mosquitoes, however, are malaria-carriers. These all belong to the genus Anopheles ; most of them may be distinguished by the possession of spotted wings, while the innocuous kinds have the wings clear. There are a few innocuous or non-malarial kinds with spotted wings, however, but no malaria-carrying kinds with wholly clear wings. Other kinds of mosquitoes are almost certainly the distributors of the germs of yellow fever, and the same kinds convey a terrible tropical disease called elephantiasis.

The most effective remedy against mosquitoes is to pour a little kerosene on the surface of the pool in which the larvæ and pupæ live. The kerosene will spread out and form a thin, oily film over the surface of the water, and no winged mosquito will be able to emerge alive through this film, contact with kerosene being fatal to almost all insects, and especially so just after a moult.

For a full and excellent account of the life of mosquitoes see "Mosquitoes," by Dr. L. O. Howard. (See page 327 for list of reference books with publishers' names and price.)

SILKWORMS

How to get silkworm eggs.—Live eggs of the silkworm moth, *Bombyx mori*, are regularly sold by dealers in Japan,* and sometimes can be got in curiosity shops in this country. They may also be obtained wherever there is a silkworm-rearing establishment in this

* Silkworm eggs can be obtained from the Kioto Agricultural School, Kioto, Japan, or from the Nishigahara Agricultural Experimental Station, Silk Culture Dep't, Tokio, Japan, or from Mr. S. I. Kuwana, Buzen, Kiushiu, Japan.

country, though unfortunately there are but few now. The author will be glad to send* a few eggs, say twenty-five, once to any teacher who will defray the cost of postage. From the first lot of eggs moths may be raised and new eggs obtained, and a generation thus be reared each year. There are four kinds or races of silkworms, one of which, known as annuals, produces but one generation a year, the second kind, called bivoltins, produces two, the third, the trivoltins, produces three, while the fourth, found in India, produces six or seven generations each year. The eggs which the author can furnish are those of the annual race, and will naturally hatch in the Middle and Eastern States from April 15 to May 1. By keeping them at a temperature of 40° F., or below, the hatching may be postponed as long as desired. Under no circumstances should it be allowed to take place before the first mulberry or osage orange-leaves appear in the spring. If it is more convenient to rear the silkworms in the fall, the eggs may be kept in some refrigerator or cold-storage room through the summer. But the natural hatching-time will be found to coincide fairly with the leafing of the mulberry and osage-orange trees, and no special care in keeping will be necessary. As the silkworms will feed on no other than mulberry or osage-orange leaves, a supply of these must be available, or some other moth chosen for this life-history study. However, both these trees are spread over the whole country, and one or the other is to be found in nearly every locality.

The advantage of using the mulberry silkworm moth for this life-history study lies in the "domesticity" of the insect; the worms have no tendency to crawl away but will remain quietly in open shallow trays as long as food is provided them, and the moths, although winged, do not

* Address V. L. Kellogg, Stanford University, California. Send five cents in stamps for postage.

fly. The larvæ are not hairy and all their markings, their changes during growth, and their behavior can be fully observed. And finally, the moths are obliging enough to lay their eggs on whatever is provided them, and do not insist on flying away into the fields ; thus the process of egg-laying can be observed and the age of the eggs be exactly known.

The eggs and hatching.—The eggs of the silkworm moth are nearly spherical, a little flattened, and about the size of a mustard-seed. When first deposited they are yellow, but soon become grayish or slate-colored and indented on top. Each female moth lays about 300 eggs. These remain unchanged in appearance, after the first change from yellow to gray, until about the hatching time, when they become paler. The tiny worm or larva inside, for the silk "worm" is of course simply the larva or first young stage of the silkworm moth, gnaws its way through the thin egg-shell and crawls out ready to begin feeding. Some newly hatched larvæ of moths and butterflies have the curious habit of eating the egg-shells as soon as they issue from them. Do the young silkworms do this ?

The larvæ, i.e., "silkworms" (figs. 3 and 4).—As soon as the eggs begin to hatch fresh leaves of the mulberry or osage orange must be supplied to the young larvæ. These leaves must not be wet, for the tiny silkworms seem to have rather delicate stomachs which object to cold damp food. They should be cut into pieces, the bits being evenly spread about in the shallow tray or box-cover in which the worms are to live. Watch the young larvæ crawl and feed. Note that they bite out little crescents and semicircles in the edges of the leaves. Does the silkworm have any particular way of moving its head when biting off bits of leaf-tissue ? Examine one of the tiny worms with a hand lens. Note that its body is composed of a series of segments or rings. How many pairs of legs are there and on what body-rings are they? Note the scattered long hairs sparsely covering the body. Can

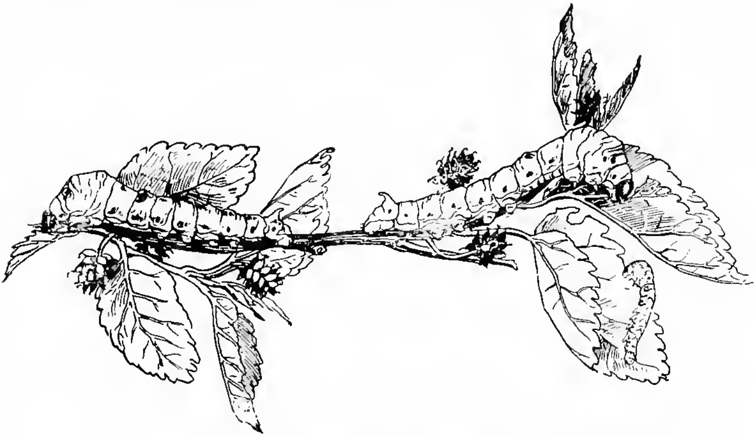


FIG. 3.—Silkworms feeding on mulberry leaves. (From life.)

you see the jaws and eyes on the head? Make a drawing of a worm as seen from the side.

Silkworms will eat a surprisingly large amount of food, and fresh leaves must be given them at least two or three times a day. Scatter the new leaves over the little pile of worms, dried old food and excrement, and the worms will soon crawl out and on to the new. It is advisable to keep the feeding-tray as clean as possible, for the larvæ are readily subject to disease. In order to remove the waste matter, spread a bit of large-meshed mosquito netting over the tray and throw the fresh food on top of it. The worms will crawl up through the meshes to the fresh leaves when

FIG. 4.—Silkworm on mulberry leaf, showing front view of head and thorax. (From life.)

the netting can be lifted up and the tray emptied. The larvæ will grow rapidly, plainly increasing in size each day. After eight or nine days they will cease feeding and crawling around. Each one stands on the legs of the middle of the body, and usually holds up the head and forepart of the body, and sometimes the tail. It is preparing to moult, i.e., to cast the skin. The moulting should be observed in detail. After moulting each larva will be noticeably larger and paler, and the long hairs of the body will be replaced by short ones. The feeding begins again, and larger and larger supplies of leaves will be found necessary to keep the worms well fed.

The larval stage of the silkworm lasts about forty-five days, with a moulting once every nine days (or eight or ten). It is easy to see why these successive moultings are necessary. The true skin of an insect is always covered over outside by a cuticle in which a horny substance called *chitin* is deposited. This chitin makes the cuticle nearly inelastic, so that the growing insect finds its body confined within a non-stretchable case. There is then but one way out of this dilemma, and that is the simple way of breaking out! And so in the life-history of all insects the phenomenon of moulting takes place. In nearly all cases the cuticle splits along the middle of the back from the head to about half way to the end of the tail, and through this rent the body issues with new cuticle. The cast skin being very light and thin, and usually colorless, soon disappears from view, and unless the insect be seen precisely at each moulting time it is not easy to ascertain how many moults occur in the life of any particular species.

The silkworms breathe through very small openings, called *spiracles*, on the sides of the body. One pair of spiracles occurs on each of nine of the body-rings. What rings are these? Each spiracle opens into an air-tube

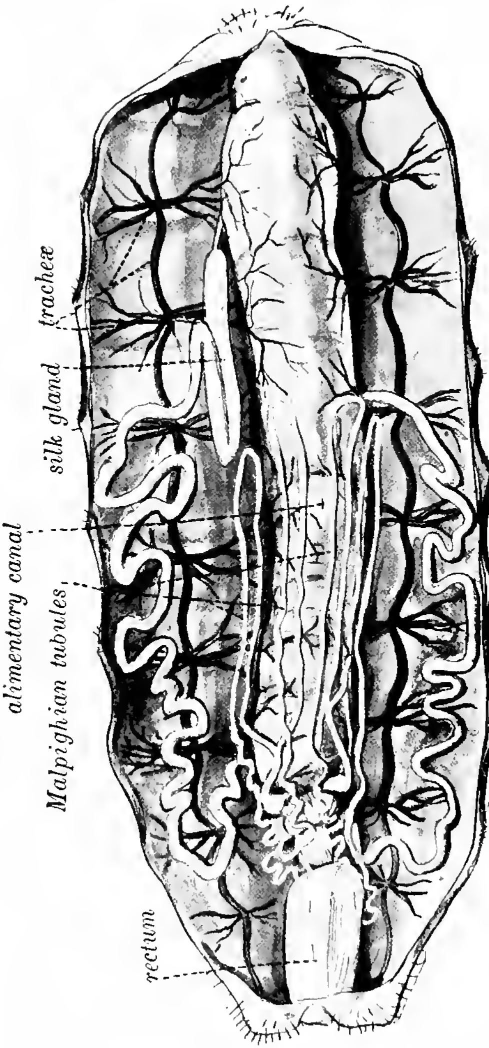


FIG. 5.—A silkworm dissected to show its internal organs. Note particularly the system of tracheæ or air-tubes. The silk-glands, one on each side, open into the mouth.

inside the body, and these various side-tubes lead into a main longitudinal tube running along each side from head to tail (fig. 5). From these main longitudinal trunks branches and sub-branches go to all parts of the body, the air being distributed in the insect's body by a distinct system of air-tubes called *tracheæ*, and not entering a pair of lungs (fig. 6).

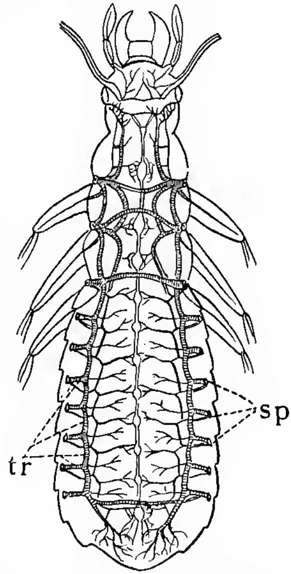


Fig. 6. — Diagram of tracheal system in body of beetle; *sp*, spiracles; *tr*, tracheæ. (After Kolbe.)

Silkworms devour an enormous amount of leaves during the last few days of larval life, much more indeed than they need at that time. Later we shall see the reason for this over-eating. They have thick, heavy bodies and reach a length of two and a half inches. Make a drawing of a full-grown larva from a lateral view, showing all the legs of one side, nine breathing holes (tiny openings each surrounded by a black ellipse), and the dorsal spine on the posterior end.

The cocoon and pupa.—About a week or nine days after the fourth moult the silkworms stop feeding and prepare for the fifth and final one. (Occasionally a silkworm moults six times.) But unusual preparations are made this time; each larva crawls alongside the edge of the tray, or approaches some object in it, and begins to spin silken thread from its mouth (fig. 5.) All of this spinning should be watched closely. At first the thread is attached irregularly and apparently aimlessly to the objects near by, but when a sort of loose and irregular net or web of silk has been made, the spinning becomes more regular, and it is plain that the larva is making a silken case or cocoon about itself. The spinning lasts about three days and results in a thick, firm, white or yellowish (rarely greenish) silken closed cocoon, within which the larva moults. Cut one of the cocoons open a few days after its making and there will be found within it the cast skin of the larva and the pupa which appears after the final larval moulting. In what habit does this pupa resemble that of the mosquito? In what habit does it differ? The pupal stage in the development of insects is a stage in which the insect takes no food, is usually quiescent, and is undergoing the final changes from worm- or grub-like larva to winged adult. The silkworm pupa lies quiescent in its silken case for about two weeks, sometimes a little longer, when the pupal cuticle splits, and one end of the silken cocoon is dissolved by a fluid secreted by the insect within. Through this opening out crawls the moth, damp and crumpled-looking, with the wings all compressed into short thick pads or sacs. But these slowly expand, the scales and hairs covering the body dry, and soon the robust fully developed white moth walks slowly about.

Make a drawing of a net and cocoon just begun, showing the larva inside at work spinning; also a drawing of a completed cocoon; and of a cocoon cut open showing the mummy-like pupa within.

As the silkworm takes no food in the pupal stage (this is true of the mosquito also) and as a great deal of development goes on in this stage during which the wingless larva is transformed into the very different winged imago, it is plain that the pupa must live on food stored in the body. It is for this reason that the larval mosquito, the wriggler, and the larval silkworm moth, the silkworm, devote themselves so steadily to eating and eat more than they need for their own use. The extra food eaten is changed into fat, or is in some way stored in the body as reserve material on which the pupa draws during its quiescent and fasting life.

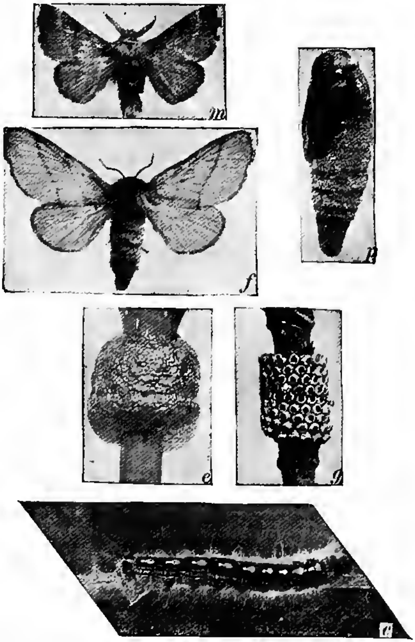


FIG. 7.—The forest tent-caterpillar moth, *Clisiocampa disstria*, in its various stages; *m*, male moth; *f*, female moth; *p*, pupa; *e*, eggs (in a ring) recently laid; *g*, eggs hatched; *c*, larva or caterpillar. Moths and caterpillar are natural size, eggs and pupa slightly enlarged. (Photograph by M. V. Slingerland.)

The moths and egg-laying.—When the silkworm moths issue from the cocoons they make no attempt to fly although each is provided with four wings. Some of them, however, will be seen to keep up a rapid gentle fluttering of the wings; these are usually males, which are more active than the females. The males and females are alike in color and marking, but the antennæ, or feelers, of the male are wider or bushier than those of the female; that is, the side branches or "pectinations," suggesting feathers in appearance, are longer in the males than in the females.

FIG. 8.—A trio of apple tent-caterpillars, *Clisiocampa americana*, natural size. These caterpillars make the large unsightly webs or "tents" in apple-trees, a colony of the caterpillars living in each tent. (Photograph from life by M. V. Slingerland.)

Examine a moth, noting the number of wings, number of legs, the antennæ and eyes, and the scales or hairs which cover the body and wings. Make a drawing, from dorsal view, of a moth with wings outspread.

The moths will soon pair, and the females will begin laying eggs at about the end of the first day. Each female will lay about 300 eggs. Provide small pieces of cloth ; place the moths on the cloths and the eggs will be laid on them. After laying the eggs the moths soon die. They take no food at all, indeed their mouth-parts

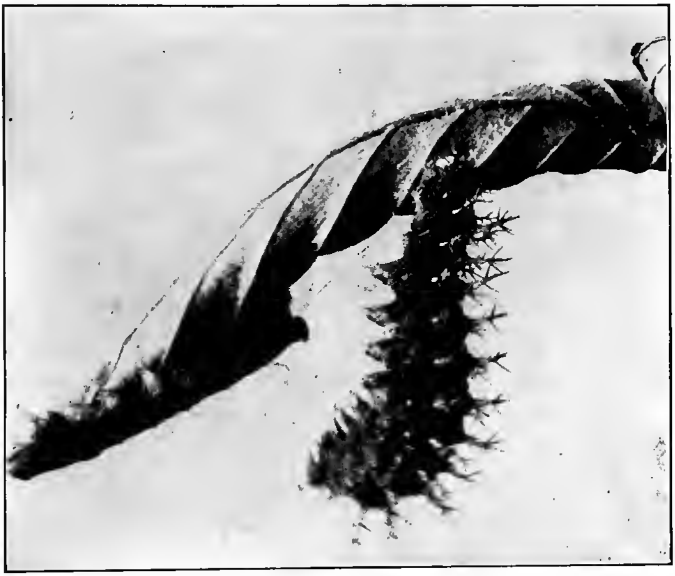


Fig. 9.—The larva of the violet-tip butterfly. *Polygonia interrogationis*, making its last moult, i.e., pupating. (Photograph from life, by the author.)

are incomplete and not able to suck flower nectar which is the usual food of moths and butterflies. The pieces of cloth covered with eggs should be put away in a closed box and kept in a fairly cool place until the following spring. When the mulberry leaves appear again, lay out the egg-cloths in trays in a warm bright room. In a few days the hatching will begin, and with it a new life-cycle.

Other moths and butterflies.—The life-history of the silkworm moth serves as an example of the life of all moths, and of butterflies too, which are closely related to moths. In every case there hatch from the eggs not small moths and butterflies, but worm-like larvæ, which we call caterpillars (figs. 7 and 8). These larvæ feed mostly on green leaves, grow rapidly, moult several times, and

FIG. 10.—Chrysalid (pupa) of the violet-tip butterfly, *Polygonia interrogationis*. From this chrysalid issues the full-fledged butterfly. (Photograph from life, by the author.)

finally change to pupæ, i.e., pupate. Before pupating some spin a silken cocoon as the silkworm does, some may burrow into the ground, and some simply crawl into a sheltered spot, or hang from some twig and change into a naked pupa or chrysalid (figs. 9 and 10). In this latter case the color of the chrysalid usually harmonizes so well with the surrounding leaves or bark that it is almost indistinguishable. Almost any caterpillars that are found may be reared in the schoolroom or at home if the proper food is known and can be obtained. While some of them will eat almost any kind of leaves most of them feed only on one or two particular kinds. Whatever plant the caterpillar selects outdoors is the kind of food plant it prefers or must have.

Directions for making breeding-cages for caterpillars are given on p. 330; so that any caterpillar found may be brought home alive and an attempt made to rear from it the moth or butterfly of which it is only a young stage.

Excellent books about the life of butterflies and moths are "Moths and Butterflies," by Mary C. Dickerson, "Every-day Butterflies," by S. H. Scudder, and "Caterpillars and Their Moths," by Ida Eliot and Caroline Soule.

DRAGON-FLIES

The adults.—Dragon-flies (fig. 11), or "devil's darning-needles," are familiar insects in any locality not wholly without ponds or streams. These long, slender-bodied, swiftly flying insects are to be seen any bright day from early spring to late autumn darting hither and thither over a pond or along a stream bank. They are usually brilliantly colored with blue or green or red, and the wings are often strongly marked with blackish bars or blotches. When they thus dart swiftly about they are capturing and devouring their prey—the little gnats and midges which dance in the air over the pond or near its shores. Dragon-flies are the hawks of the insect world.

If one of these swift flyers can be caught in an insect net it may be taken out and handled without fear, for despite popular prejudice it is wholly harmless to anything except small insects; these it catches in its wide mouth and crushes with its strong jaws. But it has no sting, nor any piercing beak or poisonous jaws. Note the long, slender hind body or abdomen, made up of several segments or body-rings; in flight this hind body acts as a rudder to help steer the dragon-fly in its quick turnings and swift dashes. Note the two pairs of long wings, transparent and delicate, but firmly supported by a complex skeleton of longitudinal and cross veins; no other insect surpasses this one in flight. Note the three pairs of slender weak legs; it uses its legs only occasionally for perching, but it uses the two front pairs to form a little sort of trap or basket which aids the great mouth in catching and holding small insects when the dragon-fly is "hawking." Note the great head, so loosely attached to the body behind it that it can be turned in any direction, and can even be so twisted on the neck that the top of the head will be directed downward with the mouth facing directly upward. This head is composed chiefly of two great shining compound eyes each made up of many thousand eye-elements. When examined under a good hand lens the shining outer surface of these eyes is seen to be composed of thousands of tiny facets, each facet being the window or transparent outer wall of one of these eye-elements. Each facet and the eye-element behind it see one small part of the object looked at, so that the image produced in the sensitive part of the back of the eye is composed of thousands of separate small parts, which make a sort of mosaic of the object looked at. This seeing by compound eyes,

FIG. 11.—A dragon-fly. (From life.)

which is the kind of sight possessed by almost all insects and crustaceans (crabs, lobsters, crayfishes, etc.), but by no other animals, is called mosaic vision, and cannot be so exact or truthful as our own.

Examine the mouth of the dragon-fly and notice the large flap-like under lip which folds over the opening, and behind it the strong brown jaws.

Make a drawing from dorsal view of an adult dragon-fly with wings outspread. Make a drawing of the head from front view.

Egg-laying.—If you watch dragon-flies darting over a pond in summer occasionally some may be seen to swoop down quite to the water's surface and to strike it repeatedly with the tip of the abdomen. These are laying eggs, and each time the water is touched a few eggs are liberated and sink slowly to the bottom. If one of these ovipositing females can be caught alive the egg-laying may be observed and the eggs obtained for the school aquarium by holding the dragon-fly by the wings and touching the tip of her abdomen to the surface of some water in a saucer. The eggs should then be poured into the aquarium (for directions for making simple school aquaria see p. 332) where, if all goes well, they will hatch into young dragon-flies. But as this hatching will not occur until late in the summer, and as the young dragon-flies, called nymphs, grow very slowly and do not change into winged adults for about a year, it will be better to find nymphs in the pond and stock the aquarium with these already partially developed individuals.

Nymphs.—With a rake or stout water-net (see p. 335) scrape over the bottom of a pond and find in the mud and slime drawn out a number of flattened, heavy-bodied, broad-headed, six-legged creatures like the one shown in figure 12. These are the nymphs of dragon-flies. Each nymph will have on its back four conspicuous wing-pads; the larger these are the older is the nymph, and the more nearly ready to change into the adult form. April and May are the best months for collecting nymphs because the oldest ones found then are nearly ready to change into winged flies, and this they may do in the schoolroom. A careful observer of these creatures gives the following directions for bringing the nymphs to maturity. "Place them [the collected nymphs] in a wooden pail or tub. If the sides are so smooth that they cannot crawl up to transform, put some sticks in the water for them to crawl out on. Tie mosquito netting tightly over the top, or better, make a screen cover; leave three or four inches of air between the water and the netting; feed at least once a week; set them where the sun will reach them; and after the advent of warm spring weather look in on them early every morning to see what is going on."

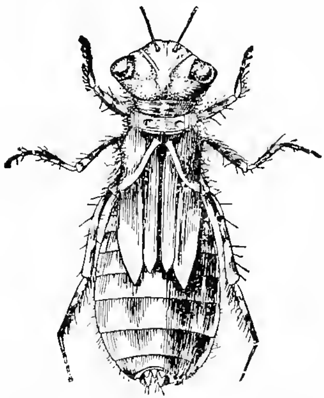


FIG. 12.—The young (nymph) of a dragon-fly. (From Jenkins and Kellogg.)

To feed the nymphs provide them with smaller live insects. Mosquito wrigglers, May-fly nymphs, small water-bugs, and any tiny swimming "beasties" that can be caught in stagnant water should be dropped alive into the tub. The nymphs, like the adult dragon-flies, are exclusively carnivorous in diet. Observe how they catch their prey. Note that they rarely come to the surface of the water, and that there is no indication of breathing. In fact they breathe under water by means of gills which are not external, but which line the posterior third of the intestine. Water, carrying air dissolved in it, enters through the anal opening at the posterior tip of the body, and, after giving up its air to the gills inside, is ejected again. The opening is guarded by some flaps which may be seen to open and close occasionally. If a nymph be taken out it may eject water with considerable force from this opening.

Kill a nymph in a killing-bottle and examine it carefully. Note the wing-pads ; note the long, strong legs ; also the large head with conspicuous compound eyes and short delicate antennæ. Examine especially the mouth-parts, and note how the long under lip is folded over the mouth-opening, but can be unfolded and extended from a third to half an inch ; note the two grasping parts at its tip (fig. 13). This long, grasping under lip is the prey-catching organ of the nymph, while the pair of strong jaws which open and shut laterally are the organs which crush the body of its prey and force its blood into the hungry

FIG. 13.—Young (nymph) dragon-fly, showing lower lip folded and extended. (From Jenkins and Kellogg.)

mouth of the destroyer. Make a drawing of a nymph from dorsal view, with its under lip extended and pinned out. Make a drawing of the front of the head, with the under lip folded like a mask over the face.

The transformation to winged stage.—During the life of the nymph it grows and develops from a very small creature without wing-pads to a much larger one with conspicuous pads. During this growth it moults several times, just as the growing silkworm does. Immediately after moulting the body wall is very soft, and light greenish or grayish in color, but it gradually hardens and darkens. When its growth and development is completed the nymph will climb out of the water on some firm object, and, fixing its feet solidly, will proceed to transform, by means of a final moult, into the adult or imago stage. The cuticle or horny outer-skin layer splits along the middle of the back of the head and front part of the body, and out of this crack the winged dragon-fly slowly emerges. When this transformation takes place outdoors it usually occurs early in the morning. "If one can be out at the pond by six o'clock some clear morning, when the adults of some dragon-fly that is known to be common are beginning to appear, he may be sure of finding them transforming. There will be some nymphs crawling up the banks, imagos pulling themselves out of their old nymph skins, others drying their wings, others ready to fly, and all within a few feet of the margin of the water. . . . At noon one would find only dry and empty nymph-skins clinging to the sedges. And there, unless beaten down by wind or rain, each empty husk still clings, useless now, or sometimes furnishing a night's shelter to some mendicant plant-bug, until the festive, sportive, aerial life of its former occupant has run its swift course."

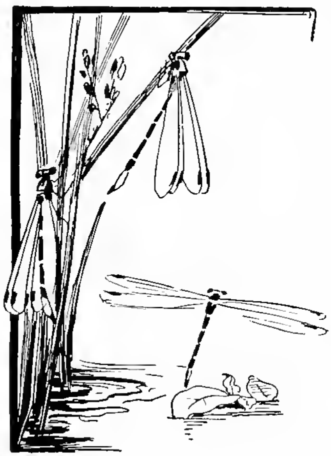


FIG. 14. — Damsel-flies (narrow-winged dragon-flies). (Natural size; from life.)

For a good account of dragon-flies see pp. 54–72, in "Outdoor Studies," by James G. Needham.

CHAPTER II

TOADS AND TADPOLES

While the life-history of most of the backboned animals shows no such startling transformations or metamorphoses as that of the insects we have studied, yet among toads, frogs, and salamanders, forming the class of backboned animals known as amphibians or batrachians, there is an interesting and well-marked metamorphosis. A newly hatched bird is much smaller and weaker than its parents, its feathers are different, and it usually has to be cared for and fed for some time, but it is unmistakably bird-like in appearance, and its development to adult form is gradual and without startling changes. The same is true of kittens and puppies, or young lions or camels, and true, also, for the most part, of fishes and of snakes and lizards. But the young toad or frog, which we call tadpole, looks, and truly is, much more like a fish than like its parent, and therefore in its growth and development it undergoes a marked transformation.

The eggs and hatching.—In the spring, April and May, the frogs and toads begin their croaking and trilling, and then is the time to look in the ponds for the eggs. Indeed the ponds had better be watched as soon as the ice goes out. Hunt in the shallow water along the banks. Toads' eggs lie in long strings of a gelatinous, jelly-like substance, usually wound about submerged sticks or the stems of water-plants, while those of the frog are found in small bunches or masses of the jelly. They are small, shining, black, and bead-like, and in the toad strings are arranged in single rows. If they have been recently laid, the enclosing jelly mass will be clean and clear, but it soon becomes partly covered with fine mud, when the eggs are not so easily seen. Bring some egg masses to the schoolroom and keep them in water in a light warm place, but not in the direct sunlight.

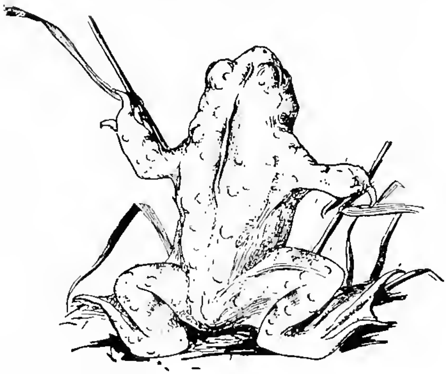


FIG. 15.—Garden toad. (From life.)

Examine the eggs several times a day, as hatching occurs in two or three days after they are laid. The developing embryo can be clearly seen through the transparent jelly. Watch for their first movements and note their change in form. Finally they wriggle out from the jelly mass and swim freely in the water, or attach themselves, by means of a little V-shaped sucker on the head, to some solid object. They are not like adult frogs or toads at all, but are the familiar little fish-like tadpoles (fig. 16).

The tadpoles.—To rear tadpoles successfully in the schoolroom requires some pains. First, a proper little artificial pond must be made. Professor Gage, of Cornell University, who has successfully reared many broods, gives the following directions for caring for them:

" To feed the tadpoles it is necessary to imitate nature as closely as possible. To do this a visit to the pond where the eggs were found will give the clue. Many plants are present, and the bottom will be seen to slope gradually from the shore. The food of the tadpole is the minute plant-life on the stones, the surface of the mud, or on the outside of the larger plants. Make an artificial

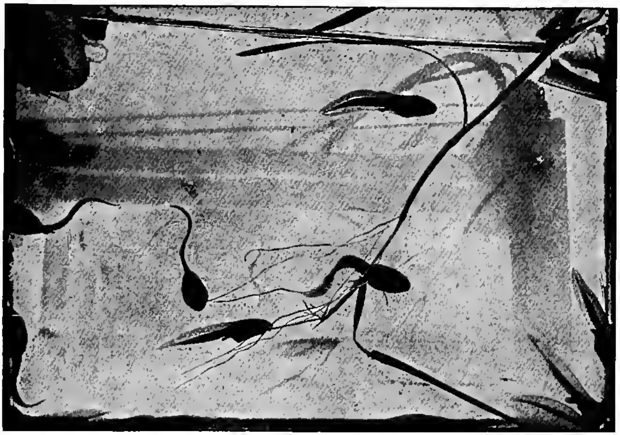


FIG. 16.—Tadpoles. (Photograph from life by Cherry Kearton ; permission of Cassell & Co.)

pond in a small milk-pan, or a large basin or earthenware dish. Put some of the mud and stones and small plants in the dish, arranging all to imitate the pond, that is, so it will be shallow on one side and deeper on the other. Take a small pail of clear water from the pond to the schoolhouse and pour it into the dish to complete the artificial pond. The next morning when all the mud has settled and the water is clear, put thirty or forty of the little tadpoles which hatched from the egg string, into the artificial pond. Keep this in the light, but not very long at any one time in the sun. . . .

"One must not attempt to raise too many tadpoles in the artificial pond or there will not be enough food, and all will be half-starved. While there may be thousands of tadpoles in a natural pond, it will be readily seen that, compared with the amount of water present, there are really rather few.

"Every week, or oftener, a little of the mud, and perhaps a small stone covered with the growth of microscopic plants, and some water should be taken from the pond to the artificial pond. The water will supply the place of that which has evaporated, and the mud and stones will carry a new supply of feed."

The tadpoles will begin to change very soon. Make a drawing of one just hatched from the egg, examining it with a hand lens. Note the gills on the sides of the neck, the V-shaped sucker on the head, and the absence of legs and eyes. Watch sharply for the first changes. What are they?

It takes a tadpole about two months from the time of hatching to complete its development and hop out of the water as a little toad or frog. In this process of development the following changes occur: eyes appear; the gills are lost; four legs develop; the tail is gradually lost, and lungs are formed inside the body. The development of the lungs cannot be actually seen, but its course is made apparent by the behavior of the tadpoles. While at first they remain under the water nearly all the time, breathing by means of their gills the air dissolved in the water, as they grow older they come more and more often to the surface and gulp down air through the mouth. Lungs are developing, and are being more and more used for breathing air from the limitless supply above.

Observe carefully the process of the disappearance of the tail. Does it drop off suddenly? Is it lost before the legs develop? Which pair of legs appears first? The order of their appearance differs in the toad tadpoles and the frog tadpoles ; if both kinds are being reared determine this by observation.

Make a drawing of a tadpole just after its legs appear, and compare with the drawing of the newly hatched tadpole ; make also a drawing of a little toad or frog when it first finishes the tailed tadpole stage and hops out of the water.

While the development of the tadpoles is going on in the schoolroom observations on the growth and changes of those in the natural ponds outdoors should be made. Does development go on more rapidly indoors than out ? Where do the little toads and frogs go after they leave the outdoor ponds ? On what do they feed now ?

Toads and frogs.—Adult toads and frogs are carnivorous, instead of feeding on tiny plants as in their tadpole stage. They snap up all kinds of insects, worms, and snails ; when full grown they will eat younger frogs, crayfish, small turtles, and fish, and may also occasionally capture small birds. A few grown-up toads and frogs should be kept in the schoolroom in a box with at least one glass-side and covered over with netting. Keep a dish of water in the box, and the bottom covered with clean moist sand. Feed the toads live insects, worms, and snails, or bits of raw meat. How does the toad catch its prey or seize the offered food ?

FIG. 17.—Garden toad. (From life.)

Both toads and frogs do much good by destroying many insects. One observer, quoted by Professor Gage, reports that a single toad disposed of twenty-four caterpillars in ten minutes, and that another ate thirty-five celery-worms within three hours. This observer estimates that a good-sized toad will destroy nearly ten thousand insects and worms in a single summer. The garden can have no more desirable animal inhabitants than toads; not only should they not be killed but it would be worth while to introduce them in flower and vegetable gardens where they are not naturally present.

For a good account of tadpole-rearing see "The Life of a Toad," by Professor S. H. Gage.

CHAPTER III

A BIRD'S NEST, AND OTHER ANIMAL HOMES

The animals whose life-history we have so far studied do not take care of their young, though making certain provision for them nevertheless. The female mosquito, although an aerial creature, is careful to lay her eggs on the surface of water so that the young will find themselves at the moment of hatching in their proper element; the female silkworm moth, although she never takes food herself, in nature would certainly lay her eggs on mulberry trees, where the young, on hatching, could find at hand their proper food. Such is the habit of all moths and butterflies. Some of them indeed take food in their adult stage, but this is always liquid nectar from flowers, or other sweet juices, and water, and their mouth-parts are formed into a long, flexible, coiling, sucking proboscis. They could not eat green leaves if they would; and yet each moth and butterfly mother seeks out, at egg-laying time, that particular plant, unknown to her as food, the green leaves of which the young caterpillars must live upon; truly a remarkable instinct! But beyond this care in laying their eggs in suitable places the butterflies and moths have nothing to do with their young.

And so it is with most of the lower or simpler animals, and with many of the vertebrates (backboned animals), most of the fishes for instance, the amphibians, and the reptiles. These animals pay little or no attention to their young after birth; indeed many of the lower ones die before the young are hatched, and those that do not may have gone a long distance away before that time. But among the higher vertebrates, the birds and mammals, and among a few particularly interesting invertebrates, as the social insects and others, the parents give much care and protection to their young, building homes for them, providing them with food, and teaching them to help themselves. Almost all animal homes are built primarily for the protection and housing of the young, although the parents, may, and during the rearing of the young naturally do, largely live in them themselves. As an example of an animal home, we may observe the construction of a bird's nest, together with the egg-laying and incubation and the care of the fledglings.

A Bird's nest.—In spring and early summer, the nesting-times, find close to the schoolroom a pair of birds that have begun a nest. By keeping sharp watch in trees and bushes they will surely be found, though most birds hide their nests as effectively as possible. Robins are especially good birds to watch, because they are not easily frightened from their work, because they build a large nest, and because they gather their nesting materials mostly in the near vicinity of the nest. Because the robin's nest is in a tree, it may not be so easy to watch as the nest of some bird that builds in hedges or bushes. Find a robin or other bird carrying a straw in its bill and trace it "home."

In observing the nest-building, egg-laying, and incubation try to answer the following questions: Do both birds take active part in building, or but one, and if one, which one, the male or female, and what does the other do? What materials are used? Is the nest composed chiefly of one kind of material, or nearly equally of several? What "tools" of the bird are used in building?

When does building begin? How long does it last? How soon after finishing the nest are the eggs laid? Are all the eggs laid at one sitting? Do both birds take part in incubation, i.e., sitting, or but one, and if but one, is it the male or the female? What does the other do? How long before the eggs hatch? Do they all hatch at the same time?

Fig. 18.—Nest of humming-bird, made of sycamore down (one-half natural size).

After hatching the care of the fledglings should be well watched. Do both parents bring food? How many times is food brought in one hour, or if so much time can be given to continuous watching, in two or three? What is the food? Is the nest cleaned? If so, how often? When are the first flying lessons given? How long do the young birds continue to come back to the nest at night after they first leave it?

Other incidents in the course of nest-building incubation, and care of the young birds will certainly be noted if sufficient observation to answer the above questions is given. Attacks by cats and bluejays (fig. 19), disputes between the parent birds, accidents from high winds or other causes are all likely to enter into the course of nesting. And the behavior of the parent birds under such more or less unnatural circumstances will be interesting to observe and record.

While some pupils are watching a robin's nest others should observe the nesting of other kinds of birds—the bluebird, wren, groundbird, catbird—any familiar kind that can be found at work.

In Chapter XV of this book, which is devoted to suggestions for studying the life of birds, further attention is given to nesting and care of the young. See Chapters XVII–XXI in Baskett's "The Story of the Birds," and Chapter VI in Chapman's "Bird-life."

FIG. 19.—Oriole's nest with skeleton of bluejay suspended from it; the bluejay probably came to the nest to eat the eggs, became entangled in the strings composing the nest, and died by hanging. (Photograph by S. J. Hunter.)

Homes of insects and spiders.—The insects which build the most elaborate homes and take the greatest care of their young are the so-called social insects—the communal ants, bees, and wasps. As a later chapter (Chapter XX) in this book is entirely devoted to the life-history and habits of these insects, we may omit any account of them here. But only a few species of bees, namely, the bumble-bees and the honey-bee, live in communities, and similarly only a few kinds of wasps. All the ants, however, and more than 2000 living species of them are known, have a communal life. But the solitary

FIG. 20.—An oak-gall (California) home of a small four-winged gall insect; in upper figure the gall on oak-branch; in lower, the gall cut open to show the inside. (Upper figure slightly reduced; lower figure, natural size; from specimen.)

bees and wasps give more or less special attention to their young, all of them building homes for them, and providing them with food either by storing it in a closed nest and leaving the young to supply themselves from it, or by leaving the nest open and bringing food daily after the larvæ hatch. The instincts connected with nest-making and caring for the young shown by the non-social or digger wasps and the solitary bees are remarkable, and offer an intensely interesting field of outdoor observation and study. (See the special account of these habits in Chapter XII on insects.)

Many insects make for themselves simple burrows or nests in the ground or wood. When not feeding they can retire to these burrows and lie there somewhat protected from their enemies, the birds and the predaceous insects. The eggs of many insects are thrust by the female into the soft tissue of leaves and stems, or even into bark and hard wood. When the young hatch they burrow about in the plant or tree, feeding on the juices or other plant substance, and remaining out of sight and reach of their outside enemies. The larvæ of certain moths burrow about in the soft inside tissue of leaves, the whole life of the moth except its short adult stage being passed inside the leaf. These moths are called leaf-miners. The larvæ of some moths and of many small four-winged hymenopterous midges live through their immature life in galls (fig. 20) on live plants. The mother, with a tiny, pointed ovipositor, thrusts her eggs into soft plant tissue, which closes over them. When the

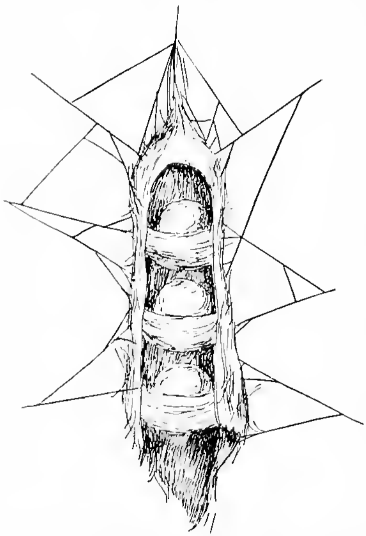


FIG. 21.—Egg-cocoon of the labyrinth spider, with side removed to show egg-packets and chambers. (Two and one-half times natural size; after Snodgrass.)

larvæ hatch, their wriggling and feeding irritate the sensitive tissue so that it grows in an abnormal way and forms a gall, often very large, about the insects.

All these burrows and galls may be looked on as the simplest kinds of houses or homes, the young insects living in them, and being protected by them.

Most spiders spin silken cocoons (fig. 21), or sacs, in which to deposit their eggs. Some spiders carry this egg-filled cocoon (fig. 22) about with them for the sake of protecting the eggs. After hatching the spiderlings remain in it a short time, feeding on each other! Thus only the strongest survive and issue from the cocoon to

FIG. 22.—A female running spider (*Lycosidæ*) carrying its egg-sac about attached to its spinnerets. (From Jenkins and Kellogg.)

earn their living in the outer world. With certain species of spiders the young after hatching leave the cocoon and gather on the back of the mother and are carried about by her for some time. In connection with their webs or snares many spiders have silken tunnels or tubes in which to lie hidden, a sort of sheltering nest. Those that live on the ground make for themselves cylindrical burrows or holes in the ground, usually lined with silk, in which they hide when not hunting for food. Especially interesting among these many kind of nests are the burrows of the various trap-door spiders (figs. 23 and 24). These spiders are common in California and some other far Western States. Their burrow or cylindrical hole is closed above by a silken, thick, hinged lid or door, a little larger than the hole in diameter, and neatly beveled on the edge, so as to fit tightly into and perfectly cover the hole when closed. Its upper surface is covered with soil, bits of leaves, and wood, and resembles very exactly the ground surface about it. We have found these trap-door nests in California in moss-covered ground, and

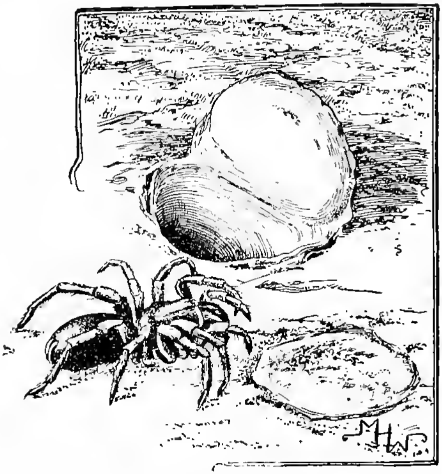


FIG. 23.—Trap-door spider (California) with two burrows, one with door open, one with door closed. (Natural size; from life and specimens.)

here the nest lids were always covered with green, growing moss.

An English naturalist who studied the habits of these spiders found that if he removed the soil and bits of bark and twigs, or the moss, from the upper surface of the lid the spider always recovered it. It is of course plain that by means of this covering the nest is perfectly concealed, the surface of the closed door not differing from the surrounding ground surface. This naturalist finally removed the moss not only from the surface of a trap-door, but also from all the ground in a circle of a few feet about the nest. The next day he found that the spider had brought moss from outside the cleared space and covered the door with it, thus making it very conspicuous in the cleared ground space. The spider's instinct was not capable of that quick modification to allow it to do what a reasoning animal would have done—namely, to cover the trap-door only with soil to make it resemble the cleared ground about it.

FIG. 24.—Burrow of trap-door spider cut open to show interior. (One-half natural size; from specimen.)

Another interesting species is the turret-spider, that builds up a little tower of sticks and soil and moss above its burrow (fig. 25). The sticks are an inch or two in length, fastened together with silk and so arranged as to make a five-sided turret two or three inches high. This turret-building spider carries about its egg-cocoon. A female of this species in captivity was observed to pay much attention to caring for the cocoon. "If the weather was cold or damp she retired to her tunnel; but if the jar in which she lived was set where the sun could shine upon it she soon reappeared and allowed the cocoon to bask in the sunlight. If the jar was placed near a stove that had a fire in it the cocoon was put on the side next the source of warmth; if the jar was turned around she lost no time in moving the cocoon to the warmer side. Two months after the eggs were laid the young spiders made their appearance and immediately perched upon their mother, many on her back, some on her head, and even on her legs. She carried them about with her and fed them, and until they were older they never left their mother for a moment."

FIG. 25.—"Turret" or above-ground part of nest of turret-spider. (Natural size; from specimen.)

Homes of the backboned animals.—Among the fishes, the lowest of the backboned animals, most species content themselves with the laying of many eggs in a situation best suited for their safe hatching. But some species show interesting domestic habits. The female catfish swims about with her brood much as a hen moves about with her chickens. Some of the larger ocean catfish of the tropics receive the eggs or the young within the mouth for safety in time of danger. Certain sunfishes care for their young, keeping them together in still places in the brook. They also make some traces of a nest, which the male defends. The male salmon scoops out gravel to make a shallow nest, in which the female deposits her eggs, after

FIG. 26.—A frogfish (*Antennarius*) and its nest. (By permission of Out West Publishing Co., Los Angeles, Cal.)

which he covers the eggs. The males of the species of pipe-fish and sea-horses receive the eggs of the female into a groove or sac between the folds of skin on the lower part of the tail. Here they are kept until the little fishes are large enough to swim about for themselves. The brave little stickleback builds a tiny nest about an inch and a half or two inches in diameter, with a small opening at the top. In this nest the eggs are laid, and the young fish remain in it some time after hatching. The male parent jealously guards it and fights bravely with would-be intruders.

The frogs and salamanders (batrachians) and the lizards and snakes (reptiles) rarely show any care for their young, the eggs of most batrachians being laid in the water and left by the female. The males of the Surinam toad receive the eggs in pits of the spongy skin of the back, where they remain until the young hatch. Snakes' eggs are laid under logs or buried in sand, and no further attention is given them by the parent.

Among the birds, as we know, nest-building and care of the young are the rule. But not all birds make nests. On the rocky islets of the northern oceans, where thousands of puffins and auks and other maritime birds gather to breed, the eggs are laid on the bare rock (fig. 27). At the other extreme is the tailor-bird of India, which sews together leaves with fibrous strips, plucked from a growing plant, to form a long, bag-like nest. The nests of the orioles and bush-tits are also good examples of elaborate nest-making. In the degree of care given the nestlings there is also much difference. The robin brings food to the helpless young for many days, and finally teaches it to fly and to hunt for food for itself. Young chickens are not so helpless as the nesting robins, but are able to run about, and, under the guiding care of the hen mother, to pick up food for themselves.

Among the mammals the young are always given some degree of care. Excepting in the case of the egg-laying

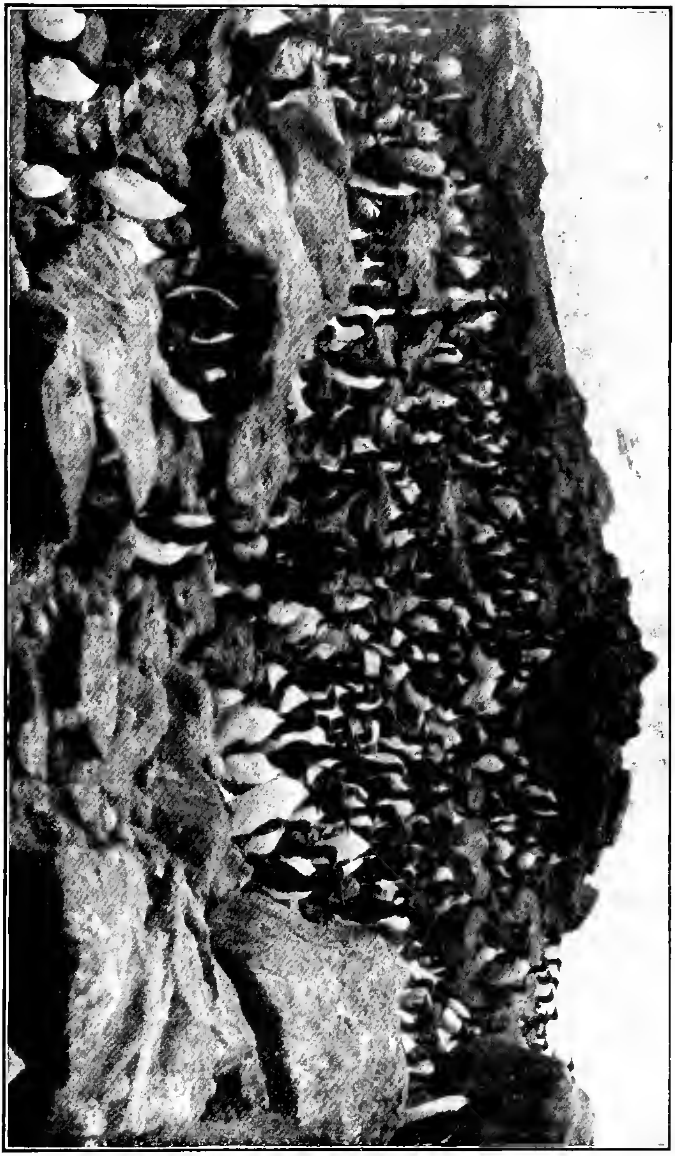


FIG. 27.—Murres on Walrus Island, Behring Sea. Note the eggs scattered about over the bare rocks. (Photograph from life by the Fur Seal Commission.)

duck-bills, the lowest of the mammals, the young are born alive—that is, not hatched from eggs laid outside the body—and are nourished after birth, for a shorter or longer time, with milk drawn from the body of the mother. The nests or homes of mammals present varying degrees of elaborateness, from a simple cave-like hole in the rocks or ground to the elaborately constructed villages of the beavers, with their dams and conical several-storied houses. The wood-rat piles together sticks and twigs in what seems, from the outside, a most haphazard fashion, but which results in the construction of a convenient and ingenious nest. The moles and pocket-gophers build underground nests composed of chambers and galleries. The prairie-dogs make burrows in groups, forming large villages.

We are familiar with the devotion to their young displayed by birds and mammals. The parent will often risk or suffer the loss of its own life in protecting its offspring from enemies. Many mother-birds have the instinct to flutter about a discovered nest, crying, and apparently broken-winged, thus leading away the predatory fox or weasel to fix his attention on them and to leave the nest unharmed.

See Beard's "Curious Homes and their Tenants."

PART II

THE PARTS OF ANIMALS AND HOW THEY ARE USED

CHAPTER IV

THE GRASSHOPPER AND THE SNAIL

An animal's body composed of parts.—The body of every animal, except the very simplest ones, is composed of a few or many parts, each part having some special use or thing to do. A dog has its body made up of head, trunk, legs, and tail—the head comprising skull with brain inside, jaws with teeth, tongue, eyes, ears, etc.; the trunk comprising a host of internal parts, as the backbone, heart, lungs, stomach, intestines, etc., and the legs in turn composed of a series of bones to which are attached muscles, among which run nerves and blood-vessels, the whole being covered with a hairy skin. The study of the parts, external and internal, of an animal is called *anatomy*, and the study of the uses or functions of the parts is called *physiology*. In earlier years anatomy and physiology were studied wholly separately, as they still sometimes are. But we know that the things animals do, and the ways in which they do them, depend upon the parts of the body and upon the special character of these parts. We know also that these parts are specially developed and fitted to do certain things or perform certain functions

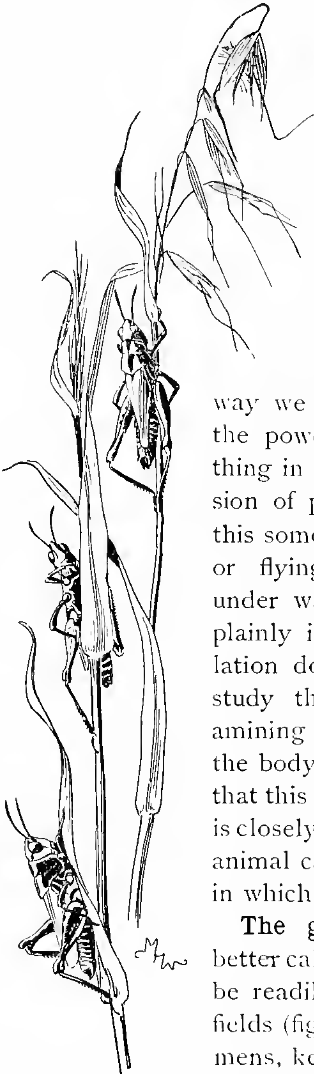


FIG. 28.—Locusts on wild oats. (Natural size; from life.)

in special ways. That is, the structure of a part and its function or business are closely related. A grasshopper's hind legs are specially long and strong so as to enable the grasshopper to hop; or we may put it differently and say that the grasshopper can hop because its hind legs are specially long and strong. In whichever way we look at this relation between the power of an animal to do something in a special way and its possession of parts specially fitted for doing this something, whether it be hopping, or flying, or singing, or breathing under water, it must be kept always plainly in mind that such a close relation does exist. Therefore when we study the make-up of an animal, examining carefully the various parts of the body, we should always remember that this particular make-up or structure is closely connected with the things the animal can do, and the special manner in which it does them.

The grasshopper. — Grasshoppers, better called locusts, of some kind can be readily found along roadsides or in fields (fig. 28). Collect several specimens, keeping some alive and dropping the others into the killing-bottle (see p. 335). Examine carefully a dead specimen. Note that the body is made up of rings or segments. In what part of the body are these rings plainest? The legs are attached to the middle part of the body called the thorax, of which the front part (to which the front legs are attached) is movable and is covered over by a sort of saddle-shaped hood, while the hinder part is solid and box-like. How many pairs of legs are there? Examine a single leg and make a drawing of it, showing of how many parts it is composed and how each part appears. Of what use are the claws and the little pads on the under surface of the foot? To what part of the body are the wings attached? Note how the narrow thicker fore wing covers and protects the plaited delicate hind wing when the wings are folded. When the locust flies for long distances it rises high into the air, until it finds an air current; then it simply lets its large outspread hind wings act as flat sails to hold it up, thus allowing it to float for many miles. In this way the Rocky Mountain locusts sail or fly sometimes a thousand miles; all the way from Wyoming to Kansas. Note the many veins in the wings. What are these for? Draw a front wing and a hind wing.

On the head find two large compound eyes (see p. 22), three very small simple eyes, a pair of many-jointed feelers or antennæ, used both for feeling and probably also for smelling, and a set of mouth parts consisting of an upper lip, a pair of hard, blackish-brown jaws or mandibles, a second pair of jaw-like parts called maxillæ, each made up of several small pieces and a small palpus or feeler, and an under lip bearing two more small palpi. With the mandibles the locust bites off, and with the help of the other parts, chews bits of leaves, green stems, etc. The palpi are believed to be organs for feeling and tasting the food. Draw the front of the head, naming the different parts.

Note that almost the whole outer surface of the body is covered with a firm, smooth coat, the chitinized cuticle, that is, the horny outer layer of the skin. The skin of the neck, however, and that at the bases of the legs and wings is soft. Why is this necessary? What is the most obvious use of this hard outer covering? Note that the soft skin of the neck is well protected by the projecting

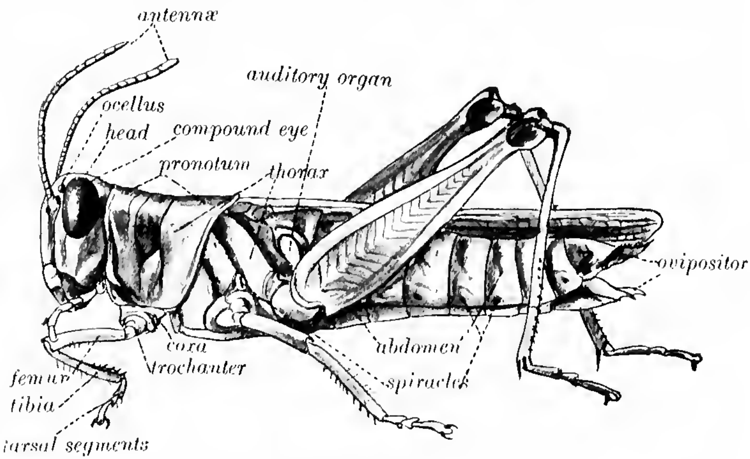


FIG. 29.—Locust with external parts named.

saddle-shaped horny piece on the front thoracic body-ring. Another use of the firm cuticle, or exo-skeleton, as it is called, is to afford solid points of attachment for the many muscles of the body, the locust having no bones or any kind of internal skeleton. (In a few places there are processes or continuations of the exo-skeleton projecting internally.)

That part of the body behind the thorax is called the abdomen. Examine the upper side of the first (nearest the thorax) body-ring of the abdomen, and find two small, nearly circular, thin places looking like little windows. These are the hearing organs, or tympana, of the locust. The sound-waves striking against these thin tightly stretched bits of the body wall, set them into vibration, and these vibrations stimulate a tiny nerve which touches each tympanic membrane on the inside and leads to one of the internal nerve-centers. This is a much simpler kind of ear than we possess, and the locust probably cannot hear nearly as well as we can. Note on each side of each abdominal body-ring (except the last) a tiny blackish spot. These are breathing pores or spiracles like those of the silkworm (see p. 13). The locust does not take in air through nostrils on the head or through the mouth, but through these numerous pores. There is also a spiracle near each tympanum, and one on each side of the thorax near the insertion of the middle legs. At the very tip of the abdomen are several small projecting parts which differ in the male and female. The female has two pairs of strong, curved, pointed pieces called the ovipositor or egg-laying organ. When the locust is ready to lay its eggs, by means of this strong ovipositor it bores a hole in the ground into which the abdomen is pushed and the eggs laid at the bottom. The male locust has a swollen, rounded, abdominal tip, with a few short inconspicuous pieces on the upper surface.

Examine now a live locust and see how it uses its legs in walking and hopping; how it moves its jaws sidewise, not up and down as with us; how its antennæ keep "feeling" about in front of it when it is walking; how the abdomen keeps up a slight but distinct and regular expanding and contracting. This movement forces air in and out of the body through the spiracles; it is the breathing motion.

Make a drawing from lateral view of the whole body of the locust, showing and naming all the parts studied.

For a more detailed account of the external structure of the locust see Comstock and Kellogg's "Elements of Insect Anatomy," Chap. II.

The pond snail.—Pond snails may be found in almost any pond, and live specimens may be easily kept in the schoolroom aquarium or simply in bowls or glass jars of water (fig. 30). They should be fed pieces of lettuce or cabbage leaves. Observe the habits of the snails;

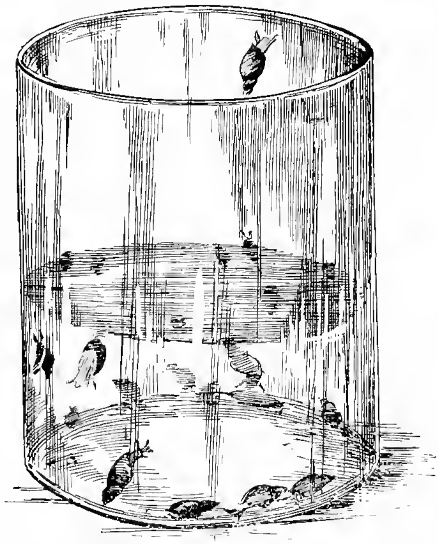


FIG. 30.—Pond snails in a battery-jar aquarium. (One third natural size; from life.)

how they come to the surface to breathe; how they crawl about; how they eat by rasping off bits of the leaves with the rough, horny tongue; how they protrude from and withdraw into the shell; how the feelers move in and out.

Examine a specimen with body extended from the shell, and note that it is not made up of segments or rings, but is a soft, unsegmented mass with a firm, muscular, flattish disk on its lower side called the foot. How does the snail "walk" by means of this "foot"? The body is covered by the mantle, an edge of which may be seen just at the margin of the shell. The soft, flexible body and firmer muscular foot can both be withdrawn into the protecting shell.

Find on the head a pair of extensible tentacles, the feelers, with the eyes (dark spots) at their bases. Most other snails and slugs have two pairs of tentacles or horns, the eyes being on the tip of the second pair. Find also the mouth, and examine with a lens the peculiar ribbon-like radula or tongue, which is covered with fine curved teeth. The radula is drawn back and forth across the food, and by it small particles of the leaf are rasped off. Leaves which have been fed on will show the rasped or scraped places.

Find also, usually just at the surface of the water, when the snail has come up to breathe, a small hole on the right side of the body; this is the breathing pore, and air entering here passes into a small sac-like space, a simple kind of lung.

Examine a shell and note the following parts: the aperture at the large end, the apex or pointed end, the lip or outer edge of the aperture, the lines of growth parallel with the lip, the suture or spiral groove on the outside, the spire comprising all the whorls or turns, and the columella or inner axis of the spire. Do the whorls of all the shells turn the same way? What is the use of the shell?

Make a drawing of the right-hand side of a snail and its shell representing the animal fully extended; name all the parts of the snail and shell.

If pond snails cannot be found, garden snails or slugs may be studied. The slug is a snail-like animal without a shell.

CHAPTER V

THE SUNFISH AND THE SPARROW

The two animals whose external structure we have studied are both backboneless or invertebrate animals. Most of the smaller animals are without internal bony skeletons and hence without backbones. This is true of the sponges and sea-anemones, the starfishes, the worms, the crayfishes, crabs and lobsters, the centipedes, and the spiders, as well as of the insects and the snails, slugs, and clams. Contrasted with these backboneless animals are the backboned ones, or vertebrates, including the fishes, amphibians, reptiles, birds, and mammals or quadrupeds. We shall now examine the external structure of two backboned animals, a fish and a bird.

The sunfish (fig. 31).—Some kind of sunfish can be found in the streams of any part of the United States, except in Washington and Oregon, and in the higher Rocky Mountains. Where sunfishes cannot be obtained, bass or perch or gold-fish may be used for study. Specimens should be taken alive if possible, and kept in a large jar or tub of fresh water.

Examine a live sunfish. Note the deep, flattened trunk of the body, and the paddle-like tail. The head is closely fitted to the trunk without any neck. How are the scales arranged? Remove a scale and examine it under a hand lens. What sort of an edge has it? Examine the fin, called the dorsal fin, on the back. Note that its front part is composed of spines, and its posterior

FIG. 31.—A sunfish. (One-half natural size; from specimen.)

part of soft rays jointed and branched, both spines and rays being connected by and supporting a thin skin. At the end of the tail is the caudal fin; in front of the tail on the under surface is the anal fin, while still in front of this is the pair of ventral fins, and on the sides of the body back of the mouth are the pectoral fins. How is each of these fins composed? The ventral fins correspond to the hind legs of other backboned animals, while the pectoral fins correspond to the forelegs, wings, or arms. Watch the fish swim and determine the use of each kind of fin. Professor Needham gives the following directions for doing this: "To learn the use of the pectoral and ventral fins catch the fish with the hand, avoiding the sharp spines at the front of the pectoral and anterior dorsal fins; fold the pectoral fins backwards, flat against the sides of the body; pass a rubber band back over the head and around these fins to keep them so. Keep the fish under water while attempting to depress the pectoral spines, for in air it will keep them rigidly erect. Pass another rubber band about the ventral fins. Then liberate the fish and watch it. What position does its body assume? Release the paired fins and fasten down the dorsal and anal fins with rubber bands. Liberate the fish again, and observe how it gets along without the use of these fins. What kind of a course does it take through the water?"

Examine the eyes. Are there eyelids? In front of the eyes are two pairs of nostrils. Examine the inside of the mouth. Is there a tongue? Where are the teeth situated, and in what direction do they point? What advantage to the fish is it to have the teeth pointing as they do?

Lift up the flap, called opercular flap, in front of one of the pectoral fins and bend it forward. Under it are four gill arches, each with a double fringe of gills. The cavities enclosed by the gills are called gill-pouches. Note the gill-rakers, short and blunt, on the first gill arch. Note also, on the under side of the flaps turned back, delicate red gill-like structures covered by a membrane. These are the false gills. The true gills are organs by means of which the fish breathes under water. Note the fish continually gulping water. This water with air dissolved in it passes through the mouth into the gill-pouches and out under the operculum. Thus the dissolved air in the water comes in contact with the gills passes through the delicate gill membranes and into the blood, which runs in many fine capillaries through the gills, while at the same time the blood itself gives up carbonic dioxide, which passes out through the gill membranes into the water. In this way the blood is purified.

Make a drawing from lateral view of the sunfish, showing and naming the parts studied.

Professor Needham gives the following directions for seeing the flow or circulation of the blood in the caudal fin of a fish:

"Wrap the fish in a wet towel, leaving the caudal fin exposed, and place it on a low box beside the microscope, with its caudal fin extending across the center of the microscope stage. Spread the fin out flat on a glass slip upon the stage, so as to bring a thin portion of it into the field, and examine it with low power. If the fish refuses to lie quietly, pour a little chloroform on the towel near its mouth.

"Observe the conspicuous, dark, irregular pigment cells scattered throughout the epidermis of the fin.

"The larger blood-vessels are of two kinds; (1) arteries, bringing blood out into the fin, and (2) veins, conveying the blood back to the body again. The smaller ones are the capillaries connecting the arteries with the veins, and distributing the blood throughout the tissues of the fin.

"Observe that the blood consists of a fluid plasma, in which floats numerous corpuscles. Observe that the blood appears red in the arteries and veins, where the corpuscles are accumulated, but only slightly reddish or yellowish in the capillaries, where the corpuscles form but a thin layer.

"Does the blood travel faster in the arteries and veins, or in the capillaries?

"Place a bit of cover-glass over a very thin portion of the fin and study it with higher power. Find two kinds of corpuscles in the blood: (1) red corpuscles (red only when a number are seen together), very numerous, and carried along in the center of the larger currents closely packed together; and (2) white corpuscles, . . . not very numerous, and usually seen trailing along the edges of the blood currents, or escaping out into the tissues."

The English sparrow (fig. 32).—As the English sparrows, which have spread over the whole country, are almost universally held to be pests, the shooting of a few to serve as specimens for the study of the external parts of a bird may be looked on more leniently than the killing of other birds should be. The habits of the live birds may be studied as the pupils go and come from school.

Examine a dead specimen. Note the division of the body into head, trunk, and appendages—namely, wings and legs. Note that the sparrow is covered with feathers, some long, some short, in some places thick and in others thin, but all fitting together to form a complete covering for the body. Only the bill and feet are exposed, and these are covered in one case (bill) with a horny sheath, and in the other (feet) with horny scales. The feathers and the horny covering of bill and feet are simply modi-

FIG. 32.—English sparrows at a drinking-place; note the black cheeks and throat of the males. (One-half natural size; from life.)

fied portions of the skin. Of what uses are the feathers to the bird?

The feathers are of several kinds or types, each of which has a name. In the wings and tail are long, stiff feathers called quill feathers; those which overlie the whole body and bear the color pattern are called contour feathers; the small soft ones which cover the body more or less completely (being, however, mostly hidden by the contour feathers) are called down feathers or plumules, while, finally, the scattered, slender, soft, or stiff hair-like ones, with the thin bare stem and small terminal tuft of branches, are called thread feathers or filoplumes.

Pull a quill feather from the wing and examine it in detail. Note the central stem or shaft, composed of two parts, a basal hollow transparent quill, which bears no web and by which the feather is inserted in the skin, and a longer terminal four-sided part, the rachis, which bears on either side a web or vane. Examine the vane with a lens and see that it is composed of many narrow linear plates called barbs, and that each barb is fringed in turn with smaller branches called barbules. Finally, each barbule bears many fine barbicels or hamules, which can be seen with a microscope. The barbs comprising the vanes are interlocked with each other (fig. 33), thus forming a true web and giving the vanes, composed of small, weak parts, much strength and power of resistance. Rub the feathers from tip to base, and, examining the vanes with

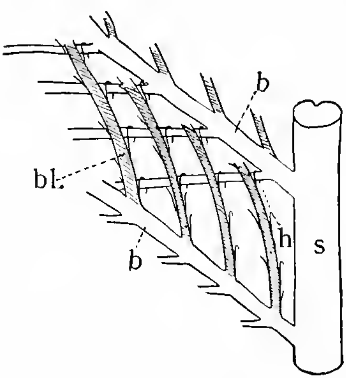


FIG. 33.—Bit of bird's feather, greatly magnified; *s*, shaft; *b*, barb; *bl*, barbule; *h*, hamule. (From specimen.)

the lens, find out what has happened ; now rub from base to tip, and note, under a lens, the result.

Examine a plucked-out contour feather. How does it differ from the quill feather? Can you understand its structure from your study of the quill feather ? Note that the tip of the feather is colored and marked while the base is not especially patterned. Why is this? Examine a down feather. How does it differ in make up from a quill feather ? From a contour feather ? What is the special use of the down feathers ? Finally, pluck out one of the hair-like thread feathers from the base of the bill and examine it with the lens to determine its structure.

Make a careful drawing of each of the four kinds of feathers, naming all the parts.

In classifying birds reference is made in the manuals of classification to differences in the shape and character of many parts of the body and to differences in the plumage of various body-regions. To understand these references it is necessary to become acquainted with the names applied to these various small parts and regions, and so in fig. 34 the names of them all are given.

Examine the bill or beak. It is composed of an upper and a lower mandible or jaw; the meeting line of the mandibles is called the commissure, and the corner of the mouth is called the rictus; the bristles at the rictus are the rictal bristles; the median ridge of the upper mandible is the culmen, and the median keel of the lower mandible the gonys. Note just above the bill two openings. What are they? How are they connected with the mouth? Note the eyes, and at the inner angle of each the delicate nictitating membrane, which can be drawn over the ball. Does the bird have external ears? The names of the regions of the head which are commonly referred to in describing its markings will be learned from fig. 34.

Examine a wing; determine by reference to fig. 34 what feathers compose the primaries, secondaries, tertiaries,

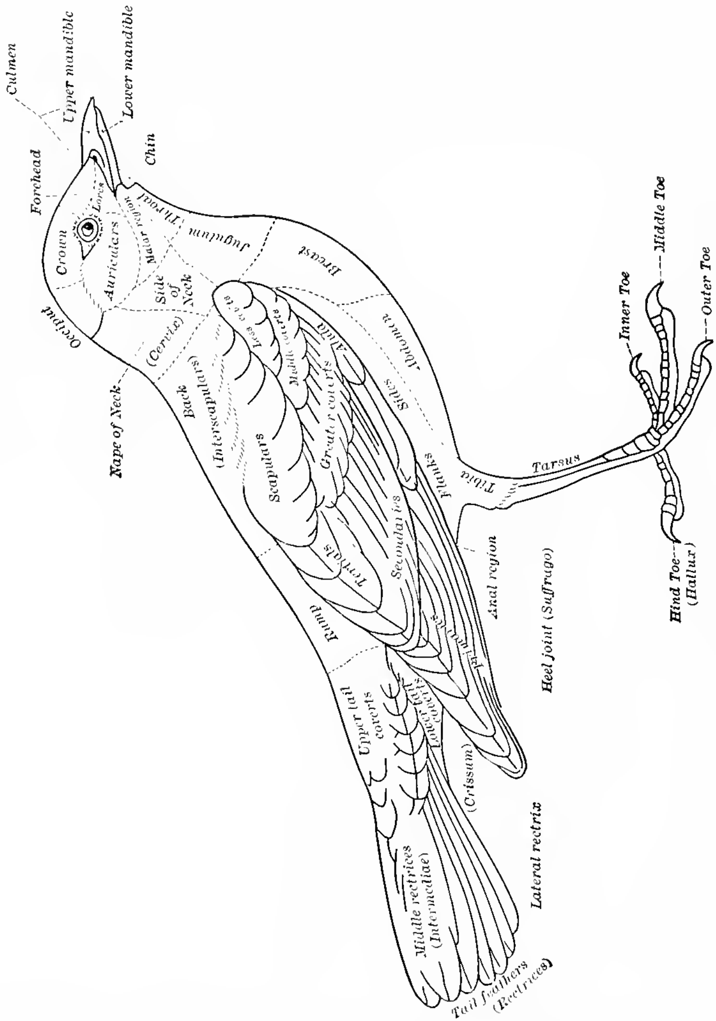


FIG. 34.—Outline of bird's body, with names of external parts and regions.

greater, middle, and lesser coverts. How many primaries are there? How many secondaries? At the bend of the wing and lying partly over the upper greater coverts is a tuft of short quills, the spurious quills; underneath the wing at its junction with the body are some long, narrow feathers, the axillars.

Spread the wing out and note where the quill feathers are inserted. Note how perfectly the feathers fit together and overlap, both when the wing is outspread and when folded. The wing corresponds to our arm and hand, the primaries being inserted on the hand (in the bird there is only one large finger, two very small ones not showing except in the skeleton), the secondaries on the forearm and the tertiaries on the upper arm. With what part of the fish does the wing of the bird correspond? If a cleaned and mounted skeleton of a bird can be had for examination the bones of the wing should be studied and drawn.

The names of the various regions of the trunk can be learned by reference to fig. 34.

How many rectrices or tail feathers are there? What is the use of the tail? Note the oil gland above the base of the tail. What is the use of the oil? How is it put on the feathers? Observe this in a chicken.

Examine a leg. It is composed of thigh, shank, and foot, the foot comprising the long slender tarsus and four toes with claws. What parts of the leg are feathered? Note the covering on the unfeathered parts. What are the toes well fitted for? There is much variety in the shape and character of birds' legs, including differences in the length of the various parts, in the covering, in the number and position of the toes, and in the size of the claws. All these differences, as well as the many in the shape and character of the bill, are correlated with habits, especially the feeding habits of the birds, and offer a most interesting subject for study. Special attention is given this subject in Chapter XV.

CHAPTER VI

THE MOTIONS OF ANIMALS, AND THE SKELETON AND MUSCLES

Motions and locomotion.—Our attention is usually first attracted to an animal by the movements it makes. These are the plainest proof that it is alive. For the animal itself the ability to move is essential to existence. Most animals move in search of food, to escape from their enemies, to find and build their homes, to seek their mates, and care for their young. In the higher forms the organs of motion constitute the great bulk of the body. The shape and size of such an animal are determined largely by these organs.

The heart and blood-vessels, the lungs and digestive system, are principally concerned with supplying the organs of motion with materials necessary for their working, and by far the larger part of the work of the sense organs and nervous system is to put these organs into action, and to direct and control them. We can see therefore that they have much to do with both the structure and physiology of animals. Indeed the most marked difference between animals and plants is the possession by the former of the organs of motion and their controlling organs, the sense organs, the brain and nerves. True, plants have the power of motion and are sensitive to light, heat, and other influences as are animals, but to a far less degree.

Among the movements made by animals, the moving of the body from place to place, usually spoken of as locomotion, generally requires the greatest energy or power. The other motions are those of parts of the body, as the arms, legs, head, etc. We shall here consider a few examples of the motion of animals illustrating the character of locomotion in different forms.

There are three different ways in which locomotion takes place, that is, by swimming in water, crawling or walking or leaping on some solid object, as the ground or the trunk of a tree, and by flying in the air. In each of these three cases the body must first be supported, then either pushed or pulled along or perhaps both pushed and pulled.

In swimming the body is supported by the water. In animals that swim it is either lighter than water, as in the duck, or just as heavy or only a little heavier, as in fishes, so that it is wholly or almost wholly held up by the water, and the full power of the leg, fin, or tail used in the motion can be devoted to pushing the animal along. Animals crawling on the bottom in water also have very little to do in holding up the body, the water supporting them. But those that move on land or fly, with their bodies immersed in air alone, have the body only very slightly supported by the air. These animals must therefore devote energy to supporting the body as well as to moving it along, and they have special means for this.

As already said the body is moved by pushes or pulls. In by far the most cases motion results from pushes given by a part of the body against something outside. Now it is plain that air is a very poor thing to push against as compared with water or a solid. Naturally since water is a liquid it gives way readily to a push, but its heaviness offers much greater resistance to motion than does the air. The solid ground, of course, offers most of all. Currents in water and air are of peculiar help in this matter. Water currents may carry an animal for great distances without any work on its part; while air currents make it possible for birds to soar with little effort. Flight by the vibration of wings, as in birds and insects, requires the greatest expenditure of energy, since the pushes against the thin air must be made quickly and with great force and be rapidly repeated to be effective for support and locomotion. Man in making locomotive machines, railway engines, automobiles, steamships, etc., has met the same conditions as the animals; but the difficulties of aerial locomotion are so great that he has not yet been successful in inventing a mechanism for it such as has been developed in the birds.

The simplest and what may be called the most imperfect mode of locomotion is shown by the simplest animals. These, the Protozoa (see Chapter IX), are extremely minute, and mostly live in water. A single drop of stagnant water may contain hundreds of them. Among these simplest animals we can readily find forms illustrating at least four different modes of motion; all, however, are really but different forms of the same action, that is, the contracting or shortening and thickening of a part or the whole of the animal. In the Amœba (see Chapter IX) the body is composed of a minute bit of soft, jelly-like living substance called protoplasm, without any special parts at all. By the varying contracting and relaxing of the soft body portions of it are protruded and withdrawn again, a slow and imperfect locomotion being accomplished by this means (fig. 35). In the most rapidly moving Amœba the motion is very slow, while in the slower ones it would take some hours to proceed a single inch.

Some kinds of Protozoa show what is called streaming motion. This is seen in forms in which the central portion of the body protoplasm will flow along for a while in one direction, then stop and flow the opposite way. It is not easy to understand the exact method by which this motion is produced.

In some of the Protozoa, instead of the whole or a large part of the body taking part in an ill-defined movement,

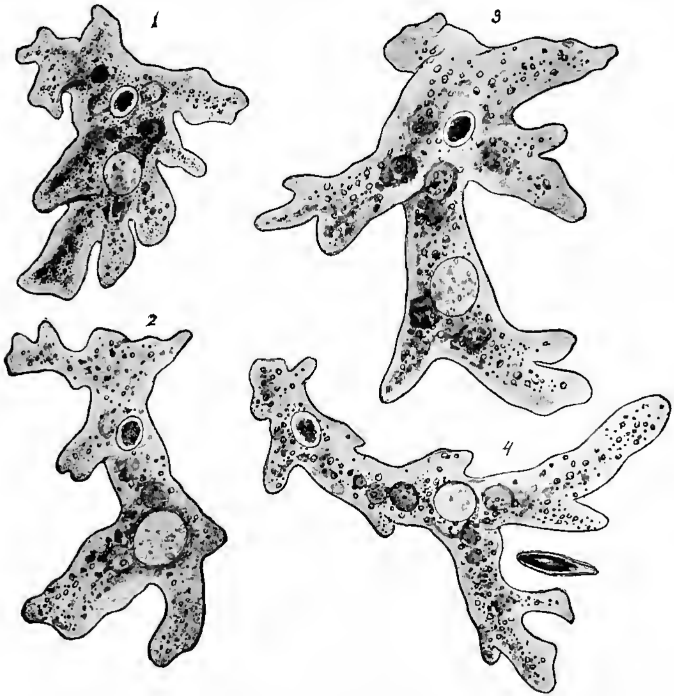


FIG. 35.—*Amœba* sp.; showing the forms assumed by a single individual in four successive changes. (Greatly magnified; from life.)

there are definite organs of motion. Small, hair-like parts of the body, called cilia or flagella, are extended into the water and struck or pushed against it. Among the ciliate and flagellate Protozoa we find some with the body covered all over with cilia, as in Paramœcium (fig. 36), and some with only very definite cilia-covered areas, or even with but one or two cilia, these being usually long and whiplash-like. In some the cilia seem to be in constant rhythmic motion, in others they seem to move only when the animal wills it. Motion by the contraction of a fiber is seen in the peculiar Protozoan called Vorticella (fig. 37).

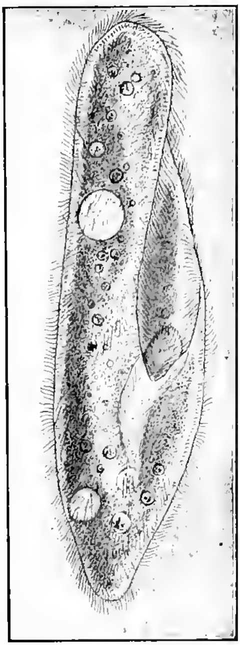


FIG. 36.—*Paramœcium* sp.; buccal groove at right. (Greatly magnified; from life.)

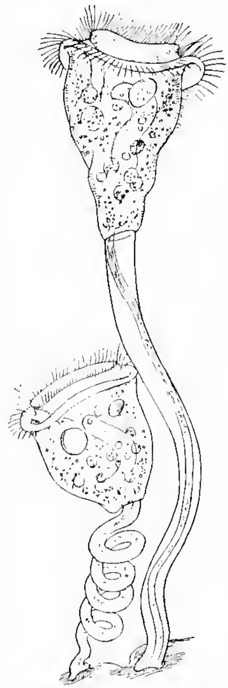


FIG. 37.—*Vorticella* sp.; one individual with stalk coiled, and one with stalk extended. (Greatly magnified; from life.)

This animal has a tiny bell-like body on the end of a slender stalk. The stalk is made up of an outer rather firm elastic substance with a contractile fiber in the core. When the fiber contracts the stalk is drawn up into a spiral and thus becomes shortened.

Muscles and skeleton.—The living elements in the body of the higher animals are small parts called cells, and all of the above-described kinds of motion are found in some of these. But motion is produced mainly by the contraction of fibers, which are grouped into masses called muscles. In the higher groups of animals the great mass of the body consists of muscles composed of contractile fibers, which are to be thought of as modifications of a fiber such as exists in the stalk of the Vorticella, one of the smallest and simplest of living animals. It is as if the contractile substance had appeared under different forms, but having proved most useful in the form of fibers as animals rose higher in the scale this form became very extensively used.

In such forms as the hydroids and jellyfishes the contractile fibers are not gathered together into such definite muscles as in the higher animals, nor are there such well-developed firm body-parts for the fibers to pull against. These contractile fibers are only extensions of certain body-cells, as in Hydra (see Chapter IX), or form a more or less scattered net-work, gathered into ill-defined bands or sheets, as in the sea-anemones and jellyfishes. From the starfishes and worms, through the crabs and insects, the muscular parts become more and more definite in form and prompt in action, and there appears more and more perfect development of firm parts. Some of these serve as points of attachment from which the muscles can pull, and some act as levers to make a push on the external water, earth, or air. The swift, strong, and accurate motions of the insects and of the backboned animals require rigid levers, firm points for levers to work against, or fulcra, and other firm points for the attachment of muscles from which to exert their pull. These firm solid parts, the levers, fulcra, and attachment points of muscles, constitute the skeleton of the animal body.

The skeleton of a backboneless or invertebrate animal differs from that of a backboned or vertebrate one not in the use made of it but in its arrangement and in the part of the body from which it is mainly developed. The skeleton of the invertebrate is developed from the skin, and forms a hard casing over the whole or part of the body. It is therefore called an exoskeleton. How this outside skeleton serves as levers, fulcra, and points of attachment may well be seen in the case of insects (fig. 38),

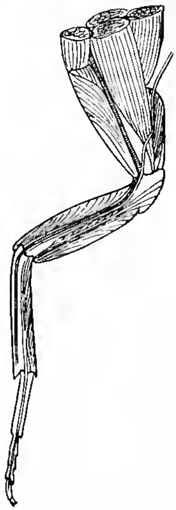


FIG. 38.—Left middle leg of cockroach, with exoskeleton partly removed, showing muscles. (Much enlarged; after Miall and Denny.)

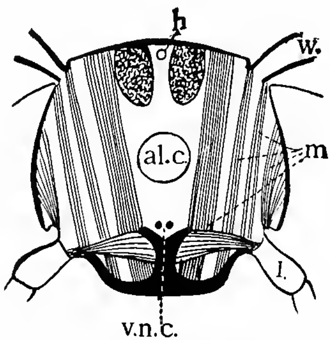


FIG. 39.—Diagram of cross-section through the thorax of an insect to show the muscles of the wings and legs; *h*, heart; *al.c*, alimentary canal; *v.n.c*, ventral nerve cord; *w*, wing; *l*, leg; *m*, muscles. (Much enlarged; after Graber.)

or crayfishes. The wall of the thorax, or carapace (fig. 39), is the central strong portion from which the great pulls are exerted, while each joint of a leg is a lever, a fulcrum for the next part, and a point of attachment for muscles. The whole system of muscles is so arranged inside the exoskeleton that the flying, crawling, and swimming of the various animals, as well as the particular motions of the eyes, feelers, and respiratory organs are well performed.

In the vertebrates the skeleton is mainly developed from tissues within the body and is called in consequence the endoskeleton. Even more than in the invertebrates it is a system (fig. 40) of levers, fulcra, and points of attachment for muscles to work with, and is as important a part of the organs of motion as is the muscular system itself.

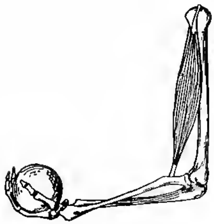


FIG. 40.—Biceps muscle attached to radius, in arm of man; to show how bones and muscle act as levers. (After Jenkins.)

To illustrate the use of the skeleton of a vertebrate we may examine the bones of the hind legs of a cat (fig. 41). The upper bone, the femur, is attached by a joint to the large irregularly shaped bone called the ilium, which is firmly bound to the backbone. Below the femur are two bones, the largest, called tibia, being bound by a joint to the femur. Below the tibia are a group of bones, the tarsal bones, pretty firmly fastened together. The largest makes a joint with the tibia. Each of the four tarsal bones toward the toes make a joint with a slender bone in the body of the foot. These are the metatarsals. At the end of each metatarsal is a series of three bones which form the skeleton of the toes. All of these bones together constitute a system of levers which the muscles of the leg can draw up in a somewhat folded position, and then straighten out with quickness and force. Since during

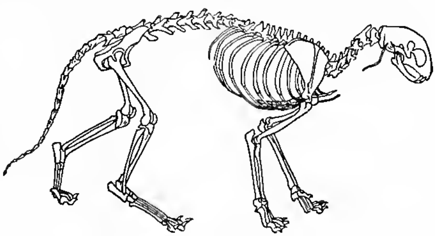


FIG. 41.—Skeleton of cat. (After Reighard and Jennings.)

such movements the toes rest on the solid ground, the body is lifted and thrown forward. There are a number of strong muscles which make the pulls for these motions, but a single pair may be studied as an example of the method of attachment and action of all.

Fig. 42 shows the large muscles of the fore leg of a cat. Each consists of a large central mass formed of the muscular or contractile substance proper bound up into a compact body by connective tissues, with strings or bands of connective tissue at the ends fastening the muscular mass to the bones. These fastenings are tendons. When the muscular substance contracts it of course pulls on the two tendonous ends. If one end of a muscle in the hind leg is attached to the hip-bone it cannot move, but the one fastened to the tibia moves this bone as a lever, with its fulcrum at the end of the femur. The tibia is brought toward the femur and we say that the limb is flexed. Another muscle in contracting will act on the tibia as a lever also, but it brings the tibia back again into a straight line with the femur. This motion is called extension. For each part of the limb from hip to toe are groups of muscles which flex and extend that part, the bones being levers and fulcra and points of attachment. Most of these levers are of the kind called in mechanics levers of the third class. By them quickness of motion is magnified. Thus by noting first what motions an animal makes, and then, by dissection, examining the muscles, the bones, and their points and means of attachment, we may come to understand clearly the uses of the muscles and skeleton in any animal.

FIG. 42.—Muscles on side of fore leg of cat. (After Reighard and Jennings.)

The plan of the skeleton in the vertebrates is the same throughout the whole great group, which includes the fishes, amphibians, reptiles, birds, and mammals. The differences lie in the varying development of the different parts and in the modification in the size and form of these parts. The plan includes a central axial portion, the spinal column, made up of a series of elements called vertebræ. In a completely developed skeleton, as that of a cat (fig. 41), the groups of vertebræ are the cervical, i.e., those of the neck; dorsal, those to which the ribs are attached; lumbar, just posterior to the dorsal; sacral, the group to which the ilium is bound, and caudal or tail vertebræ. In the higher vertebrates the vertebræ of the sacral group are fused into one bone, the sacrum; while the caudal vertebræ, posterior to the sacrum, are fused into one or a few bones in animals without a tail and in them named the coccyx. The bones of the spinal column are firmly bound together, constituting a somewhat flexible but very firm axis, to which the head and limbs are attached and from which the main pulls on these parts can be exerted. The head skeleton consists of a central group of bones in front of the axial skeleton, being an extension of it, and around it are placed the other bones of the head. To the axial skeleton are attached two pairs of limbs; an anterior pair, joined to the axis by a group of bones known as the shoulder girdle, and a posterior pair joined to the axis by the pelvic girdle. The leg of the cat, already described, may be taken as a representative limb.

Now if we examine a series of vertebrate skeletons, representative of the different groups from the lowest forms of fishes through to the highest mammals, we can see that notwithstanding the different forms and sizes of the various animals and their different ways of locomotion —swimming, flying, crawling, running, walking, and leaping—they all make use of the same plan of levers, each kind of animal, however, having it specially adapted for its peculiar motions. To see this more clearly com-

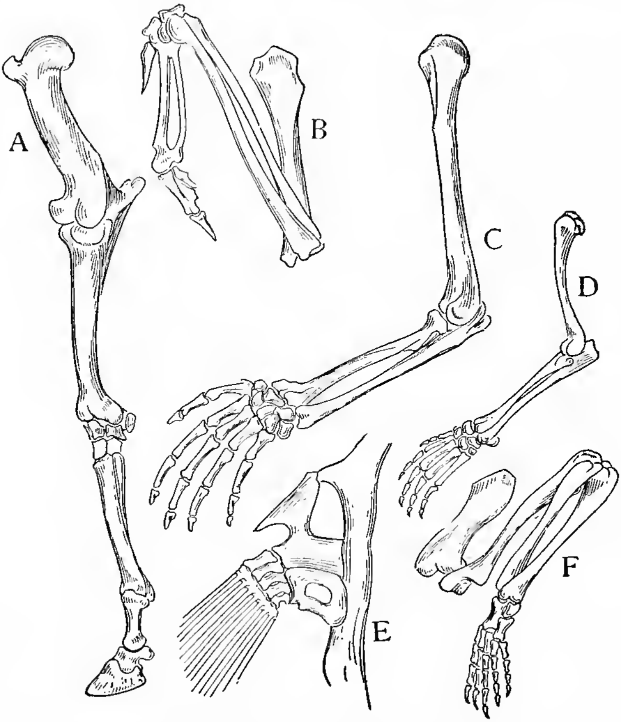


FIG. 43.—Bones of fore limb of various backboned animals; *A*, horse; *B*, bird; *C*, man; *D*, dog; *E*, fish; *F*, reptile.

pare the skeleton of the fin of a fish with the fore leg of a lizard, the wing of a bird, the fore leg of a horse, the fore leg of a dog, and the arm of man (fig. 43).

If we carefully remove the skin from the side of a fish such as a black bass or sunfish, there is shown a mass of flesh (fig. 44). The great bulk of this is one large muscle, the contraction of which makes the body curve to the same side and thus gives a stroke of the tail fin. A similar muscle on the opposite side produces a stroke in the opposite direction. These alternating strokes are the propelling power which forces the fish through the water. At the base of each of the other fins are found a few small strips of muscle. These give their varied and more gentle movements which keep the body in any particular position and aid in directing its

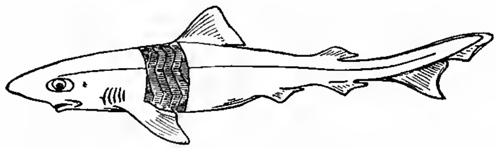


FIG. 44.—Side view of a dogfish (shark) with a strip of skin removed to show muscles. (After Parker.)

locomotion. About the head are other muscles which move the jaws, eyes, and gill-covers.

If we take the skin from the side of a body of a dog and dissect out all the muscles we find a large number of well-developed ones. The great muscular mass on the side of the fish's body used for one or a few motions is replaced in the dog by a great number of muscles used to produce a number of various movements. The few comparatively weak muscles of a ventral fin are replaced by the many large, strong, and definite ones of the hind limb of the dog, while the small group working the pectoral fin finds its representative in the large and varied group moving the fore leg.

Further differences are seen in comparing the head of the fish with that of the dog, as well as in every other part of the two bodies. These differences all show that in the dog there is a separation of the muscular system into more numerous and more definite forms of muscles, with the possibility of more numerous and more accurate motions than in the fish. If we compare the muscles and bones of the human hand and arm with those of the fore limb of other animals we find an advance in complexity over the fin of a fish or the fore limb of a salamander or even the fore leg of a dog, although all are made up on the same plan and out of the same elements. If we now go further and compare the organs of motion in the human body with the means of motion in Amœba we see what a wonderful advance the highest animal exhibits over the lowest both in structure of the motor organs and in the possibilities of movement.

CHAPTER VII

HOW ANIMALS TURN FOOD AND AIR INTO FLESH AND ENERGY

Necessity of oxygen and food.—In the organs of motion just studied the muscles and bones are only the machinery for motion. They make use of energy but cannot themselves provide it. Just as an engine and all the wheels and levers connected with it make use of heat, which is one of the forms of energy, to produce the needed motions, so the muscles and bones make use of some form of energy to produce the motions of the animal body. In the steam-engine the special form used is heat, generated by the burning of coal, oil, or wood; by means of this heat, which expands the steam, i.e., the vapor of water, energy is applied to the piston in the form of a push. The motion of the piston is passed over to the wheels and levers of the shop, and by them are given all the different directions and velocities required by the different machines of that particular shop.

In the animal body the muscle is the engine, for in it the energy is generated. In a way we do not yet exactly understand this energy makes the muscular substance contract and give a pull on the tendon, with the same effect as the push of the steam on the piston, that is, to set the rest of the machinery, the bones, in motion. The bones apply the motion in the way required for the movement of the animal. A striking difference, however, between the animal body and a shop is this, that while in even a very large shop there may be but one engine generating energy to run all the different machines, in the body every muscle is a separate engine, and one bone may be connected with a number of them. Nevertheless the essential facts are the same in both cases. The muscle-engine, like the steam-engine, produces a form of energy and applies it to machines so as to lift weights or to move things from place to place. But we learn in physics that we can get any form of energy only by changing some other form into the one desired. The forms of energy are heat, light, electricity, chemical energy, and that of a body in motion. Now the only way to get heat, for example, is by a change from one of the others. We can make a piece of iron hot by striking it with a hammer; here the energy of a moving body is converted into heat. Or the energy of the electric current may be converted into heat or motion. Man's most common way of getting heat is to take coal, wood, or oil, and apply some heat to start with, when the oxygen of the air will unite with carbon and hydrogen, substances in the coal, wood, or oil, to make two new substances, one of these being carbon dioxide, the other water. This is chemical action; it results in changing chemical energy into heat. In ordinary language this union of oxygen with carbon or hydrogen is spoken of as "burning" or "combustion."

An animal cannot make the least motion without using a certain amount of energy. And it has been shown by investigation that the energy possessed by an animal is derived from the chemical energy resulting from the union of oxygen with the carbon, hydrogen, and nitrogen in other substances. The muscles are the engines in which this energy is made use of for motion. This brings us now to see how essential it is that the animal should have in its body oxygen and substances for the oxygen to combine with.

The animal body, however, not only needs a constant supply of the substances from which this energy may be produced, but also a constant supply of those substances which compose its body. In every young animal there is a growth, an increase of size and weight, and in the adult a constant replacing of body material. And by far the greater part of an animal body is made up of just those things, namely, oxygen, carbon, hydrogen, and nitrogen, that are used in the supply of energy.

How animals breathe.—The animal gets its oxygen from the free air, or from the air mixed with water, by a process called respiration. It obtains from its food all the other substances used. Food is prepared for use by the process of digestion. Oxygen obtained by respiration and the substances obtained from food are distributed throughout the body by the process of circulation. We may now consider the ways in which respiration, digestion, and circulation are carried on among animals.

As to respiration, mention has been made only of its service in providing the animal with oxygen. It has, however, one other object. When oxygen combines with carbon, carbon dioxide is formed; if this remains in the muscle or other tissue cells it interferes with the activity of those cells. It is therefore just as necessary for the carbon dioxide to be removed as for the oxygen to be supplied. Carbon dioxide, like oxygen, is soluble in water. Blood, which is composed largely of water, and which can carry the one serves also to carry the other. Furthermore, since carbon dioxide is made by a combination with oxygen, it arises just where it can be carried away by the very apparatus that has brought the necessary oxygen. Thus the respiratory apparatus manages both the supply of oxygen and the disposal of carbon dioxide.

The fundamental fact in the process of respiration is that gases, whether free or dissolved in water, will readily pass through a thin, moist membrane. Thus if a closed sac made of thin membrane filled with water in which carbon dioxide is dissolved be immersed in water in which oxygen is dissolved, carbon dioxide will pass out of the sac and oxygen into it until there is the same amount of each outside and inside. If the water outside is constantly replaced all the carbon dioxide will be finally removed. If the oxygen inside the sac is constantly used up and the supply outside is always renewed, oxygen will be constantly going in and carbon dioxide going out. This is just what happens in the living animal. Animals get their oxygen from the air, of which it is a part. The air may be free or dissolved in water. Carbon dioxide is made in the cells of the body. Respiration takes place through the membranes covering all or part of the surface of the body. It requires the constant renewal of free air or water containing air on the outside, and the constant passage of fresh blood on the inside surface of the membrane. This end is attained in a variety of ways among animals.

In the simplest forms, the Protozoa, where we have the most primitive means of motion, we find also the simplest means of respiration. The Amœba (see Chapter IX) simply relies on its whole external surface for breathing, the thin outside layer of the body acting as a membrane through which the oxygen passes in and the carbon dioxide out. During periods of activity the processes protruding from the body increase the amount of respiratory surface sufficiently to provide for the increased respiration demanded by the activity. In ciliated forms the cilia greatly increase the surface area and respiration is further assisted by the constant contact of the moving body with fresher water. Even in more complex animals, the common earthworm and the larvæ of some insects for example, the whole external skin is sometimes the only respiratory surface. Such animals have only sluggish and weak motions however. Much increase in size and activity make certain demands on the surface of the body which unfit it for respiration. The hard covering of insects, crabs, and other animals necessary in connection with locomotion and for protection from injuries illustrate this. Again, while in a minute form like Amœba, the slight increase of surface attained by its protruded processes answers the increased respiratory needs, the surface of a large animal would fall far short of doing so, because, according to a familiar law of physics, the mass or bulk of a body increases as the cube of the diameter while the surface increases only as the square. Therefore the larger animals must have special respiratory surfaces with special respiratory apparatus to move the air or water over these surfaces externally, and special circulatory apparatus to move the blood over them internally.

Special respiratory surface is provided for in two ways. One is by the extension of a portion of the surface externally; thus gills are formed. The other is by the extension of the surface within the body in the form of tubes, as the tracheæ in insects, or of sacs, as the lungs in the vertebrates. Water-breathers have gills and air-breathers have tracheæ or lungs.

In crayfishes or crabs the gills have the form of feather-like projections from one of the upper leg joints, and extend up into a cavity formed by a projection of the carapace over the sides. It is interesting to note that these animals have a paddle for bailing the water out of the gill cavity, and that by it a constant current is kept flowing over the gills. Fishes breathe by means of gills, of which they have four pairs (fig. 45). These are placed on the sides of the head and consist of minute projections of the skin appearing as a fine red fringe. They are supported by bony or cartilaginous arches. The heart lies close to the gills and pumps the blood directly into and through them into vessels that carry it all over the body. The fish keeps a current of water passing over its gills. First it opens the mouth, spreading the gill covers, when the water rushes in, after which it closes the mouth drawing the covers together so that the water is forced back over the gills. This operation is constantly repeated.

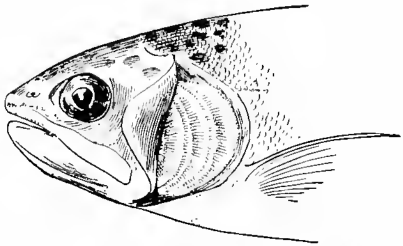


FIG. 45.—Head of trout with gill cover bent forward to show gills. (From specimen.)

If the mouth of an active fish like a sunfish is fastened open it will die, since it can no longer breathe. It must be added that the fins of most fishes no doubt aid somewhat in respiration since they are well supplied with blood and the skin on them is very thin.

Insects are mostly air-breathers. Many, the bee and dragonfly for example, show very great activity, demanding much oxygen. They have an elaborate system of tubes, called tracheæ (figs. 46, 47, and 48), which penetrate every part of the body, reaching in some cases every muscle cell. These open to the air by means of pairs of small holes, called spiracles, in most of the body segments. Air is made to come in

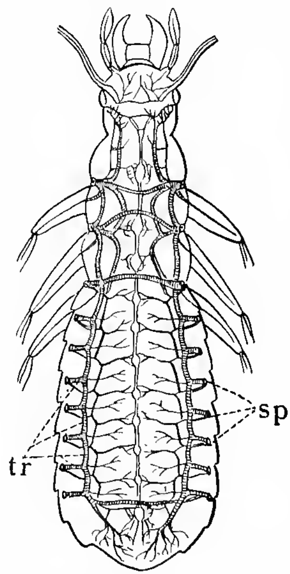


FIG. 46.—Diagram showing tracheal system of a beetle; *sp*, spiracles; *tr*, tracheæ. (After Kolbe.)

and go out through these by an alternate contraction and expansion of the body readily seen in a bee or dragon-fly at rest. The walls of the tracheæ are in part supported by a fine spirally wound elastic thread which keeps the tubes always open to the air. The spiracles are often guarded by little tufts of hairs, which being oily prevent

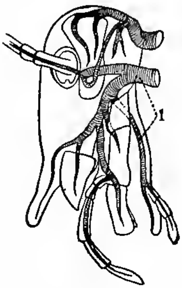


FIG. 47.

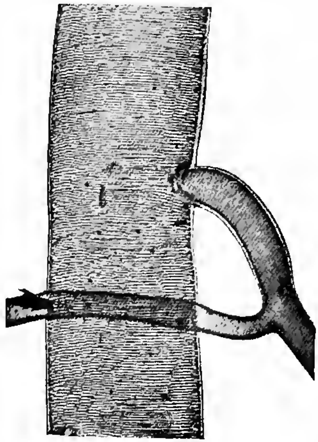


FIG. 48.

FIG. 47.—Diagram of tracheæ in head of a cockroach; note branches to all mouth parts and feelers; *t*, tracheæ or air-tubes. (After Miall and Denny.)

FIG. 48.—Piece of trachea (air-tube) from an insect. (Photomicrograph by Geo. O. Mitchell.)

water from entering easily, though oil will enter readily, and a drop of oil running over the spiracles will quickly kill an insect. Very fine dust will also choke up the spiracles and smother it. Some "insect powders" act in this way.

The amphibians, which class includes frogs, toads, and salamanders, are water-breathers during their young life and in this period have gills. But early in the tadpole stage there develops by growth from a point in the throat what is first a pouch, later a small pair of lungs, which are soon put in use. By the time the animal leaves the water the gills have disappeared and the lungs are well developed. A few of the amphibians, however, may retain the gills in addition throughout the adult stage. Such forms live in water or in very moist places. Moreover, most amphibians make use of the skin, thin and moist like that of the frog, for respiration, and thus have no necessity of great lung development. The air-bladder of fishes has the position of a lung, but is used ordinarily to regulate the weight of the body. Still in a few forms, the garpike for example, it serves sometimes as a lung.

In the higher vertebrates the exterior skin surface is not adapted for respiration, which, together with the generally greater activity of these animals, necessitates a much greater development of the lungs. Thus instead of the two simple lung sacs of the frog the lizard has a complex double sac enlarged by tube-like extensions into the body cavity. This arrangement gives a much increased respiratory surface. In birds and mammals the extent of surface is immensely increased. It is estimated that the inner surface of a man's lungs amounts to a thousand square feet in area, or one hundred times the external surface of the body. The windpipe gives off one large branch to each lung; these branches divide again and again, the last divisions bearing on their ends very small sacs of thin membrane about which is clustered a network of capillary blood-vessels. Through the walls of these small sacs the oxygen and carbon dioxide pass.

So far we have seen only how increase of surface is brought about. Accompanying this we find improved means for passing the air over the exterior and bringing the blood to the interior surface. A frog or salamander breathing quietly enlarges the mouth cavity by lowering its floor, and the air comes in through the nostrils; this air is then squeezed by the upward pressure of the floor of the mouth, the valves in the nostrils close, and it is thus pushed down into the lungs. The muscles in the walls of the body now contract and squeeze upon the air in the lungs, the nostril valves open, and the air is forced out. This method is gradually improved upon in the vertebrates until in the mammals we find a bony basket of ribs and sternum, the thorax (fig. 49), containing the lungs, with two sets of muscles between the ribs, which by their alternate contractions and expansions first elevate and extend the ribs, then lower and draw them in, thus enlarging and diminishing the thoracic cavity. We find further a muscular partition in the thorax, the diaphragm, separating it from the abdominal cavity. When the diaphragm, which is convex on the upper side, contracts it lowers the floor of the thorax, thus enlarging the thoracic cavity; the muscles in the walls of the abdomen then contract and press upon the stomach, intestines, and liver, pushing up the floor of the thorax and so diminishing the thoracic cavity. Thus in two ways this is enlarged, and in two ways diminished. As it enlarges, the pressure of the outside air expands the elastic sacs of the lungs; as it diminishes, the air is pressed out again. Along with great increase of surface and great complexity of mechanism for moving the air goes, as has been pointed out, a perfecting of the circulatory apparatus for bringing the blood to the respiratory surface, and a proportionate complexity of the nervous system for producing and regulating the movements necessary. It is to be kept in mind, however, that the respiratory apparatus

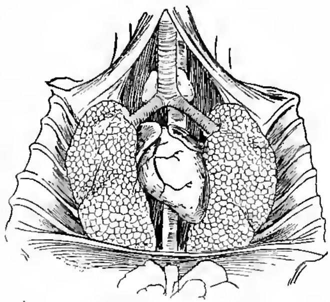


FIG. 49. — Tracheal tube, lungs, heart, and diaphragm of mouse. (From specimen.)

only brings oxygen to the respiratory surface, and before the real respiration at the tissue-cell can take place the oxygen must be carried by the blood to the cell. This process we shall later discuss under the head of circulation.

Now having seen how animals get the necessary oxygen we may next inquire how they obtain and make use of the equally necessary substances to be oxidized and to build the body out of, that is, their food.

How animals obtain and digest food.—In examining into the ways by which animals obtain and use food we may consider the processes under three heads, obtaining food, eating it, and digesting it. In obtaining food all the sense and motor organs are employed, that is, the instincts and ingenuity of the animal are brought into play as well as the parts of its body. In eating it the mouth is employed in mastication and the throat in swallowing. Digestion is carried on by liquids secreted by parts of the alimentary canal.

In the parts used for obtaining food we necessarily find the greatest range of variation on account of the great variety of food materials made use of. The food of animals consists of other animals or plants. Of the plants it may be leaves, stem, wood or bark, roots or fruit or seeds. That particular part desired may be deep in the ground, high in the air, or buried in a thick covering of its own. The plant sought may grow in a marsh, on a plain, on a mountain, or immersed in the ocean. It may be fit for food at a certain season only. To get it the animal must have the necessary equipment of wings, or legs, claws, beaks, teeth, etc., as well as eyes, ears, and organs of smell, touch, and taste, besides some means for searching out the places where it grows, selecting the proper parts and deciding upon ways of securing these parts. Acts like these last are performed by the nervous system and arise from instinct or intelligence.

In the case of carnivorous animals where prey is to be captured, the same adaptations must exist, being necessarily even more complex than those demanded for the securing of vegetable food. Some of the special adaptations of animals for food-getting are described in Chapter XVII.

But food once obtained and ready to be eaten appears under very many forms and there is accordingly great variety of structure among the parts employed in eating. Amœba eats without a mouth. It extends any part of its soft body over the little plant or animal it feeds upon. In many Protozoa, however, there is a definite mouth-place, as in Paramœcium, where the food particles are gathered together in a little ball by the cilia, and then pushed through the body-wall. The body of the fresh-water hydra (see Chapter IX), incloses a digestive cavity, the mouth being but an opening to this. In the higher animals we find mouths arranged for cutting, filing, sucking, crushing, gnawing, grinding, chiseling, piercing, sawing; in fact almost every device one could think of for working in wood, bone, shell, flesh, liquid, soft and hard material of many forms.

The study of the mouth parts of animals belonging to one group shows how the same parts may take on such different forms as to make very different kinds of apparatus. For example among the insects, the bee (fig. 50), mosquito (fig. 51), tiger-beetle, dragon-fly (fig. 52), moth (fig. 53), and squash-bug, while exhibiting great variety of mouth parts show each the same pieces, but in each so changed in form as to make up a combination peculiar to it. Among birds there is not so great a range of difference; still, the various beaks and bills of chickens, cranes, sparrows, ducks, curlews, hawks, cross-bills, puffins, and horn-bills illustrate how one form may be adapted to many operations. Birds do not use the mouth for mastication. Where mastication is necessary there is an expansion of the alimentary canal called crop or craw, which acts as a reservoir for the hard seeds or grains, and further along the gizzard, which with its strong muscular wall and hard inner coat, assisted by the small stones picked up in eating, sufficiently grinds up the

FIG. 50.

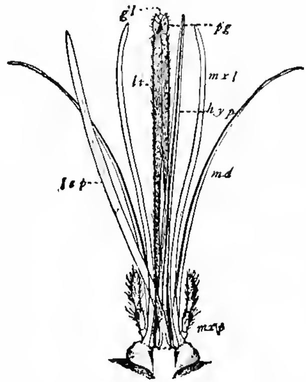


FIG. 51.

FIG. 50.—Head and mouth parts of honey-bee; note the short trowel-like mandibles for moulding wax when building comb, and the extended proboscis for sucking flower nectar. (Much enlarged; from specimen.)
FIG. 51.—Piercing and sucking beak of the mosquito (female) dissected to show its parts. (Much enlarged; from specimen.)

food. Among mammals the same large extent of variety in the mouth structure exists as among insects and birds. Compare the teeth and other mouth parts of a rat, beaver, cat, pig, horse, sheep, and man, noting how they vary in number, size, and form, and then consider how each is used in the process of eating.

To understand the process of digestion some knowledge of the nature of food substances is necessary. In considering the production of energy and making of body material we saw that the same substances provided for both. In fact whatever the form of food, animal, or plant, the elementary substances are the same, being conveniently classified into two great groups, organic and inorganic substances.

Inorganic food substances are water and certain minerals of which common salt is one. Organic food substances are of three kinds or groups. The first group, called the

FIG. 52.—Mouth, with prehensile under lip, of young dragon-fly. (From Jenkins and Kellogg.)

proteids, of which the white of egg is an example, forms a large part of the tissues of animals; the second group is made up of the fats and oils; the third, known as the carbohydrates, consists of the starches and sugars.

Now digestion consists in changing all these substances into soluble form so that they can be absorbed into the body, circulate with the blood, if there be any, and then pass into the living cells for their use. This change is accomplished by certain liquids called digestive fluids. The digestive apparatus varies like other parts of the animal organism, being most simple in some forms and very complex in others. In Amœba the food particles are retained in spaces in the cell until they are digested. So in other Protozoa. The simple digestive cavity of the hydra has been referred to (fig. 54). In the polyps and jelly-fishes (see Chapter X), this cavity is extended, the digestive surface being much increased by partitions, tubes, etc. Worms (figs. 55 and 56), crabs, and snails have a definite alimentary canal with certain parts set apart for special processes. In the vertebrates the digestive apparatus varies from a relatively simple straight tube to the very long and complex alimentary canal of the cow (fig. 57). All these forms depend much on the nature of the food of the individual animal, and the processes necessary to turn it into body material.

To illustrate what complexity of the digestive system may be reached let us consider somewhat in detail the structure of the alimentary canal of a small mammal—a rabbit, for example. First is

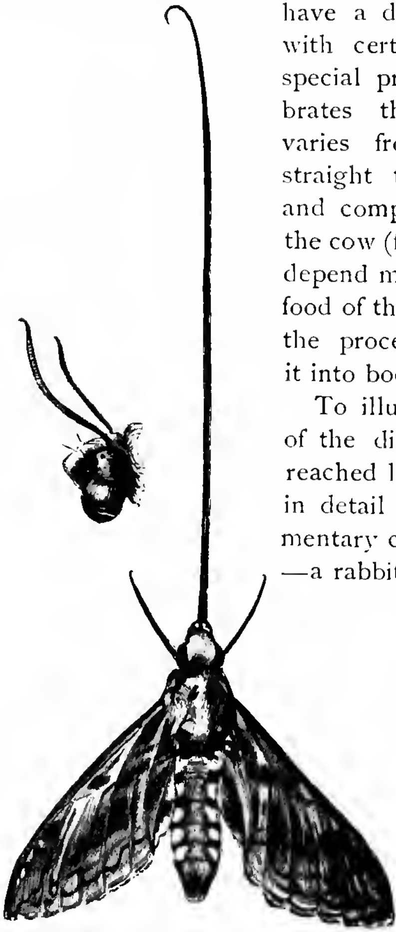


FIG. 53.—Sucking proboscis of a sphinx moth; in small figure the proboscis is shown coiled up on the under side of the head, the normal position when not in use. (One-half natural size; from specimen.)

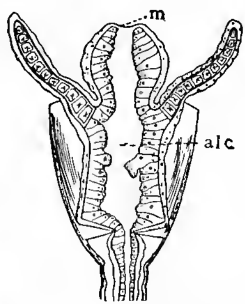


FIG. 54.—Diagram of section through a simple polyp, *Obelia*, showing digestive cavity; *m*, mouth-opening; *al.c*, alimentary cavity. (After Parker and Haswell.)

the mouth with its parts; the walls of the mouth are furnished with minute tube-like extensions or glands, which secrete mucus to aid the animal in swallowing dry substances. Other larger glands, the salivary glands, empty into the mouth, saliva being also necessary for the purpose of swallowing. Behind the mouth come the pharynx and gullet, which together make a tube with muscular walls which perform the movements of swallowing. Both pharynx and gullet are furnished with numerous mucous glands. The gullet leads to the stomach, an enlargement of the alimentary canal acting mainly as a reservoir. Its walls also are filled with small glands secreting gastric juice which makes proteid foods soluble, that is, carries on the proteid digestion. Next to the stomach is the small intestine, a very long tube in the first part of which is accomplished the digestion of starches and fats. Its walls are lined with numerous glands, and besides these, two very large glands, the pancreas and liver, pour into it large quantities of liquid. The pancreatic juice digests the starch and fat and also any left-over proteids. The liver furnishes the bile, but its functions being mainly other than digestive, they need not be discussed here.

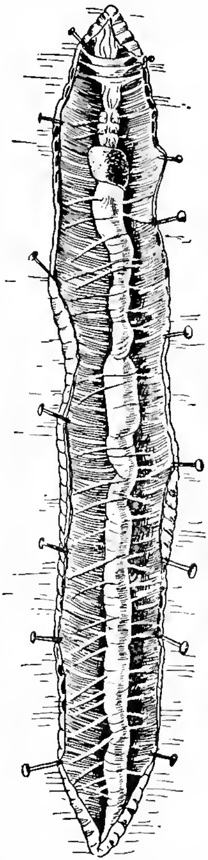


FIG. 55. — Common earthworm dissected to show alimentary canal, a straight and nearly simple tube through the middle. (Natural size; after Jordan and Kellogg.)

The walls of the small intestine furnish the principal surface for the absorption of digested food. This surface is greatly increased by millions of small projections called villi, in which are blood-vessels, and other absorbent vessels for taking up the digested food. The small intestine empties into the large intestine, which has an enlargement called the cæcum. The large intestine and the cæcum together form the last section of the alimentary canal and

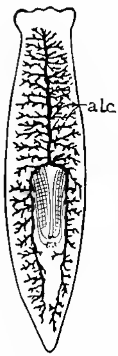


FIG. 56.

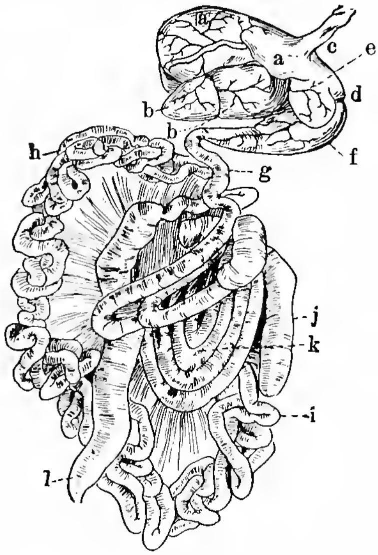


FIG. 57.

FIG. 56.—A flatworm (*Planaria*) to show branched alimentary canal, *al.c.* (About natural size; after Hatshek.)

FIG. 57.—Alimentary canal of a cow; *a*, rumen (left hemisphere); *b*, rumen (right hemisphere); *c*, insertion of œso- phagus; *d*, reticulum; *e*, omasum; *f*, abomasum; *g*, duodenum; *h* and *i*, jejunum and ileum; *j*, cæcum; *k*, colon with its various convolutions; *l*, rectum; the whole canal about 150 feet long.

retain the remaining food substances for some time to allow of more complete absorption of the digested foods. The alimentary canal of the rabbit, with all its folding and branchings into large glands and millions of small ones, furnishes a surface for secretion and absorption very many times the external surface of the body. In brief, the area concerned with the taking in of food as well as of oxygen is immensely increased in the higher animals.

We have now to consider that process which has to do with carrying oxygen and food from the respiratory and digestive surfaces to all parts of the body. This process is the circulation, and the organs for performing it compose the circulatory system.

How the blood circulates.—It has already been shown that increase of size and activity in animals necessitates blood and a means of circulating it through the body. The uses of the circulation are: to bring oxygen from the respiratory surface to every cell, to take carbon dioxide from every cell to the respiratory surface, to carry digested food substances from the absorbing surface of the alimentary canal to every cell, and, further, to remove from every cell the injurious and waste substances formed by its activity to where they may be either excreted from the body or otherwise disposed of. Circulation is accomplished by the moving of a liquid through a system of tubes and spaces channeling the whole body.

In the very smallest and most sluggish of animals there is no circulatory system. In those which are of comparatively large size and very active, and which therefore need a great amount of energy, much oxygen and food must be supplied and a large amount of waste substance is produced which must be removed. Here the circulatory system is found to be highly developed and to work with great efficiency.

In Amœba, because of its small size and the constant flowing of the body-substance there is no circulatory system. In some Protozoa the contents of the body-cell seem to have a definite movement, but there are no such organs as heart and blood-vessels. In most animals we find blood and a system of tubes and spaces for it to circulate in. In some, as the insects (fig. 58), only part of the circulatary system consists of definite tubes; these open into loose ill-defined spaces in the body-cavity. In such the blood is moved gradually throughout the animal, but not so definitely and quickly as in others where the blood runs in definite vessels. In the earthworm there is no such heart as in higher animals, but the blood-vessel along the dorsal line and some of its branches around the sides have muscular walls and "beat" by a wave of contraction running toward the head. In insects the dorsal blood-vessel beats in the same way, but generally more vigorously. In the young larva of a mosquito or nymph of a May-fly with transparent skin the beating can be easily seen under the microscope. In molluscs there is a well-developed heart; it can be well seen in the fresh-water mussel. The crustacea also have a heart. This can be seen at work in a water-flea under the microscope, or can be readily demonstrated in a crab or crayfish killed with chloroform or ether.

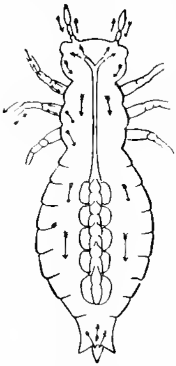


FIG. 58.—Diagram of circulatory system of young dragon-fly; in middle is the chambered dorsal vessel or heart with single artery; arrows indicate direction of blood currents. (After Kolbe.)

In vertebrates the blood circulates in a definite system of tubes through which it is pumped by a heart. The fishes (fig. 59) have the heart consisting of two parts, with muscular walls, a single auricle and a single ventricle. The auricle receives the blood pouring from all the tissues of the body through the veins. It contracts and forces the blood into the ventricle. This then contracts and drives it into a short vessel called the ventral aorta, which gives off a branch artery for each gill-arch. The gill-arteries divide up into capillaries in the gills, whence, after aeration, the blood is gathered by another artery and carried to the dorsal aorta, from which branch arteries distribute it to the capillaries of the general body-tissues. From these it is gathered by the veins and carried back to the auricle to begin again. In the course of circulation the blood reaches every part of the body, picking up certain substances here, leaving others there, thus accomplishing the results already pointed out as the objects of the circulation.

In the circulation of the higher vertebrates the most striking difference from that of the fish is in the structure

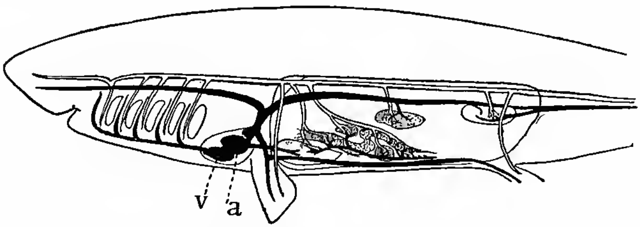


FIG. 59.—Diagram of circulatory system of a fish; *v*, ventricle; *a*, auricle. (After Parker and Haswell.)

of the heart, which adapts the circulation to lungs instead of gills, and in the more perfect control and regulation of the action of heart and blood-vessels by the nervous system.

The circulation of a gilled frog tadpole is on the same plan as that of a fish. In the adult frog, however, there is no longer a circulation through gills but one through the lungs. Moreover, the adult has two auricles instead of one (fig. 60). Of these the right receives the blood from veins draining the tissues, the other blood from the lungs. All this blood, however, is thrown together into the one ventricle, from which, mixed as it is, it is sent out both to the lungs and to the tissues through arteries.

In reptiles there are two auricles, as in the frog, and a partition partially separates the ventricle into halves (fig. 61), so that the blood coming from the tissues is kept partly separate from that out of the lungs. This separation allows the blood from the lungs to be sent to the tissues without much mixing with the impure blood from the tissues. In birds and mammals the separation of the two halves of the ventricle is complete, the blood from the lungs being sent out unmixed to the tissues and that from the tissues returned without delay to the lungs.

Fig. 62 gives the plan of the circulation in the mammals.

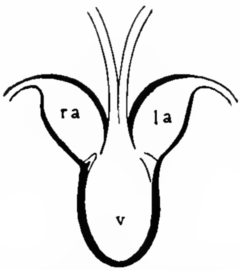


FIG. 60.—Diagram of heart of amphibian; *r.a*, right auricle; *l.a*, left auricle; *v*, ventricle. (After Ritzema-Bos.)

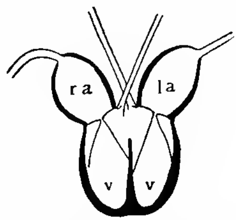


FIG. 61.—Diagram of heart of a reptile; *r.a*, right auricle; *l.a*, left auricle; *v,v*, ventricles. (After Ritzema-Bos.)

It shows how the blood is driven through the lungs by a special pump, the right ventricle, which is devoted to that purpose alone. It also makes clear how the blood is made to pass from the left ventricle to all parts of the body (fig. 63). It may be asked how, since the blood remains in vessels during circulation, the tissue-cells receive anything from it. The blood as such does not reach the tissue-cells. These are surrounded by a liquid, called lymph, which fills the spaces between them. The capillary blood-vessels run through this liquid and may not actually touch the cells themselves at all, or at only a few points. The walls of the capillaries being very thin, however, the substances needed by the cells diffuse from the blood through the walls into the liquid and thence to the cells themselves. On the other hand, substances from the cells—carbon dioxide and other waste matters—diffuse into the liquid and from this to the blood through the capillary walls. In fact each tissue-cell feeds, like certain one-celled animals, by absorption from a liquid

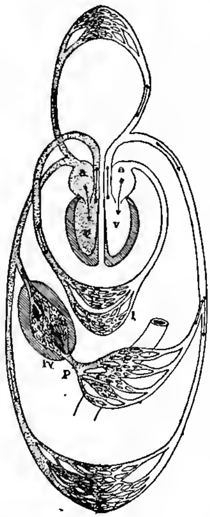


Fig. 62.

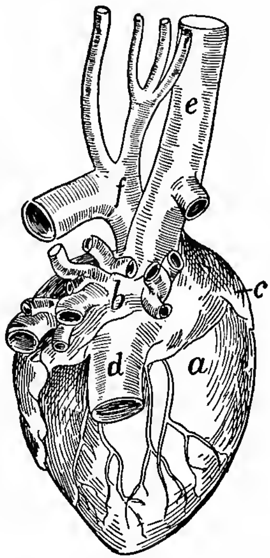


Fig. 63.

Fig. 62.—Diagram of the circulation of the blood in a mammal; *a*, auricles; *l*, lung; *lv*, liver; *p*, portal vein bringing blood from the intestine; *v*, ventricles; the arrows show the direction of the current; the shaded vessels carry venous blood, the others arterial blood. (From Kingsley.)

Fig. 63.—Heart of cat, dorsal view; *a*, right ventricle; *b*, left auricle; *c*, right auricle; *d*, vena cava inferior; *e*, vena cava superior; *f*, aorta. (After Reighard and Jennings.)

medium, but by means of the circulation this liquid has a prepared food constantly brought to it.

We may ask how the blood carries the oxygen. In the vertebrates part of the blood consists of little bodies called the red corpuscles. The color of these is due to a chemical substance called hæmoglobin. This has the capacity of absorbing oxygen at the lungs and of giving it up to the tissues.

FIG. 64. — Lower fore-leg and foot of cat, showing arteries (dotted lines), veins (black lines), and nerves (thin lines). (After Reighard and Jennings.)

The blood of vertebrates and of many invertebrates possesses a remarkable property that should be noticed, that is, of forming a jelly-like mass called a clot when a vessel is broken. In other words, it is able to close the opening with a solid plug made up of its own substances.

In higher vertebrates there is a very perfect regulation of the heart-beat, and of the narrowing or enlarging of the small arteries by the influence of the nervous system on their muscular walls. By this means and the peculiar structure of vein and arteries, and the use of valves, the flow of blood is nicely regulated to the needs of each part of the body during its activity.

CHAPTER VIII.

HOW ANIMALS KNOW THINGS AND CONTROL THEIR MOTIONS.

Thus far we have considered the mechanisms animals have for motion and for obtaining oxygen and food. A more difficult but more interesting subject is how motions take place in the animal, how they are guided, how they are stopped, in short, how the whole conduct of the life of the animal is carried on. To understand better what these processes consist of, let us consider as an example the life of a common bird. We know that after hatching from the egg it takes food, learns the notes of the parent bird, learns to fly, learns to fight or to avoid enemies, all these including motions guided by sight, hearing, touch, and smell. On the approach of winter it migrates to the south; in spring it returns, chooses a mate, builds a nest, and rears young to which it teaches in turn the ways of bird life. While the full explanation of these processes is far from being reached, and while we cannot here discuss them at length, yet we may at least examine some of the parts of the body specially concerned with these processes. In the higher animals they are determined and directed by means of the sense-organs and the nervous system. In vertebrates the special senses, as they are called, are those of sight, hearing, smell, taste, touch, cold, heat, and one called the muscular sense. A part of the eye known as the retina is specially sensitive to light; in the internal ear there are certain cells which are affected by sound vibrations; in the nasal passages there is a region in which are cells sensitive to odors; in the skin of the tongue are cells that react to sweet, sour, and bitter liquids; in various parts of the skin are cells sensitive to pressure, heat, and cold. These different kinds of cells affected by different influences are called sense-cells.

Now what the animal sees, hears, touches, etc., determines its motions, and we find that the sense-cells are

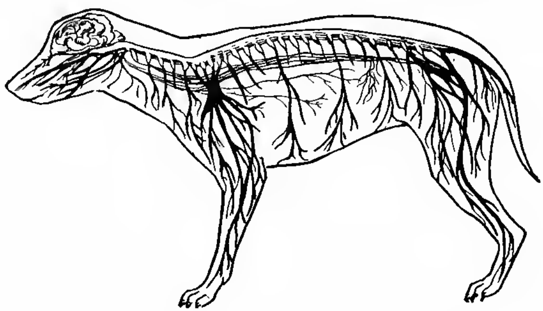


FIG. 65.—Central nervous system of a dog. (After Ritzema-Bos.)

connected with the muscles by means of the nervous system. Through this connection light, heat, sound, etc., guide muscular action. For example, the hawk's eye is connected through the nervous system with the wing and leg muscles of the bird, and by this means the wings and legs may be made to make the motions necessary to catch the chicken. To understand the makeup of the nervous system, that of some small vertebrate should be examined in connection with the following description.

The central nervous system.—The nervous system of a vertebrate (fig. 65), consists of a central portion, the brain (fig. 66), and spinal cord, from which branches called nerves extend in pairs; the nerves then branch and branch again until their divisions reach every part of the body in the shape of very numerous white threads, too small to be detected by the naked eye. These very small nerve-threads or fibers end at last in connection with certain of the tissue-cells. All the sense-cells of the retina, ear, nose, tongue, and skin are connected with minute nerve-fibers as are also all the muscle-fibers. Now all the nerve-fibers from both sense-cells and muscle-cells run to the central portions of the nervous system, the brain and spinal cord, and are there in some way definitely connected with one another, thus making pathways over which everything that affects the eye, ear, and other sense-organs may affect the muscles.

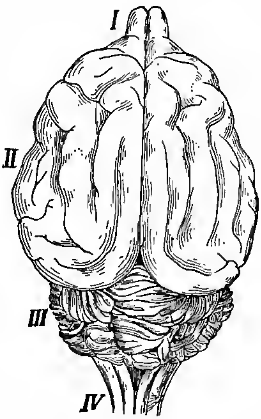


Fig. 66.—Brain of a cat, dorsal surface; *I*, olfactory bulbs; *II*, cerebral hemispheres; *III*, cerebellum; *IV*, medulla oblongata. (After Reighard and Jennings.)

The nervous system of all vertebrates is on the same general plan, being, however, less complex in the lower forms. All animals with a definite nervous system have nerve-fibers connecting both sense-cells and muscle-cells with certain central parts. They differ, however, in the arrangement of these parts. And since they differ also in muscular arrangement, and in the kind and position of the sense-organs, the arrangement of the nerve-fibers connecting muscles and sense-organs with these central parts differs accordingly.

In the worms, crustacea, and insects, which have much the same body-plan, the central nervous system (figs. 67 and 68), consists of a chain of ganglia (small nerve-centers) along the ventral portion of the body, this chain being connected at the anterior end by a cord on each side of the gullet, with a large head ganglion which stands in the position of the vertebrate brain. In the starfishes and sea-urchins, the central nervous system has the form of a ring with radiating branches, but with no head ganglia. In sea-anemones and jellyfishes it is somewhat similar, but is less distinctly set apart from the other tissue-cells. In the one-celled animals we recognize no trace of a

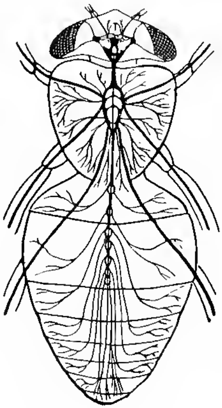


FIG. 67.

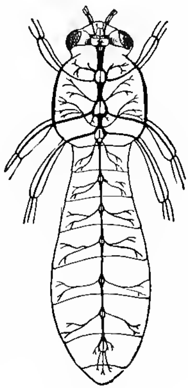


FIG. 68.

FIG. 67.—Nervous system of the house-fly, the central nerve-cord and ganglia lie in the ventral (under) part of the body. (After Brandt.)
FIG. 68.—Nervous system of a midge (*Chironomus*); note the separation of all the ganglia. (After Brandt.)

nervous system any more than we do of a muscular or bony system.

In comparing the nervous systems of various animals as we have their muscular, bony, and circulatory systems we find the same variety and progressive degree of development holding true. In Amœba the whole cell is in a weak way sensitive to light, heat, jars, odors, acids, alkalis, and the various other things that affect the sense-organs of higher animals. The cell as a whole conducts the effects of these to all its parts and the response of the animal is slow and indefinite.

As we proceed higher in the animal scale we find a gradual grouping in definite positions of a number of cells that are specially sensitive to the different influences acting on the organisms, and along with this definite groups of muscular cells and definite nerve pathways for impulses to pass from the sensitive to the motor cells, and more and more complex connections of groups with groups. In the highest organisms we have sense-organs which

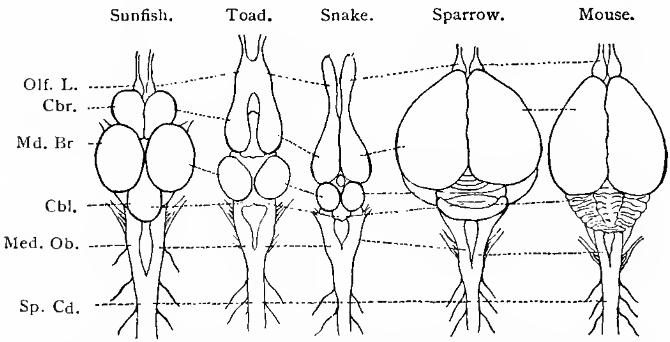


FIG. 69.—Diagram of brains of vetebrates; *Olf. L.*, olfactory lobes; *Cbr.*, cerebrum; *Md. Br.*, midbrain (optic lobes); *Cbl.*, cerebellum; *Med. Ob.*, medulla oblongata; *Sp. Cd.*, spinal cord. (From specimens.)

make us exactly acquainted with the outside world; we have brain, spinal cord, and nerves, which receive the impulses from these and turn them through the muscles into all the motions our bodies are capable of; besides we have all those wonderful processes included under what we call instinct, memory, and reason.

The special senses and their organs.—The organs of sight, the eyes, are the only organs of special sense generally conspicuous and unmistakably recognizable when present. In the vertebrates the eyes, ears, nose, and taste organs are always situated on the head, but in the invertebrates the sense-organs corresponding to these are often scattered over the body, and certain other organs are found which from their structure seem to be sense-organs although we are by no means sure what kind of sense they serve.

In some of the lower animals, as the polyps, there are on the skin certain sense-cells, either isolated or in small groups that are not limited to a single special sense. They seem to be stimulated not alone by the touching of foreign substances, but also by warmth and light. These simple sense-cells from which the more complex or special ones may develop are called primitive or generalized sense-organs.

The tactile sense or sense of touch is the simplest and most wide-spread of the special senses, with the simplest organs. The special organs are usually simple hairs or papillæ connecting with a nerve. They may be distributed pretty evenly over most of the body or may be mainly concentrated upon certain parts in crowded groups. Many of the lower animals have projecting parts, like the feeling tentacles of many marine invertebrates, or the antennæ (feelers) of crabs and insects, which are the special seat of the tactile organs. Among the vertebrates the tactile organs are either like those of the invertebrates, or are little sac-like bodies of connective tissue in which the end of a nerve is curiously folded and convoluted. These little touch-corpuscles (fig. 70) lie in the cell layer of the skin, covered over thinly by the cuticle. Sometimes they are simply free, branched nerve-endings in the skin. In either case they are especially abundant in those parts of the body which can be best used for feeling. In man the finger-tips are thus specially supplied, in certain tailed monkeys the tip of the tail, and in hogs the end of the snout.

The taste organs are much like the tactile organs except that the special taste cell must be exposed, so that small particles of the substance to be tasted can come into actual contact with it. The taste organs (fig. 71) of man and the other air-breathing animals are located in the mouth or on the mouth parts. It is also necessary that the food substance to be tasted be dissolved. This is accomplished by the fluids poured into the mouth from the salivary glands. With the lower aquatic animals it is not improbable that taste organs are situated on other parts of the body besides the mouth, and that taste is

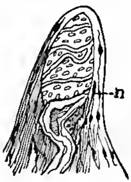


FIG. 70.

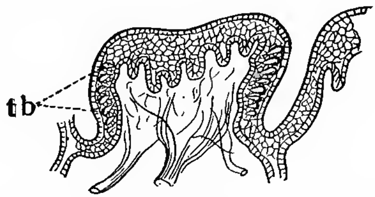


FIG. 71.

FIG. 70.—Tactile (touch) corpuscle of the skin of man; *n*, nerve. (Greatly magnified; after Kölliker.)

FIG. 71.—Papilla with taste buds (*t.b*) from tongue of a calf. (Greatly magnified; after Loven.)

used not only to test food substances but also the chemical character of the fluid medium in which they live.

Smelling and tasting are closely allied, the one testing substances dissolved, the other substances vaporized. The organs of the sense of smell are, like those of taste, simple nerve-endings in papillæ or pits. By smell animals can discover food, avoid enemies, and find their mates. With the strictly aquatic animals the sense of smell is probably but little developed. There is little opportunity for a gas or vapor to reach them, and only as gas or vapor can a substance be smelled. With these animals the sense of taste must take the place of the olfactory sense. But among the insects, mostly terrestrial animals, there is an extraordinary development of the sense of smell. It is indeed probably their principal special sense. Insects must depend on smell far more than on sight or hearing for the discovery of food, and for becoming aware of the presence of their enemies and the proximity of their mates and companions. The organs of smell of insects are situated principally on the antennæ or feelers (fig. 72), a single pair of which is borne on the head of every insect. That many insects have an amazingly keen sense of smell has been shown by numerous experiments, and is constantly proved by well-known habits. If a small bit of decaying flesh be inclosed in a box so that it is wholly concealed, it will nevertheless soon be found by the flies and carrion beetles that either feed on carrion or must always lay their eggs in decaying matter so that their carrion-eating larvæ may be provided with food. In Jordan and Kellogg's "Animal Life" is given the following illustration of the remarkable sense of smell possessed by certain insects: "In the insectary at Cornell University, a few years ago, a few females of the beautiful Promethea moth were inclosed in a box, which was kept inside the insectary building. No males had been seen about the insectary nor in its immediate vicinity, although they had been sought for by collectors. A few hours after the beginning of the captivity of the female moths there were forty male Prometheas fluttering about over the glass roof of the insectary. They could not see the females, and yet had

FIG. 72.—The antenna of a carrion beetle, with the terminal three segments enlarged and flattened, and bearing many "smelling-pits," the antenna thus serving as an olfactory organ. (Much enlarged; photomicrograph by Geo. O. Mitchell.)

discovered their presence in the building. The discovery was undoubtedly made by the sense of smell. These moths have very elaborately developed antennæ, finely branched or feathered, affording opportunity for the existence of very many smelling-pits.''

Hearing is the perception of certain vibrations of bodies. These vibrations give rise to waves—sound-waves as they are called—which proceed from the vibrating body in all directions, and which, coming to an animal, stimulate the special auditory or hearing organs, which transmit this stimulation along the auditory nerve to the brain, where it is translated as sound. These sound-waves come to animals usually through the air or, in the case of aquatic animals, through water, or through both air and water.

The organs of hearing are of very complex structure in the case of man and the higher vertebrates. Our ears (fig. 73), which are adapted for perceiving or being stimulated by vibrations ranging from 16 to 40,000 a second—that is, for hearing all those sounds produced by vibrations of a rapidity not less than 16 to a second nor greater than 40,000 to a second—are of such complexity of structure that many pages would be required for their description. But among the lower or less highly organized animals the ears, or auditory organs, are much simpler.

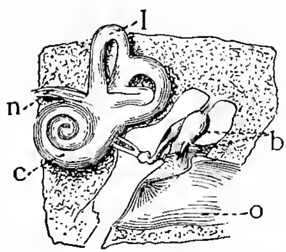


FIG. 73.—Diagram of human ear; *o*, external opening; *b*, bones of the ear; *l*, labyrinth; *c*, cochlea or "snail shell"; *n*, auditory nerve. (After Headly.)

In most animals the auditory organs show the common characteristic of being wholly composed of, or having, as an essential part, a small sac filled with liquid in which one or more tiny spherical hard bodies called otoliths are held. This auditory sac is formed of, or lined internally by, auditory cells, specialized nerve-cells, which often bear delicate vibratile hairs. Auditory organs of this general character are known among the polyps, the worms, the crustaceans, and the molluscs. Recent studies seem to show that the otoliths have a special use as organs which help the animal to keep its equilibrium. In the common crayfish the "ears" are situated in the basal segment of the inner antennæ or feelers. They consist each of a small sac filled with liquid, in which are suspended several grains of sand or other hard bodies. The inner surface of the sac is lined with fine auditory hairs. The sound-waves coming through the air or water outside strike against this sac, which lies in a hollow on the upper or outer side of the antennæ. The sound-waves are taken up by the contents of the sac and stimulate the fine hairs, which in turn give this stimulus to the nerves which run from them to the principal auditory nerve and thus to the brain of the crayfish. Among the insects other kinds of auditory organs exist. The common locust or grasshopper has on the upper surface of the first abdominal segment a pair of tympana or ear-drums (fig. 74), composed simply of the thinned, tightly-stretched chitinous cuticle of the body. On the inner surface of this ear-drum there are a tiny auditory sac, a fine nerve leading from it to a small auditory ganglion lying near the tympanum, and a large nerve leading from this ganglion to one of the larger ganglia situated on the floor of the thorax. In the crickets and katydids, insects related to the locusts, the auditory organs or ears are situated in the fore legs.

Certain other insects, as the mosquitoes and other midges or gnats, undoubtedly hear by means of numerous delicate hairs borne on the antennæ. The male mosquitoes have many hundreds of these long, fine antennal hairs, and on the sounding of a tuning-fork they have been observed to vibrate strongly. In the base of each antenna there is a most elaborate organ, composed of fine chitinous rods, and accompanying nerves and nerve-cells

FIG. 74.—The auditory organ of a locust (*Melanoplus* sp.). The large clear part in the center of the figure is the thin tympanum, with the auditory vesicle (small black pear-shaped spot) and auditory ganglion (at left of vesicle and connected with it by a nerve) on its inner surface. (Greatly magnified; photomicrograph by Geo. O. Mitchell.)

whose function it is to take up and transmit through the auditory nerve to the brain the stimuli received from the external auditory hairs.

Concerning the sense of sight and the seeing organs the following brief discussion is taken from Jordan and Kellogg's "Animal Life":

"Not all animals have eyes. The moles, which live underground, insects and other animals that live in caves, and the deep-sea fishes which live in waters so deep that the light of the sun never comes to them, have no eyes at all, or have eyes of so rudimentary a character that they can no longer be used for seeing. But all these animals have no eyes or only rudimentary ones because they live under conditions where eyes are useless. They have lost their eyes by degeneration. There are, however, many animals that have no eyes, nor have they or their ancestors ever had eyes. These are the simplest, most lowly organized animals. Many, perhaps all eyeless animals, are, however, capable of distinguishing light from darkness. They are sensitive to light. An investigator placed several individuals of the common, tiny fresh-water polyp (Hydra) in a glass cylinder the walls of which were painted black. He left a small part of the cylinder unpainted, and in this part of the cylinder where the light penetrated the Hydras all gathered. The eyeless maggots or larvæ of flies, when placed in the light will wriggle and squirm away into dark crevices. They are conscious of light when exposed to it, and endeavor to shun it. Most plants turn their leaves toward the light; the sunflower turns on its stem to face the sun. Light seems to stimulate organisms whether they have eyes or not, and the organisms either try to get into the light or to avoid it. But this is not seeing.

"The simplest eyes, if we may call them eyes, are not capable of forming an image or picture of external objects. They only make the animal better capable of distinguishing between light and darkness or shadow. Many lowly organized animals, as some polyps, and worms, have certain cells of the skin specially provided with pigment. These cells grouped together form what is called a pigment-fleck, which can, because of the presence of the pigment, absorb more light than the skin-cells, and are more sensitive to the light. By such pigment-flecks, or eye-spots, the animals can detect, by their shadows, the passing near them of moving bodies, and thus be in some measure informed of the approach of enemies or of prey. Some of these eye-flecks are provided not simply with pigment but with a simple sort of lens that serves to concentrate rays of light and make this simplest sort of eye even more sensitive to changes in the intensity of light (fig. 75).

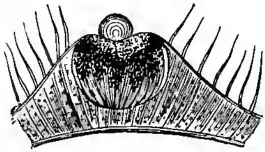


FIG. 75.—Simple eye of a jellyfish. (Greatly magnified; after Hertwig.)

"Most of the many-celled animals possess eyes by means of which a picture of external objects more or less nearly complete and perfect can be formed. There is

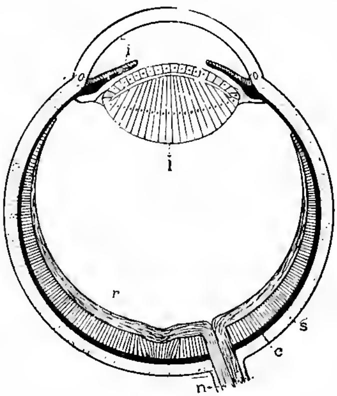


FIG. 76.

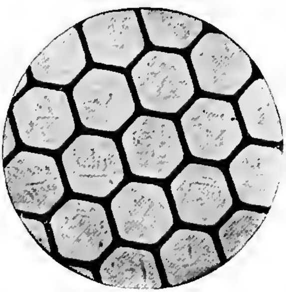


FIG. 77.

FIG. 76.—Diagram of vertebrate eye; *c*, choroid; *i*, iris; *l*, lens; *n*, optic nerve; *r*, retina; *s*, sclerotic. (From Kingsley.)

FIG 77.—Part of cornea, showing facets, of the compound eye of a horse-fly (*Therioplectes* sp.). (Greatly magnified; photomicrograph by Geo. O. Mitchell.)

great variety in the finer structure of these picture-forming eyes, but each consists essentially of an inner delicate or sensitive nervous surface called the retina, which is stimulated by light, and is connected with the brain by a large optic nerve, and of a transparent light-refracting lens lying outside of the retina and exposed to the light.

These are the constant essential parts of an image-forming and image-perceiving eye. In most eyes there are other accessory parts which may make the whole eye an organ of excessively complicated structure and of remarkably perfect seeing capacity. Our own eyes (fig. 76) are organs of extreme structural complexity and of high development, although some of the other vertebrates have undoubtedly a keener and more nearly perfected sight.

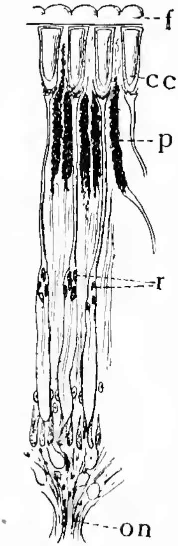


FIG. 78.—Section through a few facets and eye elements of the compound eye of a moth; *f*, corneal facets; *c.c*, crystalline cones; *p*, pigment; *r*, retinal parts; *o.n*, optic nerve. (Greatly magnified; after Exner.)

"The crustaceans and insects have eyes of a peculiar character called compound eyes (figs. 77 and 78). In addition most insects have smaller simple eyes. Each of the compound eyes is composed of many (from a few, as in certain ants, to as many as twenty-five thousand, as in certain beetles) eye elements, each eye element seeing independently of the others and seeing only a very small part of any object in front of the whole eye. All the small parts of the external object seen by the many distinct eye elements combine so as to form an image in mosaic, that is, made up of separate small parts of the external object. If the head of a dragon-fly be examined it will be seen that two-thirds or more of the whole head is made up of the two large compound eyes, and with a lens it may be seen that the outer surface of each of these eyes is composed of many small spaces or facets, which are the outer lenses of the many eye elements composing the whole eye."

PART III.

VARIOUS KINDS OF ANIMALS, AND THEIR LIFE.

CHAPTER IX.

THE AMŒBA, HYDRA, AND OTHER SIMPLE ANIMALS.

Although the animals we know best are pretty large, and the tiny midges which dance in swarms in the air, and the little mosquito wrigglers which squirm in stagnant water seem to us among the smallest of animals, as a matter of fact there are thousands of kinds much smaller than the smallest we can see. Almost all of these minute animals live either in fresh water or the ocean, and among them are the simplest kinds in the entire animal kingdom. Because they are too small to be seen by the unaided eye they can be studied only with the compound microscope. If the schoolroom is provided with one, bring in a little water, together with a few small sticks or decaying leaves, from the bottom of some stagnant pool, and examine a drop or two of it under the microscope. It will prove to be a tiny ocean world inhabited by miniature animals and plants. In it will be found a few larger animals preying on the smaller ones. There is sudden and violent death here, and births, and locomotion and food-getting and growth, and all the activities and functions of life which we are accustomed to see in the more familiar world of larger animals.

Amœba.—The simplest and one of the smallest of all known animals is Amœba. If in a drop of stagnant water taken from the slime on a dead leaf or stick from the bottom of the pool you discover a microscopic, nearly transparent, granular, jelly-like speck which slowly but constantly changes its form then you have an Amœba. Its whole body is nothing but a tiny, formless, viscous speck of protoplasm. It is an animal without legs or feelers, skeleton or muscles, without mouth or stomach, eyes or brain; without heart or lungs, nerves or blood, and yet is as truly an animal as a horse, and as capable as the horse of performing, although in the simplest possible way, all the processes necessary to life, such as taking in and digesting food, taking up oxygen and giving off carbon dioxide, feeling and moving about. Its whole body is composed of a single one of the units called cells, thousands and millions of which are included in the body of any one of the larger and more familiar animals.

Having found an Amœba note its irregular shape and observe its mode of moving (fig. 79). How does it move? The little processes which stick out in various directions are called false feet or pseudopodia. They are simply parts of the body protoplasm. Has Amœba a definite body-wall? Do the false feet protrude from certain parts of the body only? Inside note a clear globular spot which contracts and expands or pulsates more or less regularly. This is the contractile vacuole. Note the small granules which move about in the body. These are food particles which have been taken in through the body-wall. Note how the false feet flow about food particles (tiny one-celled plants or other bits of organic matter) in the water. When these are surrounded by the body protoplasm they are digested, the undigestible parts being forced out through the surface of the body. Note within the body an oval transparent spot which shows no pulsations. This is called the nucleus and is charac-

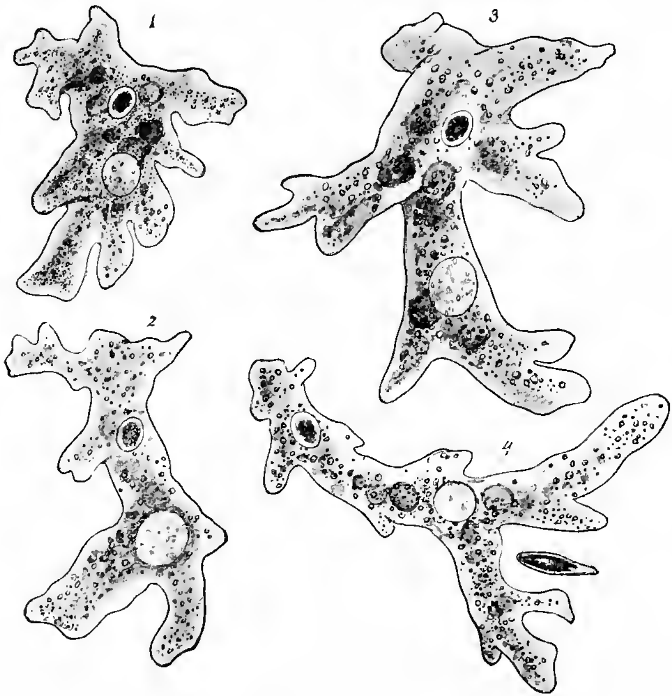


FIG. 79.—*Amœba* sp.; showing the forms assumed by a single individual in four successive changes. (Greatly magnified; from life.)

teristic of all cells. Make drawings showing Amœba in three different shapes.

Amœba produces young Amœbæ by simply dividing in halves, half of the nucleus going with each half of the rest of the protoplasm. Each half begins at once to move about and to feed and behave just like the parent, soon growing to be as large as the original Amœba. In this simple way of producing young the parent does not die at all, but merely divides in two and goes on living as two new individuals.

Amœbæ continue to live and multiply by this simple process of division as long as the conditions for living are satisfactory. But when the stagnant pool dries up they would be exterminated were it not for a careful provision of nature. When water begins to fail each Amœba contracts its pseudopodia and the protoplasmic body secretes a horny capsule about itself. It is now protected from dry weather, and can be blown by the winds from place to place until the rains begin, when it expands, throws off the capsule, and commences active life again in the new puddle in which it finds itself.

Other one-celled animals.—In the same water with Amœbæ numerous other simple one-celled animals will certainly live. A common kind is the slipper animalcule (Paramœcium), shown in fig. 80. This swims swiftly about and has a body of fixed form. If specimens cannot be readily found put some bits of hay or finely cut dry clover in a glass dish, cover with water and leave in the sun for several days. In this infusion slipper animalcules will develop by thousands. Examine a drop of it under the microscope and observe the animalcules. Has the body of Paramœcium an anterior and posterior end? The short, delicate, hair-like processes on its surface are called cilia, and are simply fine prolongations of the body protoplasm. What is their use? At one side, beginning near one end of the body, note a groove. What is this for? Rejected or waste particles are occasionally ejected from the body. Where? There are two contractile vacuoles in Paramœcium (instead of one as in Amœba), and there are also two nuclei instead of one. Try to find them. In comparing Paramœcium with Amœba it is apparent that the body of the first is less simple than that of the second. The definite opening for food, the two nuclei and two contractile vacuoles, the many fixed cilia, and the definite form of the body, which is inclosed by a thin skin or cell-wall, are all slight advances toward a

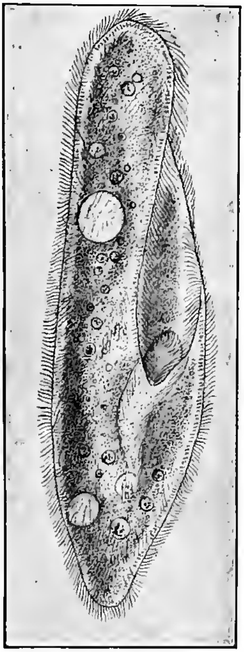


FIG. 80.

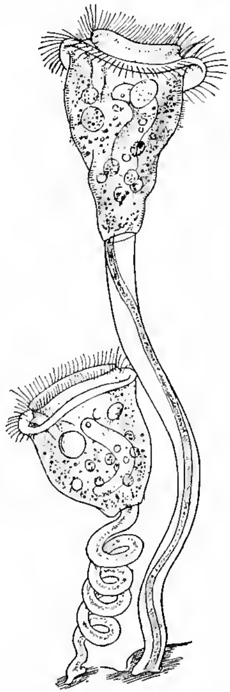


FIG. 81.

FIG. 80.—*Paramœcium* sp.; buccal groove at right. (Greatly magnified; from life.)

FIG. 81.—*Vorticella* sp.; one individual with stalk coiled, and one with stalk extended. (Greatly magnified; from life.)

more complex make-up. But Paramœcium is still a single cell. Make a drawing of a Paramœcium.

Another common one-celled animal, and a curious and interesting one, is the bell animalcule (Vorticella) (fig. 81). The individuals of this group live together in colonies, a single colony appearing to the naked eye as a tiny, whitish, mould-like tuft or spot on the surface of some leaf or stem or root in the water of a stagnant pool. Touch such a spot with a needle, and if it is a bell-animalcule colony it will contract instantly. Bring several colonies into the schoolroom and keep in a glass of stagnant water. Examine a colony in a drop of water in a watch-glass or on a slide under the microscope. Note the stemmed bell-shaped bodies which compose it. Each bell and stem together form an individual. Tap the slide and note the sudden contraction of the colony. Observe the contraction of a single individual. Just what takes place? Watch an individual expand. Examine carefully the "bell." Its upper margin is fringed with cilia, and there is a mouth opening on the upper surface. Find a contractile vacuole in the body, and also numerous food particles which move about. The nucleus, hard to see, is elongate and curved. The body is inclosed by a thin cuticle. Make a drawing of a Vorticella expanded, and of one contracted.

Both Paramœcium and Vorticella multiply by division; that is, by the simple dividing of the body in two, as with Amœba. But each of these halves, or new animals, is not exactly like its parent, and has to undergo some change or development as well as growth (increase in size) to become a complete Paramœcium or Vorticella. These two kinds of one-celled animals, and most others, also have another process of multiplication slightly more complex than the one just described. Two individuals sometimes come together and a part of the nucleus of each passes into the body and fuses with the remaining part of the nucleus of the other. Then the individuals move apart, and each divides in halves. This process is called multiplication by conjugation and division. Perhaps Amœbæ conjugate occasionally, but if so they do it rarely. On the other hand Paramœcium and Vorticella cannot go on indefinitely having generations by simple division. An occasional generation must be produced by the method in which conjugation precedes division.

Other kinds of one-celled animals, or *Protozoa*, are common in stagnant water, and under the microscope a variety of forms may be seen swimming quickly about. Locomotion is effected usually by many fine cilia or by fewer, usually two, longer whiplash-like processes called

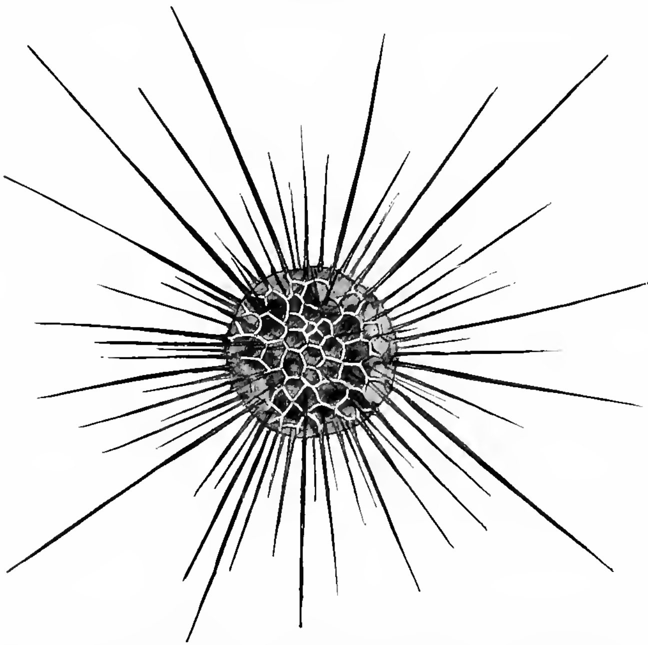


FIG. 82.—Sun animalcule, a fresh-water protozoan with a siliceous skeleton, and long thread-like protoplasmic prolongations. (Greatly magnified; from life.)

flagella. Some have the soft body inclosed in a tiny shell, as is the case with the sun animalcule shown in fig. 82.

Ocean Protozoa.—One usually thinks of the ocean as the home of the whales and the seals and the sea-lions, and of the countless fishes—the cod, the herring, and the mackerel. Those who have been on the seashore will recall the sea-urchins and starfishes and sea-anemones which live in the tide-pools. On the beach, too, there are innumerable shells, each representing a dead ocean animal. But more abundant than all of these, and in one way more important than all, are the myriads of the marine Protozoa.

Fig. 83.—*Stentor* sp.; a protozoan which may be fixed, like *Vorticella*, or free-swimming, at will, and which has the nucleus in the shape of a string or chain of bead-like bodies. The figure shows a single individual as it appeared when fixed, with elongate, stalked body, and as it appeared when swimming about, with contracted body. (Greatly magnified; from life.)

Although the water at the surface of the ocean appears clear, and on superficial examination seems to contain no animals, yet in certain parts of the world (especially in the southern seas) a microscopical examination of it shows it to be swarming with Protozoa. And not only is the water just at the surface inhabited by one-celled animals, but they can be found all the way down to a great depth. In a pint of ocean water there may be millions of these minute animals. In the oceans of the world the number of them is inconceivable. And it is necessary that these Protozoa exist in such great numbers, for they and the marine one-celled plants (Protophyta), supply directly or indirectly the food of all the other animals of the ocean.

Among these ocean Protozoa there are numerous kinds with the body inclosed in a minute shell (fig. 84). These tiny shells present a great variety of shape and pattern, many being of the most exquisite symmetry and beauty. They are perforated by many small holes through which project long, delicate, protoplasmic pseudopodia. These fine pseudopodia often interlace and fuse when they touch each other, thus forming a sort of protoplasmic network outside of the shell. In some cases there is a complete layer of protoplasm—part of the body protoplasm of the Protozoan—surrounding the cell externally.

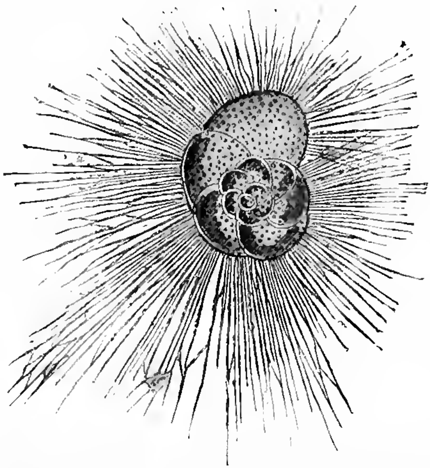


FIG. 84.—*Rosalina varians*, a marine protozoan (Foraminifera) with calcareous shell. (Greatly magnified; after Schultze.)

When these tiny animals die their hard shells sink to the bottom of the ocean, and accumulate slowly, in inconceivable numbers, until they form a thick bed on its floor. Large areas of the bottom of the Atlantic Ocean are covered with these beds. Nor is it only in present times that such beds have been formed by the marine Protozoa. All over the world there are thick rock strata composed almost exclusively of the fossil shells of these simple animals. The chalk-beds and cliffs of England and of France, Greece, Spain, and America, were made by marine Protozoa. Where now is land were once oceans, the bottoms of which have been gradually lifted above the water's surface. Similarly the rock called Tripoli, found in Sicily, and the Barbados earth from the island of Barbados, are composed of the shells of ancient Protozoa.

Hydra.—One of the most interesting of the simple animals found in fresh-water ponds is Hydra (fig. 85).

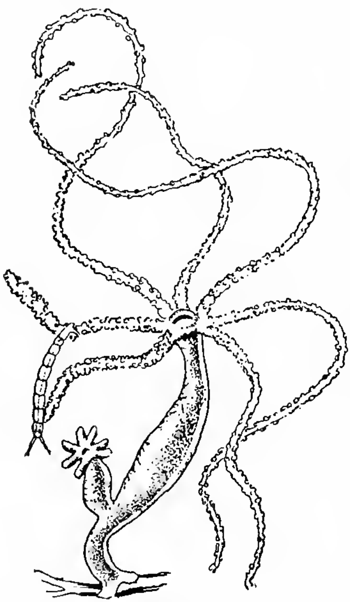


FIG. 85.—Hydra; note two tentacles catching an insect larva; note the budding young Hydra. (Natural size, one-sixth inch; from life.)

Though very small compared with most animals we know, it is much larger than any of the Protozoa, being when expanded nearly one-fourth of an inch long. It is also not composed of a single cell but of hundreds of cells. It is one of the simplest of the many-celled animals, i.e., Metazoa. Hydra may be found attached to bits of sticks, stones, and leaves in pools not too stagnant. There are two common kinds, one brown and one green. Specimens should be brought into the schoolroom alive, and kept in a dish of water in the light. To observe the habits of Hydra, examine a live specimen, attached to a bit of leaf or stick, in a watch-glass, under the low power of a compound microscope, or with a good magnifier.

Note the cylindrical body, attached at its base, and with a series of tentacles projecting from its free end. How many tentacles are there? They arise in a circle about the mouth. Have some small water-fleas in the water and observe Hydra's method of catching and eating food. Note that when it captures one of the water-fleas with its tentacles the flea soon ceases to struggle. It is paralyzed. On the tentacles are many extremely fine, little, stinging threads, which lie coiled up in small pockets until prey is captured, when they uncoil, shoot out, and sting. If Hydra catches an animal too large to be crowded into its mouth it releases it.

Note that Hydra can contract its tentacles and its whole body until it looks like a small egg with a rosette of short blunt fingers at one end (fig. 85). Sometimes Hydra may be seen with another much smaller one growing out from it. This is a new one, forming by the process of "budding." It will grow and develop until about as large as the parent, when it will break off, and attaching itself elsewhere will begin an independent existence. Hydra has the interesting power of being able to regenerate itself if cut in two. In such a case each half will usually develop into a new complete Hydra.

Hydra belongs to the branch of animals called *Cœlenterata*, which includes also the sea-anemones, corals, and jellyfishes (see next chapter).

For detailed accounts of the structure and life-history of Amœba, Paramœcium, Vorticella, other Protozoa, and Hydra, see Parker's "Lessons in Elementary Biology."

CHAPTER X

OCEAN ANIMALS: SPONGES, SEA-ANEMONES, JELLYFISHES, CORALS, STARFISHES, OYSTERS, CLAMS, AND SEA-SHELLS

As but few schools are situated near the seashore not many pupils using this book will be able to see for themselves the interesting animals which live in the tide-pools and on the rocks and sand floor of the coast. That a host of curious creatures inhabit the sea is of course familiar knowledge. The whales, dolphins, and porpoises, and the thousands of kinds of fishes from the great sharks to the tiny gobies and swarming herrings, are the marine representatives of the vertebrates; the invertebrates are represented by the plant-like sponges and sea-anemones, the colored corals, whose skeletons form great reefs and islands, the translucent, delicately tinted jellyfishes that swim gracefully through the water by opening and closing their umbrella-like bodies, the crawling starfishes, the spiny sea-urchins, and by the host of snail-like animals that we commonly know by their houses, the various sea-shells which are washed up on the beach. Some of these ocean invertebrates live far out on the open sea, like the jellyfishes, which swarm in tropical waters; some live on the bottom, and even at great depths, like the sponges, but the more familiar ones, such as the sea-anemones, starfishes, and sea-urchins live in the tide-pools along the shore. Pupils who cannot observe the ocean animals alive should, if possible, examine some preserved specimens in connection with the following brief account. The hard parts of the sponges, sea-urchins, starfishes, and corals, and various sea-shells, are common curiosities, and may be found in somebody's house in almost every town.

Sponges.—A bath or slate sponge is simply the skeleton, or part of it, of a sponge animal. In life all of this skeleton is inclosed or covered by a soft, tough mass of sponge flesh. Sponges are fixed, except when very young, when they swim freely about. They are found at all depths and in all seas, growing especially abundantly

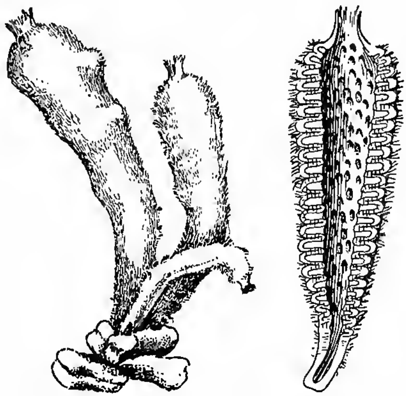


FIG. 86.—A simple sponge, *Grantia;* at right a longitudinal section to show the simple body-cavity. (One-half natural size; after Jordan and Kellogg.)

in the Atlantic Ocean and the Mediterranean. A very few kinds live in fresh water, being found in lakes, rivers, and canals, in all parts of the world. The shape of the simplest sponges is that of a small vase, or nearly cylindrical cup, attached at its base, and having at the free end a large opening (fig. 86). But most sponges are very unsymmetrical and grow more like a low, compact, bushy plant than like the animals we are familiar with. The smallest sponges are only 1 mm. (1/25 in.) high, while the largest may be over a meter (39 in.) in height. In color they may be red, purple, orange, gray, and sometimes blue.

Examine a bath sponge and note the holes in it. These are to let in and out the sea-water, in which float the minute bits of animal or plant substance on which the sponge feeds. This water also brings oxygen for the breathing of the sponge, and carries away the carbon dioxide given off by it. But the sponge has no special organs, its soft flesh being able to digest food and take up oxygen without stomach or lungs.

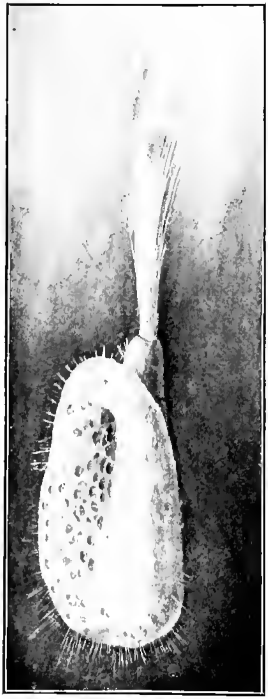


FIG. 87. — The skeleton of a "glass" sponge (skeleton composed of siliceous spicules) from Japan. (Natural size; from specimen.)

The living sponges are collected by divers, or are dragged up by men in boats with long-poled hooks or dredges.

They are first killed by exposure to the air, and then thrown into tanks of water. Here the flesh decays away, leaving the tough, horny, or leathery skeleton, which, when cleaned, bleached, and trimmed, is ready for market. Some sponges have a lime and some a glass skeleton instead of a horny one, and the glass skeletons are often very beautiful (see fig. 87). All the sponges compose the animal branch called *Porifera*.

Sea-anemones and corals.—The sea-anemones which are common in tide-pools, and the coral animals which live in tropic and sub-tropic oceans, have the same type of body as that shown by Hydra (described in Chapter IX), but are much larger. When the tide is out, exposing the dripping seaweed-covered rocks, and the little

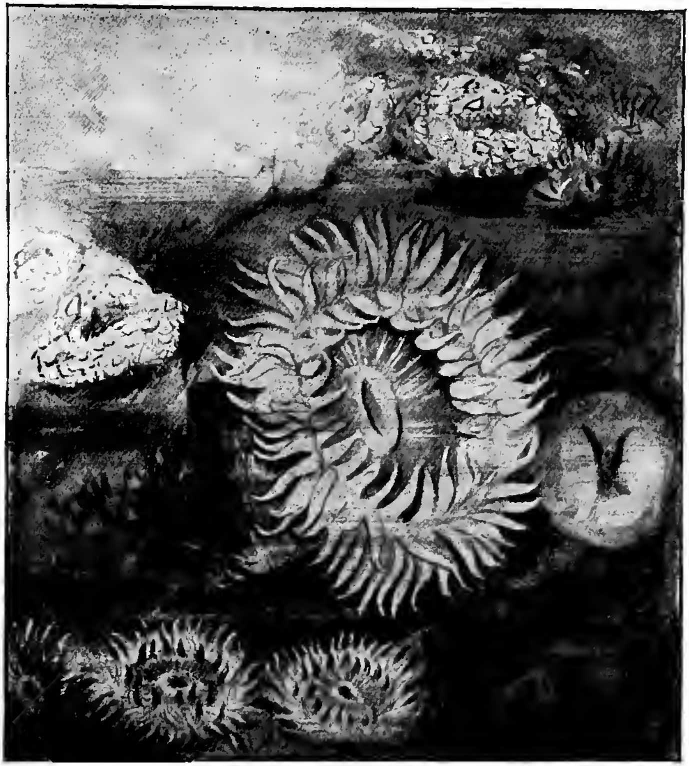


FIG. 88.—Sea-anemones, *Bunodes californica*, open and closed individuals, one-half natural size. The closed individuals in upper right-hand corner show the external covering of small bits of rock and shell, characteristic of most individuals of this species. (From living specimens in a tide-pool on the Bay of Monterey, California.)

basins are left filled with clear sea-water, the brown and green and purple "sea-flowers" may be seen fixed to the rocks by the base, with the mouth opening and circlet of slowly moving tentacles hungrily ready for food (figs. 88

and 89). Touch the fringe of tentacles with your finger-tip and feel how they cling to it. If it were a small animal, like a sea-snail, these deadly tentacles would hold it fast and slowly carry it into the mouth. Inside the body is a cylindrical hollow, which is really a primitive kind of stomach. But there is no heart nor brain nor lungs in

FIG. 89.—Sea-anemones in a tide-pool at Point Lobos, near Monterey, Cal.; these specimens are six inches in diameter across the mouth end. (Photograph by author, from living specimens *in situ.*)

this simple body. It is only a thick-walled sac, with the mouth surrounded by food-catching tentacles.

The coral animals, or coral polyps, are simply a kind of sea-anemone which secretes in its otherwise soft body-wall a stony skeleton of carbonate of lime which persists after the polyp is dead. We know these animals chiefly by their skeletons, which we see in masses in collections, or made into ornaments. But in tropical oceans there are whole islands of coral (figs. 90, 91), or long coral reefs

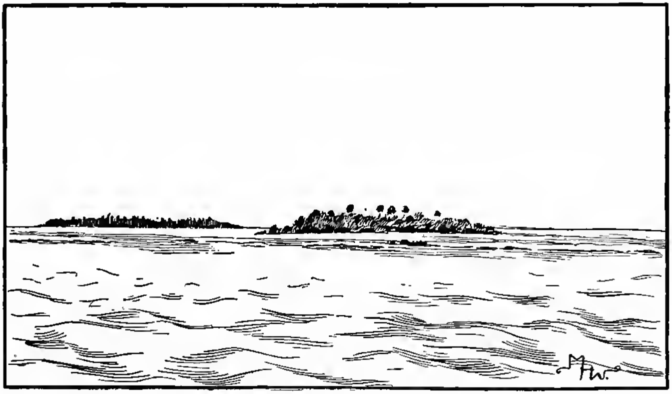


FIG. 90.—Coral islands, Nukulai and Mokaluwa, of the Fiji group. (After photograph by W. C. McWoodworth.)

(fig. 92) fringing the shores of continents, formed by the skeletons of millions of polyps. For as they live closely

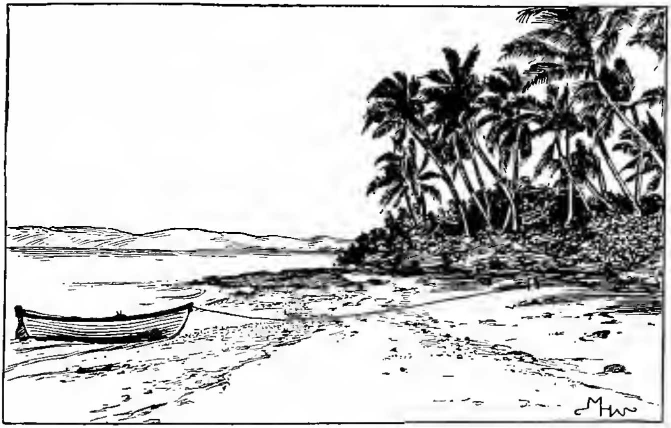


FIG. 91.—Western part of Storm Island (Fijis), a coral island; the trees are cocoanut palms. (After photograph by W. C. McWoodworth.)

massed together in great colonies their skeletons form solid stony banks. Coral islands have a great variety of form, but the elongated, circular, ring-shaped, and crescent forms predominate. In the Atlantic Ocean they are found along the coasts of Southern Florida, Brazil, and the West Indies; in the Pacific and Indian oceans there

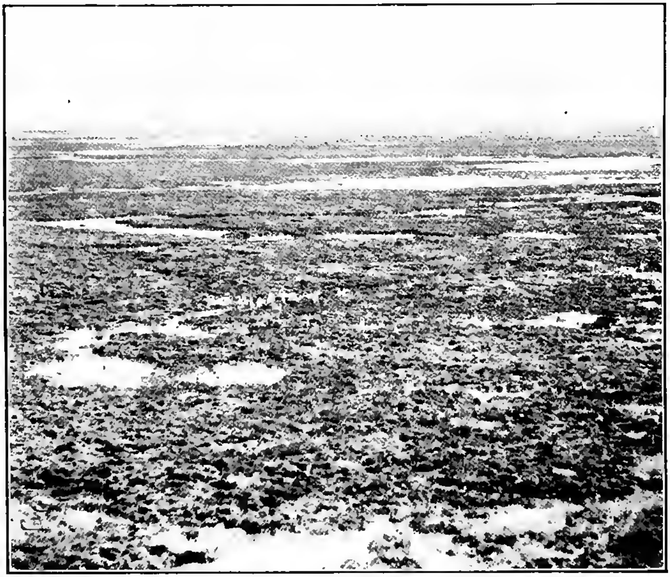


FIG. 92.—View of a coral reef off the coast of Brazil (near Bahia); photograph taken at low tide with the coral projecting just above the surface (Photograph by J. C. Branner.)

are great coral reefs on the coasts of Australia, Madagascar, and elsewhere; and certain large groups of inhabited islands, as the Fiji, Society, and Friendly Islands are almost exclusively of coral formation.

There are over 2000 kinds of coral polyps known, and their skeletons vary much in appearance (fig. 93). Because of the suggestive appearance of some of these they have received common names, as the organ-pipe coral, brain coral, etc. The red coral of which jewelry is made grows chiefly in the Mediterranean Sea. It is gathered specially on the western coast of Italy, and on the coasts of Sicily and Sardinia. Most of this coral is sent to Naples, where it is cut into ornaments.

Jellyfishes.—By walking along the sea-beach soon after a storm one may find many shapeless masses of a

FIG. 93.—Skeleton of a branching coral, *Madrepora cervicornis*. (From specimen.)

clear jelly-like substance scattered here and there on the sand. These are the bodies or parts of bodies of jellyfishes which have been cast up by the waves. Exposed to the sun and wind they soon die or evaporate away to a small shrivelled mass. The flesh of a jellyfish contains hardly more than one per cent of solid matter, all the rest of it being water.

Jellyfishes, although closely related to the fixed polyps, some indeed being the immediate offspring of them, have a body of quite different appearance. It corresponds in general to an umbrella or bell (fig. 94), around the edge of which are disposed numerous threads or tentacles (corresponding to the tentacles of the polyp). The

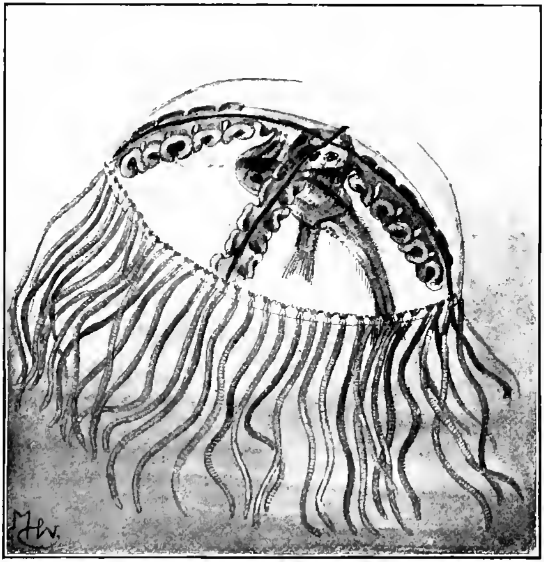


FIG. 94.—A jellyfish or medusa, *Gonionema vertens*, eating two small fishes. (Natural size; from specimen from Atlantic Coast.)

mouth-opening is at the end of a longer or shorter projection which hangs from the middle of the under side of the umbrella, like a short, thick handle. The body cavity, or primitive stomach, extends out into the umbrella-shaped part of the body. By alternately clapping shut and opening the umbrella the jellyfish swims about.

Jellyfishes occur in great numbers on the surface of the ocean, and are familiar to sailors under the name of "sea-blubs." Some live in the deeper waters; a few specimens have been dredged up from depths of a mile below the surface. They range in size from "umbrellas" or disks a few millimeters in diameter to disks of a diameter of two meters ($2\frac{1}{6}$ yards). They are all carnivorous, preying on other small ocean animals, which they catch by means of their tentacles, provided with stinging-threads. The tentacles of some of the largest jellyfishes "reach the astonishing length of 40 meters, or about 130 feet." Many of the jellyfishes are beautifully colored, although all are nearly transparent. Almost all of them are phosphorescent, and when irritated some emit a very strong light.

The so-called "colonial jellyfishes" are floating or swimming colonies of jellyfishes and polyps composed of many individuals closely joined. These individuals are all of one species, but are of different forms or kinds, each kind having a special function to perform in the life of the colony. For example, some individuals catch all the food for the colony; some make the motions; some are especially sensitive to the presence of enemies or prey, and some produce all the young. These various individuals act like the separate organs of our own body. The beautiful Portuguese "man-of-war" (fig. 95) is one of these colonial jellyfishes. It appears as a delicate bladder-like float, brilliant blue or orange in color, usually about six inches long, and bearing on its upper surface, which projects above the water, a raised parti-colored crest, and on its under surface a tangle of various appendages, thread-like, with grape-like clusters of little bell- or pear-shaped bodies. Each of these parts is a specially modified individual, produced by budding from an original central polyp. The Portuguese man-of-war is very common in tropical oceans, and sometimes vast numbers swimming together make the surface look like a splendid flower-garden.

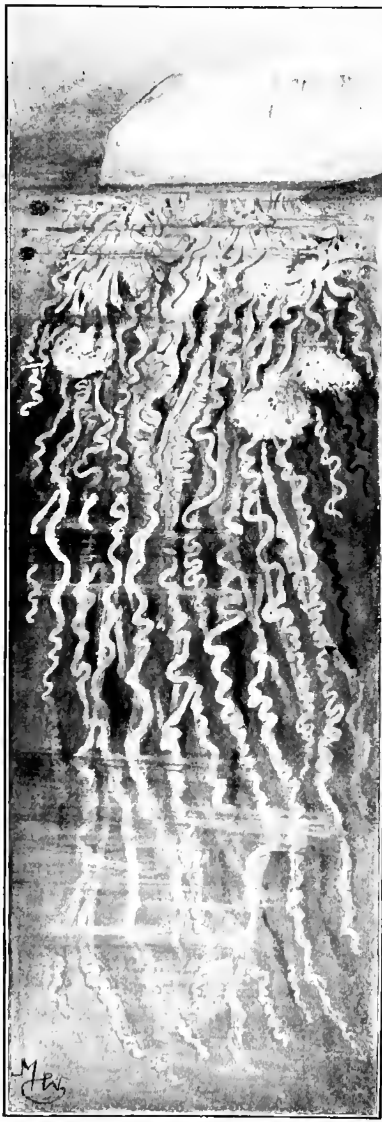


FIG. 95. — The Portuguese man-of-war (*Physalia* sp.) (One-half natural size; from specimen from Atlantic Coast.)

The sea-anemones, corals, and jellyfishes compose the animal branch *Cœlenterata*.

Starfishes and sea-urchins. — Among the most easily found and most readily recognized seashore invertebrates are the starfishes and sea-urchins, which belong to the animal branch called *Echinodermata* (fig. 96). Although these animals do not look at all alike, the starfishes having a body composed of central disk and long rays or radiating arms, and the sea-urchins looking like spiny flattened balls, they are really closely related. In each the body, with its various organs, is built on a radiate plan of strucin the center of the under side and all the body parts radiating out from this center.

If a starfish, either fresh or preserved in alcohol, can

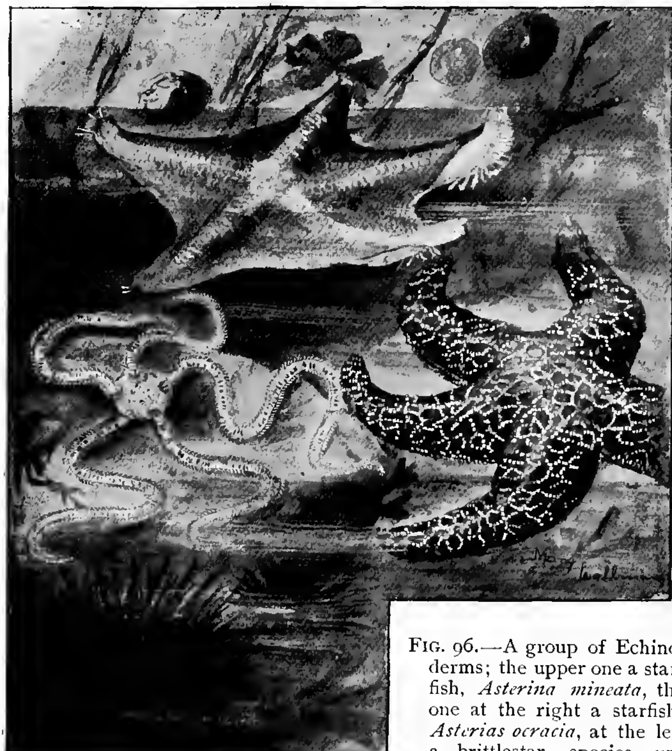


FIG. 96.—A group of Echinoderms; the upper one a starfish, *Asterina mineata*, the one at the right a starfish, *Asterias ocracia*, at the left a brittlestar, species unknown, and at bottom two sea-urchins, *Strongylocentrotus franciscanus*. (One-third natural size; from living specimens in a tide-pool on the Bay of Monterey, California.)

be had for examination, note that the body is covered by a skeleton composed of little plates, on which are short stout spines arranged in irregular rows. At the tip of each arm or ray there is a small red speck, the very simple eye of the animal. The starfish cannot see with this "eye"; it can only distinguish between light and darkness. On the under side the mouth is in the center, and from it along each ray runs a groove. In each groove may be seen two double rows of soft, tubular processes with sucker-like tips called the tube-feet. These are the organs of locomotion. If live star-

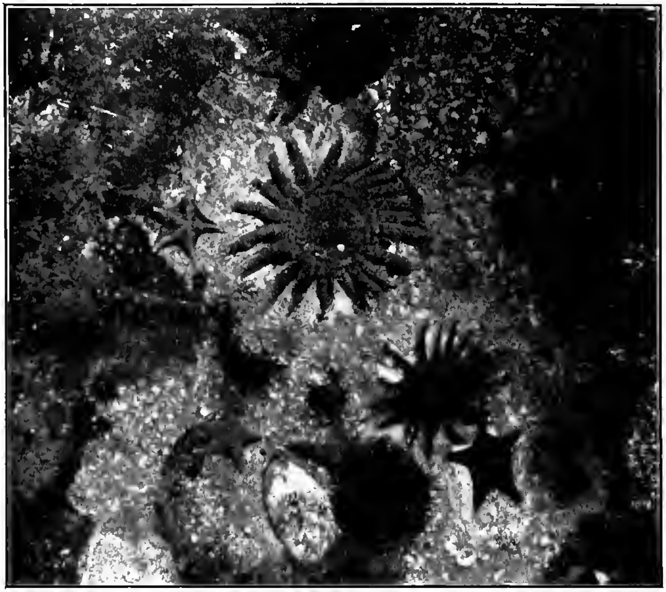


Fig. 97.—Starfishes of various kinds in a tide-pool on the Bay of Monterey, California; note two with five rays, three pentagonal, and two with many rays; also see large sea-urchins. (Photograph by author, from living specimens *in situ*.)

fishes can be watched the slow locomotion by means of the tube-feet may be seen, and perhaps also the peculiar mode of taking food. Starfishes are carnivorous, feeding on crabs, snails, and the like. If the live prey is too large to be taken into the mouth it is surrounded by the stomach, which is pushed outward for this purpose. It secretes fluids which kill the prey, after which the soft parts are digested.

Starfishes hatch from eggs, and in their early stages are very different in appearance from the adults, being more or less ellipsoidal in shape, and having many cilia on the outer surface. They swim freely about in the sea, feeding on microscopic organisms. In size starfishes vary from a fraction of an inch in diameter to three feet. They are yellow or red, or brown or purple, and the number of rays varies from five to thirty or more in different kinds (fig. 97). Some have the spaces between the rays filled out nearly to the tips of the arms, making the animal

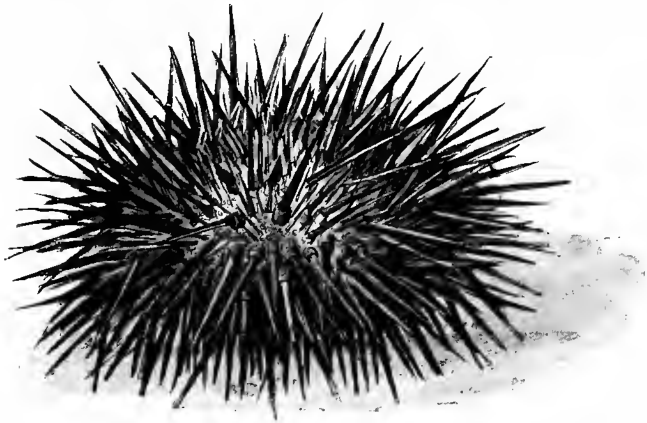


FIG. 98.—A sea-urchin, *Strongylocentrotus franciscanus.* (One-half natural size; from specimen from Bay of Monterey, Calif.)

simply a pentagonal disk. Starfishes are able to regenerate a lost ray—that is, if one or more rays are bitten off by enemies, new ones grow out in their places. I once found a starfish in Samoa which was regenerating four new rays and the central disk from a single old ray!

The sea-urchins (fig. 98), of which more than three hundred species are known, while without arms or rays yet show their radiate structure in having the tube-feet arranged in five rows radiating from the center. This can be seen in a "shell" or body-wall, from which the spines have been removed (fig. 99). Around the mouth, which is at the center of the under side, are five strong teeth. Like the starfishes, the young sea-urchins are free swimming creatures of very different appearance from the adults. Their food consists of small marine animals and of bits of organic matter which they collect from the sand and débris of the ocean floor. Many of the sea-urchins are gregarious, living togther in great numbers. Some have the habit of boring into the rocks of the shore between tide-lines. I have seen thousands of small, beautifully colored purple sea-urchins lying each in a spherical pit or hole in hard conglomerate rock on the California coast. How they

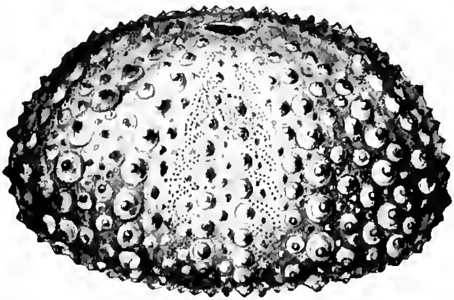


FIG. 99.—"Test" of sea-urchin, *Strongylocentrotus franciscanus*, with spines removed. (From specimen.)

are enabled to bore these holes is not yet known. There is great variety in size and color among these animals. The colors are brown, olive, purple red, greenish blue, etc.

A few kinds of sea-urchins have a flexible shell or test. The Challenger expedition dredged up from the sea bottom some sea-urchins, and when placed on the ship's deck "the test moved and shrank from touch when handled, and felt like a starfish." The cake-urchins or sand-dollars are sea-urchins having a very flat body with short spines. They lie buried in the sand, and are often very brightly colored.

Their hard bleached tests with the spines all rubbed off are common on the sands of both the Atlantic and Pacific coasts.

Oysters, clams, and sea-shells.—Very different from the sea-anemones, jellyfishes and starfishes are those inhabitants of the ocean commonly called "shell-fish." These include the oysters, clams, pectens, shipworms, and the host of snail-like creatures whose lime "houses" of manifold shapes and colors we know under the ex-

FIG. 100.

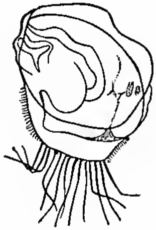


FIG. 101.

FIG. 100.—The eastern oyster, *Ostrea virginiana*. (One-third natural size; after photograph by W. H. C. Pynchon.)
FIG. 101.—Young oyster. (Greatly magnified; after Brooks.)

pressive name of sea-shells. All these animals which with the fresh-water mussels and the pond and land snails and slugs make up the branch of *Mollusca*, have a soft, sac-like body, not built on the radiate plan like the starfishes nor on the segmented plan like the insects, but on the plan well shown by the snail. The body is protected by a firm shell of carbonate of lime, which may be in two pieces, bivalved, as in the oyster and clams, or in one piece, univalved, as in the usual spiral sea-shell type.

The oyster (fig. 100) is carefully cultivated by man in many countries. It has two shells, or two dissimilar shell halves, one valve being hollowed out to receive the body, while the other is nearly flat. It is attached to the sea bottom by the outside of the hollowed-out valve. When first hatched the young oyster (fig. 101) swims freely about by means of its cilia; after a few days it attaches itself to some solid object and grows truly oyster-like. Much care has to be taken in cultivating oysters to furnish proper conditions for growth and development. The young oysters when first attached are called "spat"; when a little older this "spat," now called

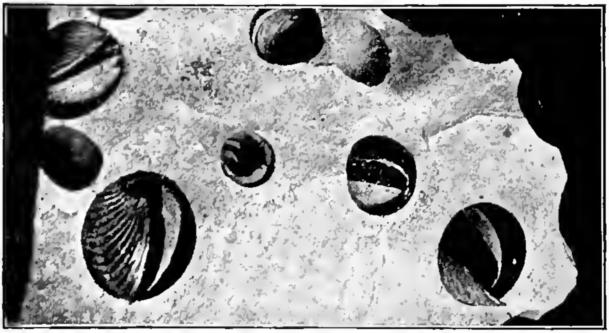


Fig. 102.—*Pholas* sp., a mollusc, burrowing in sandstone. (Photograph by C. H. Snow; permission of Amer. Soc. Civil Engineers.)

"seed," may be transplanted to new beds, which are stocked in this way. In fact some beds have constantly to be thus restocked, the young oysters produced on them not finding good places to attach themselves, and so swimming away. Sometimes pieces of slate, pottery, etc., are strewed about the oyster-beds to serve as "collectors"—that is, as places for the attachment of the young oysters. The extent of the acreage of the American oyster-beds is larger than that of any other country. The Baltimore oyster-beds on the Chesapeake River and its tributaries cover 3000 acres, and produce an annual crop of 25,000,000 bushels.

The edible clams are of several different species. The hard-shell clam or "quohog" as it is often called, is

FIG. 103.—The giant yellow slug of California, *Ariolimax californica.* This slug reaches a length when outstretched of twelve inches. (From living specimen.)

found along the Atlantic coast from Texas to Cape Cod. It is common on sandy shores, living chiefly on the sandy and muddy plots just beyond low-water mark. It

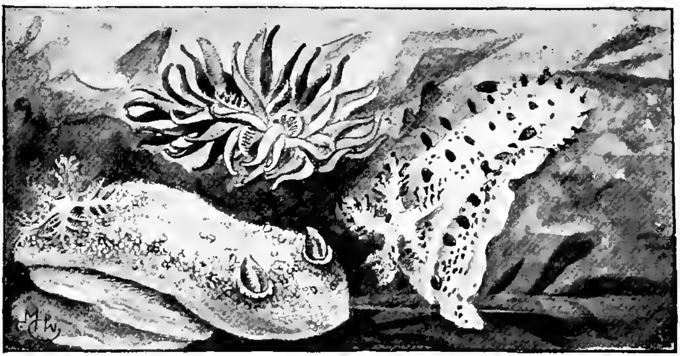


FIG. 104.—Three Pacific Coast nudibranchs or sea slugs; *Doris tuberculata* (in lower left-hand corner), *Echinodoris* sp. (upper one), and *Triopha modesta* (at right). (Natural size; from living specimens in a tide-pool on the Bay of Monterey, California.)

also inhabits estuaries, where it most abounds. It burrows a short distance below the surface, but is frequently found crawling at the surface with the shell partly exposed. The soft-shell clam, "the clam par excellence, which figures so largely in the celebrated New England clambake, is found in all the northern seas of the world. . . . All along the coasts of the eastern States every sandy shore, every mud flat, is full of them, and from every village and hamlet the clam-digger goes forth at low tide to dig these esculent bivalves. The clams live in deep burrows in the firm mud or sand, the shells sometimes being a foot or fifteen inches below the surface.

FIG. 105.—A group of marine Pacific Coast molluscs; in upper left-hand corner, *Purpura saxicola;* next to the right, *Littorina scutulata;* farthest to right, limpets, *Acmæa spectrum;* left-hand lower corner, *Mytilus californianus;* in right-hand lower corner the black shells just above the large clam-shell, *Chlorostomum funebrale.* (Natural size; from living specimens in a tide-pool on the Bay of Monterey, California.)

When the flats are covered with water his clamship extends his long siphon up through the burrow to the surface of the sand, and through one of these tubes the water and its myriads of animalcules is drawn down into the shell, furnishing the gills with oxygen and the mouth with food, and then the water charged with carbonic acid and refuse is forced out of the other siphon. When the tide ebbs the siphons are closed and partly withdrawn."

Among the univalved ocean molluscs there is a great variety in the size and shape and coloring of the shells. Many are beautifully colored and patterned; others are oddly and fantastically shaped. The cowries, or porcelain shells, familiar in collections of ocean curiosities, have a large body whorl and a very short flat spire, and the brightly colored shell looks as if enamelled. Some of the coast tribes of Africa once used, and perhaps still

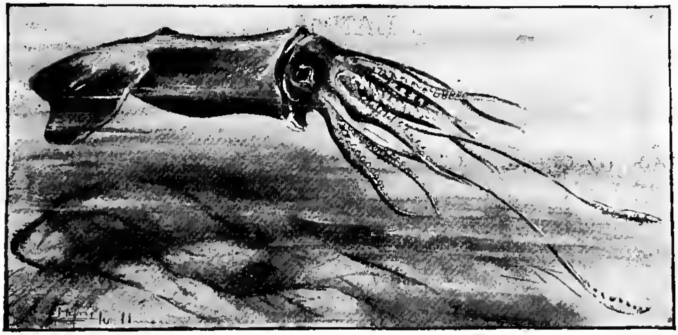


FIG. 106.—The giant squid, *Ommatostrephes californica*. (From specimen with body (exclusive of tentacles) four feet long, thrown by waves on shore of the Bay of Monterey, California.)

use, to some extent, cowries as money. The limpets are among the most abundant of the seashore molluscs, their low, broadly conical shells being plentifully scattered over the rocks between tide-lines (fig. 105). The oyster-drills are molluscs with odd spiny shells, which do much harm by settling down on the oysters, boring holes through the shells, and eating the soft parts within. The helmet-shells, from which shell cameos are cut, are composed of layers of shell material of different colors. Among the specially beautiful shells are the cone-shells, the olive-shells, the ivory-shells, etc.

CHAPTER XI.

WORMS, CRAYFISH, CENTIPEDS, AND OTHER SMALL LAND ANIMALS.

Earthworms and leeches.—Bring into the schoolroom large live earthworms. They may be found in the daytime by digging, or at night by searching with a lantern. They often come above ground in the daytime after a heavy rain. They may be kept in flower-pots filled with damp soil, and should be fed bits of raw meat, preferably fat, bits of onion, celery, cabbage, etc.

Examine a live specimen put on a piece of moist paper. Note that the body is made up of rings or segments. Are there any legs? How does the earthworm move along? Can you find some short fine bristles, called setæ, on the body? The broad thickened ring or girdle, including several segments near the head, is called the clitellum. It secretes the cases in which the eggs are laid. Make a drawing of the worm, showing all the external features you can make out.

Earthworms live in soft moist soil which is rich in organic matter. Their food is taken into the mouth mixed with dirt and sand. As this mixture passes through the long alimentary canal the organic particles are taken up and digested. The eggs are laid in a horny capsule which lies in the earth until the young worms emerge. Only a part of the eggs develop in each capsule, the rest being eaten by the growing young. Earthworms of various kinds are found in all parts of the world except in desert or arid regions. In size these different kinds vary from 1 mm. ($\frac{1}{25}$ in.) to 2 meters ($2\frac{1}{6}$ yards) in length.

Leeches (fig. 107) are familiar to boys who go in swimming. Some live specimens should be brought into the schoolroom. The body of a leech is flattened instead of being cylindrical as in the earthworm, and tapers at both

FIG. 107. — A leech, *Clepsine*, ventral view; posterior sucker at left. (Natural size; after photograph by E. R. Downing, in Davenport's Zoology.)

ends. In the live animal it can be greatly elongated and narrowed, or much shortened and broadened. It is composed of many segments (not as many as there are cross lines, however, each segment being transversely annulated), and bears at each end on the ventral surface a sucker, the posterior one being the larger. These suckers enable the leech to cling firmly to other animals. The mouth is at the front end of the body on the ventral surface and is provided with sharp jaws. Leeches live mostly on the blood of other animals. The common leech fastens itself upon its victim by means of its suckers, then cuts the skin, fastens its oral sucker over the wound, and pumps away until it has completely gorged itself with blood, distending enormously its elastic body, when it loosens its hold and drops off. Its biting and sucking cause very little pain, and in olden days physicians used the leeches when they wanted to "bleed" a person. A common European species much used for this purpose is known as the "medicinal leech." Most of the leeches lay their eggs in small packets or cocoons. These cocoons are dropped in soil on the banks of a pond or stream so that the young may have a moist but not too wet environment. The young issue from the eggs in four or five weeks, but they grow very slowly and it is several years before they attain their full size. Leeches are long-lived animals, some being said to live for twenty years.

Vinegar-eels, hairworms, and trichinæ.—The group of roundworms, so called from their slender, smooth, cylindrical bodies, contains some interesting animals. Familiar examples are the vinegar-eels (fig. 108) which can be found in mouldy vinegar, and the hairworms or horse-hair snakes which are often seen in fresh-water pools after a rain. Some people believe these worms to be horsehairs which have turned into animals, and others believe that they come down with the rain. They have in reality come from the bodies of insects in which they pass their young or larval stages as parasites. The hairworms all live as parasites during their larval stages, and as free independent animals in the adult. A parasite is an animal which lives for part or all of its life in or on the body of another animal called the host, and which feeds on the blood or other tissues of this host. Some of the hairworms require two distinct hosts for the completion of their larval life, living for a while in the body of one, and later in the body of another. The first host is usually a kind of insect which is eaten by the second. The eggs are deposited by the free adult female in slender strings twisted around the stems of water-plants. The young hairworm on hatching sinks to the bottom of the pond, where it moves about hunting for a host in which to take up its abode.

The terrible *Trichina spiralis*, which produces the disease called trichinosis, is another roundworm of which much is heard. This very small worm lives in its adult condition in the intestine of man as well as in the pig

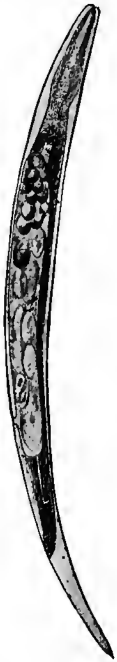


FIG. 108.

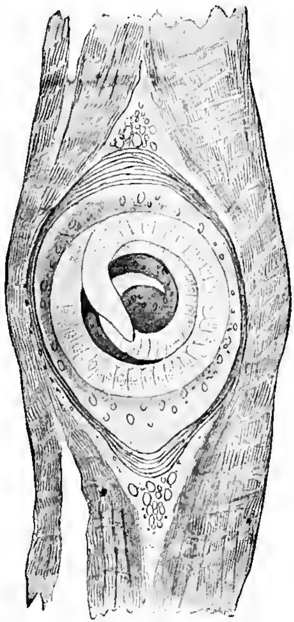


FIG. 109.

FIG. 108.—A vinegar eel, *Anguillula* sp. (Much enlarged; from a living specimen.)

FIG. 109.—*Trichina spiralis*, encysted in muscle of a pig. (Greatly magnified; from specimen.)

and other mammals. The young, which are born alive, burrow through the walls of the intestine, and are either carried by the blood, or force their way, all over the body, lodging usually in the muscles. Here they form for themselves little cells or cysts in which they lie (fig. 109).

The forming of these thousands of tiny cysts injures the muscles and causes great pain, sometimes death to the host. Such infested muscle or flesh is said to be "trichinosed," and the flesh of a trichinosed human subject has been estimated to contain 100,000,000 encysted worms. To complete the development of the encysted and sexless Trichinæ the infested flesh of the host must be eaten by another animal in which the worm can live, e.g., the flesh of man by a pig or rat, and that of a pig by man. In

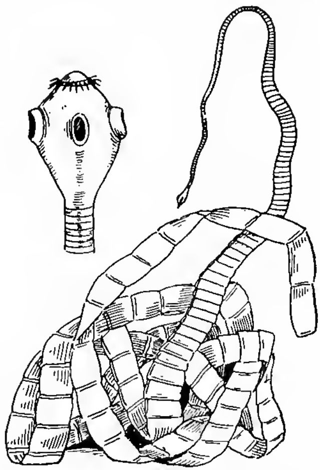


FIG. 110.—Tapeworm; head magnified, at left; whole worm may be several yards long. (After Leuckart.)

such a case the cysts being dissolved by the digestive juices, the worms escape, develop reproductive organs and produce young, which then migrate into the muscles and induce trichinosis as before. But, however badly trichinosed a piece of pork may be, thorough cooking of it will kill the encysted trichinæ, so that it may be eaten without danger. Some people, however, are accustomed to eat ham, which is simply smoked pork, without cooking it, and in such cases there is always great danger.

The earthworms, leeches, vinegar-eels, hairworms, and trichinæ belong to the great branch *Vermes*.

The crayfish.—The crayfish, or crawfish, is found in most fresh-water ponds and streams of the United States west of Massachusetts. Crayfishes may be taken by a net baited with dead fish, or may be caught in a trap

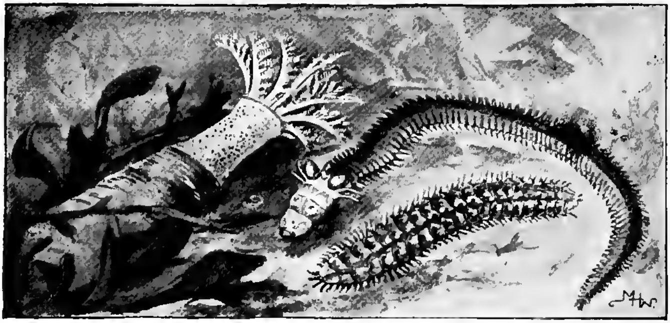


FIG. 111.—A group of marine worms; at the left a gephyrean, *Dendrostomum cronjhelmi*, the upper right-hand one a nereid, *Nereis* sp., the lower right-hand one, *Polynoe brevisetosa*. (From living specimens in a tide-pool on the Bay of Monterey, California.)

made from a box with ends which open in, and baited with dead fish or animal refuse of any sort. They should be brought alive into the schoolroom and kept in a moist chamber. Observe live specimens to see the characteristics of locomotion, and the use of the pincers and the mouth-parts in taking food.

Kill some specimens with chloroform and study the external structure. Note that the body is made up of a series of body-rings or segments (as in the case of insects and worms), which are distinct in the hinder part of the body (abdomen), but are fused in the front forming the cephalothorax. The whole body is covered with a firm, calcareous exoskeleton, which acts as a protective covering for the soft parts within, and also as a firm place for the attachment of the muscles.

The cephalothorax is covered above and on the sides by the carapace, which is divided by a transverse line into a front part or head and a hinder part or thorax. At the anterior end of the head is a sharp projection, the rostrum. Where is the mouth? Where are the eyes? Remove one of the eyes and examine its outer surface with a microscope. A bit of the outer wall should be torn off and mounted on a glass slide. Note that it is made up of a great many little facets placed side by side. Each of these is the external window of a single eye element or ommatidium. An eye composed in this way is called a compound eye. (See accounts of the compound eyes of insects on pp. 22 and 112.) Make a drawing of the surface of part of an eye. In front of the eyes note two pairs of slender many-segmented appendages. The shorter pair, the antennules, are two-branched. Remove one of them and note at its base a small slit along the upper surface. This opens into a small, bag-like structure which contains fine sand-grains. The bag is protected by a series of fine bristles along the edge of the slit. The structure is believed to be an auditory or hearing organ. The longer pair of appendages are the antennæ, and in the fine, hair-like projections upon the joints is believed to be located the sense of smell. Beneath the basal portion of each antenna there is a flat, plate-like projection, at the base of which on the upper edge will be noted a small opening, the exit of the kidney, or green gland.

Stick one point of the scissors under the posterior end of the carapace on the right side, and cut forward, thus exposing a large cavity, the gill-chamber. Remove all of the mouth-parts, legs, and abdominal appendages from the right side, being careful to leave the fringe-like parts, the gills, attached to their respective legs. Place all of the appendages in order on a piece of cardboard.

Examine the abdominal appendages, called pleopods,

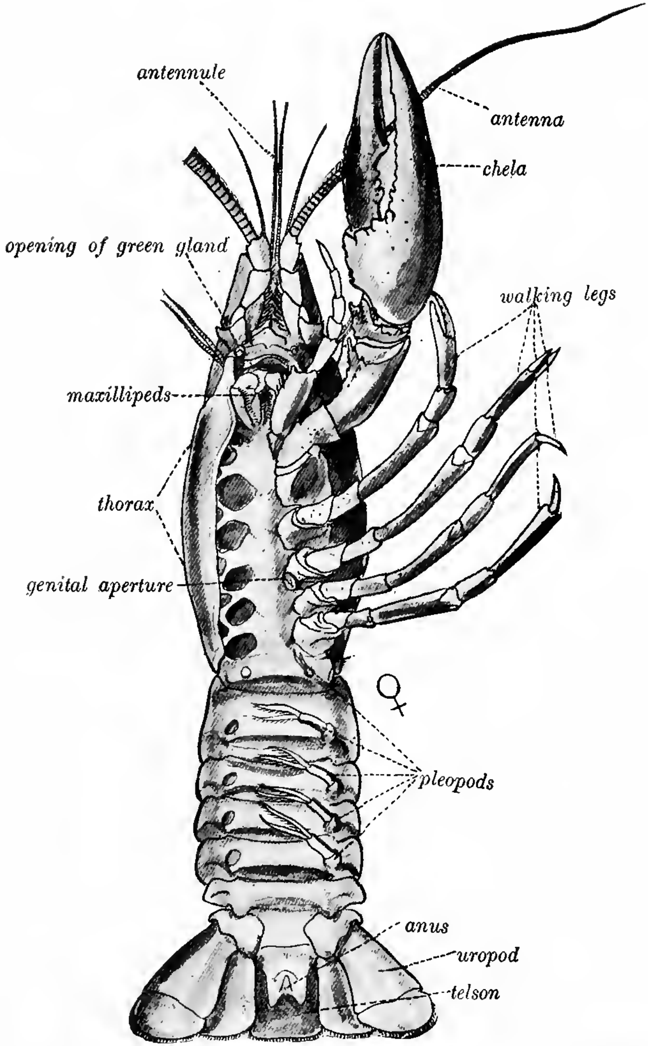


FIG. 112.—Ventral aspect of crayfish (*Cambarus* sp.). with the appendages of one side disarticulated.

or swimming feet. Has each abdominal segment a pair of these? Each is composed of a basal part, the protopodite, and two terminal parts, an inner one, endopodite, and an outer one, exopodite. In the males the first and second pleopods are larger than the others. In the females the pleopods serve to carry the eggs, and the first two pairs are very small or absent. The last pair of abdominal appendages are called uropods, and together with the last segment, called the telson, form a broad, flap-like tail. Is there any correspondence between the uropods and pleopods?

Examine the appendages of the cephalothorax. They may be divided into three groups, an anterior group of three pairs of mouth-parts (belonging to the head) of which the first pair are the mandibles and the others the maxillæ; a second group of three pairs of foot-jaws or maxillipeds, belonging to the thorax; and a third group of five pairs of walking-legs. The mandibles, lying next to the mouth-opening are hard and jaw-like, and lack the exopodite; the second maxillæ have a large paddle-like structure which extends back over the gills on each side within the space above them called the branchial chamber. It is by means of this paddle-like structure (the scaphognathite) that currents of water are kept up through the gill-chambers. The maxillipeds increase in size from first to third pair. What pairs of walking-legs bear gills? These gills are the organs by which the blood is purified. The blood of the crayfish flows into the large vessels on the outer side of the gill, and thence into the fine vessels in the leaf-like lamellæ. It thus flows by the thin membranous wall of the gill on the inside; while the water with air dissolved in it flows by the thin membranous wall on the outside. The oxygen of the air in the water passes through the thin walls of the gill and blood-vessels into the blood, while the carbon dioxide passes from the blood out through the thin walls into the water. Note the pincer-like appendages of the first pair of legs. These are the chelæ with which food is torn into bits and placed in the mouth.

In meadows where water stands for certain seasons of the year there may be noticed many scattered holes with slight elevations of mud about them. These are mostly the burrows of crayfish. During the dry season the animal digs down until it reaches water, or at least a damp place, where it rests until wet weather brings it to the surface once more. One of these burrows followed in the process of digging a mining shaft extended vertically down to a distance of twenty-six feet, where the crayfish was tucked snugly away.

The eggs are carried by the female on her abdominal appendages. Previous to laying them she rubs off, with the fifth pair of legs, all the dirt from the appendages and smears them with a sticky secretion. When the eggs are laid, which is during the last of March or April in the Central States, they are caught on the sticky pleopods, where they remain attached in clusters. After some weeks the young crayfishes issue from the eggs. In general appearance they are not very unlike the adults. They grow very rapidly at this stage. As the animal is inclosed in a hard shell, growth can take place only during the period just following the moult, for the crayfish casts its hard shell periodically, and it is while the new shell is forming that it does its growing. When it moults it casts not only the exoskeleton, but also the lining of part of the alimentary canal. After the females have hatched their young many of them die in the shallow pools, in which places the dried-up skeletons are noticeable during the summer months.

For an exhaustive account of the biology of the crayfish, see Huxley's "The Crayfish: An Introduction to Zoology."

Lobsters and crabs.—Lobsters and crabs are not land animals, as they live only in the ocean, but they belong to the same class as the crayfish, and are therefore briefly discussed here. The crayfishes, lobsters, crabs, pill-bugs and water-fleas (described in the next section) all belong to the class *Crustacea* of the branch *Arthropoda.* The lobsters are very much like crayfish in all structural characters, although much larger. They live on the rocky sandy ocean-bottom at shallow depths. They are caught in great numbers in so-called "lobster-pots," a kind of wooden trap baited with refuse. The number thus taken upon the shores of New England and Canada amounts to between twenty and thirty million annually. Live lobsters are brownish or greenish, with bluish mottling; they turn red when boiled. A single female will lay several thousand eggs. They are greenish, and are carried about by the mother until the young hatch. The young are free-swimming larvæ until they reach a length of half an inch.

Most crabs (fig. 113) differ from the lobsters, crayfishes, and shrimps in having the body short and broad, instead of elongate. This is due to the special widening of the carapace and the marked shortening of the abdomen. The abdomen, moreover, is permanently bent under the body, so that but little of it is visible from the dorsal aspect. The number of abdominal legs or appendages is reduced. When the tide is out the rocks and tide-pools of the ocean are alive with crabs. They "scuttle" about noisily over the rocks, withdrawing into crevices or sinking to the bottom of the pools when disturbed. They move as readily backward or sidewise, "crab-fashion," as forward. They are of various colors and markings, often so patterned as to harmonize very perfectly with the general color and appearance of the rocks and sea-weeds among which they live. The spider-crabs are especially strange-looking creatures, with unusually long and slender

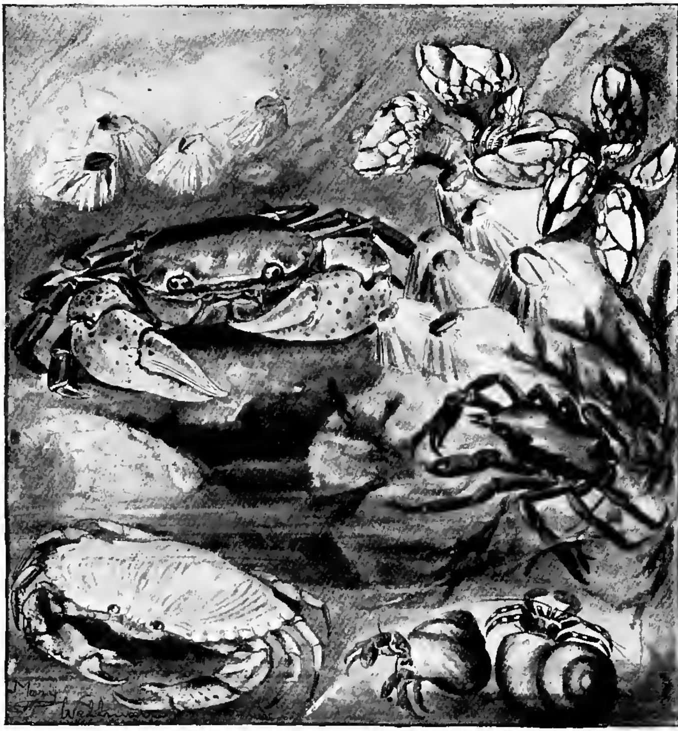


FIG. 113.—Some crabs and barnacles of the Pacific coast; the short sessile acorn barnacles in the upper left-hand corner belong to the genus *Balanus;* the stalked barnacles in the upper right-hand corner are or the species *Pollicipes polymerus;* the largest crab (upper left-hand) is *Brachynotus nudus;* the one in the left-hand lower corner is a young rock-crab, *Cancer productus;* the crab in the seaweed at the right is a kelp-crab, *Epialtus productus*, while the two in snail-shells in lower corner are hermit-crabs, *Pagurus samuelis.* (About one-half natural size; from living specimens in a tide-pool on the Bay of Monterey, California.)

legs and a comparatively small body-trunk. They include the Macrocheira of Japan, the largest of the crustaceans. Specimens of this crab are known measuring twelve to sixteen feet from tip to tip of extended legs; the carapace is only as many inches in width or length. The soft-shelled crab is a species common along our Atlantic coast. It is "soft-shelled" only at the time of moulting, and has to be caught in the few days intervening between the shedding of the old hard shell and the hardening of the new body-wall. The little oyster-crabs (Pinnotheres) which live with the live oyster in the cavity inclosed by the oyster-shell are well-known and interesting creatures. They are not parasites preying on the body of the oyster, but are simply messmates feeding on particles of food brought into the shell by the currents of water created by the oysters.

Among the most interesting members of this family are the hermit-crabs (fig. 113), familiar to all who know the sea-shore. There are numerous species of these, all of which have the habit of carrying about with them, as a protective covering into which to withdraw, the spiral shell of some gastropod mollusc. The abdomen of the crab remains always in the cavity of the shell; the head, thorax, and legs projecting from the opening, to be withdrawn into it when the animal is alarmed or at rest. The abdomen being always in the shell, and thus protected, loses the hard body-wall, and is soft, often curiously shaped and twisted to correspond to the spiral cavity of the shell. It has on it no legs or appendages except a pair for the hindmost segment, which are modified into hooks for holding fast to the interior of the shell. As the hermit-crab grows it takes up its abode in larger and larger shells, sometimes killing and removing piecemeal the original inhabitant. Certain hermit-crabs spend much of their time on land, traveling far inland, and making burrows in the ground. These "land-crabs" are common in the South Pacific islands. Some hermit-crabs always have attached to the shell certain kinds of sea-anemones. It is believed that both crab and sea-anemones derive advantage from this arrangement. The sea-anemone, which otherwise cannot move, is carried from place to place by the crab, and so may get a larger supply of food, while the crab is protected from its enemies, the predaceous fishes, by the stinging-threads of the sea-anemone, and also perhaps by the concealment of the shell its presence affords. This living together by two kinds of animals to their mutual advantage is called commensalism or symbiosis.

Pill-bugs and water-fleas.—Pill-bugs, wood-lice, or damp-bugs (fig. 114), as they are variously called, may be readily found in concealed moist places, under stones or boards, on damp soil, etc. They run about quickly, and feed chiefly on decaying vegetable matter. They are night-scavengers. Although commonly called "bugs" and supposed to be insects, they really belong to the crustaceans, that class of animals which includes the crayfish, lobster, and crab. Examine the body of a dead pill-bug. It is oval and convex above, rather purplish or grayish brown, and smooth. Note its division into head, thorax, and abdomen. Find the eyes, the antennæ, and the mouth-parts. All the locomotory appendages are adapted for walking or running, not swimming. How many pairs of legs are there? Find gills and gill-covers. Although pill-bugs do not live in the water they breathe partly at least by means of gills (though they may breathe partly through the skin). It is therefore necessary for them to live in a damp atmosphere, so that the gill membranes may be kept damp. If these are not moist, they will not permit the exchange of gases.

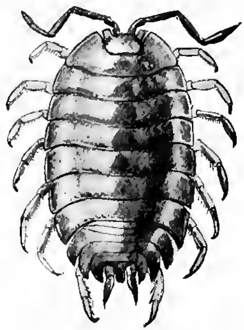


FIG. 114.—A damp-bug, Isopod, species not determined. (Four times natural size; from specimen.)

The water-fleas (Cyclops) (fig. 116) are among the smallest of the crustaceans. They are common in ponds and slow streams; and some should be kept in glasses of water in the schoolroom. Though only about 1 mm. (1/25 in.) long, they are readily seen with the unaided eye. They are white, rather elongate, and have

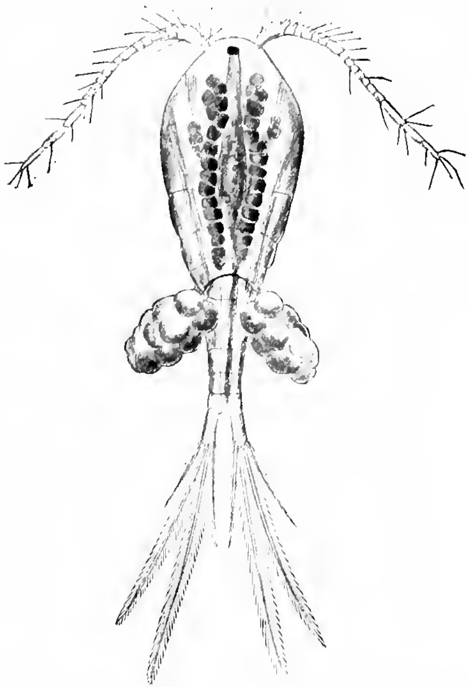


FIG. 115.—A water-flea, *Cyclops* sp. Female with egg-masses. (Much enlarged; from living specimen.)

a rapid, jerky movement. Examine live specimens in a watch-glass. Note the "split-pear" shape, the body being broadest near the front, tapering posteriorly, flat beneath, and convex above. Note the forked processes at the tip of the abdomen; also the two pairs of antennæ, the single median eye, the mouth-parts, and five pairs of legs (the last pair very small). There are no gills. Some of the specimens, females, may have attached to the first abdominal segment on either side an egg sac. Watch the Cyclops capturing and feeding Paramœcium and other microscopic animals. Make a drawing of Cyclops, showing its parts.

Water-fleas are extremely abundant, having great power of multiplication. "An old Cyclops may produce forty or fifty eggs at once, and may give birth to eight or ten broods of children, living five or six months. As the young begin to reproduce at an early age, the rate of multiplication is astonishing. The descendants of one Cyclops may number in one year nearly 4,500,000,000, or more than three times the total population of the earth, provided that all the young reach maturity and produce the full number of offspring." The Cyclops feed on smaller aquatic animals, such as Protozoa, Rotifera, etc. They in turn serve as food for fishes; and because of their immense numbers and occurrence in all except the swiftest fresh waters they form the main food of most of our fresh-water fishes while young. Many aquatic insect larvæ feed almost exclusively on them.

Thousand-legged worms and centipeds.— Under stones and logs, or buried in the soil, will be found at almost any time of the year, in almost any part of the country, specimens of thousand-legged worms. There are two general types of animals belonging to this group, the true thousand-legged worms, of which a common representative is the large, blackish, cylindrical galley-worm (fig. 116), that coils itself and emits an ill-smelling fluid when disturbed; and the flattened, usually brownish or pale greenish slender centipeds or hundred-legged worms (fig. 117). In both kinds the body is plainly composed of rings or segments, but while in the centipeds there is but one pair of legs on each body-ring, in the thousand-legged worms or millipeds there are two pairs to each segment. The millipeds feed on vegetable matter, although they may take some dead animal matter, while the centipeds which can run rapidly, are predaceous, catching and kill-

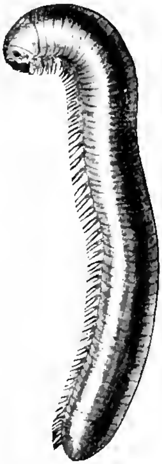


Fig. 116.

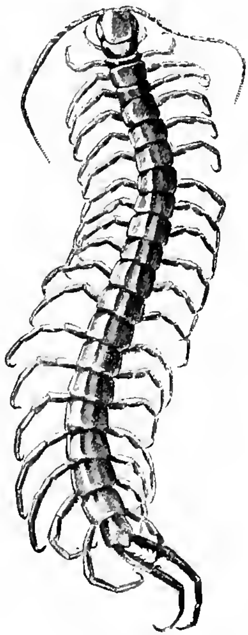


Fig. 117.

Fig. 116.—A galley-worm (milliped), *Julus* sp. (Natural size; from specimen.)
Fig. 117.—A centiped, *Scolopendra* sp. (Natural size; from specimen.)

ing insects, snails, earthworms, etc. Centipeds have the first pair of legs modified into a pair of poison-claws, which are bent forward so as to lie near the mouth. The common "skein centiped" (fig. 118) is yellowish in color and has fifteen pairs of legs, long, forty-segmented antennæ, and nine large and six small or dorsal segmental plates. The true centipeds (fig. 117), have twenty-one to twenty-three body-rings, each with a pair of legs, and the antennæ have seventeen to twenty segments. They live in warm regions, some growing to be very large, as long as twelve inches or more. The bite or wound made by the poison-claws is fatal to insects and other small animals, their prey, and painful, or occasionally even dangerous, to man. The popular notion that a centiped stings with all of its feet is fallacious.

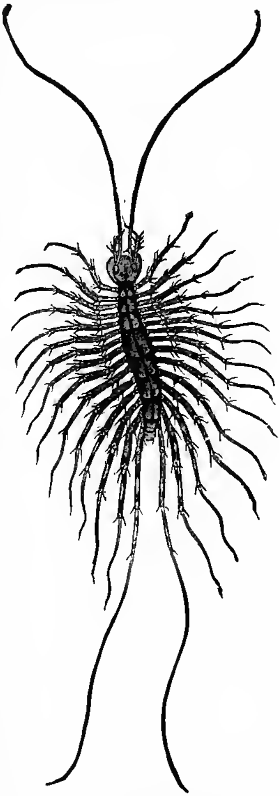


FIG. 118.—The skein centiped, *Scutigera forceps*, natural size, common in houses and conservatories. (From Marlatt.)

Galley-worms (millipeds) (fig. 116) can easily be kept alive in shallow glass vessels with a layer of earth in the bottom, and their habits and life-history be studied. They should be fed sliced apples, green leaves, grass, strawberries, fresh ears of corn, etc. They are not poisonous and may be handled with impunity. They lay their eggs in little spherical cells, or nests, in the ground. An English species, of which the life-history has been studied, lays from sixty to one hundred eggs at a time. The eggs of this species hatch in about twelve days.

Centipeds and millipeds compose the class *Myriapoda* of the branch *Arthropoda*.

CHAPTER XII

INSECTS

Insects are the most familiar and abundant of land animals, and number more species than are known of all other kinds of animals together. Nearly 400,000 different species of living insects have so far been found, and thousands of new ones are discovered each year. Beetles, moths and butterflies, flies, wasps, bees and ants, dragonflies, plant-bugs and grasshoppers are to be found in the vicinity of any schoolroom, and the interesting habits of insects, their great variety and abundance, and the readiness with which they may be collected, kept alive, and studied, make them unusually fit animals for the special attention of beginning students of zoology.

Our studies with the silkworm, moth, mosquito, dragonfly, and grasshopper have already made us acquainted with the elementary facts concerning the body-form, structure, and life-history of insects, while our later study of the communal life of the honey-bee and ants will show us the fascinating interest which the special study of certain of the more highly organized insects may have.

Insects are classified into various groups called orders, of which all the beetles constitute one, the moths and butterflies one, the two-winged flies one, the ants, bees, wasps, etc., one, and so on. But to learn much about this classification, which constitutes systematic entomology, requires a great deal of time and persistence on account of the great numbers of species concerned. Therefore it may well be postponed until after we know more of the life of some of the more familiar and interesting insects. A good way to begin the study of systematic entomology is to make a collection of insects of all kinds. Directions for collecting and preserving insects are given in Appendix B. The best book of insect classification is Comstock's "Manual of Insects."

Pond and brook insects.—There is space in this book to take up but few of the many interesting insects which can be readily found and observed. Among the most available are the common pond and brook insects. Land insects live under most diverse conditions, that is, on the ground, in the leaves, fruits, and stems of plants, in the trunks of trees, or in dead wood, in the soil, in decaying animal or plant matter, and as parasites on or in other animals, but the aquatic kinds are almost wholly limited to fresh water. A few species live on the surface of the ocean, however, and a few others on the water-drenched rocks and seaweeds between tide-lines.

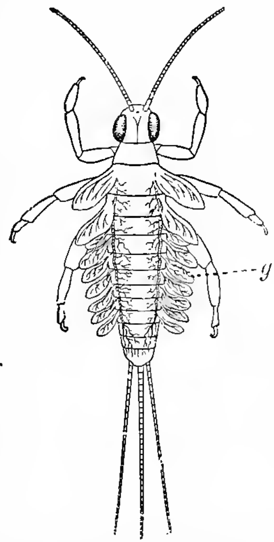


FIG. 119.—Young (nymph) of Mayfly, showing (*g*) tracheal gills. (From Jenkins and Kellogg.)

On the under side of stones, in brook "riffles," and in pools and watering-troughs not too frequently used are to be found commonly the young, i.e., nymphs (fig. 119), of Mayflies, recognizable by the rapidly vibrating flap-like tracheal gills along each side of the flattened delicate body, three pairs of legs, and two or three long, slender filaments projecting from the tip of the abdomen. Those found in ponds or other quiet water may be kept alive for some time in the school aquarium (see p. 332). Examine a live specimen in water in a watch-glass with a magnifier. The body-wall is so transparent that many of the internal organs can be seen. Note especially the beat-

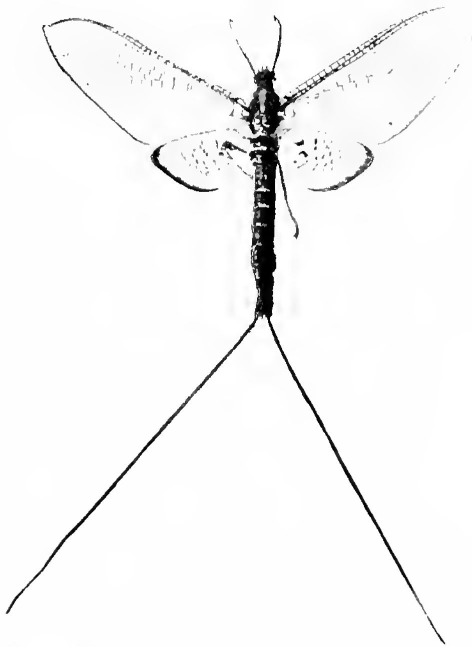


FIG. 120.—A Mayfly (adult). (Natural size; photograph by the author.)

ing of the heart, a slender tube running along the middle of the back. See the dark air-tubes (tracheæ) running out into the thin gills, and note the rapid vibration of these gills to keep in contact with fresh water. The young Mayflies feed on minute organisms such as diatoms and other algæ. They live as nymphs for a year, or even two or three years in some species, and then crawl out of the water on a stone or plant-stem, or come simply to the surface when the delicate, gauzy-winged adult quickly issues. The adult Mayfly (fig. 120) takes no food and lives only a few hours, or at most a few days. It has the shortest adult stage of all insects. The female drops her eggs into the water.

Firmly attached to stones, especially large ones, in swift parts of the stream, may be found small cases, or houses, composed of many small pebbles fastened together with silk (fig. 121). In more quiet places in the stream,

FIG. 121.—Two cases or "houses" of caddis-worms. (Natural size; from specimens.)

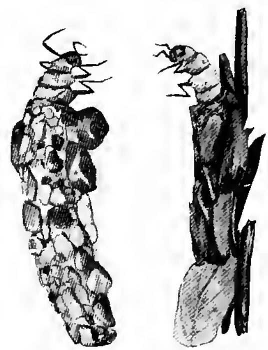


FIG. 122.—Two cases of caddis-worms, with the insects showing head and thorax projecting. (Natural size; from specimens.)

either attached to stones or resting on the bottom, or sometimes floating in the water, may be found elongate cases, an inch to two inches long, made of bits of wood fastened together with silk, or of bits of pine-needles, or even grass stems tied cleverly together by silken threads, or it may be tiny cornucopias composed of sand grains. All these are the cases of the caddis-worms or case-worms, and a caddis-worm itself may be found snugly concealed in each case. Find cases with the head and fore part of the worm projecting (fig. 122) and cases moving, dragged by the slowly walking caddis-worm. Pull a worm from its case and examine it. How does it hold itself so firmly in the case? What is the case for? Why is the head and front part of the body so much harder than the rest? How does the caddis-worm breathe?

Not all of the caddis-worms live in cases, and some which make cases do not remain in them all of the time, so that you may sometimes find them crawling about on the stones. Some of these make tiny nets of silk stretched between two near-by stones. These nets are "usually funnel-shaped, opening up-stream, and in the center of them there is a portion composed of threads of silk extending in two directions at right angles to each other, so as to form meshes of surprising regularity. It is as if a spider had stretched a small web in the water where the current is swiftest." In these nets are caught bits of organic matter which serve as food for the insects. The caddis-worms which build these nets live in rude cases, on the under sides of stones, composed of an inner silken tube partly covered with little pebbles.

All these creatures are the young, or larvæ, of caddis-flies, which, when adult, are moth-like flying insects, with four wings covered with hairs, among which are distributed many flattened scale-like ones; the antennæ are very long and thread-like. The insects may be found fluttering among the foliage, or alight upon it, at the brook's margin. Caddis-flies have a complete metamorphosis. When ready to pupate the caddis-worm closes the opening of its case by spinning a silken sheet across it or filling it with a stone. The opening is of course not absolutely closed, space being left for the ingress of water which carries oxygen to the pupa within. This lies quietly in its case until ready to emerge as the winged caddis-fly, when it crawls out of its case, up on some plant stem or stick and there moults the pupal cuticle.

In quiet pools in the brook and in almost any pond may be found water-bugs and water-beetles. Collect various kinds alive and keep in the schoolroom aquarium (p. 332). Running swiftly about on the surface may be seen rather large, blackish, narrow-bodied, long-legged insects known as water-striders or pond-skaters (fig. 123). When at rest they hold the front pair of legs, which are short and stout, projecting forward close to the head, ready to grasp and hold small insects, the blood of which they suck by means of a sharp, strong, piercing beak. Their feet make small dents or dimples in the surface film, but do not break through. Do they ever dive or swim in the water? Can they leap? Are they winged or wingless? The immature water-striders have the body much shorter than that of the adult. To be found also at the surface of the pool are small, oval, flattened, shining black insects that dart swiftly about in curving paths on the water. These are whirligig beetles. Do they run on the water or swim? Do they ever dive and swim beneath the surface? Examine one with a magnifier, and note that it has four compound eyes instead of two, the usual number in insects. Where is the extra pair situated? Note the peculiar shape of the legs. What are the legs specially fitted for?

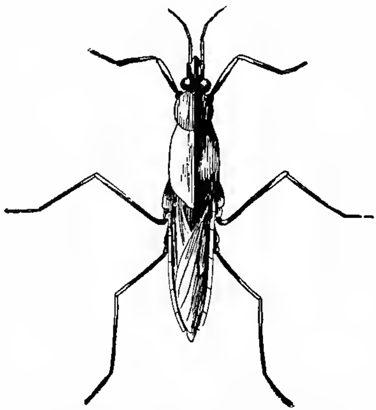


FIG. 123.—A water-strider, *Hygrotrechus* sp. (From Jenkins and Kellogg.)

Swimming about below the surface may sometimes be found large, shining, black beetles (fig. 124) from half an inch to an inch and a half long. There are two principal kinds, the predaceous diving-beetles, which kill and eat other insects, and the water scavenger-beetles which feed on decaying vegetation in the water. The first have slender thread-like antennæ, while the second have antennæ with thickened or club-like tips. As neither kind has

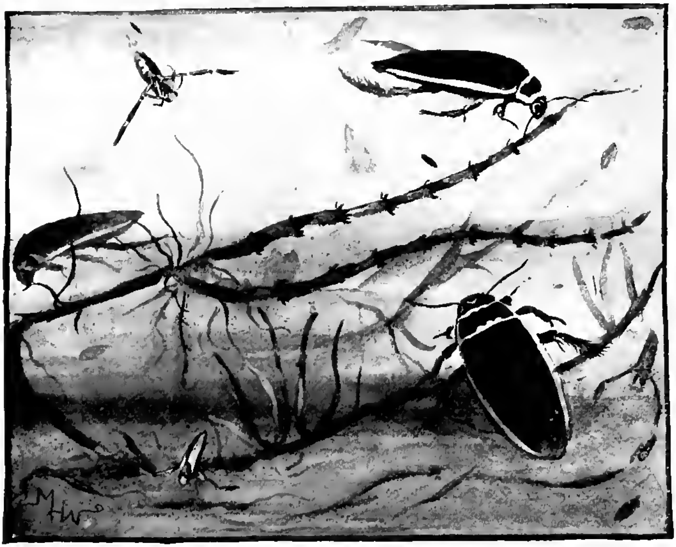


FIG. 124.—Predaceous diving-beetles (large) and back-swimmers in water. (Slightly less than natural size; drawn from living specimens.)

gills both have to come to the surface to get air, but they always carry down with them a supply sufficient to last some time. They do this in two different ways. The predaceous diving-beetles force the posterior tip of the body above the surface (they always hang head downward when at the surface) and slightly lift the tips of the horny black wing-covers which lie on the back. Air rushes in under the wing-covers and is held there by the closing of the tips. The breathing pores or spiracles of the beetle are situated along each side of its back, underneath the wing-covers, so that the air held there readily enters the body. The water scavenger-beetle when at the surface keeps its head uppermost. It carries most of its air supply on its under or ventral surface, where it is held in a coat of fine short hairs. The air gives the under side of the beetle a shining silvery appearance. It is held by the fine hairs by virtue of the surface film. If you dip a bit of cloth having a pile, as velvet, into water, you will see that it retains underneath the water a nearly complete coating of air. The under side of the water scavenger-beetle is covered in places with a fine pubescence which acts like the pile of the velvet.

FIG. 125.—Water-tiger, the larva of the predaceous water-beetle, *Dyticus* sp. (Natural size; from specimen.)

The water-bugs are about half an inch long, and are grayish or black and white in color. There are two common kinds, one called back-swimmers (fig. 124), which swim with under side uppermost, and have the back black with large creamy patches, the other called water-boatmen (fig. 126), which swim with back uppermost, and are greenish gray, with fine black mottling. Both kinds come to the surface for air, and carry a supply of it down with them. Observe this, and note the difference in the disposition of the air (revealed by its silvery

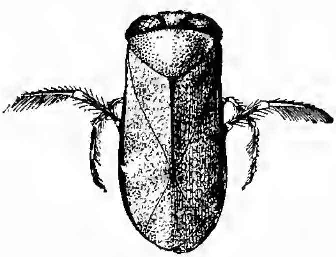


FIG. 126.—A water-boatman, *Corisa* sp. (Twice natural size; from Jenkins and Kellogg.)

FIG. 127.—Swallow-tail butterflies, *Papilio rutulus*. (One-half natural size; drawn from life.)

appearance) in the two kinds. What is the favorite resting position of each? Which pair of legs do the back-swimmers use for oars? Which pair do the water-boatmen use? Water-bugs are predaceous, sucking the blood of captured insects by means of a piercing beak.

Moths and butterflies.—So many good books have

FIG. 128.—Caterpillar (larva) of the regal walnut-moth, *Citheronia regalis*. (Natural size; photograph by the author.)

been written about the life of moths and butterflies, and so surely ought one or more of these to be found in the school library, that I shall make no attempt here to do more than call the attention of teacher and pupils to the admirable opportunity these insects afford for field and

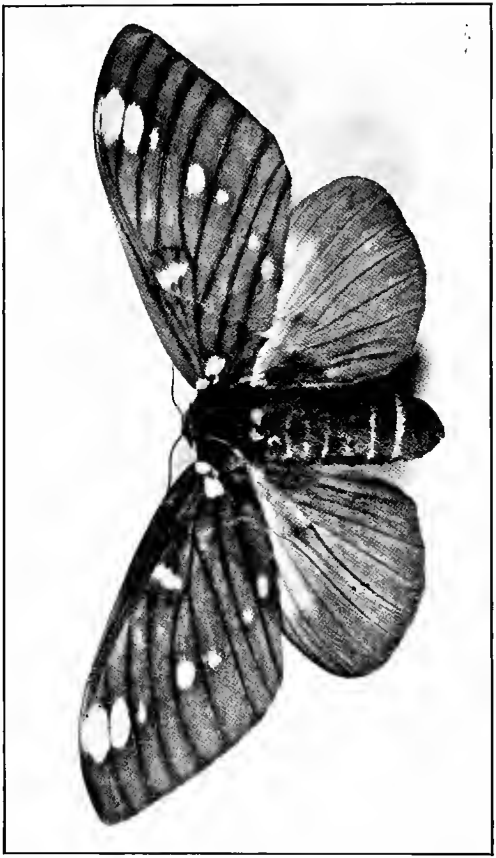


FIG. 129.—Adult (imago) of the regal walnut-moth, *Citheronia regalis*. (Natural size; photograph by the author.)

schoolroom study. Some of the most beautiful butterflies are common all over the country, and their eggs, or caterpillars at least, can certainly be found and reared in simple breeding-cages (for directions for making see p. 332) in the schoolroom. Such are the black and yellow swallow-tail butterflies (fig. 127), the black and red-brown monarch or milkweed butterfly, the somber mourning-cloak, and the abundant cabbage-whites and sulphurs of the fields. The same is true, too, of some of the largest and most beautiful moths. The great silken cocoons of the cecropia and polyphemous moths can be found in winter, when the branches are bare, in orchard trees. They can be kept in the schoolroom, where the issuance of the great moth can be carefully watched; how the wings gradually unfold and expand and dry, and the colors grow brighter and sharper, until the splendid creature is ready to take wing in search of food or mates.

FIG. 130.—Grape-vine sphinx moth, *Ampelophaga myron*. (Natural size; drawn from photograph by M. V. Slingerland.)

In the recent wide interest which the popular study of animals has attained, birds and moths and butterflies have been given special attention by the writers of books, and by means of pictures made from photographs of the live animals many finely illustrated accounts of the life of various birds and insects have been published. Scudder's "Every-day Butterflies," Mary Dickerson's "Moths and Butterflies," and Eliot and Soule's "Caterpillars and their Moths" are admirable examples of such books. Reference to them will give suggestions for an unlimited amount of observation. Scudder's "Life of a Butterfly" is a detailed account of the monarch butterfly. Holland's "Butterfly Book" is a finely illustrated manual of our butterflies by the use of which any butterfly specimen can be named.

Aphids, ants, and aphis-lions.—On the new shoots and buds of roses, on fruit-trees, or on cultivated plants in the greenhouse or garden may often be found many of the small, soft-bodied, greenish or purplish insects familiarly

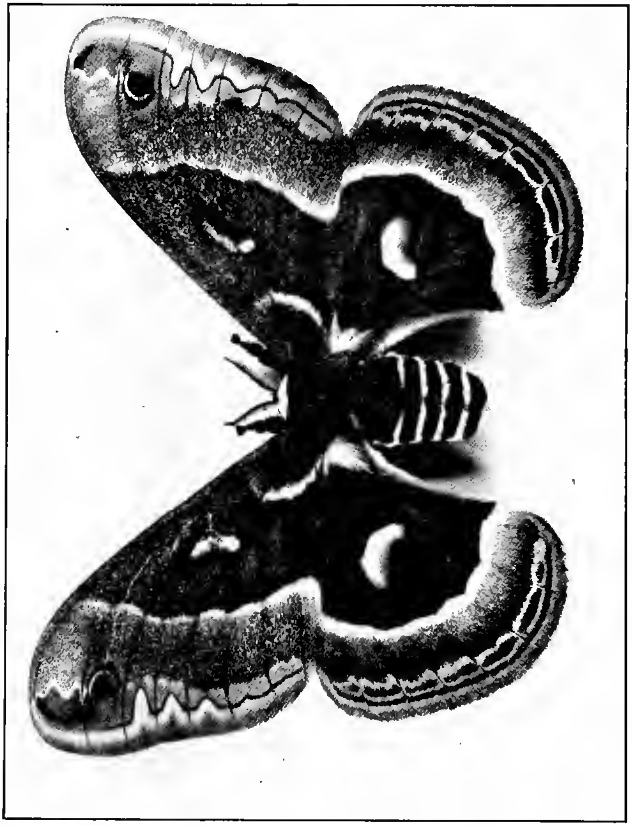


Fig. 131.—Cecropia moth. (Natural size; photograph by the author.)

known as plant-lice, green-fly, or aphids (fig. 135). They usually occur clustered together in large numbers. Most of the individuals are wingless and of various sizes, but a few winged specimens, all of one size, will probably be found. By observing a colony of aphids from day to day it may be discovered that the young are born alive, and are without wings; that feeding is accomplished by a tiny sucking beak, which is thrust into the soft, fresh, plant tissue to suck up the sap; and that each aphid has a

FIG. 132.—A family of forest tent-caterpillars (*Clisiocampa disstria*), resting during the day on the bark, about one-third natural size. (Photograph from life by M. V. Slingerland.)

pair of curious little tubes on its back, which are called honey-tubes. It was long supposed that the honey-dew, a sweetish secretion which the aphids produce, came from these tubes, but it is now known to come from the alimentary canal. Several generations of aphids are born alive during the summer, but in the autumn the females each lay one or a few eggs, which usually last through the winter, new "stem mothers" hatching from them the following spring. When the aphids get too crowded on a plant or tree some winged individuals are produced

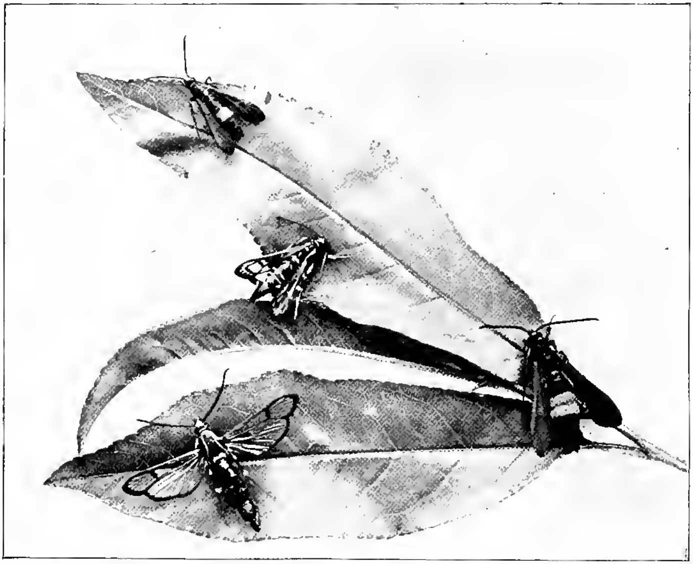


FIG. 133.—Moths of the peach-tree borer, *Sanninoidea exitiosa*, natural size; the upper one and the one at the right are females. (Photograph by M. V. Slingerland.)

which can fly to another food-plant and establish a new colony.

It will almost certainly be noted during the course of observing that the aphids are visited by ants (fig. 135), and by careful watching it may be seen that these ants lick up the sweet honey-dew secreted by the aphids. So much do the ants like this honey-dew that sometimes they take special care of a colony of aphids, driving away their enemies, and visiting them regularly to feed. Aphids have been called the cattle of the ants.

FIG. 134.—Army-worms, larvæ of the moth, *Leucania unipuncta*, on corn. (Natural size; photograph by M. V. Slingerland.)

FIG. 135.—Rose aphids and ants. (Natural size; from life.)

FIG. 136.—The golden-eyed or lace-winged fly (*Chrysopa*); adult, eggs, larva (aphis-lion), and pupal cocoons. (Natural size; from specimens.)

But other visitors still may be noted, and ones which make anything but friendly calls. They, too, come for food, the soft juicy body of the plump little aphid. Among the most interesting and fatal of these carnivorous visitors are the aphis-lions, the fierce larvæ of the beautiful golden-eyed, lace-winged fly (fig. 136). These may be recognized by their long, slender, pointed mandibles projecting far in front of the head. These mandibles are each grooved along the inner side. When the sharp tips are thrust into the soft body of an aphid its blood runs along the groove into the mouth of the lion. The eggs of the aphis-lion are laid on the tips of slender stalks, to protect them from wandering predaceous insects, including other aphis-lions. When the larva has made its full growth it spins a spherical silken cocoon, within which it pupates. Finally, there emerges the beautiful slender-bodied adult, the lace-winged fly, with four large, gauzy, green wings, and eyes which shine with a fiery golden color.

Cicadas, katydids, crickets, and their sound-making organs.—Insects familiarly known because of their shrill summer song are the periodical cicadas, or seventeen-year locusts. The second name is really no exaggeration. Although the adult cicadas live in trees and lay their eggs in small slits cut in the twigs, the young, on hatching, drop to the ground and dig down to the roots of the tree. There they suck the juices from the roots by means of a strong piercing beak until the beginning of the summer of the seventeenth year. They then crawl up to the surface of the ground, and, clinging usually to the tree trunk, moult and transform into the fully winged adult, with its shrill song. This is made by a curious musical apparatus on the under side of the body (fig. 137), consisting of a tympanic membrane or thin plate which can be set into vibration by a muscle attached to its center. It is practically a musical instrument of the type of the tin pan with a string fastened to the middle of the bottom. There are other species of cicadas besides the seventeen-year-old kind, with shorter lives, a common one being the familiar harvest-fly or dog-day locust, which requires only two

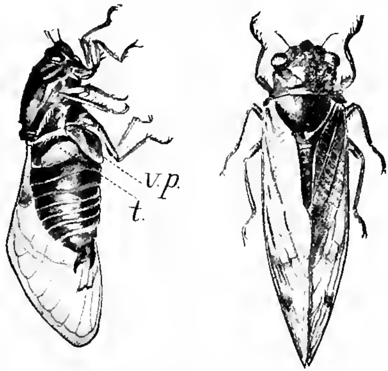


FIG. 137.—The seventeen-year cicada, *Cicada septendecim*; the specimen at left showing sound-making organ; *v.p*, ventral plate; *t*, tympanum. (From specimens.)

years for its development. This is large, and black and green in color, while the seventeen-year cicada is smaller, and black and reddish-brown.

Other insects conspicuous for the sounds they make are the katydids and crickets. The loud sounds of insects are not made by a "voice" that is, by vocal cords set into vibration by the breath. In the katydids and crickets the familiar shrill sounds are made by rubbing together the bases of the front wings, which are specially modified for this purpose. The veins are thickened and roughened by little transverse ridges forming a sort of scraper or rasp, so that the membranes are set into strong vibration when the base of one wing is scraped or rubbed over the base of the other. Only the males are provided with these musical organs.

There are about a dozen species of tree and bush katydids in the United States, all with broad, green, leaf-like front wings, long, slender antennæ and large, leaping hind legs (fig. 138). The large, flat, seed-like eggs (fig. 138) are

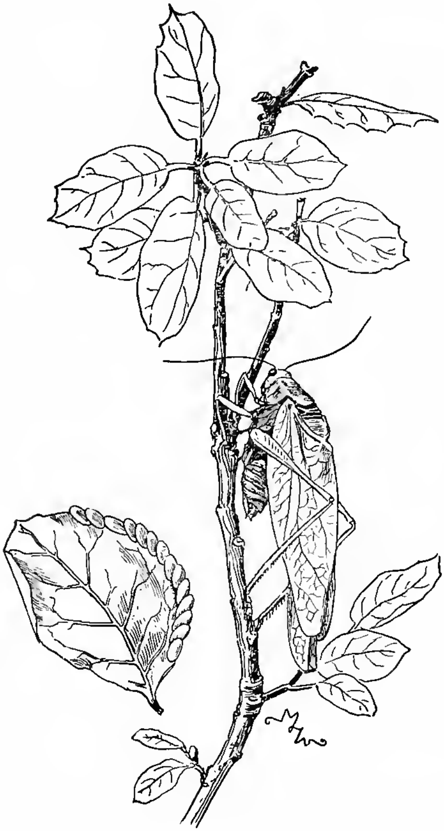


FIG. 138.—Katydid, and leaf with eggs of katydid along edge. (Natural size; from specimens.)

laid overlapping each other in regular rows along a twig or the edge of a leaf, and the young undergo an incomplete metamorphosis. In both immature and adult stage katydids feed on the foliage of trees. The crickets are closely related to the katydids, although differing much from them in appearance. They are black, and live in holes in the ground or in concealed places in houses, coming out at night to hunt for food and to "sing." The eggs are laid in autumn and are hatched the following spring.

Obtain some crickets and distinguish the males from the female. The female has a long pointed ovipositor (egg-laying organ) lacking in the males, while the bases of the fore wings of the male are peculiarly modified. Examine carefully these modified parts. Under the microscope the principal vein, which extends diagonally across the base of the wing, will be seen to be furnished with transverse ridges like a file (fig. 139). On the inner margin of the wing, a short distance from the base toward the end of the principal vein, is a hardened portion which may be called the scraper. Each fore wing is therefore provided with a file and scraper. When the cricket wishes to make his call he elevates his fore wings at an angle of about forty-five degrees with the body; then holding them in such a position that the scraper of one rests on the file of the other, he moves them back and forth laterally, so that the two parts rasp upon each other. This throws the wing membranes into vibration and produces the call.

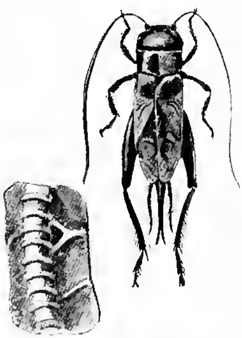


FIG. 139.—Cricket and file (part of the sound-making apparatus). (Cricket natural size; the file greatly magnified; from specimens.)

The solitary bees and the digger-wasps.—The solitary bees are so called because of their manner of living apart and not in communities as do the social bees, like the bumble- and honey-bee. Among them there are no neuter-worker individuals, each female making a nest for her own eggs and doing for herself all the work of burrowing the nest tunnel, and provisioning it with food for the young. These solitary bees are of many kinds, and exhibit a wide variety of nest-making habits. For example, the mining-bees make a tunnel in the ground lined with a sort of glaze, and more or less branched, each branch ending in a cell in which a single egg is laid and a small mass of pollen and nectar paste stored to serve as food for the bee grub. The carpenter-bees tunnel into dead or live wood. One of these, known as the little carpenter-bee, bores into dead twigs of sumac or the canes of brambles, or other soft-pithed plants, making a long tunnel through the pith (fig. 140). At the bottom of this an egg with a pellet of pollen paste is deposited. With some pith chips a partition is made across the tunnel above the egg; another egg and food pellet are put in on this second story, and so on until the tunnel is divided into half a dozen cells. The mother bee then rests in the space above the last cell and waits for her children to grow up. The lower one hatches first; after attaining its growth it tears down the partition above it, and then waits patiently for the one above to do the same. The two now wait for the third to mature, and so on. Finally, when the last one in the top cell has come out, the mother leads forth her fullfledged family for a flight into the sunshine. After the last of the brood has emerged from its cell the substance of which the partitions were made, and which

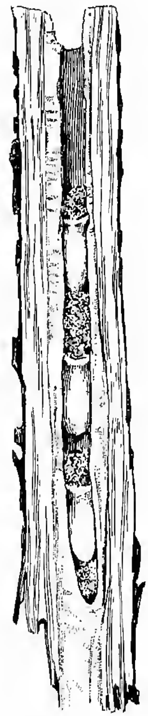


FIG. 140. — Nest or burrow of carpenter-bee. (Natural size; from specimen.)

has been forced to the bottom of the nest by the young bees making their escape, is cleaned out by the family, the old bee and the young ones all working together. Then the nest is ready to be used again by one of the bees.

Some solitary bees make cells for their young out of neatly cut pieces of leaves. The common leaf-cutter bee first makes a tunnel in wood, often selecting that which is partly decayed; it then proceeds to build a thimble-shaped tube at the bottom of the tunnel. For this purpose it cuts from the leaves oblong pieces, each of which forms a part of a side and the bottom of the thimble-shaped tube. The tube being completed the bee partially fills it with a paste of pollen and nectar upon which she then places an egg. Lastly, she cuts several circular leaf pieces, the diameter of which is a little greater than the diameter of the tube, and forces them into the open end of it, thus making a tightly fitting plug. Usually several cells of this kind are placed end to end in a burrow; and sometimes many bees will build their nests together in the same piece of wood.

For an account of the life of the bumble-bees and honey-bee, see Chap. XX.

The digger-wasps differ from the social kinds, such as the yellow-jackets and hornets, just as the solitary bees do from the honey-bees. There are no neuter-worker wasps, but each female makes a separate nest and provisions it by her own labor. The stored food consists, not of pollen and nectar, as with the bees, but of paralyzed or killed insects or spiders. In some cases a new nest is made for each egg. "The nests may be made of mud, and attached, for shelter, under leaves, rocks, or eaves of buildings, or may be burrows hollowed out in the ground, in trees, or in the stems of plants. The adult wasp lives upon fruit or nectar, but the young grub or larva must have animal food, and here the parent wasp shows a rigid conservatism, each species providing the sort of food that has been approved by its family for generations, one taking flies, another bugs, and another beetles, caterpillars, grass-

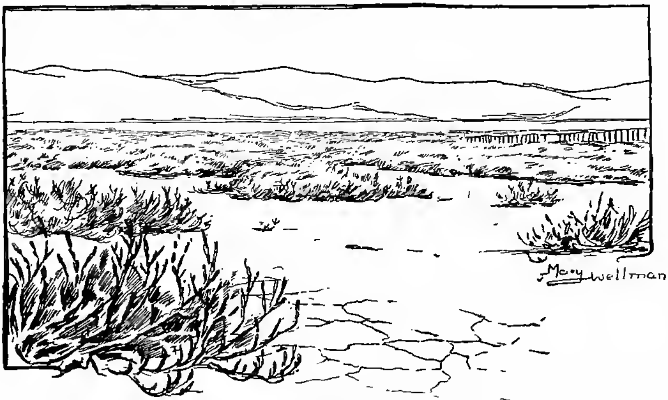


FIG. 141.—Nesting grounds of *Ammophila* in the salt marshes of San Francisco Bay. (From nature.)

hoppers, crickets, locusts, spiders, cockroaches, aphids, or other creatures as the case may be.

"The solitary wasps mate shortly after leaving the nest, in the spring or summer. The males are irrespon-

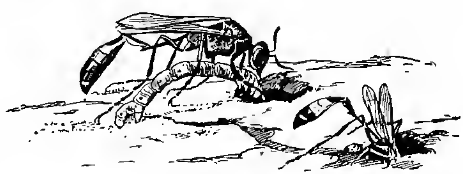


FIG. 142.—*Ammophila* putting inch-worm into nest-burrow. (Natural size; from life.)

sible creatures, aiding little, if at all, in the care of the family. When the egg-laying time arrives the female secures her prey, which she either kills or paralyzes, places it in the nest, lays the egg upon it, and then, in most cases, closes the hole, and takes no further interest in it, going on to make new nests from day to day. In some genera the female maintains a longer connection with her offspring, not bringing all the provisions at once but returning to feed the larva as it grows, and only leaving the nest permanently when the grub has spun its cocoon and becomes a pupa.

"The egg develops in from one to three days into a footless maggot-like creature, which feeds upon the store

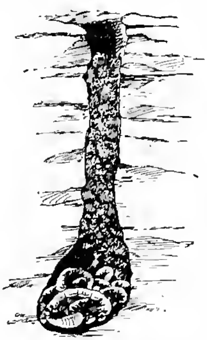


FIG. 143.

FIG. 144.

FIG. 143.—Nest-burrow of *Ammophila* with food for the young (paralyzed inch-worms) in bottom, and burrow nearly filled. (From nature.)

FIG. 144.—*Ammophila* bringing covering bit of salt incrustation to put over stored and filled nest-burrow. (Natural size; from life.)

provided for it, increasing rapidly in size, and entering the pupal stage in from three days to two weeks. In the cocoon it passes through its final metamorphosis, emerging as a perfect insect, perhaps in two or three weeks, or, in many cases, after the winter months have passed and summer has come again. Probably no solitary wasp lives through the winter, those that come out in the spring or summer perishing in the autumn."

The nest-making habits of any solitary wasp when carefully observed will prove to be of absorbing interest. The author has often watched individuals of one kind (a species of the genus *Ammophila*) at work on the salt marshes of San Francisco Bay near Stanford University. These marshes (fig. 141) are nearly covered with a dense growth of a low fleshy-leaved plant, but here and there are small, perfectly bare, level sandy places, which shine white and sparkling in the sun because of a thin incrusta-

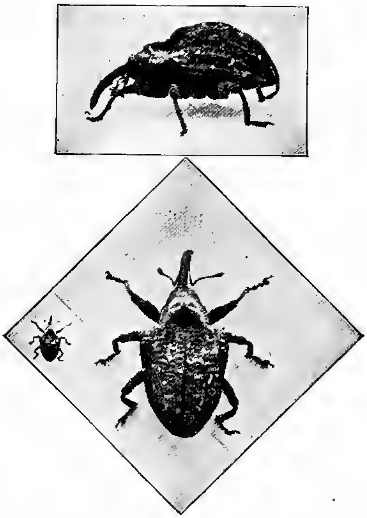


FIG. 145.—The quince curculio (a beetle), *Conotrachelus cratægi*, natural size and enlarged. (Photograph by M. V. Slingerland.)

tion of salt. In September these bare places are taken possession of by many female Ammophilas, which make short vertical nest-burrows all over the ground. An Ammophila having chosen a site for its nest bites out a small circular piece of the salty crust, and with its strong jaws digs out bit by bit a little well. Each pellet dug out is carried by the wasp, flying a foot or two from the mouth of the tunnel, and dropped. To emerge from the hole the wasp always backs upward out of it and while digging keeps up a low humming sound. After the tunnel is dug about three inches deep she covers up the mouth with a bit of salt crust or little pebbles, and flies away. After some minutes she comes back carrying a limp inch-worm about an inch long, which she drags down into the nest (fig. 142). Away she goes again and soon returns with another inch-worm; repeating the process until from five

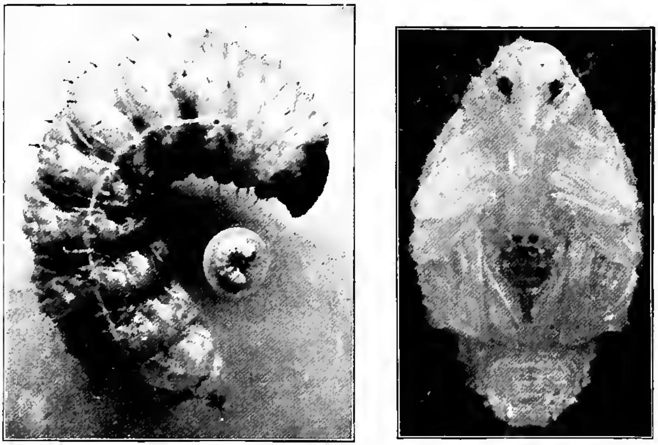


FIG. 146.—Immature stages of the quince curculio, *Conotrachelus cratægi*; at the left, the larva natural size and enlarged; at the right, the pupa. The beetle lays its eggs in pits on quinces, and the larva lives inside the quince as a grub; the pupa lives in the ground. (Photograph by M. V. Slingerland.)

to ten caterpillars have been stored in the tunnel. All these are alive, but each has been stung in one of its nerve-centers (ganglia) so that it is paralyzed. Finally, down goes the mother Ammophila and lays a single egg, attaching it to one of the paralyzed caterpillars. She then fills the tunnel with pellets of earth, carefully chewing up the larger pieces so as to make a close, well-packed filling (fig. 143). Lastly, she carefully smooths off the surface and puts a small flat piece of salt crust on top (fig. 144), so that the site of the tunnel shall be as nearly indistinguishable as possible.

Ammophilas are common all over the country, and the nest-building of various species has been watched by other observers. The use by an individual Ammophila of a small pebble, held in the jaws, as a tool to pound down and smooth off the earth has been twice recorded, once in Wisconsin and once in Kansas. These are perhaps our only records of the use of a tool by an insect.

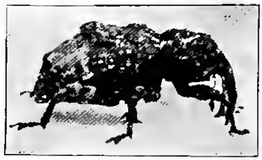
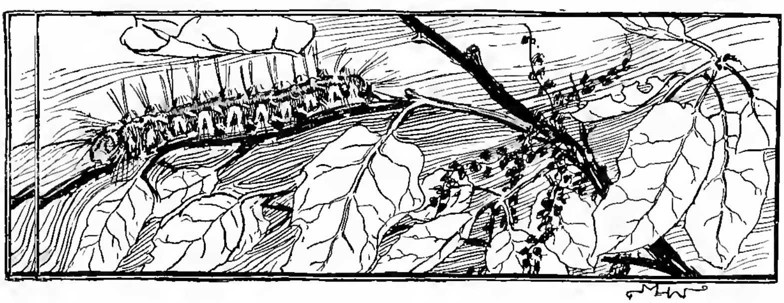


FIG. 147.—The plum curculio, *Conotrachelus nenuphar*, a beetle very injurious to plums. (Photograph by M. V. Slingerland.)

Very interesting accounts of the habits of various digger-wasps may be found in "The Solitary Wasps," by George W. and Elizabeth G. Peckham; also in "Insect Life" by Fabre.

The best general reference-book for American students of insects is Comstock's "Manual for the Study of Insects." "Insect Life," by the same author, gives practical directions for much interesting observational work on habits and external structures. Howard's "Insect Book" is recent and interestingly written.



CHAPTER XIII

SPIDERS AND THEIR WEB-MAKING

The abundance, variety, wide distribution, and interesting habits of spiders, and the ease with which they may be kept alive and observed in captivity make them excellent subjects of observation by young zoologists. The bite of no one of the common small spiders of house and field and garden causes any more pain than the prick of a needle. The bite of the tarantula and of a few of the large running spiders may cause some pain, but in studying spiders there is no necessity of being bitten at all.

The animals should be observed both in the schoolroom and out-of-doors. One can get acquainted with the make-up of the spider body and with some of the feeding habits, and even some of the spinning, in the schoolroom. The rearing of spiders from eggs and the observation and growth of the "spiderlings" can also be managed in the schoolroom. But the study of spiders' homes, the different kinds of webs they spin, with the processes of web-building, and the general habits of the various common kinds must, most of it, be done in the field or garden or along the roadside; in a word, out-of-doors.

Collecting spiders.—To collect live spiders for the schoolroom one should provide himself with a number of empty pill-boxes, cap-boxes, or other small paper-, wooden-, or tin-boxes with well-fitting cover. Each of these will serve as collecting tool for one spider, and as cage to keep it in until the schoolroom is reached. Search for spiders in or near their webs, in the corolla of flowers, on the bark of trees, under stones and sticks on the ground, and (for tarantulas and other spiders with tubular nests in the ground) in their burrows. Spiders living on webs, flowers, trees, etc., are very prone to drop quickly to the ground when disturbed. Take advantage of this and be ready to catch a falling spider in a pill-box, quickly clapping the lid on. Use the pill-box and lid as catching equipment (fig. 148); you will soon get expert in the work. Small spiders, especially those in webs or flower-cups, can be caught with perfect impunity in the

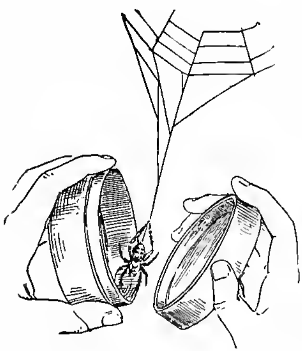


FIG. 148.

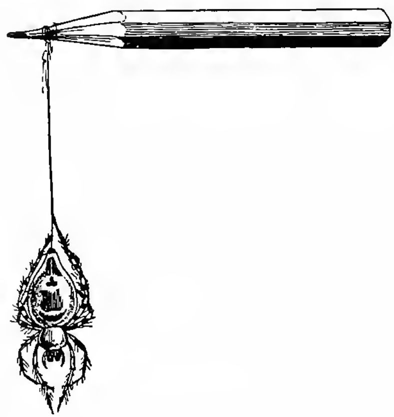


FIG. 149.

FIG. 148.—Catching a spider. (After Jenkins and Kellogg.)
FIG. 149.—Spider dropping from a pencil supported by suspending line. (After Jenkins and Kellogg.)

hands. But there is always danger of crushing the soft body of the creature, or pulling off a leg or two in handling. Trust chiefly to manipulation of the box and lid. There need be no holes in the box for the admission of air, the boxes being by no means air-tight. The silken egg-sacs or cocoons of spiders, if recognized, may also be collected, and the young spiders reared in the schoolroom. Some thoroughly interesting experiments may be made with them.

The make-up of the spider body.—Have a number of common house-spiders (readily found in wood-sheds, stables, attics, etc.), and of ground-spiders (to be found under stones and boards) alive in glass jars. Put some small live insects in the jars for food. Observe the behavior of the spiders. If they capture the insects note what is done with them. Is there any difference in the behavior of the two kinds of spiders? Do they spin silk about their prey? If they spin silk about the prey do they spin any more? Do they eat the whole body of the captured insect? Where does the silk come from? Take out from the jar one of the house-spiders on the end of a pencil. It will drop, not free, but attached to a delicate, almost invisible, silken thread, which issues from the posterior tip of the body (fig. 149). By quickly lifting the pencil before the spider reaches the table or floor the holding thread may be observed.

Kill some of the larger individuals in a killing-bottle (see p. 335) and carefully examine them. How many legs has a spider? A pair of short processes which look, at first glance, like legs and are situated in front of the first pair of true legs, are feelers or palpi—not the same kind of feelers as the antennæ of insects, but feelers belonging to the mouth. Into how many principal parts is the body divided? These parts have the same name as those of the crayfish. The spider body is really built on the segmented plan (like the worms, crustaceans, centipeds, and insects), but the segments have grown together so that the lines or sutures between them are obsolete. To which part of the body are the legs attached? Are there

FIG. 150.—The eyes and jaws, showing falx and fang of a spider. (After Jenkins and Kellogg.)

any antennæ? The eyes of spiders are simple (not compound as in the insects and crustaceans), and they vary in number and size and arrangement in the different kinds. Find the mandibles or jaws; with a pin press them apart and examine them. How do they work? Note that each jaw (fig. 150) is composed of a firm, smooth, sharp-pointed tip called the fang, and a thicker hairy basal part, the falx. In the falx is the tiny poison-sac, from which the poison runs through the fang and out through a hole near the point. All spiders have poison-sacs, but with only a few of the larger ones is enough poison introduced into the wound to make a bite at all painful to us.

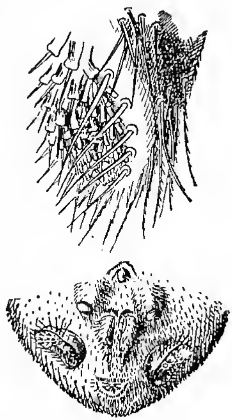


FIG. 151.—The six spinnerets enlarged (below) of a spider, with one spinneret magnified (above) to show the spinning "spools" or tubes. (From Jenkins and Kellogg.)

Examine now the spinning-organs. At the posterior tip of the abdomen may be seen a few small finger-like projections, the spinnerets (fig. 151). Each of these movable spinnerets bears on its surface many very small papillæ, the spinning-tubes (fig. 151). These can be seen by examining a spinneret under the microscope. In spinning, a slender silken thread issues from each of the spinning-tubes on each spinneret. All of these fine threads unite to form one strong line which we see.

The hunting-spiders.—Some kinds of spiders spin webs for catching their prey, while some do not, but trust to pursuit by running and leaping. The house-spiders with their cobwebs, the field-spiders with their silken sheets among the grasses, and garden-spiders with their geometrically regular orbs hung in the shrubbery, belong to the web-weaving group. The black, swift pursuers that lurk under stones, the fierce-eyed little black and red fellows hiding on the bark of trees, and the daintily colored crab-like ones lying quietly in flower-cups, belong to the non-web-weaving group. We shall

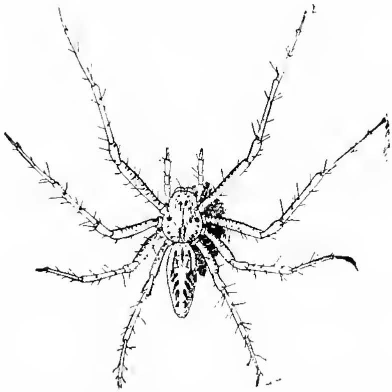


FIG. 152.—A web-weaving spider. (Natural size; from life.)

first consider those of this second group, which we may call the hunting-spiders.

Under stones or lurking in half-concealment elsewhere on the ground may be readily found certain blackish, rather hairy, spiders, mostly of large size (fig. 153). These are the running spiders, and they catch their prey by swift running. Their legs are long, the hindmost

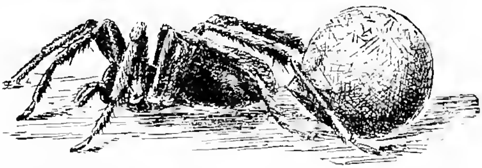


FIG. 153.—A female running spider (Lycosidæ) carrying its egg-sac about attached to its spinnerets. (Natural size; from Jenkins and Kellogg.)

pair being the longest. Some of these spiders have the body, exclusive of legs, an inch or even more in length.

A large one may be found, perhaps, dragging after it a dirty white silken ball (fig. 153). This is the egg-sac, which is strongly attached to the spinnerets of the female, being carried about by her until the spiderlings hatch. Issuing from the egg-sac they climb on the back of the mother, and are thus further carried and protected by her until they are able to care for themselves.

Upon fences, the sides of out-buildings, on the bark of trees, or fallen logs, may be found certain small, robust, short-legged spiders which move chiefly by sudden leaps. These are the jumping spiders (fig. 154). They are usually black, with red or other striking color-markings, and two of the eight shining black eyes are much larger and more

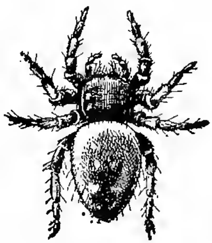


FIG. 154.

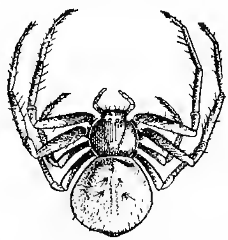


FIG 155.

FIG. 154.—A jumping spider (Attidæ). (From Jenkins and Kellogg.)
FIG. 155.—A crab-spider (Thomisidæ). (From Jenkins and Kellogg.)

conspicuous than the others—much larger, indeed, than the eyes of any other spiders of equal size, and they give the jumping spiders a peculiarly threatening appearance. These can walk sidewise or backwards with facility, but are readily distinguished by their leaping and their big eyes from the true crab-spiders described in the next paragraph.

In the cracks and crevices of fence and bark, and on plants, may be found certain short, broad, flattish, usually greyish spiders, which can run sidewise or backward more readily than forward. These are known as crab-spiders (fig. 155). Some of them lie in wait for their prey in flower-cups, being usually white and parti-colored, so as to harmonize with the bright corolla. They are rendered inconspicuous by this sort of color mimicry, and small insects alight unsuspectingly within reach of them as they wait. The front two pairs of legs in these spiders are longer than the other two pairs, and "so bent that the spider can use them when in a narrow crack."

The running spiders, jumping spiders, and crab-spiders are the most easily found and easily recognized of those

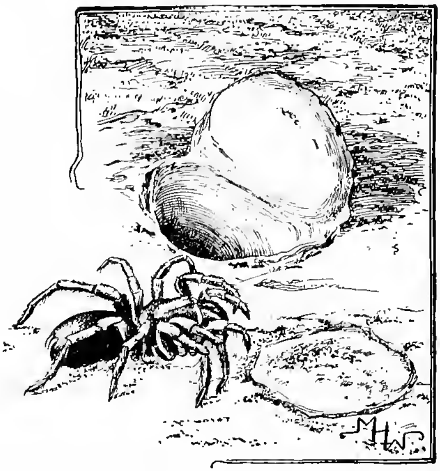


FIG. 156.—Trap-door spider (California) with two burrows, one with door open, one with door closed. (Natural size; from life and specimens.)

which do not spin webs to catch prey. But there are other groups characterized by this habit, among them the giant California tarantulas or Mygales, and the trap-door spiders. The nests (figs. 156 and 157) of these spiders are described in Chapter III, page 39.

The web-weaving spiders.—The webs or snares of spiders present a great variety in form and type of construction. The webs made by the various individuals of any one species of spiders are always alike, however; indeed, each family of web-weavers has its own peculiar type-plan of web construction, and as we could distinguish various families of non-web-weaving spiders by their habits of locomotion, so we can distinguish the various families of web-weavers by the character of the webs.

FIG. 157.—Burrow of trap-door spider cut open to show interior. (One-half natural size; from specimen.)

Most familiar to us probably are the "cobwebs" of the neglected corners and byways of the house and out-buildings. The family of cobweb weavers is a large one, and its species are not restricted to an indoor habitat, but many spin their loose, irregular webs in bushes. With them all the web is a tangled maze of silken threads, mostly in the form of a flat or curved sheet of silk, on the under side of which the spider stands or runs, back downward. Sometimes the owner has a silken nest in a crack near the web, and there is sometimes a short silken tube leading to the nest. The spiders themselves are usually small and very slim-legged.

Examine a cobweb carefully. Note its irregular, unsymmetrical character. Can its general sheet-like form be made out ? Are there vertical threads running to it from above? Is the web sticky, i.e., are the threads of the web sticky? Are they all sticky? (see description of orb-webs). Are there any remains of insects in the web? Throw a house-fly in, and if the spider comes to it watch carefully all the spider's movements. Does it run out on the upper or under surface of the web? Does it swathe

FIG. 158.—"Turret" or above ground part of nest of turret-spider. (Natural size; from specimen.)

the fly's body with silk? Does it carry the fly to its nest or to another part of the web to eat it?

A grade higher in point of symmetry of construction are the snares of the funnel-web weavers. These are spun in the grass of meadows, pastures, gardens, and roadsides, and because of their lowly and obscure situation do not usually appear to be very abundant; they are, in fact, the most abundant of all. Some dewy morning we are surprised to find the grass nearly covered with glistening webs. These are revealed to us by the tiny drops of water, which, clinging to the silken threads, reflect the sun's rays, and make the otherwise almost invisible webs very conspicuous. It is desirable to choose a dewy morning or the first hour after the lifting of a heavy fog for spider-web hunting. The webs are not only easily found then, but are then especially beautiful. The funnel-webs are horizontal concave silken sheets,

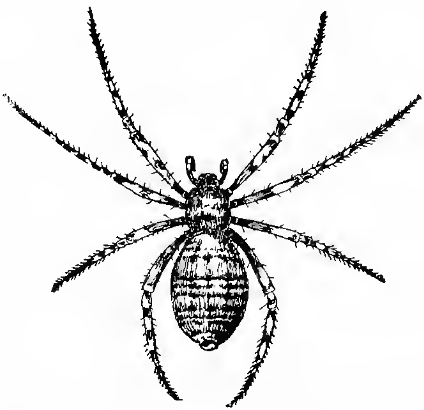


FIG. 159.—*Argiope* sp., a large orb-weaver (Epeiridæ). (Natural size; from Jenkins and Kellogg.)

supported in the grass by strong silken lines or cables attached to the grass stems and blades. They have at one side a funnel-shaped tube running downwards and opening near the ground. In this tube the spider lies in hiding, and from it runs out upon the upper surface of the web to seize its prey, or runs away when necessary from out the lower end, escaping unseen on the ground among the grass roots. The funnel-web weavers are long-legged, usually brownish in color, very often of considerable size, and with one of the pairs of spinnerets unusually long. Note how the web is suspended by stout supporting lines. Note the funnel-shaped tube, with its upper and lower openings. Find a tube with the spider in it. Touch the tube lightly with a pencil point, trying

FIG. 160.—Spider and its web in a rose-bush. (Photograph from life by Cherry Kearton; from "Wild Life at Home," by permission of Cassell & Co.)

to induce the spider to come out upon the web. Observe its manner of escape.

A great advance in point of symmetry and elaboration of design is shown by the round webs or orb-webs (fig. 161). These are the most interesting as well as the most beautiful of spider's snares. They may be found suspended between the branches of shrubby plants, or between the bushes themselves, in fences, in open doorways, or wherever in the garden a convenient framework presents itself. They are characterized by their circular outline, within which are disposed numerous radii and a series of concentric circular or spiral threads. The circular snare is usually placed within an irregular triangle, or quadrangle, or polygon, which is held in shape and position by stout stay-lines fastened to the adjacent

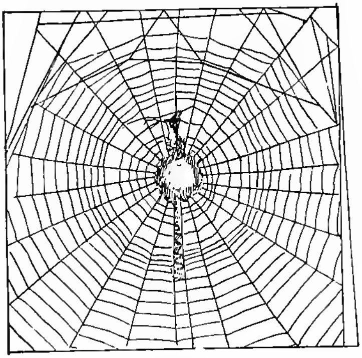


FIG. 161.

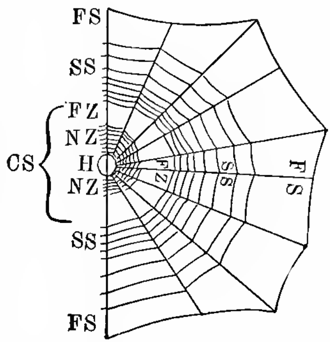


FIG. 162.

FIG. 161.—An orb-web of *Argiope;* this web may be from one to two feet in diameter. (After McCook.)

FIG. 162.—Diagram of (one-half) an orb-web; *f.s*, free space; *s.s*, spiral space; *c.s*, central space; *f.z*, free zone; *n.z*, notched zone; *h*, hub. (After McCook.)

branches, or fence-rails, or door-frames, or whatever serves as a framework for it. The webs vary greatly in size, the largest being sometimes a foot and a half to two feet in diameter. The spiders which spin them are called garden-spiders or orb-web weavers, and most of them are highly colored, and have a nearly spherical abdomen. They may be found "hanging head downwards, usually near the center of the net; others have a retreat near one edge of the net, in which they hang back downwards. While resting in these retreats they keep hold of some of the lines leading from the net, so that they can instantly detect any jar caused by an entrapped insect."

Find one of these orb-webs in good condition, i.e., not torn and ragged, but new and complete. Examine it, and note the regularity of its construction (fig. 162). Trace the stay-lines to their attachments; note the shape of the outer polygon; note the "spiral zone," i.e., that part of the snare filled with lines laid down in apparently con-

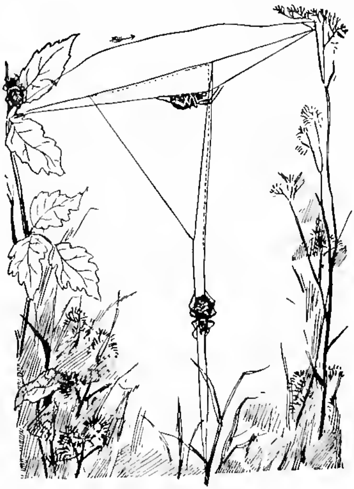


FIG. 163.—Spider putting in foundation lines for an orb-web; the spider shown at different positions in the work. The first (uppermost) line is carried across by an air-current. (After McCook.)

centric circles; note that these are not separate circles, but are spiral, and that the line composing it is continuous; between the outer polygon and the spiral zone there is a region crossed by the radii, but without other lines, the "outer free zone"; between the spiral zone and the center of the snare there is another zone free from spiral or circular lines, or with these lines very far apart, the "inner free zone"; the central part or central zone of the snare has a close spiral in it, and here the spider, if it has no side retreat, usually rests. Touch one of the radii or one of the foundation lines with a pencil point; touch the spiral with a pencil; a difference in the character of the two kinds of lines is at once manifest. The spiral thread is "sticky," the radii and foundation lines are not so; the web is made of two kinds of silk. If a bit of the spiral line be examined under a magnifier it will be seen that, ranged along the silken thread, like beads on a string, are many tiny globules or drops. These are a sticky, viscous sort of silk, which does not dry and harden as the usual silk does. These sticky drops make

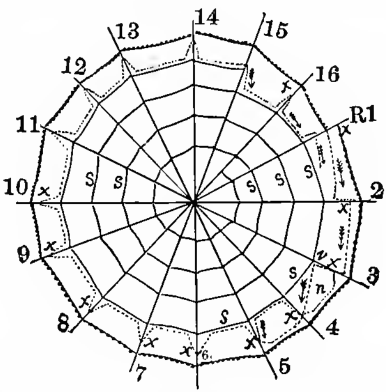


FIG. 164.—How the spider "swings round the circle" in putting in the spiral line; R1......16 = radii 1 to 16; *s*, scaffolding line, to be torn out; *x*, the spider in various positions. The spider crawls and drops along the course indicated by the dotted line, holding the new sticky line free from the old one. (After McCook.)

the spiral line much more effective as a snare. Throw an insect into the web and observe the behavior of the spider.

If possible observe the spinning of an orb-web. A bridge which has a metal or wooden fretwork on each side affords a particularly good place to watch this. In the square or diamond-shaped open spaces the spider can be readily seen at work. It works in a regular way, putting in first the foundation (fig. 163), and radial lines, and then the spiral ones (fig. 164). Two sets of spiral lines are put in, a first set, which is made from the center outwards, is not sticky, and serves as scaffolding upon which the spider works when putting in the second set. The latter is sticky and is put in from the outer part of the web toward the center. The temporary spiral or scaffolding is torn out as the work of putting in the sticky permanent spiral progresses. The web building includes a great deal of interesting behavior on the part of the spider, the delicate manipulation of the viscid lines, and the almost geometrically accurate disposition of the lines composing the snare, combining to render the whole performance little short of marvellous.

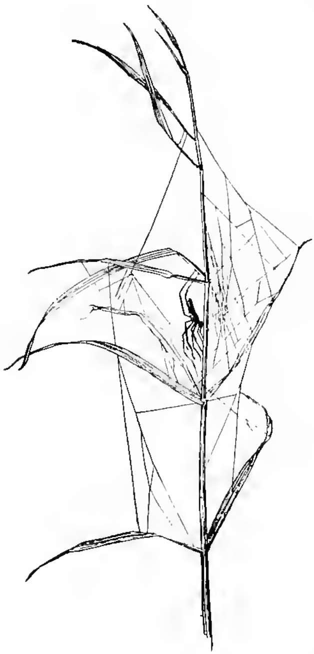


FIG. 165.—A long-legged spider, *Tetragnatha* sp., on its web. (One-half natural size; from life.)

There are other kinds of webs spun by other kinds of spiders. Indeed among the orb-weavers alone there is a great variety in the character of the webs; some, for example, lack a sector of the circle, being otherwise constructed on regular orb-web plan; others are composed of perhaps less than one-half a circle, although still with radii, and with concentric arcs of circles in place of complete circles in the spiral zone. Certain kinds of spiders spin a peculiar broad line, or rather band, of curling silk, which leads from the snare to the side retreat. Or they make of this band of curled silk a central zone not composed of a spiral line but of a closed oval or circular shield. The very small triangle spider spins a triangular web (fig. 166), from which a main stay-line runs, upon which the creature rests with a loop of the stay-line held between the fore and hind legs. When an insect alights upon the snare the spider looses the hold of the hind legs on the stay-line and the web springs suddenly, further en-

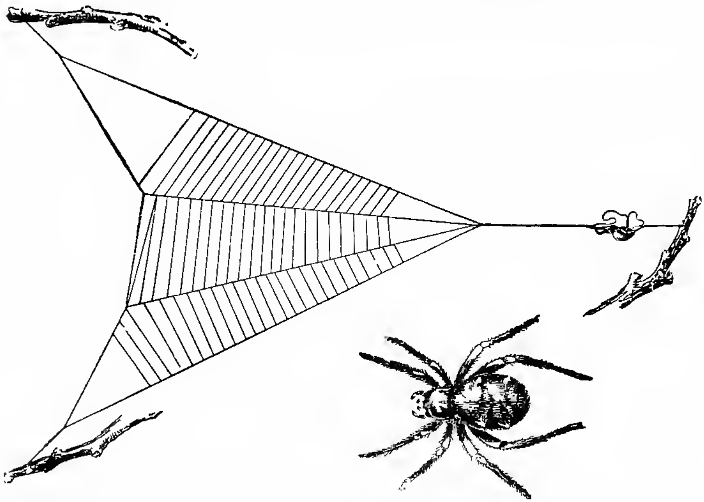


FIG. 166.—The triangle spider, *Hyptiotes* sp. (California), with its web; the spider rests on the taut guy-line, with a loop of the line held between its fore and hind legs; when an insect gets into the web the spider loosens the hold of its hind feet on the guy-line, thus allowing the web to spring forward sharply and further entangle the prey. (Web with spider on one-half natural size; spider below twice natural size; from Jenkins and Kellogg.)

tangling the prey. Search should be made for these and other kinds of webs.

There is another peculiar phenomenon to be observed in connection with spider's silk. On some bright warm days there may be noticed many "spider webs" or long threads of spider silk, floating in the air, some of them at considerable heights. Careful observation will show that not only are "spider webs" floating, but attached to many of them are small spiders sailing or "ballooning" through the air. These are called ballooning or aeronautic spiders. Examine carefully the top of fence-posts or other exposed raised points and you may be fortunate enough to discover one of these about to make an ascension (fig. 167). It will be standing with its legs close together and straight, the body being thus lifted as high as possible, and the tip of the abdomen pointing upward.

FIG. 167.—Ballooning spider ready to sail. (Natural size; after McCook.)

From the spinnerets (at the tip of the abdomen) are issuing lines floating freely. These lines are gradually spun out (being really drawn out by the pull of the wind) until they become so long that the wind bears them off with the spider attached to them. Spiders may make long journeys in this manner, and get themselves widely dispersed from their original habitat. These adventurers are mostly young, and hence small individuals of various species; but some adult spiders of small size are also aeronauts.

Life-history of spiders.—The eggs of spiders are inclosed in silken cases, or cocoons of various shapes. Most common are the flattened circular or elongate kinds attached to the under side of boards or stones. Some-

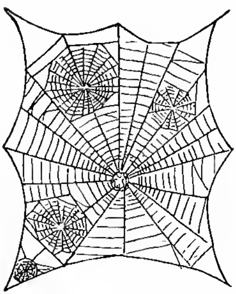


FIG. 168.

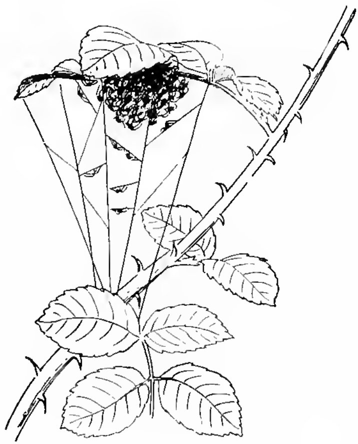


FIG. 169.

FIG. 168.—Webs of young orb-web spiders on a large web of an old spider. (After McCook.)

FIG. 169.—Assembly of young spiders just after issuance from cocoon, "balled" underneath a rose-leaf. (After McCook.)

times they are spherical or vase-shaped and are suspended among the leaves. As already noted the females of certain running spiders carry the egg-sac about attached to the spinnerets.

The eggs hatch in from fifteen to thirty days in summer, but if laid in the fall may not hatch until the following spring. The young rarely leave the egg-sac immediately but remain in it for a period ranging from a few days to several weeks. With some species the spiderlings feed on each other, the stronger overcoming the weaker and devouring them. When they issue, which they do by cutting a hole in the cocoon, they look like the adult spiders, but are of course much smaller. They are also usually lighter in color, and without the patterns and markings which characterize the species. As they grow they moult several times, but do not acquire the final arrangement of hairs, spines, markings, etc., until the last moulting.

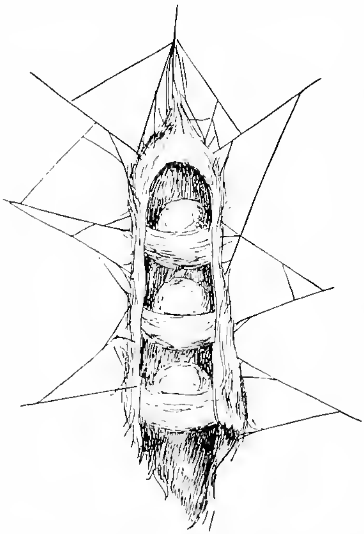


FIG. 170.—Egg-cocoon of the labyrinth spider, with sides removed to show egg-packets and chambers. (Two and one-half times natural size; after Snodgrass.)

Nothing more interesting in spider life is to be observed than the behavior of spiderlings that have just issued. The first silk-spinning, the attempts at web-making, the gregarious habit leading to "balling" (fig. 169) or "snugging" of the brood, and the gradual dispersion and assumption of independent life all offer a fascinating and readily accessible field of observation.

The best book about the life of spiders is McCook's "American Spiders and their Spinning Work." A smaller book is Emerton's "Life of Spiders," and one describing all of the common spiders of the Eastern and Southern States is Emerton's "Common Spiders."

CHAPTER XIV

FISHES, BATRACHIANS, AND REPTILES

The great branch of vertebrate or backboned animals includes the classes of fishes, the batrachians, the reptiles, the birds, and the mammals. All these possess a bony (or cartilaginous) spinal column, which distinguishes them from the invertebrates or backboneless animals. In addition they possess a further internal bony skeleton (cartilaginous in some fishes, as the sharks and sturgeons), including in all but the most primitive forms two pairs of appendages or limbs. In some these limbs are mere rudiments, as in the snakes, where only a few (pythons) show any external sign of them; but in most vertebrates they are well developed organs of locomotion, appearing as fins in the fishes, as legs in the batrachians, reptiles, and most mammals, as wings and legs in the birds, and as arms and legs in the monkeys and man. In almost all vertebrates the blood is red, and is always confined in a special circulatory system consisting of heart, arteries, veins, and capillaries. Air is taken up by the gills or lungs, to which the blood is brought to be purified, i.e., to give up its carbon dioxide and receive oxygen. The nervous system is highly developed, with a large brain and with complex and highly efficient sense-organs, as eyes, ears, etc.

Except for the insects the vertebrates include most of the animals we familiarly know. They are pre-eminently the "intelligent animals" (ants, bees, and wasps, and some other insects and spiders are also, of course, intelligent), and hence their ways and lives have more interest for us than those of the lower animals.

The fishes.—We have already studied (Chapter V) an example of the class of fishes. The sunfish is common in streams and ponds all over the country, and its habits can be well observed by patient students. It lives in quiet corners of brooks and rivers, preferably under a log or at the root of an old stump. It is a beautiful fish, shining "like a coin fresh from the mint." Its body is mottled golden, orange, and blue, with metallic luster, darker above, pale or yellowish below. Its fins are of the same color. The tip of its opercle or gill-cover is prolonged like an ear, and jet black in color, with a dash of bright scarlet along its lower edge. Nearly all of the thirty species of sunfish found in the United States have this black ear-like opercle, but some have it long, some short, and in some it is trimmed with yellow or blue instead of scarlet.

The sunfish lays its eggs in the spring in a rude nest it scoops in the gravel and over which it stands guard with its bright fins spread, looking as big and dangerous as possible. When thus employed it takes the hook savagely, perhaps regarding the worm as a dangerous enemy. The young fishes soon hatch, looking very much like their parents, although more transparent and not so brightly colored. They grow rapidly, feeding on insects and other small creatures, and reach their growth in two or three years. They do not wander far and never willingly migrate. Students should verify this account on the different species. A more exact study of the nests of the different species and the fishes' defense of them would be a valuable addition to our knowledge. The most striking traits of this fish are its vivacity and courage. The sexes are similar in appearance and both defend the nest.

Closely related to the sunfish are the various kinds of bass, the "crappies," the calico bass, the rock-bass, and the large-mouthed and small-mouthed bass. All the members of the sunfish and bass family are carnivorous fishes, especially common in the Mississippi Valley.

Another family of many species especially common in the clear, swift, and strong Eastern rivers is that of the darters and perches. The darters are little, slender-bodied forms, which lie motionless on the bottom, moving like a flash when disturbed and slipping under stones out of sight of their enemies. Some are most brilliantly colored, surpassing in this respect all other fresh-water fishes.

Unlike the sunfishes and the darters are the catfishes. The catfish gets its name from the long feelers about its mouth; from these also come its other names of horned pout, and bull-head. It has no scales, but its spines are sharp and often barbed or jagged and capable of making a severe wound.

Remotely allied to the catfishes are the suckers, minnows, and chubs, with smooth scales, soft fins, and soft bodies, and the flesh full of small bones. These little fish are very numerous in species, some kinds swarming in all fresh water in America, Europe, and Asia. They usually swim in the open water, the prey of every carnivorous fish, making up by their fecundity or ability to produce young in great numbers and their insignificance for their lack of defensive armature. In some species the male is adorned in the spring with bright pigment —red, black, blue, or milk-white. In some cases, too, it has bony warts or horns on its head or body. Such forms are known to the boys as horned dace.

Most interesting to the angler are the members of the salmon and trout family (fig. 171), because they are gamy, beautiful, excellent as food, and above all perhaps, because they live in the swiftest and clearest waters in the most charming forests. The salmon live in the ocean most of their lives, but ascend the rivers from the sea to deposit their eggs. The king salmon of the Columbia goes up the great river more than a thousand miles, taking the whole summer for it, and never feeding while in fresh water. Besides the different kinds of salmon the black-spotted or true trout, the charr or red-spotted trout of various species, the whitefish, the

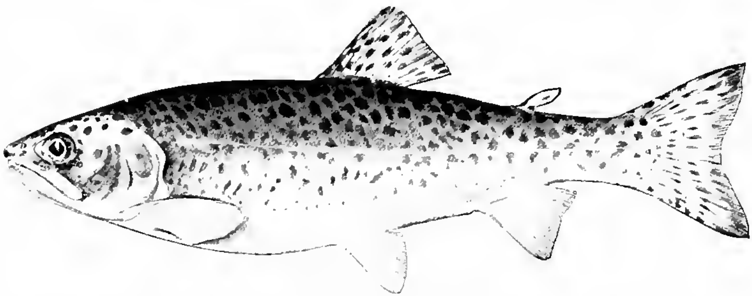


FIG. 171.—The rainbow-trout. *Salmo irideus.* (From specimen.)

grayling, and the famous ayu of Japan belong to this family.

In the sea are multitudes of fish forms. The myriad species of eels agree in having a long, flexible, snake-like body, without ventral fins. Most of them live in the sea, but the single genus of true eels which ascends the rivers is exceedingly abundant and widely distributed. Most eels are extremely voracious, but some of them have mouths that would barely admit a pin-head. Codfishes are creatures of little beauty but of great usefulness, swarming in arctic and subarctic seas. The herring, soft and weak in body, are more numerous in individuals than any other fishes. The flounders, of many kinds, lie flat on the sea bottom. They have the head so twisted that the two eyes occur both together on the uppermost side (fig. 172). The members of the great mackerel tribe swim in the open sea, often in great schools. Largest and swiftest of these is the swordfish, in which the whole upper jaw is grown together to form a long bony sword, a weapon of offense that can pierce the wooden bottom of a boat.

Many of the ocean fishes are of strange form and appearance. The sea-horses (fig. 174) are odd fishes, covered with a bony shell, and with the head shaped like that of a horse. They are little fishes, rarely a foot long,

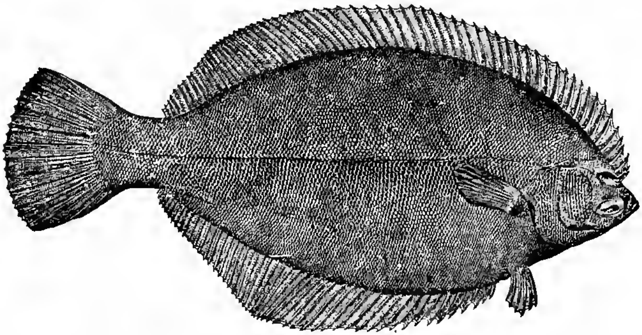


FIG. 172.—The winter flounder, *Pseudopleuronectes americanus*. (After Goode.)

and cling by their curved tails to floating seaweed. The porcupine fishes and swell fishes have the power of filling the stomach with air, which they gulp from the surface. They then escape from their pursuers by floating as a round spiny ball on the surface. The flying fishes leap out of the water, and sail for long distances through the air like grasshoppers. They cannot flap their long pectoral fins, and do not truly fly, but strike the anal fin with great force against the water in making a leap so that they move swiftly, and thus escape their pursuers. In its structure a flying fish differs little from a pike or other ordinary fish.

The rays and skates are peculiar ocean fishes, which lie at the bottom of shallow shore-waters. They feed on crabs, molluscs, and bottom-fishes. The small common skates, "tobacco-boxes" (fig. 174), about twenty inches long, and the larger "barn-door" skates are numerous along the Atlantic coast from Virginia northward. Especially interesting members of this group, because of the peculiar character of the injuries produced by them, are the sting-rays and torpedoes, or electric-rays. The sting-rays have spines near the base of the tail which cause very painful wounds. The torpedoes have two large electrical organs, one on each side of the body, just behind the head, with which they can give a strong electric shock. "The discharge from a large individual is sufficient to temporarily disable a man, and were these animals at all numerous they would prove dangerous to bathers." Very different from the typical rays in external appearance are the sawfishes, which belong to this group. The body is elongate and shark-like, and has a long, saw-like snout. This saw, which in large individuals may reach a length of six feet and a breadth of twelve inches,

FIG. 173.—A sea-horse, *Hippocampus kelloggi*. (This fish is eight inches long; after Jordan and Snyder.)

makes its owner formidable among the small sardines and herring-like fishes on which it feeds. The sawfishes live in tropical rivers, descending to the sea.

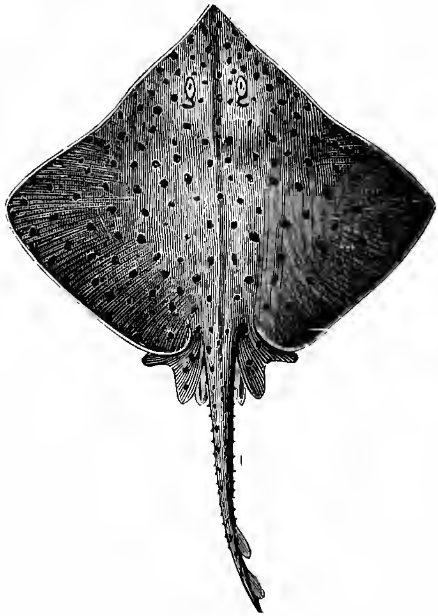


FIG. 174.—The common skate, *Raja erinacea*. (From Kingsley.)

Baskett's "Story of the Fishes," McCarthy's "Familiar Fish," and Jordan and Evermann's "Food and Game Fishes of America" are good books for elementary students of fishes.

The batrachians.—We have made the acquaintance of the most familiar batrachians in our study of the life-history of the toad and frog (Chapter II). Other familiar members of this class are the salamanders. All batrachians breathe by means of gills for a longer or shorter time after birth. But except in very few cases these gills are lost and lungs developed so that the adults cannot breathe under water. The toads and frogs are closely related, and have about the same life-history and habits, except that the fully-grown toads live on land instead of in and about ponds. In structure toads differ from frogs in having no teeth. There are only a few toad species in North America, but one of these is very abundant and widespread. It appears in two or three varieties, the common toad of the Southern States differing in several particulars from that of the Northern. The toad is a familiar inhabitant of gardens, and does much good by feeding on noxious insects. It is most active at twilight. Its eggs are laid in a single line in the center of a long, slender, gelatinous string or rope, which is nearly always tangled

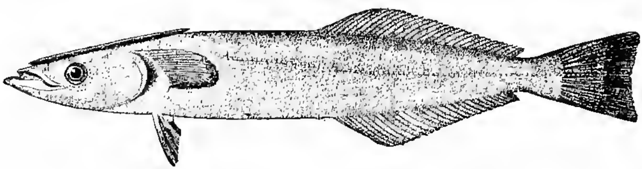


FIG. 175.—The remora or cling fish, *Remoropsis brachyptera;* by means of the curious sucker on top of the head this fish clings to sharks and is thus carried swiftly for long distances. (After Goode.)

and wound round some water-plant or stick near the shore on the bottom of a pond. The eggs are jet black, and when freshly laid are nearly spherical. At the time of the egg-laying the toads croak or call, making a sort of whistling sound, and at the same time pronouncing deep in the throat "bu-rr-r-r-r." The toad does not open its mouth when croaking, but expands a large sac or resonator in its throat. The toad tadpoles are blacker than those of frogs or salamanders, and undergo their metamorphosis while of smaller size than those of frogs. When they leave the water they travel for long distances, hopping along so vigorously that in a few days they may be as far as a mile from the pond where they were hatched. They conceal themselves by day, but will appear after a warm shower; this sudden appearance of many small toads sometimes gives rise to the false notion that they have fallen with the rain.

There are about a dozen species of frogs in the United States. The largest of these, and indeed the largest of all the frogs, is the well-known bullfrog, which reaches a length (head to the posterior end of the body) of eight inches. It is found in ponds and sluggish streams all over the eastern United States and in the Mississippi valley. It is greenish in color, with the head usually bright pale-green. Its croaking is very deep and sonorous. The pickerel-frog, which is bright brown on the back, with two rows of large, oblong, square blotches of dark brown, is found in the mountains of the eastern United States. The little, pale, reddish-brown wood-frog, with arms and legs barred above, is common in damp woods, and is "an almost silent frog." The peculiar frogs, infrequently seen, known as the "spade-foots," are subterranean in habit, and usually live in dry fields, or even arid plains and deserts. They pass through their development and metamorphosis very rapidly, appearing immediately after a rain, and laying their eggs in temporary pools. At this time they utter extraordinarily loud and strange cries. Some frogs, in other parts of the world, live in trees, and the eggs of one species are deposited on the leaves of the trees, leaves which overhang the water being selected, so that the issuing young may drop into it.

The true tree-frogs, or tree-toads, constitute a family especially well represented in tropical America. They have little disk- or pad-like swellings on the tips of their toes, to enable them to hold firmly to the branches of the trees in which they live. Some, like the swamp tree-frog and the cricket-frog, are not arboreal in habit, remaining almost always on the ground. The common tree-frog of the Eastern States is green, gray, or brown above, with irregular dark blotches, and yellow below. It croaks or trills, especially at evening or in damp

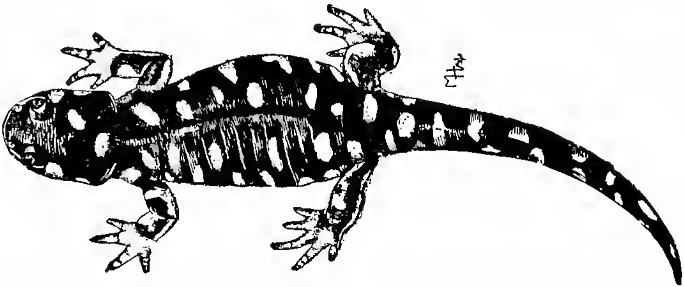


FIG. 176.—The tiger salamander. (From Jenkins and Kellogg.)

weather. Pickering's tree-frog makes the "first note of spring" in the Eastern States. This is the one most frequently heard in the autumn, too, but "its voice is less vivacious than in the spring, and its lonely pipe in dry woodlands is always associated with goldenrods and asters and falling leaves." The tree-frogs of North America lay their eggs in the water on some fixed object like an aquatic plant, in smaller packets than those of the true frogs, and not in strings as do the toads.

FIG. 177.—The Western brown eft, or salamander, *Diemyctylus torosus*. (From living specimen.)

The salamanders (figs. 176 and 177) are batrachians, with the body not short and tailless as in the frogs and toads, but elongate and slender and tailed. Their life-history is like that of the frogs, although some salamanders which live on land (they are to be found under logs and stones in the woods) produce their young alive. To compare the external structure of a salamander with that of a frog or toad one of the tiger salamanders or one of the little tritons or efts, common all over the country, should be used. The little green triton or eft of the Eastern States, or its larger brown-backed congener (fig. 177) of the Pacific coast, is common in water, while another eft, the little red-backed salamander, is common in the woods under logs and stones.

The reptiles.—The class of reptiles includes the lizards, snakes, tortoises, turtles, crocodiles, and alligators. They are cold-blooded and breathe for their whole life exclusively by means of lungs, the forms which live in water coming to the surface to breathe. They are covered with horny scales or plates, which with the entire absence of gills after hatching readily distinguish them from all the batrachians. While most reptiles live on land, some inhabit fresh water and some the ocean. As the young have the same habitat and general habits as the adult, there is no such metamorphosis in their life-history as is shown by the batrachians. The reptiles are widespread geographically, occurring, however, in greatest abundance in tropical regions, and being wholly absent from the arctic zone. They are not capable of such migrations as are accomplished by birds and many mammals, but withstand severely hot or cold seasons by passing into a state of suspended animation or seasonal sleep or torpor.

The chief variations in body-form among the reptiles are manifest when a turtle, lizard, and snake are compared. In the turtles (fig. 178) the body is short, flattened, and heavy, and provided always with four limbs, each terminating in a five-toed foot; in the lizards the body is more elongate, and with usually four legs, but sometimes with two only, or even none at all; while in the snakes the long, slender, cylindrical body is legless, or at most has mere rudiments of the hinder limbs. With the reptiles, locomotion is as often effected by the bending or serpen-

FIG. 178.—A sea-turtle, *Chelone mydas*, common in tropic oceans. (This turtle is six feet long; drawn from a photograph by R. E. Snodgrass, made on the Galapagos Islands, Pacific Ocean.)

tine movements of the trunk as by the use of the legs. Among lizards and snakes the body is covered with horny epidermal scales or plates, while among the turtles and crocodiles there may be, in addition to the epidermal plates, a real deposit of bone in the skin whereby the effectiveness of the armor is increased. The epidermal covering of snakes and lizards is periodically moulted, or, as we say, the skin is shed. The bright colors and patterns of snakes and of many lizards are due to the presence and arrangement of pigment cells in the skin. Among some reptiles, notably the chameleons, the colors and markings can be quickly and radically changed by an automatic change in the tension of the skin.

Specimens of some pond or land turtle common in the vicinity of the school should be obtained. The red-bellied and yellow-bellied terrapins, or the painted or mud-turtles are common over most of the United States. They may be raked up from creek bottoms or fished for with

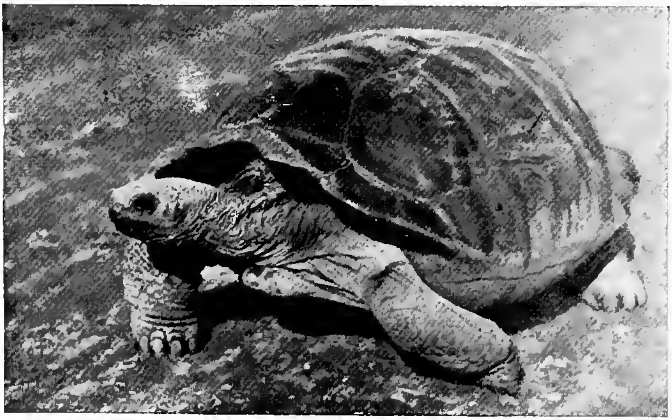


FIG. 179.—The giant land-tortoise of the Galapagos Islands, *Testudo* sp. These tortoises reach a length of four feet. (Photograph from life by Geo. Coleman from specimen brought to Stanford University by Snodgrass and Heller.)

strong hook and line, using meat as a bait. They will live through the winter, if kept in a cool place, without food or special care of any kind. Observe their swimming and diving, the retraction of head and limbs into the shell, the use of the third eyelid (nictitating membrane), and the swallowing of the air. Note the "shell," consisting of a dorsal plate, the carapace and ventral plate, plastron, and the lateral uniting parts, the bridge. Almost all the fresh-water and land turtles are carnivorous, but few catch any very active prey. While some are strictly aquatic others are as strictly terrestrial, never entering the water. The eggs of all are oblong and are deposited in hollows, sometimes covered in the sand. The newly hatched young are usually circular in shape, and differ in color and pattern from the adults.

The group of lizards (fig. 180) is a very large one, about 1500 species being known in the world, but it is represented in the United States by comparatively few species. Specimens of some species of the com-

FIG. 180.—A lizard in the grass. (Photograph from life by Cherry Kearton; permission of Cassell & Co.)

mon swift are obtainable almost anywhere in the United States. They may be looked for in woods, along fences, and especially on warm rocks. In certain regions the glass-snake or joint-snake is common. This lizard, popularly considered to be a snake, has no external limbs, and its tail is so brittle, the vertebræ composing it being very fragile, that part of it may break off at the slightest blow. In time a new tail is regenerated. It lives in the central and northern part of the United States, and burrows in dry places. In the western part of the country horned toads are common, about ten different species being known. These are lizards with shortened and depressed body and well-developed legs. The body is covered with protective spiny protuberances, and in individual color and pattern re-

FIG. 181.—The blue-tailed skink, *Eumeces skeltonianus*. (From living specimen.)

sembles closely the soil, rocks, and cactuses among which the particular horned toad lives. All the species of horned toads are viviparous, seven or eight young being born alive at a time.

In New Mexico, Arizona, and northern Mexico the only existing poisonous lizard, the Gila monster (fig. 182),

FIG. 182.—The Gila monster, *Heloderma horridum*, the only poisonous lizard. (One-fourth natural size; photograph from life by J. O. Snyder.)

is found. This is a heavy, deep-black, orange-mottled lizard about sixteen inches long. There is much variance of belief among people regarding the Gila monster, but recent experiments have proved the poisonous nature of the animal. The poison, which is secreted by the glands in the lower jaw, flows along the grooved teeth into the wound. A beautiful and interesting little lizard found in the south is the green chameleon. Its body is about three inches long, with a slender tail of about five or six inches. The normal color of the chameleon is grass-green, but it may "assume almost instantly shades varying from a beautiful emerald to a dark and iridescent bronze color."

About 1000 living species of snakes are known. Usually they have the body regularly cylindrical, and without distinct division into body-regions. Legs are wanting, locomotion being effected by the help of the scales and ribs. No snake can move forward on a perfectly smooth surface, and no snake can leap. In some forms, such as

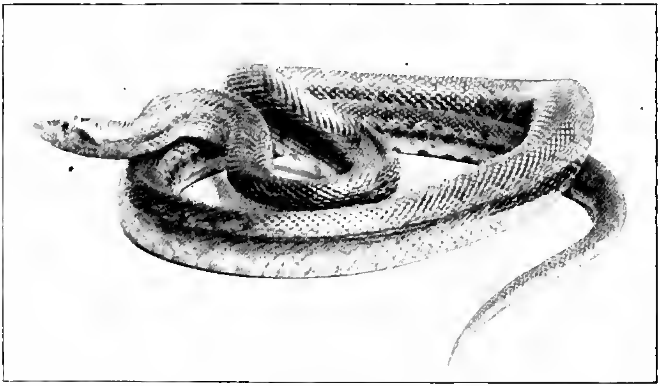


FIG. 183.—The gopher-snake, *Pituophis bellona*. (Photograph from life by J. O. Snyder.)

the pythons, external rudiments of the hind limbs are present, but do not aid in locomotion. The mouth is large and distensible, so that prey of considerably greater size than the normal diameter of the snake's body is frequently swallowed whole. The sense of taste is very little if at all developed, as the food is swallowed without mastication. The tongue, which is protrusible, and usually red or blue-black, serves as a special organ of touch. Hearing is poor, the ears being very little developed. The sense of sight is also probably not at all keen. Snakes rely chiefly on the sense of smell for finding their prey and their mates. The colors of snakes are often brilliant, and in many cases serve to produce an effective protective resemblance by harmonizing with the usual surroundings of the animal. The food of snakes consists almost exclusively of other animals, which are caught alive. Some of the poisonous snakes kill their prey before swallowing it, as do some of the constrictors. While most snakes

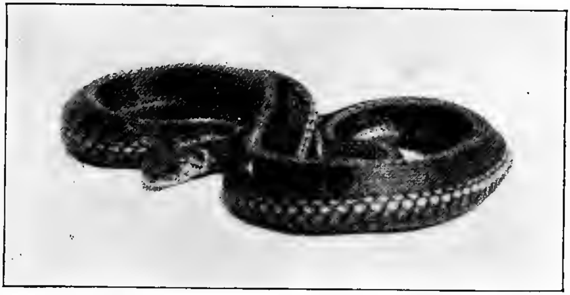


FIG. 184.—A garter-snake, *Thamnophis parietalis*. (Photograph from life by J. O. Snyder.)

live on the ground, some are semi-arboreal and others spend part or all of their time in the water. Cold-region snakes spend the winter in a state of suspended animation; in the tropics, on the contrary, the hottest part of the year is spent by some species in a similar "sleep."

Among the commonest members of this group are the garter-snakes (fig. 184), always striped, and not more than three feet long. The most widespread species is rather dully colored, with three series of small dark spots along each side. The common water-snake is brownish, with back and sides each with a series of about eighty large, square, dark blotches alternating with each other. It feeds on fishes and frogs, and, although unpleasant and ill-tempered, is harmless. One of the prettiest and most gentle of snakes is the familiar little green-snake, common in the East and South in moist meadows and in bushes near the water. It feeds on insects, and can be easily kept alive in confinement. A familiar larger snake is the black-snake, or "blue-racer," lustrous pitch-black, general color greenish below, and with white throat. It is "often found in the neighborhood of water, and is particularly partial to the thickets of alders, where it can hunt for toads, mice, and birds, and, being an excellent climber, it is often seen among the branches of small trees and bushes, hunting for young birds in the nest." The chain-snake of the Southeast and the king-snake (fig. 185) of the Central States are beautiful, lustrous, black-and-yellow-

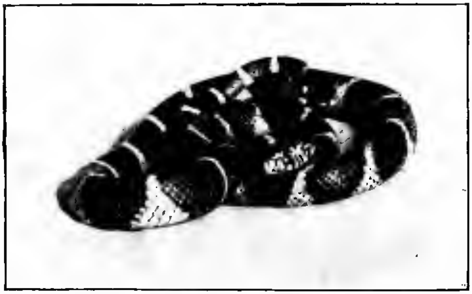


FIG 185.—A king-snake, *Lampropeltis boylii*. (Photograph from life by J. O. Snyder.)

spotted snakes, which feed not only on lizards, salamanders, small birds, and mice, but also on other snakes. The king-snake should be protected in regions infested by "rattlers." The spreading-adder, or blowing-viper, a common snake in the Eastern States, brownish or reddish, with dark dorsal and lateral blotches, depresses and expands the head when angry, hissing and threatening. Despite the popular belief in its poisonous nature this ugly reptile is quite harmless. It specially infests dry and sandy places.

With the exception of the coral- or bead-snake, a rather small, jet-black snake, with seventeen broad, yellow-bordered crimson rings, found in the Southern States, the only poisonous snakes of the United States are the rattlesnakes and their immediate relatives, the copperhead and water-moccasin. These snakes all have a large triangular head, and in the rattlesnakes the posterior tip of the body is provided with a "rattle," composed of a series of partly overlapping, thin, horny capsules, or cones, of shape as shown in fig. 186. These horny pieces are simply the somewhat modified, successively formed epidermal coverings of the tip of the body, which instead of being entirely moulted as the rest of the skin is, are, because of their peculiar shape, loosely attached to one another, and by the basal one to the body of the snake. The number of rattles does not correspond to the snake's years for several reasons, partly because more than one rattle can be added in a year, and especially because rattles are easily and often broken off. As many as thirty rattles have been found on one snake. There are two species of ground-rattlesnakes, or massasaugas, in the United States, and ten species of the true rattlesnakes. The center of distribution of the rattlesnakes is the dry tablelands of the Southwest in New Mexico, Arizona, and Texas. But there are few localities in the United States outside the high mountains in which "rattlers" do not occur, or did not occur before they were exterminated by man. The copperhead is light chestnut in color, with inverted Y-shaped darker blotches on the sides, and seldom exceeds three feet in length. It occurs in the

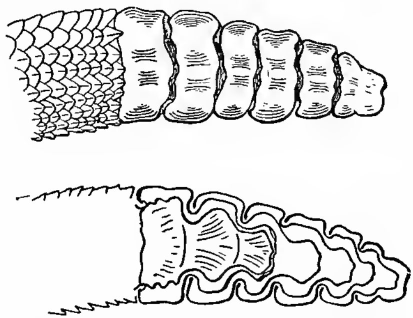


FIG. 186.—The rattles of the rattlesnake; the lower figure shows a longitudinal section of the rattle.

Eastern and Middle United States, from Pennsylvania and Nebraska southward. It is a vicious and dangerous snake, striking without warning. The water-moccasin is dark chestnut-brown, with darker markings. The head is purplish-black above. It is found along the Atlantic and Gulf coasts from North Carolina to Mexico, extending also some distance up the Mississippi valley. It is distinctively a water-snake, being found in damp, swampy places or actually in water. It reaches a length of over four feet, and is a very venomous snake, striking on the slightest provocation. The common, harmless water-snake is often called water-moccasin in the Southern States, being popularly confounded with this most dangerous of our serpents. The poison of all of these snakes is a rather yellowish, transparent, sticky fluid, secreted by glands in the head, from which it flows through the hollow maxillary fangs. The character and position of the fangs are shown in fig. 187. Remedial measures for the bite of poisonous snakes are, first, to stop, if possible, the flow of blood from the wound to the heart by compressing the veins between the wound and the heart; then (if the lips are unbroken) to suck the poison from the wound; next to introduce by hypodermic injection permanganate of potash, bichloride of mercury, or chromic acid into the wound; and finally, perhaps, to take some strong stimulant, as brandy or whiskey.

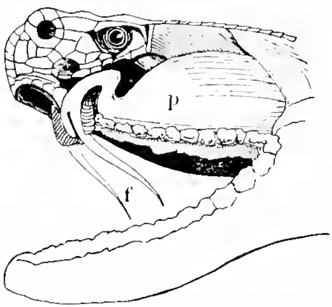


FIG. 187.—Dissection of head of rattlesnake; *f*, poison-fangs; *p*, poison-sac.

The crocodiles and alligators are reptiles familiar by name and appearance, though seen in nature only by the inhabitants or visitors in tropical and semi-tropical lands.

In the United States there are two species of these great reptiles: the American crocodile, living in the West Indies and South America, and occasionally found in Florida; and the American alligator, common in the morasses and stagnant pools of the Southern States. The alligator differs from the crocodiles in having a broader snout. It is rarely more than twelve feet long. The best-known crocodile is the Nile crocodile, which is not limited to the Nile, but is found throughout Africa. In the Ganges of India is found another member of this group of reptiles, called the gavial. It is among the largest of the order, reaching a length of twenty feet. The crocodiles, alligators, and gavials comprise not more than a score of species altogether, but because of their wide distribution, great size, and carnivorous habits they are among the most conspicuous of the larger living animals. They live mostly in the water, going on land to sun themselves or to lay their eggs. They move very quickly and swiftly in water, but are awkward on land. Fish, aquatic mammals, and other animals which occasionally visit the water are their prey. The gavial and Nile crocodile are both known to attack and devour human beings, and these species annually cause a considerable loss of life. But few such fatalities, however, are accredited to the American alligator.

CHAPTER XV

BIRDS

The English sparrow.—We have already studied (Chapter V) the external parts of a bird, the English sparrow, and have thus become acquainted with the superficial characteristics of a bird's body. The life-history and habits of the sparrow can also be readily observed, and will serve as an introduction to the study of the life-history of more interesting birds.

The English sparrow was first introduced into the United States in 1850, and since that time has rapidly populated most of the cities and towns of the country. On account of its extreme adaptability to surroundings, its omnivorous food-habits, and its fecundity, it survives where other birds would die out. It also crowds out and has caused the disappearance or death of other birds more attractive and more useful. The sparrow annually rears five or six broods of young, laying from six to ten eggs at each sitting. Unmolested a single pair would multiply to a most astonishing number. It has, however, many enemies, most common among them perhaps being the "small boy," but birds and mammals play the chief part in the destruction. The smaller hawks prey upon it, and rats and mice destroy great numbers of its young and of its eggs whenever the nests can be reached. The sparrow is omnivorous and when driven to it is a loathsome scavenger, though at other times its tastes are for dainty fruits. Its senses of perception are of the keenest;

it can determine friend or foe at long range. The nesting habits are simple, the nests being roughly made of any sort of twigs and stems mixed with hair and feathers and placed in cornices or trees. A maple-tree in a small

FIG. 188.—Cardinal grosbeak, or redbird (*Cardinalis cardinalis*). (One-half natural size; from life.)

Missouri town contained at one time thirty-seven of these nests.

The beginning study of birds.—In Chapter III are given directions for the observation of the nesting habits of birds. Such observations constitute probably the best kind of beginning in bird-study, but certain other phases will suggest themselves at once to the student. One will need to recognize the different common kinds of birds and to know their names; also to learn the facts about the annual history of each familiar one, finding out if it lives in the neighborhood of the school all the year, or in summer alone or winter alone, or is only a bird of passage, a migrant, appearing in the spring and

FIG. 189.—The nest and eggs of the black phœbe, *Sayornis nigricans*. (Photograph by J. O. Snyder.)

autumn for a brief period each year. There will be interesting observations to be made on the food habits of each kind, the getting acquainted with its calls and song, its manner of flight, and the special details of its nest-making and care of young. In the following paragraphs are given suggestions for the guidance of the student in all of these different phases of bird-study. So many books about bird-life have been published recently that no trouble should be experienced in finding such guides to further study along any or all of the lines pointed out in this chapter.

Classification and identification.—The class of birds, Aves, is divided into various orders, of which seventeen are represented in North America. There are eight hundred (approximately) different species of North American birds, but in any one locality not more than about a third of these species can be found, and of these only comparatively few are common or numerous. So that to learn the common birds of a single locality is not a

FIG. 190.—Western chipping sparrow, *Spizella socialis arizonæ.* (Photograph from life by Eliz. and Jos. Grinnell.)

large matter; it means getting acquainted with perhaps fifty or sixty different kinds. As birds can usually be readily identified by their size and shape, and the color pattern of their plumage, this class is especially well adapted for the beginning study of systematic zoology, which concerns the identification and classification of species.

To identify the various species of birds in the locality of the school it will be necessary to have some book giving the descriptions of all or most of the species of the region, with tables and keys for tracing out the different forms. The best general manual is Coues' "Key to the Birds of North America," which includes not only keys for tracing and descriptions of all the known species of birds on this continent, but also accounts of the distribution, of the nesting and eggs, and of the plumage of the young birds, besides a thorough introduction to the anat-

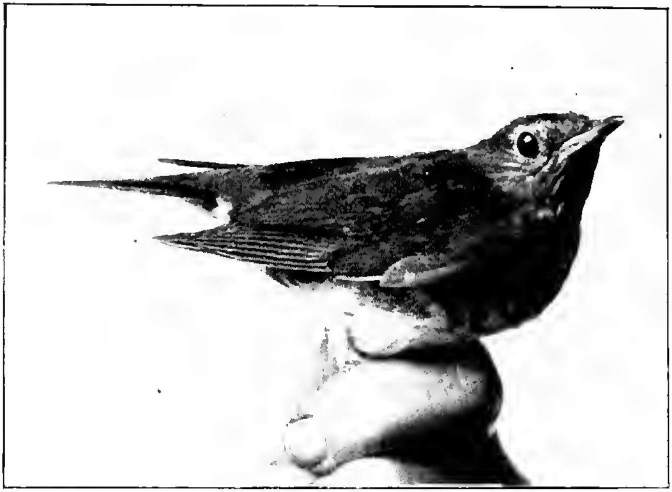


FIG. 191.—Russet-backed thrush, *Turdus ustulatus*. (Photograph from life by Eliz. and Jos Grinnell.)

omy and physiology of birds, and directions for collecting and preserving them. Jordan's "Manual of Vertebrates" gives keys and compact but clear descriptions of the birds found east of the Missouri River; Chapman's "Handbook of the Birds of Eastern North America," and Florence Bailey's "Birds of the Western States," are excellent. To use these manuals effectively it is necessary to have the bird's body in hand; and that means usually death for the bird. Recently there have been published several bird-keys which attempt to make it possible to determine species, the commoner ones at any rate, by examination of the living bird in the trees by means of an opera-glass, or often with the unaided eye. Chapman's "Bird-Life" is an example of the better sort of these books. From this the following is quoted:

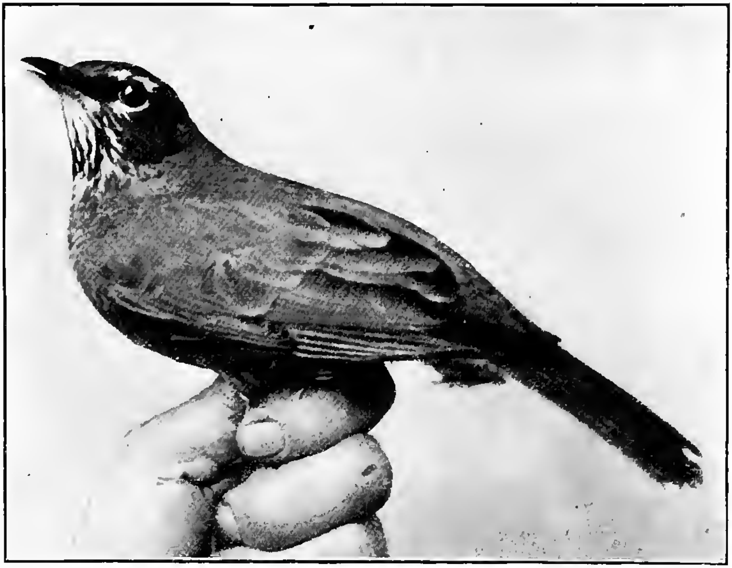


FIG. 192.—Western robin, *Merula migratoria propinqua*. (Photograph from life by Eliz. and Jos. Grinnell.)

"We come now to the practical question of identification. How are we to find birds, and having found them, how are we to learn their names?

"From April to August there is probably not a minute of the day when in a favorable locality one cannot see or hear birds; and there is not a day in the year when at least some birds cannot be found. In the beginning, therefore, the question of finding them is simply a matter of looking and listening. Later will come the delightful hunts for certain rarer species whose acquaintance we may make only through a knowledge of their haunts and habits.

"Having found your bird, there is one thing absolutely necessary to its identification; you must see it definitely.

FIG. 193.—Sickle-billed thrasher, *Harporhynchus redivivus*. (Photograph from life by Eliz. and Jos. Grinnell.)

Do not describe a bird to an ornithologist as 'brown, with white spots on its wings,' and then expect him to tell you what it is. Would you think of trying to identify flowers of which you caught only a glimpse from a car-window in passing? You did not see them definitely, and at best you can only carry their image in your mind until you have opportunity to see them in detail.

FIG. 194.—Nest and eggs of ruby-throat humming-bird, *Trochilus colubris*, seen from above, in apple-tree. (Photograph by E. G. Tabor; permission of Macmillan Co.)

"So it is with birds. Do not be discouraged if the books fail to show you the brown bird with white spots on its wings. Probably it exists only through your hasty observation.

"Arm yourself with a field- or opera-glass, therefore, without which you will be badly handicapped, and look your bird over with enough care to get a general idea of its size, form—particularly the form of the bill—color, and markings. Then—and I cannot emphasize this too strongly—put what you have seen into your notebook at once. For, as I have elsewhere said, 'not only do our memories sometimes deceive us, but we really see nothing with exactness until we attempt to describe it.'

"It is true that all the birds will not pose before your glasses long enough for you to examine them at your leisure, but many of them will, and in following the others you will have all the excitement of the chase. Who knows what rare species the stranger may prove to be!

"From your description, and what added notes on voice and actions you may obtain, the field-key and illus-

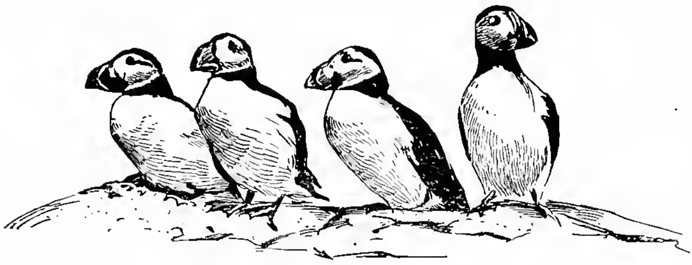


FIG. 195.—Puffins. (After photograph from life by C. Kearton.)

trations on the succeeding pages should make identification a simple matter."

Birds and the seasons.—In trying to become acquainted with the birds of a locality it must be borne in mind that the bird-fauna of any region varies with the season. Some birds live in it all the year through; these are called residents. Some spend only the summer or breeding season in the locality, coming up from the South in spring and flying back in autumn; these are summer residents. Some spend only the winter in the locality, coming down from the severer North at the beginning of winter, and going back with the coming of spring; these are winter residents. Some are to be found in the locality only in spring and autumn, as they are migrating north and south between their tropical winter quarters and their northern summer or breeding home; these are migrants. And, finally, an occasional representative of certain bird species, whose normal range does not include the given locality at all, will appear now and then, blown aside from its regular path of migration, or otherwise astray; these are visitants. As to the relative importance, numerically, of these various categories among the birds which may be found in a certain region, and thus form its bird-fauna, we may illustrate by reference to a definite region. Of the 351 species of birds which have been found in the State of Kansas (a region without distinct natural boundaries, and fairly representative of any Mississippi valley region of similar extent), 51 are all-year residents, 125 are summer residents, 36 are winter residents, 104 are migrants, and 35 are rare visitants.

The all-year residents and the summer residents, comprising about one-half of the species to be found in a locality are the only ones which breed there, and which thus present opportunity for observations on their nest-building habits and care of the young. Numerous suggestive questions present themselves in connection with breeding in addition to the simpler ones already propounded in Chapter III. Why is it that some species nest early and some late? Can the character of the food of the young have anything to do with this? If so, how? Does the condition of the particular trees, bushes or other favorite sites for nests help determine the nesting time? Why should some birds raise but one brood a year, and others two or even three? Does the fact that a bird is an all-year resident or only a summer resident have any influence in determining its nesting time and the number of broods it rears? Compare the habits of the various breeding species of the locality, and find out if the summer residents have any breeding habits in common as distinguished from the all-year residents.

Observe the behavior of the birds in courting time. Do the males have "singing contests," as is sometimes reported? Do they fight with each other? Do the males or females show any differences, at this time, from their more usual plumage? After mating which bird selects the nesting site? Are old nesting sites preferred to new ones? If two broods are reared is a new nest built? What are the principal causes of mortality among the eggs and young during the breeding season? What instincts or habits of the parents have direct reference to these dangerous conditions? What means of protecting the nest are resorted to? What is the behavior of the parents towards enemies of the young?

FIG. 196.—Razorbill auk and egg. (After photograph from life by C. Kearton.)

As explained in Chapter XXI, the geographical distribution of animals is a subject of much importance, and offers good opportunities in its more local features for student field-work. The field-study of the birds of a given locality will comprise much observation bearing directly on zoogeography, or the distribution of animals. Certain birds will be found to be limited to certain parts of even a small region; the swimmers will be found in ponds and streams, and the long-legged shore-birds on the pond- or stream-banks, or in the marshes and wet meadows, although a few, like the upland-plover, curlews, and godwits are common on the dry upland pastures. Distinguish the ground-birds from the birds of the shrubs and hedge-rows, and these again from the strictly forest-birds. Find the special haunts of swallows and kingfishers. Which are the shy birds driven constantly deeper into the wild places, or being exterminated by the advance of man? Which birds do not retreat, but even find an advantage in man's seizure of the land, obtaining food from his fields and gardens?

Make a map on large scale of the locality of the school, showing on it the topographic features of the region, such as streams, ponds, marshes, hills, woods, springs, wild pastures, etc., also roads and paths, and such landmarks as schoolhouses, country churches, etc. On this map indicate the local distribution of the birds, as determined by the data gradually gathered; mark favorite nesting-places of various species, roosting-places of crows and blackbirds, feeding-places, and bathing- and drinking-places of certain kinds, the exact spots of finding rare visitants, rare nests, etc.

As already mentioned, many of the birds of a locality are "migrants," that is, they breed farther north, but spend the winter in more southern latitudes. These migrants pass through the locality twice each year, going North in the spring and South in the autumn. They are much more likely to be observed during the spring migration than in the fall, as the flight South is usually more hurried. The observation of the migration of birds is very interesting, and much can be done by beginning students. Notes should be made recording the first time each spring a migrating species is seen, the time when it is most abundant, and the last time it is seen the same spring. Similar records should be made showing the movements of the birds in the fall. A series of such records, covering a few years, will show which are the earliest to appear, which the later, and which the last. Such records of appearance and disappearance should also be kept for the summer residents, those birds that come from the South in the spring, breed in the locality, and then depart for

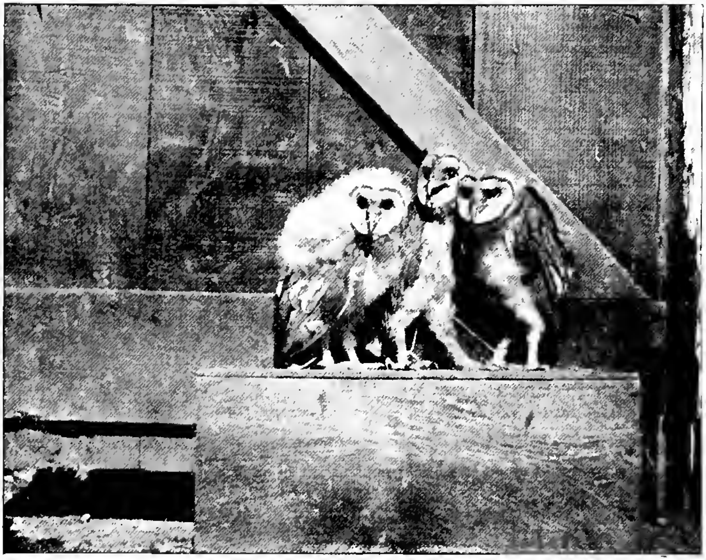


FIG. 197.—Young barn-owls. (Photograph by Geo. Towne; permission of The Condor.)

the South again in the autumn. Notes on the kinds of days, as stormy, clear, cold, warm, etc., on which the migration seems to be most active; on the greater prevalence of migratory flights by day or by night; on the height from the earth at which the migrants fly, etc., are all worth while. For an excellent simple account of migration see Chapman's "Bird-Life," Chapter IV. A book about migration, and one giving the records for many species at many points in the Mississippi Valley, is Cooke's "Bird Migration in the Mississippi Valley."

It must also be kept in mind in using bird-keys and descriptions to determine species that the descriptions and

FIG. 198.—Nest of buff-breasted flycatcher, *Empidonax fulvifrons pygmæus*, on cone of pine-tree. (Photograph by R. D. Lusk; permission of The Condor.)

keys refer to adult birds, and in ordinary plumage. Among numerous birds the young of the year, old enough to fly and as large as the adults, still differ considerably in plumage from the latter; males differ from females, and finally both males and females may change their plumage (hence color and markings) with the season. The seasonal changes of plumage accomplished by moulting may be marked or hardly noticeable. "All birds get new suits at least once a year, changing in the fall. Some change in the spring also, either partially or wholly, while others have as many as three changes—perhaps, to a slight extent, a few more. . . . It is claimed by some that now all new colors are acquired by moult, and by others that in some instances (young hawks) an infusion or loss, as the case may be, of pigment takes place as the feather forms, and continues so long as it grows."

There is much lack and uncertainty of knowledge concerning the moulting and change of plumage by birds, and careful observations by bird-students should be made on the subject.

The uses of colors and patterns in animals are discussed in Chapter XVIII. For accounts of the plumage and color of birds see Chapter III in Chapman's "Bird-Life," and Chapters VIII and IX in Baskett's "Story of the Birds."

Structure and habit.—In connection with learning the different kinds of birds in a locality, observations should be made, and notes of them recorded, on their habits, and on their external structure and its relation to the habits of the bird. The interesting adaptation of structure to special use is particularly well shown in the varying character of the bill and feet of birds. The various feeding habits and uses of the feet of different birds are readily observed, and the accompanying modification of bills and feet can be readily seen in birds either freshly killed or preserved as "bird-skins." Such skins may be made as directed on p. 338, or may be bought cheaply of taxidermists. A set of such skins, properly named, will be of great help in studying birds, and should be in the high-school collection. In some cases the general structure of feet and bills may be seen in the live birds by the use of an opera-glass. The characters of bills and feet are much used in the classification of birds, so that any knowledge of them gained primarily in the study of adaptations will have a secondary use in classification work.

FIG. 199.—Ostriches on ostrich-farm at Pasadena, California. (Photograph from life.)

Note the foot of the robin, bluebird, catbird, wren, warbler, and other passerine or perching birds. It has three unwebbed toes in front and a long hind toe perfectly opposable to the middle front one. This is the perching foot. Note the so-called zygodactyl foot of the woodpecker, with two toes projecting in front and partly yoked together, and two similarly yoked projecting behind. Note the webbed swimming-foot of the aquatic birds; note the different degrees of webbing, from the totipalmate, where all four toes are completely webbed, palmate, where the three front toes only are bound together but the web runs out to the claws, to the semipalmate, where the web runs out only about half-way.

FIG. 200.—Young ostriches just from egg, at ostrich-farm at Pasadena, California. (Photograph from life.)

Note the lobate foot of the coots and phalaropes. Note the long, slender, wading legs of the sandpipers, snipe, and other shore-birds; the short, heavy, strong leg of the divers; the small, weak leg of the swifts and humming-birds, almost always on the wing; the stout, heavily nailed foot of the scratchers, as the hens, grouse, and turkeys; and the strong, grasping talons, with their sharp, long, curving nails, of the hawks and owls, and other birds of prey. In all these cases the fitness of the structure of the foot to the special habits of the bird is apparent.

Similarly the shape and structural character of the bill should be noted, as related to its use, this being chiefly concerned of course with the feeding habits. Note the strong, hooked, and dentate bill of the birds of prey; they

FIG. 201.—The yellowhammer, *Colaptes auratus*. (Photograph by W. E. Carlin; permission of G. O. Shields.)

tear their prey. Note the long, slender, sensitive bill of the sandpipers; they probe the wet sand for worms. Note the short, weak bill and wide mouth of the night-hawk and whippoorwill, and of the swifts and swallows; they catch insects in this wide mouth while on the wing. Note the flat, lamellate bill of the ducks; they scoop up mud and water and strain their food from it. Note the firm, chisel-like bill (fig. 201) of the woodpeckers; they bore into hard wood for insects. Note the peculiarly crossed mandibles of the cross-bills; they tear open pine cones for seeds. Note the long, sharp, slender bill of the hum-

FIG. 202.—Screech-owl, *Megascops asio*. (Photograph by A. L. Princeton; permission of Macmillan Co.)

ming-birds; they get insects from the bottom of flower-cups. Note the bill and foot of any bird you examine, and see if you can recognize their special adaptation to the habits of the bird.

The most casual observation of birds reveals differences in the flight of different kinds so characteristic and distinctive as to give much aid in determining the identity of birds in nature. Note the flight of the woodpeckers; it identifies them unmistakably in the air. Note the rapid beating of the wings of quail and grouse; also of wild ducks; the slow, heavy, flapping of the larger hawks and owls, and of the crows; and the splendid soaring of the turkey-buzzard and of the gulls. This soaring has been the subject of much observation and study, but is

FIG. 203.—Gulls soaring. (Photograph by Otto von Bargen, on San Francisco Bay; permission of Camera Craft.)

still imperfectly understood. The soaring bird evidently takes advantage of horizontal air-currents, and some observers maintain that upward currents also must be present. The principal hopes for the invention of a successful flying-machine rest on the power of soaring possessed by birds. The speed of flight of some birds is enormous, the passenger-pigeon having been estimated to attain a speed of one hundred miles an hour. The long distances covered in a single continuous flight by certain birds are also extraordinary, as is also the total distance covered by some of the migrants. The differences in the structural character of the wings should be noted in connection with the observation of the differences in flight habit.

The tongues and tails of birds are two other structures the modifications and special uses of which may be readily observed and studied. Note the structure and special use of the tongue and tail (fig. 201) of the woodpeckers; note the tongue of the humming-bird; the tail of the grackles.

Feeding habits, economics, and protection of birds.— The feeding habits of birds are not only interesting, but their determination decides the economic relation of birds to man, that is, whether a particular bird species is harmful or beneficial to man. Casual observation shows that birds eat worms, grains, seeds, fruits, insects. A single species often is both fruit-eating and insect-eating. Do fruits or do insects compose the chief food-supply of the species? To determine this more than casual observation is necessary. The birds must be watched when feeding at different seasons. The most effective way of determining the kind of food which the bird takes is to examine the stomach of many individuals taken at various times and localities. Much work of this kind has been done, especially by investigators connected with the Division of Biological Survey of the United States Department of Agriculture, and pamphlets giving the results of these investigations can be had from the Division. It has been distinctly shown that a great majority of birds are chiefly beneficial to man by eating noxious insects and the seeds of weeds. Most birds commonly reputed to be harmful, and for that reason shot by farmers and fruit-growers, have been proved to do much more good than harm. Some few birds have been proved to be, on the whole, harmful. An investigation of the food habits of the crow, a bird of ill-repute among farmers, based on an examination of 909 stomachs, shows that about 29 per cent of the food for the year consists of

FIG. 204.—Horned larks, *Otocoris alpestris*, and snowflakes, *Plectrophenax nivalis*. (Photograph from life by H. W. Menke; permission of Macmillan Co.)

grain, of which corn constitutes something more than 21 per cent, the greatest quantity being eaten in the three winter months. All of this must be either waste grain picked up in fields and roads, or corn stolen from cribs and shocks. May, the month of sprouting corn, shows a slight increase over the other spring and summer months. On the other hand, the loss of grain is offset by the destruction of insects. These constitute more than

23 per cent of the crow's yearly diet, and the larger part of them are noxious. The remainder of the crow's food consists of wild fruit, seeds, and various animal substances which may on the whole be considered neutral.

The slaughter of birds for millinery purposes has become so fearful and apparent in recent years that a strong movement for their protection has been inaugurated. Rapacious egg-collecting, legislation against birds wrongly thought to be harmful to grains and fruit, and the selfish wholesale killing of birds by professional and amateur hunters, help in the work of destruction. Apart from the brutality of such slaughter, and the extermination of the most beautiful and enjoyable of our animal companions, this destruction works strongly against our material interests. Birds are the natural enemies of insect pests, and the destroying of the birds means the rapid increase and spread, and the enhanced destructive power of the pests. It is asserted by investigators that during the past fifteen years the number of our common song-birds has been reduced to one-fourth. At the present rate, says one author, extermination of many species will occur during the lives of most of us. Already the passenger-pigeon and Carolina paroquet, only a few years ago abundant, are practically exterminated. Protect the birds!

CHAPTER XVI

MAMMALS

The mammals constitute the highest group of animals, including man, the monkeys and apes, the bird-like bats and fish-like seals and whales, and all the various beasts we commonly call quadrupeds; altogether about 2,500 known species. They are found in all parts of the world except on a few small South Sea islands. The name mammals is derived from the mammary or milk glands which enable the mothers to suckle their young. In size mammals range from the tiny pigmy shrew and harvest-mouse which can climb a stem of wheat, to the great sulphur-bottom whale of the Pacific Ocean, that attains a length of a hundred feet and a weight of many tons. Mammals differ from fishes and batrachians and agree with reptiles and birds in never having external gills; they differ from reptiles and agree with birds in being warm-blooded and in having a heart with two distinct ventricles and a complete double circulation; finally, they differ from both reptiles and birds in having the skin more or less clothed with hair, the lungs freely suspended in a thoracic cavity separated from the abdominal by a muscular partition, the diaphragm, and in the possession by the females of mammary glands. In economic uses to man mammals are the most important of all animals. They furnish a great portion of the animal food of many human races, likewise a large amount of their clothing. Horses, asses, oxen, camels, reindeer, elephants, and llamas are beasts of burden and draught; swine, sheep, cattle, and goats furnish flesh, and the two latter milk, for food; the wool of sheep, the furs of the carnivores, and the leather of cattle, horses, and others are used for clothing, while the bones and horns of various mammals serve many useful purposes.

FIG. 205.—Chipmunk. (Permission of Camera Craft.)

The house-mouse; an example.—Specimens of the house-mouse should be obtained by trapping, and its external structure compared with that of the frog and sparrow. The mouse, unlike the other vertebrates so far studied, is thickly covered with hair all over its body except on the tip of the nose and the soles of the feet. Where are the nostrils placed? What are the large leaf-like expansions, called pinnæ, situated just back of the eyes? Pull open the mouth and note the large incisor teeth on the upper and lower jaws. Cut one corner of the mouth back and observe the large flat-topped molar teeth on both jaws. How does the attachment of the large fleshy tongue differ from the condition in the toad? The toad's tongue is for snapping up insects, whereas in the mouse this organ serves to move food about in the mouth. On the tongue are numerous small taste-papillæ. Notice the long hairs, "feelers," on each side of the nose. Note the similarity between the front paws and our own hands; each has four fingers, with a small rudimentary thumb on the inner side of the paw. How does the hind foot of the mouse differ from the foot of man? Posteriorly the body is terminated by a long tail.

The house-mouse is not a native of North America, but was introduced from Europe, to which, in turn, it came from Asia, its original habitat. The mouse came to this country in the vessels of early explorers. Similarly the brown and black rats, now so abundant all over North America, and members of the same genus as the mouse, were introduced from Europe. Accompanying man in his travels the mouse has spread from Asia until it is now to be found over the whole world.

The habits of mice are well known, their fondness for living in our homes and outbuildings making them familiar acquaintances. Their food is varied; they seem to thrive best, however, on a vegetable diet. Grains and nuts are favorite foods. The house-cat is their greatest enemy, but man takes advantage of their instinct to go into holes by constructing traps with funnel or tunnel entrances, which, baited with cheese or other favorite food, are fatally attractive. In climbing, mice are aided by the tail. Their strong hind legs enable them to stand erect, and even to take several steps in this posture. They can swim readily, although naturally they rarely take to water. Their special senses are keen, the senses of hearing and taste being unusually well developed. Their "singing," which has been the subject of much discussion, seems to be actually a voluntary and normal performance, which, however, hardly deserves to be called singing, but rather a slightly varied peeping or whistling.

The mouse is a prolific mammal, producing from four to six times a year broods of from four to eight young. A cozy nest of straw, bits of paper, feathers, wool, or other soft materials is made, and in this the young are born. The newly born mice are very small and are blind and helpless. They are odd little creatures, being naked and almost transparent. They grow rapidly, being covered with hair in a week, although not opening their eyes for about two weeks. A day or two after their eyes are open they begin to leave the nest, and hunt for food for themselves.

Classification.—The mammals of North America represent eight orders. Three additional orders, namely, the Monotremata, including the extraordinary duckbills of Australia, the Edentata, including the sloths, armadillos and ant-eaters found in tropical regions, and the Sirenia, including the marine manatees and dugongs are not represented (except by a single manatee) in North America. In the following paragraphs some of the more familiar mammals representing each of the eight orders represented in North America are referred to.

The opossums and kangaroos (Marsupialia).—The opossum (*Didelphys virginiana*) is the only North American representative of the order Marsupialia, the other members of which are limited exclusively to Australia and certain neighboring islands. The kangaroos are the

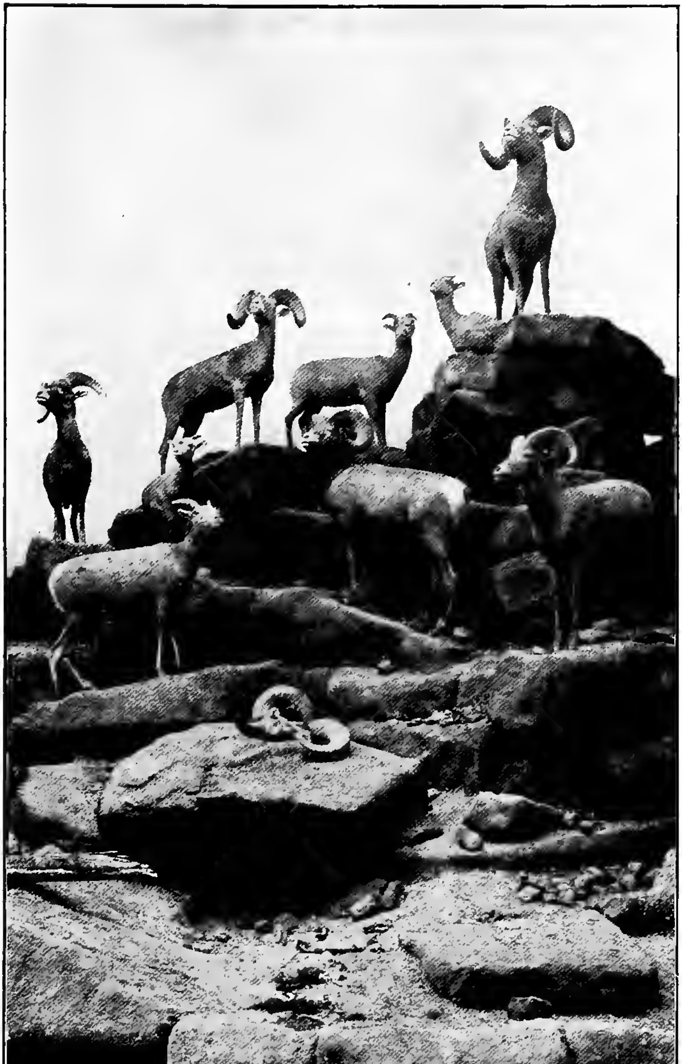


FIG. 206.—A group of Rocky Mountain sheep, or "big horns," *Ovis canadensis*, including males, females, and young. (Photograph by E. Willis from specimens mounted by Prof. L. L. Dyche, University of Kansas.)

best known of the foreign marsupials. The members of this order are characterized by the birth of the young while very small and incompletely developed, and the transference of the young to an external pouch, the marsupium, in which they are carried for a longer or shorter time. The opossum lives in trees, is about the size of a common cat, and has a dirty-yellowish woolly fur. Its tail is long and scaly, like a rat's. Its food consists chiefly of insects, although small reptiles, birds, and bird's eggs are eaten. When ready to bear young the opossum makes a nest of dried grass in the hollow of a tree, and produces about thirteen very small (half an inch long) helpless creatures. These are then placed by the mother in her pouch, where each clings to a teat. Here they remain until two months or more after birth. Probably all the North American opossums, found from New York to California, and especially common in the Southern States, belong to a single species, but there is much variety among the individuals.

The rodents or gnawers (Glires).—The rabbits, porcupines, gophers, chipmunks, beavers, squirrels, and rats and mice compose the largest order among the mammals. They are called rodents or gnawers (Glires) because of their well-known gnawing powers and proclivities. The special arrangement and character of the teeth are characteristic of this order. There are no canines, a toothless space being left between the incisors and molars on each side. There are only two incisor teeth in each jaw (rarely four in the upper jaw), and these teeth grow continuously and are kept sharp and of uniform length by the gnawing on hard substances and the constant rubbing on each other. The food of rodents is chiefly vegetable.

Of the hares and rabbits the cottontail (*Lepus nuttalli*) and the common jack-rabbit (*L. campestris*) are the best known. The cottontail is found all over the United

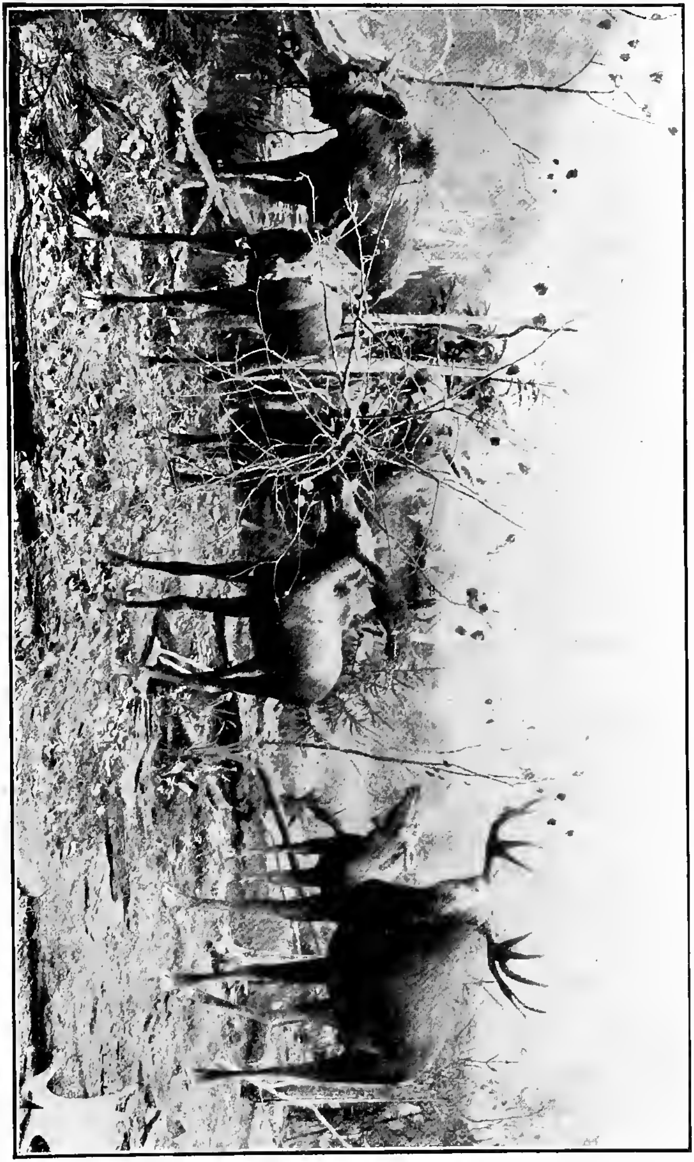


FIG. 207.—A group of moose, *Alce americana*, showing male, female, and young. (Photograph by E. Willis from specimens mounted by Prof. L. L. Dyche, University of Kansas.)

States, but shows some variation in the different regions. There are several species of jack-rabbits, all limited to the plains and mountain regions west of the Mississippi River. The food of rabbits is strictly vegetable, consisting of succulent roots, branches, or leaves. Rabbits are very prolific, and yearly rear from three to six broods of from three to six young each. There are two North American species of porcupines—an Eastern one, *Erethizon dorsatus*, and a Western one, *E. epixanthus*. The quills in both these species are short, being only an inch or two in length, and are barbed. In some foreign porcupines they are a foot long. They are loosely attached in the skin, and may be readily pulled out, but they cannot be shot out by the porcupine, as is popularly told. The little guinea-pigs (*Cavia*), kept as pets, are South American animals related to the porcupines.

The pocket gophers, of which there are several species, mostly inhabiting the central plains, are rodents, found only in North America. They all live underground, making extensive galleries and feeding chiefly on bulbous roots. The mice and rats constitute a large family, of which the house-mice and rats, the various field-mice, the wood-rat (*Neotoma pennsylvanica*), and the muskrat (*Fiber zibethicus*) are familiar representatives. The common brown rat (*Mus decumanus*) was introduced into this country from Europe about 1775, and has now nearly wholly supplanted the black rat (*M. rattus*), also a European species, introduced about 1544. The beaver (*Castor canadensis*) is the largest rodent. It seems to be doomed to extermination through the relentless hunting of it for its fur. The woodchuck or ground-hog (*Arctomys monax*) is another familiar rodent, larger than most members of the order. The chipmunks (fig. 205) and ground-squirrels are commonly known rodents found all over the country. They are terrestrial members of the squirrel family, the best known arboreal members of which are the red squirrel (*Sciurus hudsonicus*), the fox squirrel (*S. ludovicianus*), and the gray or black squirrel (*S. carolinensis*). The little flying squirrel (*Sciuropterus volans*) is abundant in the Eastern States.

The shrews and moles (Insectivora).—The shrews and moles are all small carnivorous animals, which, because of their size, confine their attacks chiefly to insects. The shrews are small and mouse-like; certain kinds of them lead a semi-aquatic life. There are nearly a score of species in North America. Of the moles, of which there are but few species, the common mole (*Scalops aquaticus*) is well known, while the star-nosed mole (*Condylura cristata*) is recognizable by the peculiar rosette of about twenty cartilaginous rays at the tip of its snout. Moles live underground, and have the fore feet wide and shovel-like for digging. The European hedgehogs are members of this order.

The bats (Chiroptera).—The bats (fig. 209), order Chiroptera, differ from all other mammals in having the fore

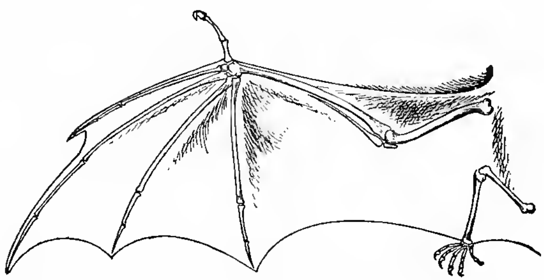


FIG. 208.—Wing of bat showing elongated bones of fore limb.

limbs modified for flight by the elongation of the fore arms and especially of four of the fingers (fig. 208), all of which are connected by a thin leathery membrane, which includes also the hind feet and usually the tail. Bats are chiefly nocturnal, hanging head downward by their hind claws in caves, hollow trees, or dark rooms through the day. They feed chiefly on insects, although some foreign kinds live on fruits. There are a dozen or more species of bats in North America, the most abundant kinds in the East-

FIG. 209.—The hoary bat, *Lasiurus cinereus*. (Photograph from life by J. O. Snyder.)

ern States being the little brown bat (*Myotis subulatus*), about three inches long, with small fox-like face, high slender ears, and a uniform dull olive-brown color, and the red bat (*Lasiurus borealis*), nearly four inches long, covered with long, silky, reddish-brown fur, mostly white at tips of the hairs.

The dolphins, porpoises, and whales (Cete).—The dolphins, porpoises, and whales (Cete) compose an order of more or less fish-like aquatic mammals, among which are the largest of living animals. In all the posterior limbs are wanting, and the fore limbs are developed as broad flattened paddles without distinct fingers or nails. The tail ends in a broad horizontal fin or paddle. The Cete are all predaceous—fish, pelagic crustaceans, and especially squids and cuttlefishes forming their principal food. Most of the species are gregarious, the individuals swimming together in "schools." The dolphins and porpoises compose a family (Delphinidæ) including the smaller and many of the most active and voracious of the Cete. The whales compose two families—the sperm-whales (Physeteridæ), with numerous teeth (in the lower jaw only) and the whalebone whales (Balænidæ) without teeth, their place being taken in the upper jaw by an array of parallel plates with fringed edges known as "whalebone." The great sperm whales or cachalots (*Physeter macrocephalus*), found in southern oceans, reach a length (males) of eighty feet, of which the head forms nearly one-third. Of the whalebone whales the sulphur-bottom (*Balænoptera sulfurea*) of the Pacific Ocean, attaining a length of nearly one hundred feet, is the largest, and hence the largest of all living animals. The common large whale of the Eastern coast and North Atlantic is the right whale (*Balæna glacialis*); a near relative is the great bowhead (*B. mysticetus*) of the Arctic seas, the most valuable of all whales to man. Whales are hunted for their whalebone and the oil yielded by their fat or blubber. The story of whale-fishing is an extremely interesting one, the great size and strength of the "game" making the "fishing" a hazardous business.

The hoofed mammals (Ungulata).—The order Ungulata includes some of the most familiar mammal forms. Most of the domestic animals, as the horse, cow, hog, sheep, and goat, belong to this order, as well as the familiar deer, antelope, and buffalo of our own land, and the elephant, rhinoceros, hippopotamus, giraffe, camel, zebra, etc., familiar in zoological gardens and menageries. The order is a large one, its members being characterized by the presence of from one to four hooves,

FIG. 210.—Male elk or wapiti, *Cervus canadensis*. Photograph by E. Willis from specimen mounted by Prof. L. L. Dyche, University of Kansas.)

which are the enlarged and thickened claws of the toes. The Ungulates are all herbivorous, and have their molar teeth fitted for grinding, the canines being absent or small. The order is divided into the Perissodactyla or odd-toed forms, like the horse, zebra, tapir, and rhinoceros, and the Artiodactyla or even-toed forms, like the oxen, sheep, deer, camels, pigs, and hippopotami. The Artiodactyls comprise two groups, the ruminants and non-ruminants. All of the native Ungulata of our Northern States belongs to the ruminants, so called because of

FIG. 211.—Antelope, male, female, and young, *Antilocapra americana*. (Photograph by E. Willis from specimens mounted by Prof. L. L. Dyche, University of Kansas.)

their habit of chewing a cud. A ruminant first presses its food into a ball, swallows it into a particular one of the divisions of its four-chambered stomach, and later regurgitates it into the mouth, thoroughly masticates it, and swallows it again, but into another stomach-chamber. From this it passes through the other two into the intestine.

The deer family (Cervidæ) comprises the familiar Virginia or red deer (*Odocoileus americanus*) of the Eastern and Central States and the white-tailed, black-tailed, and mule deers of the West, the great-antlered elk or wapiti (*Cervus canadensis*), (fig. 210), the great moose (*Alce americana*), (fig. 207), largest of the deer family, and the American reindeer or caribou (*Rangifer caribou*). All species of the Cervidæ have solid horns, more or less branched, which are shed annually. Only the males (except with the reindeer) have horns. The antelope (*Antilocapra americana*), (fig. 211), common on the Western plains, also sheds its horns, which, however, are not solid and do not break off at the base as in the deer, but are composed of an inner bony core and an outer horny sheath, the outer sheath only being shed. The family Bovidæ includes the once abundant buffalo or bison (*Bison bison*), (fig. 212), the big-horn or Rocky Mountain sheep (*Ovis canadensis*), (fig. 206), and the strange pure-white Rocky Mountain goat (*Oreamnos montanus*). The buffalo was once abundant on the Western plains, traveling in enormous herds. But so relentlessly has this fine animal been hunted for its skin and flesh that it is now practically exterminated (fig. 213). A small herd is still to be found in Yellowstone Park, and a few individuals live in parks and zoological gardens. In all of the Bovidæ the horns are simple, hollow, and permanent, each inclosing a bony core.

The carnivorous mammals (**Feræ**).—The order Feræ includes all those mammals usually called the carnivora, such as the lions, tigers, cats, wolves, dogs, bears, panthers, foxes, weasels, seals, etc. All of them feed chiefly on animal substance and are predatory, pursuing and killing

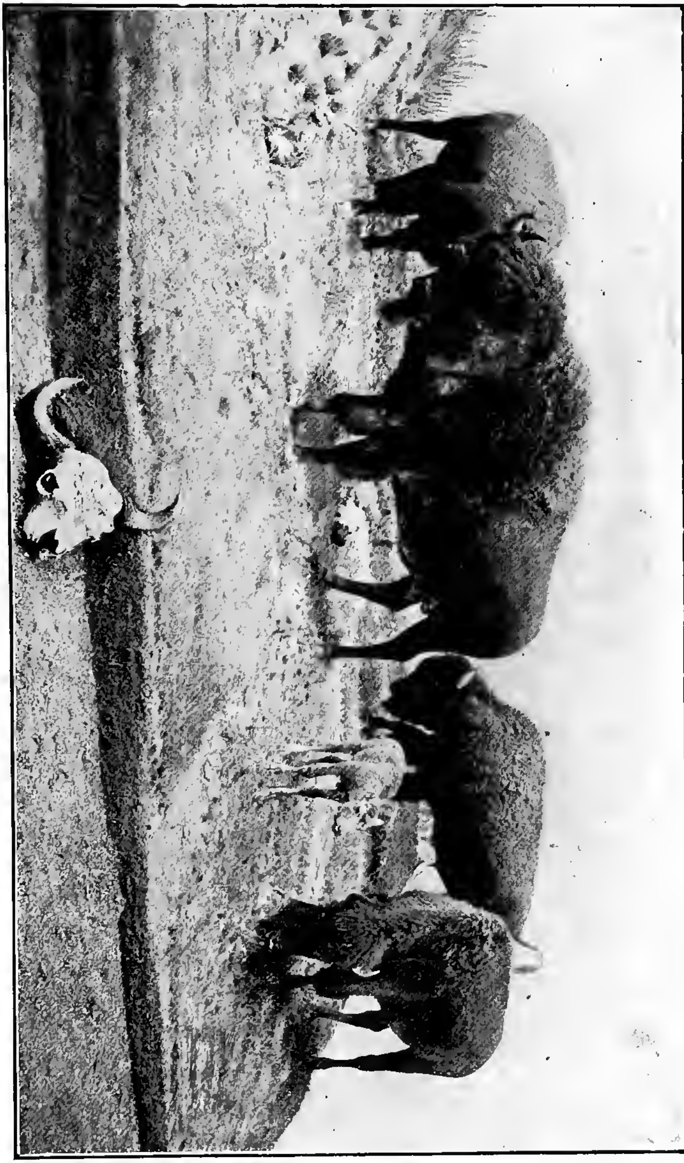


FIG. 212.—Group of American buffalo or bison (*Bison bison*), including male, female, and young. (Photograph by E. Willis from specimens mounted by Prof. L. L. Dyche, University of Kansas.)

their prey. They are mostly fur-covered, and many are hunted for their skin. They have never less than four toes, which are provided with strong claws that are frequently more or less retractile. The canine teeth are usually large, curved, and pointed.

While most of the Feræ live on land, some are strictly aquatic. The true seals, fur-seals, sea-lions, and wal-

FIG. 213.—A buffalo, *Bison bison*, killed for its skin and tongue, on the plains of Western Kansas thirty years ago. (Photograph by J. Lee Knight.)

ruses comprise the aquatic forms, all being inhabitants of the ocean. The true seals, of which the common harbor seal (*Phoca vitulina*) is our most familiar representative, have the limbs so thoroughly modified for swimming that they are useless on land. The fur-seals, sea-lions, and walruses use the hind legs to scramble about on the rocks or beaches of the shore. The fur-seals (fig. 214) live gregariously in great rookeries on the Pribilof or Fur Seal Islands, and the Commander Islands in Bering Sea. The bears are represented in our country by the widespread brown, black, or cinnamon bear (*Ursus americanus*) and the huge grizzly bear (*U. horribilis*) of the West. The great polar bear (*Thalarctos maritimus*) lives in arctic regions. The otters, skunks, badgers, wolverines, sables, minks, and weasels compose the family Mustelidæ, which includes most of the valuable fur-bearing animals. Some of the members of this family lead a semi-aquatic, or even strictly aquatic, life and have webbed feet. The wolves, foxes, and dogs belong to the family Canidæ. The coyote (*Canis latrans*), the gray wolf (*C. nubilus*), and the red fox (*Vulpes pennsylvanicus*) are the most familiar representatives of this family, in addition to the dog (*C. familiaris*), which is closely allied to the wolf. "Most carnivorous of the carnivora, formed to devour, with every offensive weapon specialized to its utmost, the Felidæ, whether large or small, are, relatively to their size, the fiercest, strongest, and most terrible of beasts." The Felidæ, or cat family, includes the lions, tigers, hyenas, leopards, jaguars, panthers, wildcats, and lynxes. In this country the most formidable of the Felidæ is the American panther or puma (*Felis concolor*). It reaches a length from nose to root of tail of over four feet. Its tail is long. The wildcat (*Lynx rufus*) is much smaller and has a short tail.

The man-like mammals (Primates).—The Primates, the highest order of mammals, includes the lemurs, monkeys, baboons, apes, and men. Man (*Homo sapiens*) is the only native representative of this order in our country. All the races and kinds of men known, although really showing much variety in appearance and body

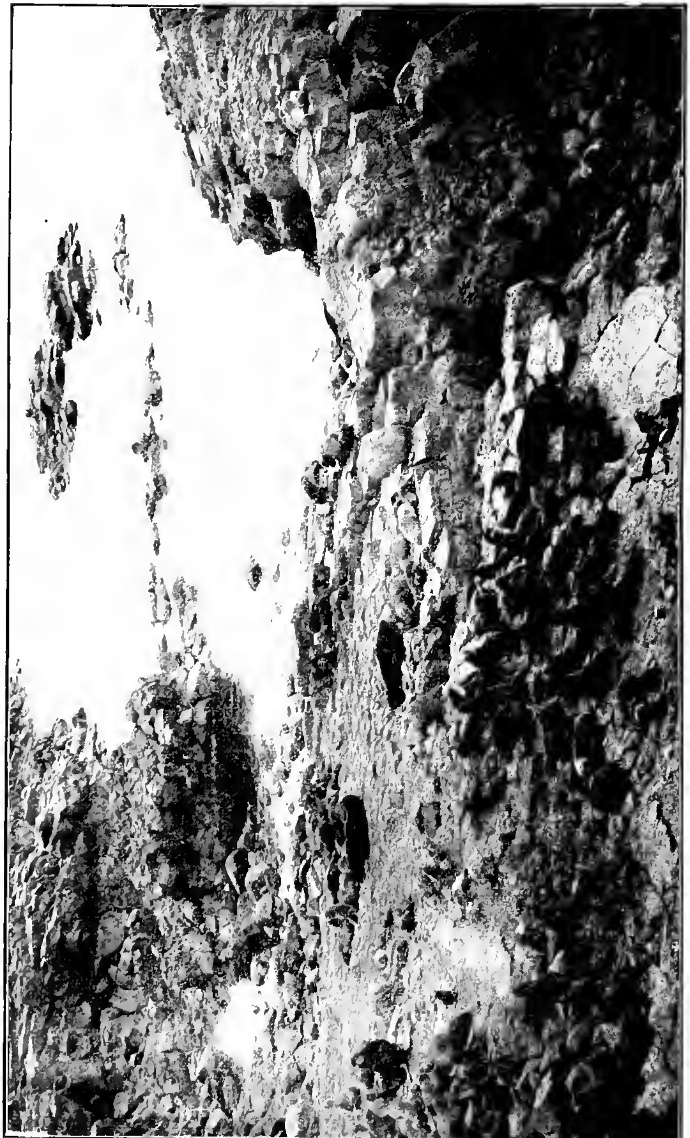


FIG. 214.—The Lukanin rookery of fur-seals, *Callorhinus alascanus*, on St. Paul Island, Pribilof Group, Bering Sea. (Photograph from life by the Fur Seal Commission.)

structure, are commonly included in one species. The chief structural characteristics which distinguish man from the other members of this order are the great development of his brain and the non-opposability of his great toe. Despite the similarity in general structure between him and the anthropoid apes of the Old World, in par-

FIG. 215.—"Bob Jordan," a monkey of the genus *Cercopithecus*. (Photograph from life by D. S. Jordan.)

ticular the chimpanzee and orang-outang, the disparity in size of brain is enormous.

The lowest Primates are the lemurs found in Madagascar, in which island they include about one-half of all the mammalian species found there. The brain is much less developed in the lemurs than in any of the other monkeys. The monkeys and apes may be divided into two groups, the lower, platyrrhine monkeys, found in the New World, and the higher, catarrhine forms, limited to the Old World. The platyrrhine monkeys have wide noses in which the nostrils are separated by a broad septum and with the openings directed laterally. These monkeys are mostly smaller and weaker than the Old World forms and are always long-tailed, the tail being frequently prehensile. They include the howling, squirrel, spider, and capuchin monkeys common in the forests of tropical South America. The catarrhine monkeys have the nose-septum narrow and the openings of the nostrils directed forwards, and the tail is wanting in numerous members of the group. They include the baboons, gorillas, orang-outangs, and chimpanzees. These apes have a dentition approaching that of man, and in all ways are the animals which most nearly resemble man in physical character.

Interesting accounts of the lives of familiar mammals are given in three books by Wm. T. Long, entitled "Ways of Wood Folk," "Wilderness Ways," and "Secrets of the Woods."

PART IV

ANIMALS IN RELATION TO EACH OTHER AND TO THE OUTSIDE WORLD

CHAPTER XVII

THE STRUGGLE FOR FOOD AND ROOM, AND THE SPECIAL MEANS FOR FOOD-GETTING AND PROTECTION

The multiplication of animals.—The English sparrow, now a common bird over our whole country, rears five or six broods every year, each brood containing six to ten young. That is, each pair of healthy English sparrows produces from thirty to sixty new sparrows each year. Now if all these young come safely to maturity and each pair maintains the same rate of increase, and every sparrow lives to its normal age, how long will it take to cover the face of the land with these pugnacious, noisy, little birds? As a matter of fact a professor of mathematics has solved this problem, and finds that at the normal rate of increase, and if no sparrows were to die save naturally of old age, it would take about twenty-five years to give one sparrow to every square inch in the United States.

But English sparrows are not the only birds in the country, and although the robins, bluebirds, woodpeckers, and the scores of other kinds do not lay so many eggs nor lay so many times a year, yet each pair does produce more than two eggs yearly, that is, each pair yearly multiplies, not simply replaces itself. Most birds, however, are slow multipliers. But what of the host of insects where each female lays from a few dozen to many hundred or even thousand eggs each year; and the fishes, almost none of which lays less than several thousand a year? A few years of uninterrupted normal increase among sunfishes would fill every stream and pond solidly full of them. Even certain of the tiniest animals, microscopic animalcules which live in the ocean, if left to multiply at their usual rate with no losses except by natural death, would, it has been estimated, completely fill the ocean in about a week!

Of course no such appalling increase in the number of living animals occurs, although we may fairly consider that each kind of animal is constantly trying to usurp far more food and space in the world than it now has. But there are about as many squirrels in the forest one year as another, about as many butterflies in the field, about as many frogs in the pond. Sometimes a particular kind of animal gets into a new part of the world and suddenly multiplies with great rapidity. A few rabbits were introduced into Australia (where there were none) in 1860, and in fifteen years had become so abundant as to be a great pest. The government pays large sums in bounties every year to rabbit-hunters.

The struggle to live.—All animals tend to increase in geometrical ratio, that is, the production of new individuals is by multiplication, not by simple addition. But food and space on the earth have definite limits, and so there is constantly going on a great struggle for existence. In the case of any individual the struggle is threefold; (1) with the other animals of his own kind or species for food and room; (2) with other kinds of animals which want the same food and space, or which may want him for food; and finally, (3) with the conditions of life, such as cold and heat, and drouth and flood. No living being can escape from this struggle. Each strives to feed itself, to save its own life, to produce and protect its young. But in spite of all their efforts only a few individuals out of the hundreds and thousands born live to maturity. The great majority are killed in the egg stage, or during adolescence.

Selection by nature.—What individuals survive of the many which are born? Those best fitted for life; those which are a little stronger, a little swifter, a little hardier, a little less readily perceived by their enemies than the others. We know from our observation of a brood of young kittens or puppies that there are differences in new-born individuals of the same kind, and even among those born from the same mother. Thus it is with all animals. No two individuals even in the same brood are exactly alike at birth. And the very few members of each brood which do survive are almost always the hardier, stronger, and swifter. They are the winners in the struggle for existence. And this survival of the fittest, as it is called, is practically a weeding out or selecting process of Nature. She selects the fittest to live and to perpetuate their kind. Their young in turn must undergo the struggle and the selecting process, and again the fittest live. And so on until the adjustment or harmonizing of the bodies and habits of animals with the conditions of their life, their environment, comes to be extremely fine and nearly perfect.

Special means to get food.—With such a constant struggle, such a race for food, it is not strange that we find different animals having various kinds of special arrangement for getting it. Those which live on plants can get it in two ways, either by biting off the green leaves and stems and crushing them in the mouth, or by thrusting a sucking beak into the plant tissue and drawing out the sap. So the different plant-feeding animals have the mouth specially arranged for one or the other of these ways. Cattle and horses and sheep have teeth for biting off and crushing dry or green plant food, while many insects, like the plant-lice and various flower-bugs, have a tiny, sharp, hollow beak, which they thrust into a green leaf or stem, and through which they suck up the sap. Similarly with those animals which feed on animal matter. Lions, tigers, dogs, and cats have strong teeth for tearing and broad teeth for crushing the flesh of other animals, while the mosquito, flea, and other insects which live principally on animal blood have a piercing and sucking beak.

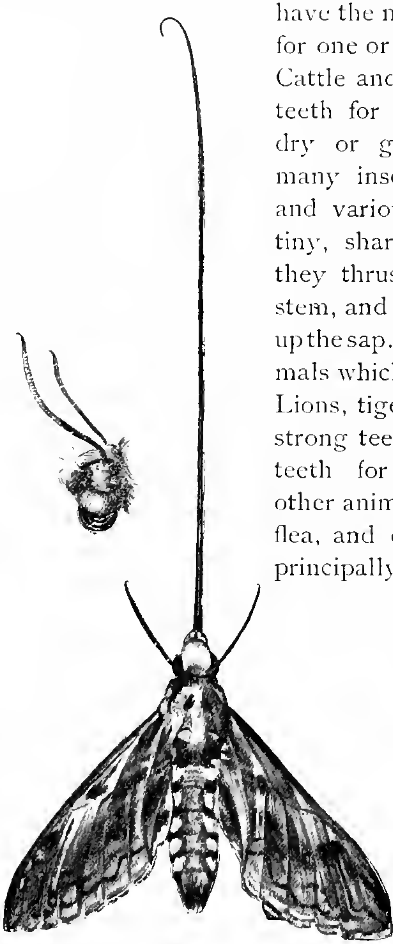


FIG. 216.—Sucking proboscis of a sphinx-moth; in small figure the proboscis is shown coiled up on the under side of the head, the normal position when not in use. (One-half natural size; from specimen.)

But animals must first obtain their food. Giraffes get theirs from high trees and they have wonderfully long necks to enable them to reach up; the moths and butterflies which feed on nectar from flowers have long, slender sucking-tubes with which to reach down to the base of a flower-cup. The common hawk-moths or humming-bird moths that hover over petunias and other deep-cupped flowers have sucking-tubes three or four inches long (fig. 216), and a famous member of this family in Madagascar has its sucking-tube fourteen inches long, which enables it to reach to the bottom of a great trumpet-shaped flower. Lions and tigers, wolves, and the like which feed upon other live animals must have specially developed legs and muscles for swift running, or springing, or swimming. The otter can swim and dive better than most fishes, and with his greater cleverness has little difficulty in capturing the swiftest of them. The eagle has great talons for grasping its prey, and a strong hooked beak for tearing it. The pelican has a large pouch or sac on its lower jaw which it uses as a scoop-net for catching fish. The spoon-bill duck takes up mouthfuls of mud and water which it strains out through a close fringe of small thin plates at the sides. The preying mantis (fig. 217) has great spiny fore legs for seizing its prey, the unwary house-flies, on the window-panes, while the dragon-fly has a large mouth which it can open very wide, and can engulf in this fatal trap many tiny midges as it flies swiftly through their dancing swarms.

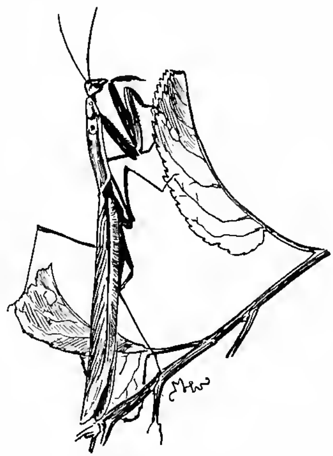


FIG. 217.—Preying mantis. (Natural size; from specimen.)

Special means for protection.—Some animals have poison-fangs, like the rattlesnake and the ugly lizard of the desert called Gila monster, and others stings, like the scorpion, to kill their prey. These weapons are of course also used in self-defense. The same is true also of numerous other special means of food-getting, such as the power to run swiftly, to leap, and swim. But there are in addition many special means of defense and protection which have nothing to do with food-getting. The males of most members of the deer family—the moose, elk, and red deer for example—have antlers strong and sharp-pointed, which they can use effectively in fighting wolves and other enemies as well as each other. At the same time they have legs finely developed for swift running, and to run away is often better protection than to fight. The porcupine has long, sharp quills which make a bad mouthful for any animal that attempts to nip the prickly ball; the armadillo of tropical countries has its body covered with horny shields, and when it draws in its head and curls up tightly it is as well protected as a turtle in its box-like armor. Numerous fishes have other means of protection besides their ability to swim

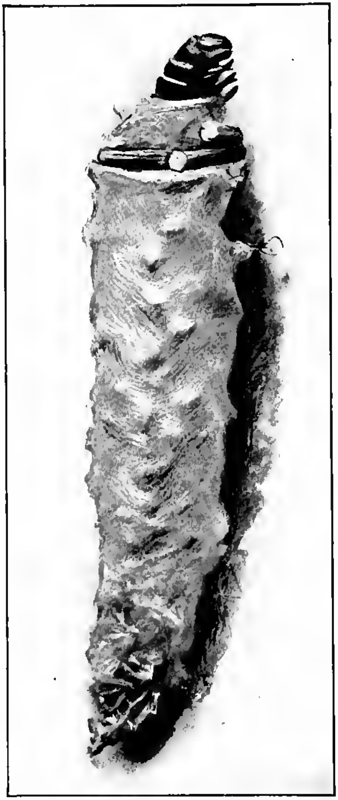


FIG. 218.—Bag-worm; the larva of a moth that builds a protecting case out of silk and bits of sticks, in which its whole body, except horny head, thorax, and legs, is concealed. (Natural size; from specimen.)

swiftly; the catfishes stiffen a long spine in each pectoral fin, which makes a bad wound; the so-called poison-fishes of the ocean have spines provided with poison glands; the sting-rays, common on the coast, have a strong, jagged spine in the tail, armed with broad saw-like teeth, which inflicts a bad, ragged cut. The torpedoes or electric rays found on the sandy shores of all warm seas have on each side of the head a large honeycomb-like structure which gives a strong electric shock whenever the live fish is touched. Among the reptiles of our country the poisonous bite of the rattlesnake, copperhead, and water-moccasin is a familiar example of a very effective special means of defense.

Certain special habits of animals, too, help much to protect them, and to save their lives. The migration of birds takes many from a bleak, foodless winter to the luxuriant tropical forests, where there is plenty of food and the weather is mild. The hibernation or "winter sleep" of bears, snakes, and lizards carries them safely through a season when food is scarce or wanting altogether. And some animals come from their holes and hiding-places to hunt food only at night, when most of their enemies are asleep.

Finally (as we shall learn particularly in the next chapter), many animals are colored and marked in such manner that they match or fit in so well with the soil or leaves or stones on which they rest as to be indistinguishable. And this scheme of harmonious coloration is one of the most successful and wide-spread of all the special protective devices.

Examples to be looked for by the pupils.—Only a few of the special means for food-getting and protection are mentioned in this chapter, and those animals which may be most readily observed by the pupils have purposely not been referred to. When we come upon such a peculiar device as the long neck of the giraffe or the fishing-pouch of the pelican our attention is specially attracted, and we are likely to consider such cases unusual and exceptional. But they are not exceptional, they are simply unusual and unfamiliar and specially conspicuous. All animals, including all those we know best, have special means of food-getting and protection, and many of them, particularly the insects and birds, have just as unusual and just as wonderful and interesting devices as any mentioned in the preceding paragraphs. Let each pupil observe carefully and thoughtfully the animals familiar and accessible to him, remembering that smallness does not at all mean lack of wonderful and interesting structures and habits. Let each make a list from personal observation of the special devices and habits for getting food and for protection possessed by the animals he knows.

CHAPTER XVIII

COLORS AND MARKINGS OF ANIMALS, AND THEIR USES

The colors and markings of animals are among the most conspicuous of their external characters, and constantly incite us to ask how they are produced and why they are of such great variety. As no more familiar or interesting examples of color patterns can be found than those on the wings of butterflies and moths, we can very advantageously use these beautiful insects in beginning the study of animal colors.

The scales and colors of butterflies' wings.—Catch a few butterflies of different kinds and kill in the killing-bottle. With the finger rub lightly one of the wings and note that a fine dust-like substance comes off on the finger-tip, and that at the same time the pattern and color disappear. By gentle steady rubbing with thumb and finger just opposite each other on the upper and lower sides of the wings, a clear, transparent spot may be made. It is evident that the color and pattern of the wing depends upon its covering of fine particles.

Rub some of this color-dust from the finger-tip on a glass slide and examine under the microscope. Note that the fine particles are all scale-like in shape and character, each being composed of a tiny short stem and a broader flattened blade which may have the margin of its broad free end even or dentate, that is, showing little teeth or fingers (fig. 220). These tiny scales are hollow and inside they may contain only air, in which case they are transparent or whitish under the microscope, or they may hold small granules of pigment, a colored substance which makes them brown or yellowish or reddish or blackish.

Some butterflies have blue or green or purple colors, irridescent and changeable, on their wings. The common

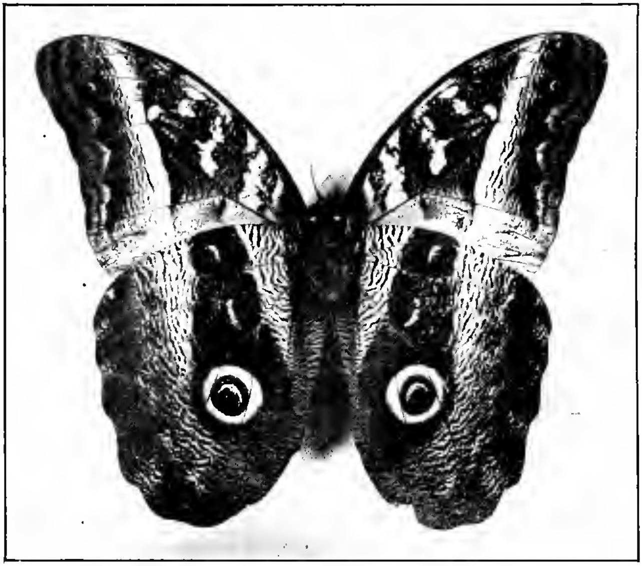


FIG. 219.—Owl-butterfly (*Caligo*), under side (Two-thirds natural size; photograph by the author.)

little "blues" have the upper side of the whole wing metallic blue. Examine under the microscope some scales from one of these blue wings, or from a blue or greenish iridescent spot on any butterfly's wing. They will be seen to be not blue or green (as long as light is allowed to come from the mirror of the microscope up through them) but either colorless or of a pale yellowish or brownish shade. But if the light from below is cut off by placing a hand over the microscope mirror they will show an iridescent blue or green.

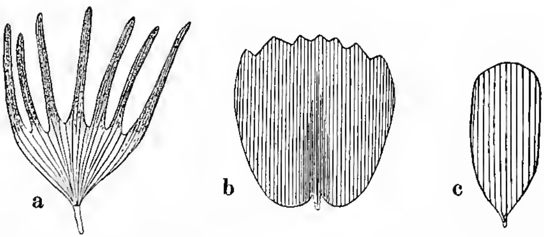


FIG. 220.—Single scales from moths and butterflies; *a*, from *Tolype velleda*; *b*, from *Castnia* sp.; *c*, from *Micropteryx aruncella*. (Greatly magnified; from specimens.)

Examine under the microscope a bit of wing from which most of the scales have been rubbed (figs. 221 and 222).

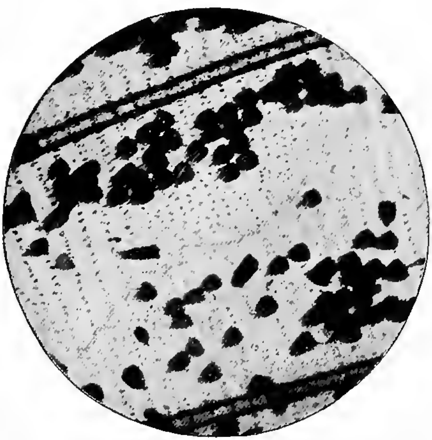


FIG. 221.—A small, partly denuded part, much magnified, of a wing of a "blue" butterfly, *Lycæna* sp., showing the wing. scales, and the pits in the wing-membrane, in which the tiny stems of the scales are inserted. (Photomicrograph by Geo. O. Mitchell.)

Note rows of tiny pits or pockets in which the stems of the scales fit. The scales are fastened, though not very firmly, to the wing membrane by their stems, and are arranged in fairly even rows. In each row they are so thick that they overlap each other's sides, and the rows are so close together that the tips of the scales of one row overlap the bases of those of the one in front. This arrangement is much like that of shingles on a roof, and each wing is thus shingled above and below (fig. 223) by thousands of tiny scales which produce all its colors and markings. These colors are made in two ways; either the scales are actually brownish or reddish or yellowish or black themselves because they contain pigment granules inside, or else they reflect white light in such a way that it is broken up, as by a prism, into colors, only some of which reach our eyes. The metallic and iridescent kinds, the greens, blues, coppers, purples, etc., all of which change somewhat as we change the position

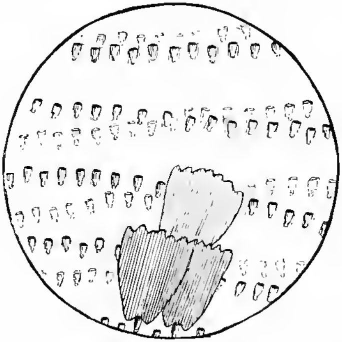


FIG. 222.—Bit of denuded wing of a butterfly, *Grapta*, greatly magnified, to show rows of insertion pits on upper and lower sides, and three scales. (From specimen.)

FIG. 223.—Diagram to show shingling arrangement of scales over surface of butterfly's wing; the short black bars indicate scales in cross-section, the broad central bar, the wing in cross-section.

of our eyes, are produced in the second way. The duller and the fixed colors, such as the reds, yellows, browns, etc., are produced by scales containing pigments of the same shade.

Colors of other animals.—The colors of other animals are also produced in one or both of these two ways; that is, either by colored pigment, or by reflections from structures which act as the prism does. Only a few other animals have scales, and almost no others have scales just like those of the butterfly, but they have other kinds of structures on the outside of the skin, such as feathers or hairs, which contain pigment, or break up white light into colors.

Observe the coloring on a blackbird; note the fine iridescent blue and purple or bronze-green reflections. These are made by the feathers reflecting broken-up white light. Such iridescent colors produced by structure, and hence called structural colors, are especially pronounced and beautiful on humming-birds. On the other hand the red brown of the robin's breast and the yellow of the meadow-lark's are produced by feathers containing reddish and yellowish pigment granules.

The colors of most quadrupeds, which are covered with hair, are dull and almost entirely due to pigment in the hair. Those of live fishes, often brilliant and iridescent in the water, fade and sometimes wholly disappear when the fish is dead and dry. Colors such as these are structural, the scales being mostly transparent.

Observe as many animals as possible and try to find out how their colors and markings are produced, what the external structures are which make them, and whether they are made by pigment or by prismatic reflection.

Uses of color.—Although we have been long accustomed to see the beautiful and varied markings of birds and butterflies, have we asked ourselves of what use these colors and patterns are to the animals possessing them? We cannot think that they exist just to please us. We have found that in animals' bodies the parts are all made so as to be just as useful as possible, each part having some special thing to do to help the animals along. The same is true of the colors and patterns which are such conspicuous features of their external appearance.

Try to catch a locust. The insect will be plainly seen as it flies or leaps through the air, but how when it alights on the ground? If you do not watch carefully to see it alight, you will have great difficulty in finding it now.

FIG. 224.—The death's-head sphinx-moth; note skull-like markings on thorax (between wings). This moth is looked on with superstitious dread by many people. (Natural size; photograph by the author.)

It is almost indistinguishable among the pebbles, bits of twigs, and soil of the surface. It resembles its surroundings in coloration and undoubtedly is thus often saved from pursuing enemies. A bird sees a locust flying. The locust alights and rests quietly on the ground; if distinguished the bird seizes it and it loses its life; if not distinguished the locust is saved, and saved by its color. So color is of use to the locust.

But how about the birds themselves—the crouching, immovable, dust-colored quail which waits until the hawk, not perceiving it, flies away; and the rabbit, colored like the dead grass and ground about it, which lies rigid until you are fairly upon it, although it sees your every movement? Swift of foot as the rabbit is, it relies more for safety on its protective color than on its fleetness. Among the green leaves of trees live the katydids; they are all green. On the great everlasting snow-fields of the arctic regions live foxes and hares and ptarmigan, all white as the snow itself, although their near cousins the foxes, hares, and ptarmigans of warmer regions, where the snow falls but occasionally, and the earth surface is usually brown and dark, are reddish or gray or brown. In the desert the lizards and snakes and insects are mottled gray and sand-colored, while in the ever-green foliage of trees in warm regions live green tree-frogs and tree-snakes and insects.

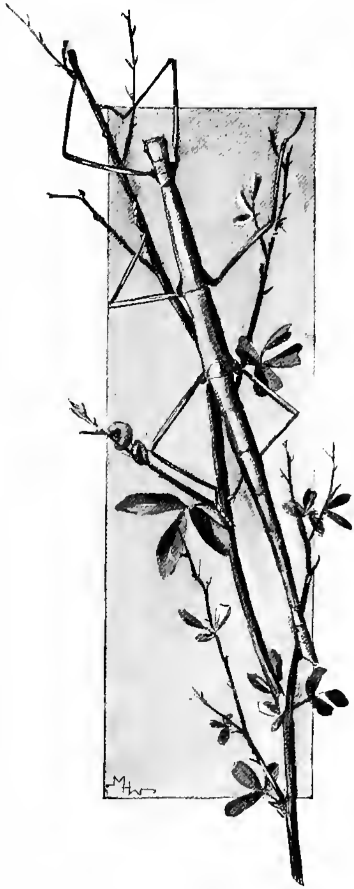


FIG. 225.—The twig or walking-stick insect, *Diapheromera femorata* (From specimen.)

Special protective resemblance.—But some animals show more than just a general resemblance to, or harmony with, the color tone of their surroundings; they show a striking resemblance to some particular part of their surroundings. An insect common all over the country, but only rarely distinguished and recognized, is the walking-stick insect (fig. 225). Its body is long and slender, its legs very long and held stiffly and angularly, and it has no wings. Its body and legs are colored either dull green all over, or blackish brown. And when not walking slowly about it always rests quietly on a twig or branch, from which the eye with difficulty separates it. In the tropics the so-called green-leaf insect, Phyllium, resembles in great detail a broad green leaf. Its body is broad and leaf-shaped, its color bright green with delicate lines to imitate the midrib and veins of a leaf, and it even has pale irregular yellow spots which imitate mouldy and yellow places on a real leaf. But most remarkable of all is the famous dead-leaf insect, Kallima (fig. 226), not uncommon in tropical Africa, South America, and the Australasian islands. The upper surfaces of the wings of this butterfly are brownish gray with a broad purplish bar on each wing, making a rather conspicuous pattern; but the under sides are so colored and are marked with such faithfulness of detail that when Kallima alights and folds its wings together above its back, as butterflies do, it resembles exactly a large, brown, dead leaf, still attached to the twig by a short pedicel or stem (imitated by a "tail" on the hind wings). The mock leaf is veined by means of lines of darker scales exactly as leaves are veined.

In this country are certain butterflies, the Graptas, sometimes called dead-leaf butterflies, which resemble in color and shape, and in the ragged edges of the wing, dead and torn autumn leaves, but the resemblance is not carried out in such detail as with Kallima.

Warning colors.—But not all insects or other animals

FIG. 226.—The dead-leaf butterfly, *Kallima* sp., a remarkable case of special protective resemblance (From specimen.)

are colored like their surroundings. Often indeed color and pattern are such as to make an animal very noticeable.

FIG. 227.—Larva of the monarch butterfly, conspicuously marked with black and whitish-yellow rings, and distasteful to birds. (Natural size; from specimen.)

The common large red-brown monarch, or milkweed butterfly (fig. 228), is a conspicuous object whether in flight

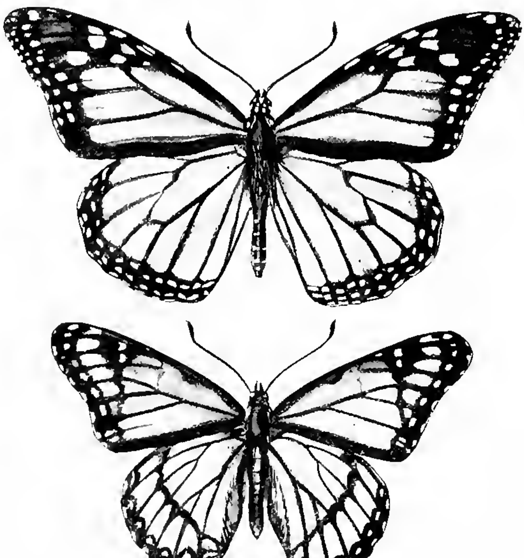


FIG. 228.—The monarch butterfly, *Anosia plexippus* (above), distasteful to birds, and the viceroy, *Basilarchia archippus* (below), which mimics it. (From specimens.)

or alighted on some flower or branch. But the birds do not attack it; and for this reason, that it contains, as has been proved, an ill-tasting fluid which makes it a very disagreeable mouthful for them. Now it is apparently so brightly colored that the birds generally recognize it before actually nipping it, and thus it often escapes with its life—for to be nipped is death to a butterfly. Other conspicuously marked butterflies and insects and some other forms, in particular a famous little blue and red frog of Nicaragua, are thought to be so marked for a similar reason. They are easily recognized as animals having a bad taste and so are generally let alone. Accordingly naturalists believe that conspicuous color and markings often advertise some disagreeable quality or some special means of defense in the animal bearing them and thus ward off its enemies.

Mimicry.—Certain other insects derive strange advantage from the inedibleness of the warningly colored bad-tasting kinds. There is, for example, another kind of butterfly called the viceroy (fig. 229), which looks so much like the monarch (although not nearly related to it), that it requires careful examination to distinguish the two kinds. But the viceroy is not inedible. And yet it, too, escapes very largely the attacks of birds because they mistake it for the other. By mimicking in color and pattern the appearance of the inedible monarch it gains a great advantage. Numerous other examples of protective mimicry are known among butterflies, especially tropical ones.

Other uses of color and marking not yet understood.—Protective resemblance and mimicry and warning coloration do not account for the color-markings of all animals, although it is probably true that the most widespread use of color in the animal kingdom is for protective resemblance. For example, the conspicuous white spot on the rabbit's tail is thought by some naturalists to be a means whereby it can be recognized by others of its kind at long distances. Some naturalists believe that the bright colors and conspicuous markings of male birds are for the purpose of pleasing and attracting the females

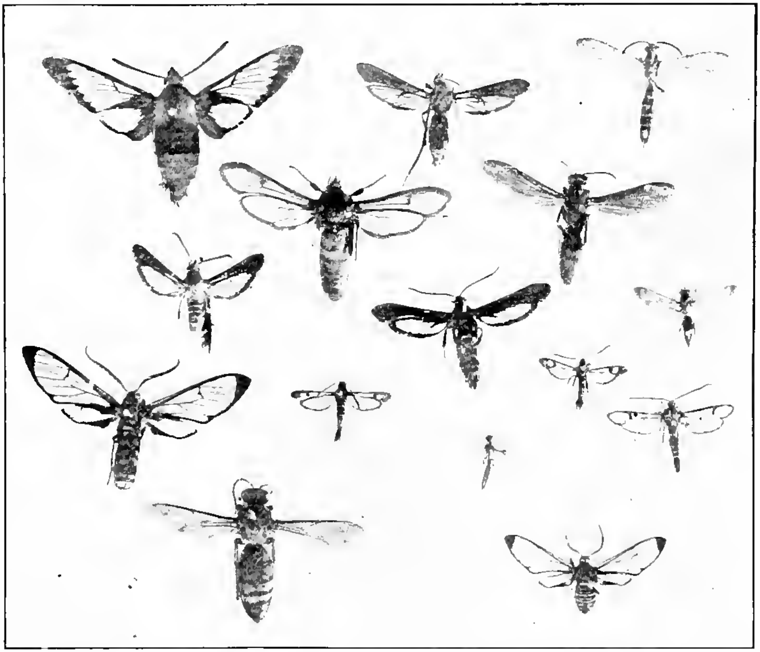


FIG. 229.—Various moths and wasps, the moths having the appearance of wasps, probably through mimicry, and protected by being mistaken for the stinging insects. (Natural size; photograph by the author.)

at mating time. And still other uses have been ascribed to color-markings in various animals. But with all these different explanations there are still many cases for which we can give no satisfactory explanation based on usefulness. There is much yet to be learned about color and pattern in animals.

Poulton's the "Colors of Animals" is an interesting book on this subject; see also Newbigin's "Color in Nature," and Beddard's "Animal Coloration."

CHAPTER XIX

ANIMAL PARASITES

An animal parasite is an animal which lives and feeds for all or part of its life on or in the body of another which is called the host. Fleas, dogticks, and lice are familiar parasites; they are not very pleasant to think about perhaps, but their mode of life is interesting because it presents one way of getting a living which has been adopted by many different kinds of animals, and which always results in a more or less marked change in their structure. This change usually involves the loss or imperfect development of some part of the body.

Degeneration of parasites.—Fleas and lice are insects, but, unlike most of their kind, they have no wings. Being carried about by the host they do not need to fly. One of the most striking examples of loss of parts due to a parasitic habit is shown by an animal called Sacculina (fig. 231), which belongs to the crab and crayfish group. The young Sacculina, hatched from eggs laid in ocean tide-pools, has legs and eyes and a mouth and feelers, and can swim actively about. It looks much like a young crab or prawn. But after a short period of free active life it finds a full-grown crab and attaches itself to its body. There grow out from the Sacculina and penetrate the body of the crab slender root-like processes by means of which the parasite sucks up the juices of its host. Soon it moults and loses its legs, eyes, and feelers; it is now simply a pulsating tumor-like sac fastened

FIG. 230.—A flying fish (*Exonautes unicolor*), from Tasman Sea, on which are growing three copepod parasites (*Penella*) to which in turn small barnacles (*Cochoderma virgatum*) are attached. (One-half natural size; from specimen.)

to the crab by means of the feeding rootlets. Loss by degeneration of the body-parts is carried very far in this case.

Internal parasites.—Inside the body of most animals live various parasites belonging to the great branch of

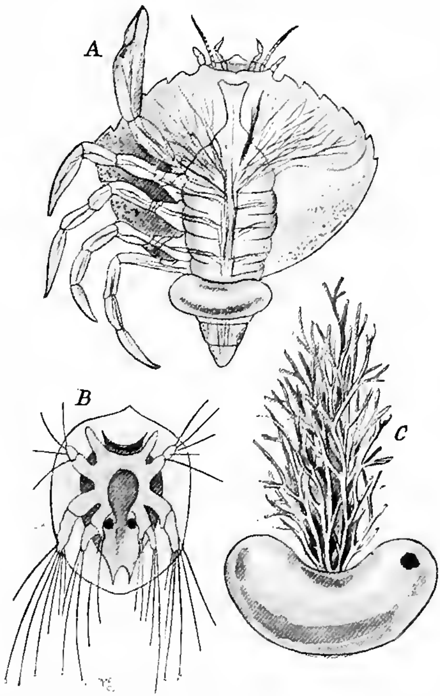


FIG. 231.—*Sacculina*, a parasitic crustacean; *A*, attached to a crab, the root-like processes of the parasite penetrating the body of the host; *B*, the active larval condition; *C*, the adult removed from its host. (After Haeckel.)

worms. The tapeworm and the deadly trichina (see p. 146) are conspicuous examples of these. The tapeworm (fig. 233) has the form of a narrow ribbon, perhaps several yards long, attached at one end to the wall of the intestine, while the remainder hangs freely in the interior. Its body is composed of segments or serially arranged parts, of which there are about 850 altogether. It has no mouth or stomach. It feeds simply by absorbing into its body, through the skin, the nutritious already digested food in the intestine of its host. It has no eyes or other special sense-organs, nor any organ of locomo-

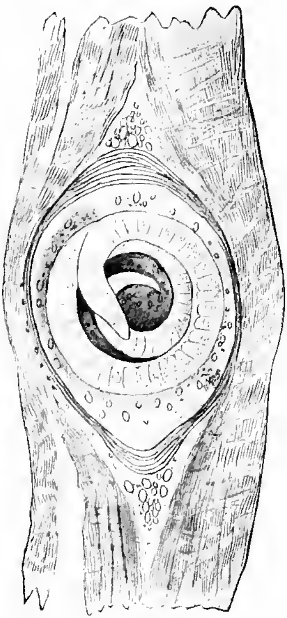


FIG. 232.

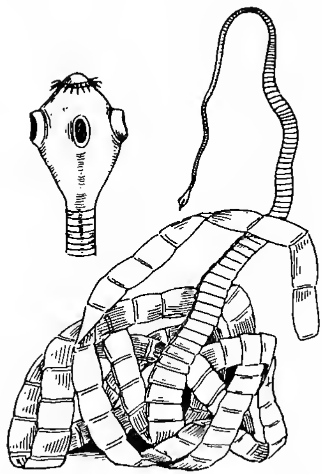


FIG. 233.

FIG. 232.—*Trichina spiralis*, encysted in muscle of a pig. (Greatly magnified; from specimen.)
FIG. 233.—Tapeworm; head magnified, at left; whole worm may be several yards long. (After Leuckart.)

tion. Thus its body is very degenerate. The life-history of the tapeworm is interesting, because it lives in two hosts during its life. The eggs of this parasite pass from the intestine with the excreta, and to develop must be taken into the body of some other animal. In the case of one of several species infesting man this second host is the pig. In the alimentary canal of the pig the young tapeworm develops, to bore its way later through the walls of the canal and become imbedded in the muscles. There it lies until the diseased flesh containing it is eaten (without being perfectly cooked), and it thus finds its way into the alimentary canal and thence into the intestine of man. It now continues to develop until it becomes full grown.

Parasitic insects.—Among the insects many live as parasites during their immature or larval life, but as adults are free and independent creatures. From the chrysalid of a butterfly or moth there will often come not a butter-

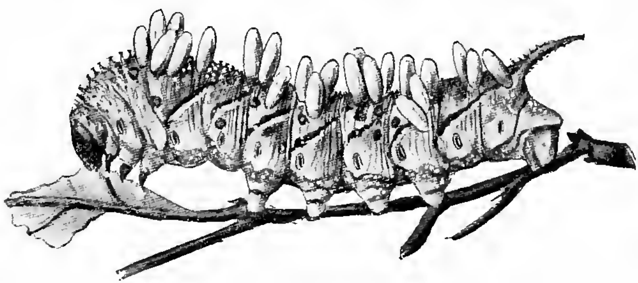


FIG. 234.—Larva of a sphinx-moth, with cocoons of a parasitic ichneumon fly. (From specimen.)

fly but numerous tiny four-winged gnats, called ichneumon flies. This is what happened. When the butterfly caterpillar was crawling about a female ichneumon darted down on it, and with her sharp ovipositor either laid several eggs beneath its skin or glued them to its outer surface. These eggs hatched in two or three days as tiny white ichneumon grubs, which immediately burrowed deep into the caterpillar and lay there feeding on the blood and tissues of its body. But the caterpillar went on eating and finally changed into a chrysalid, with the ichneumon grubs still inside. Soon the grubs, having eaten up most of the body of the developing butterfly and thus killed it, changed into tiny pupæ, and later into fully developed ichneumon flies which gnawed their way out through the horny case of the dead chrysalid.

Sometimes yellow-jackets are infested by a strange parasitic beetle called Stylops. The adult male Stylops

FIG. 235.—Caterpillar killed by parasitic ichneumon flies which have left the body through small holes in the skin. (Natural size; from specimen.)

beetles have four wings, but the females are wingless. The young Stylops, a grub or larva, attaches itself to a wasp or bee and burrows into its abdomen. Here it pupates and lies with its head projecting slightly from a

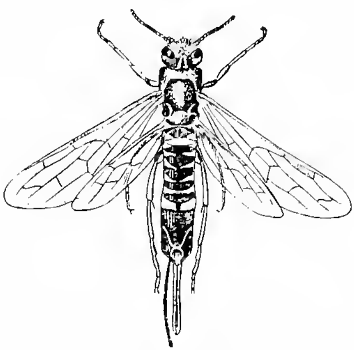


FIG. 236.

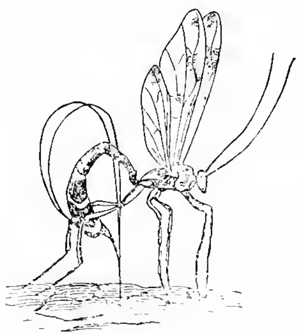


FIG. 237.

FIG. 236.—The pigeon horn-tail (*Tremex*). (Natural size; from specimen.)
FIG. 237.—*Thalessa* drilling into the burrow of *Tremex*. (Natural size; after Comstock.)

slit between two of the body-rings of the wasp. Finally the adult Stylops issues and deserts the body of its host.

One of the most interesting ichneumon flies is Thalessa, which has a remarkably long, slender, flexible ovipositor. Another insect, known as the pigeon horn-tail (fig. 236), upon which Thalessa preys, deposits its eggs by means of a strong, piercing ovipositor, half an inch deep, in the trunks of growing trees. The young or larval horn-tail hatches as a soft-bodied white grub, which bores more deeply into the tree, filling up the burrow behind it with small chips. When a female Thalessa finds a tree infested by the horn-tail she selects a place which she judges is opposite one of its burrows, and elevating her long ovipositor in a loop over her back, with its tip on the bark of the tree, she makes a derrick out of her body and proceeds with great skill and precision to drill a hole (fig. 237). Having reached the horn-tail's burrow she deposits an egg in it. When the larva hatches it creeps along the burrow until it reaches and fastens itself upon the larval horn-tail which it destroys by sucking its blood. When full grown it changes to a pupa within the burrow of its host, and finally the adult Thalessa gnaws a hole out through the bark if it does not find the one already made by the horn-tail.

FIG. 238.—A bird-louse (*Nirmus praestans*) from a tern (*Sterna maxima*). (About one-twelfth inch long; photomicrograph by Geo. E. Mitchell.)

Almost all birds are infested with small, flattened, wingless, parasitic insects which live among the feathers, and feed by biting off small bits of barbs. Chickens and pigeons are specially infested by these biting bird-lice (called biting to distinguish them from the common true lice of other animals, which have a piercing beak and suck blood) (fig. 238). Specimens of these parasites should be obtained and examined under a microscope to

FIG. 239.—Young fur-seals, *Callorhinus ursinus*, of the Tolstoi rookery, St. Paul Island, Bering Sea, killed by a parasitic intestinal worm, *Uncinaria* sp. (Photograph by the Fur Seal Commission.)

note the absence of wings and compound eyes, and the peculiarly shaped body well fitted for swift running among the feathers. Note bits of feathers in the stomach showing through the body-wall.

There are many other examples of parasitic life to be found among common and familiar animals. Careful watch for them should be kept by the pupils in their field work and in their rearing of insects and other animals in the schoolroom.

For an account of many parasites see Van Beneden's "Animal Parasites and Messmates."

CHAPTER XX

THE HONEY-BEE AND OTHER SOCIAL ANIMALS

We have learned (Chapter XVII) of the great struggle going on in the animal world for room and food. We know that each animal has to battle against adverse physical conditions, such as cold and heat, drouth and flood; against other kinds of animals which try to occupy the same region and to eat the same food that it does; and finally, with other individuals of its own kind, its own brothers and sisters and cousins indeed, which compete for the room and food that can support but few of them. But in this great threefold struggle some one phase may be much less severe than the others, or, indeed, as occurs in some cases, with individuals of the same kind it may be to a certain extent replaced by a relation of mutual helpfulness. That is, the individuals of a certain species may and do adopt a social or communal life, helping each other to get food, to build homes, and to fight off enemies. Of these social animals the honey-bee is the most familiar and one of the best examples. The ants, too, are well-known communal animals.

The life of a honey-bee.—In studying the life of the honey-bees one must observe them in the hive as well as in the field. It is therefore highly desirable to have an "observation" hive (fig. 240), i.e., one made with glass sides and glass top, covered with outer wooden sides which are swung on hinges like doors, and with the usual removable wooden roof. Ordinarily the wooden sides and top are closed, thus leaving the hive in darkness. However, when it is desired to observe the bees at work within, the wooden sides are swung open; the glass still incloses the busy community, but affords an opportunity to see the actual performance of such interesting duties as wax-making, comb-building, food-storing, egg-laying, nursing, etc. An observation hive may be obtained from a dealer in beehives or be made out of an ordinary hive

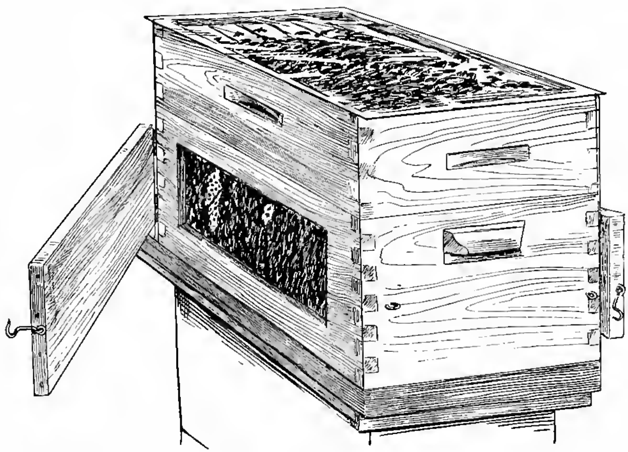


FIG. 240.—An "observation" beehive with glass top and sides. (Drawn from hive in the author's laboratory.)

by any carpenter or ingenious boy. It should be set up in the spring. It can be kept in the schoolyard, or even better, in the schoolroom itself. Substitute for a pane of glass in a window a thin wooden pane in which is cut a narrow horizontal opening, the size of the regular hive opening. If the latter is too broad it may be covered over at the ends. Set the observation hive on a table or box against the window so that its opening corresponds with that in the window. Or better, place it about six or eight inches from the window and build an inclosed broad shallow tunnel, covered above with glass, connecting the two openings. Over the glass top of the tunnel lay a sheet of dark cardboard, which can be simply lifted off whenever it is desired to see what is going on at the entrance. Here can be seen the "ventilating," the alertness of the sentinels and guards, the killing of drones, the constant arrival of pollen-laden food-gatherers, etc.

But observations may well begin in the field (fig. 241). Note the gathering of flower pollen. Where does the bee

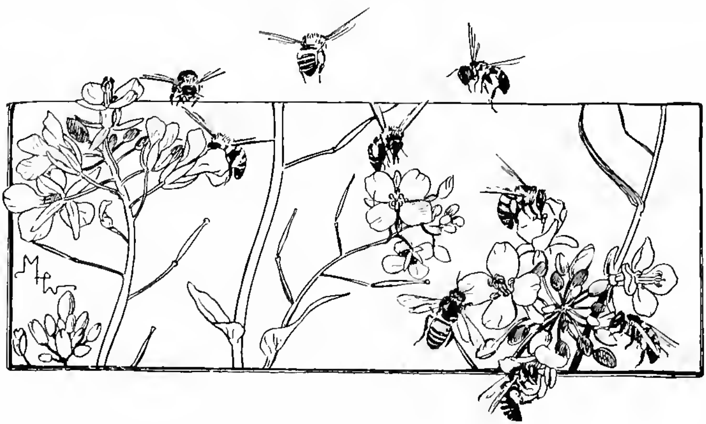


FIG. 241.—Honey-bees gathering pollen and nectar. (From life.)

put the pollen as it collects it? Why doesn't the pollen fall off? Kill a bee in a killing-bottle and examine carefully one of its hind legs. Make a drawing showing the pollen basket. At the flowers some of the bees do not collect pollen but nectar. Where do they find it, and how do they collect and carry it? Examine the complex "tongue" of a dead bee. By means of this tongue nectar is sucked or lapped up and swallowed into a crop, where it is not digested but retained until the bee returns to the hive. By observing the bees there and examining the comb-cells find out what is done with the pollen and nectar collected by the food-gatherers.

Try to observe the making of wax and the building of comb in the hive (fig. 242). The process is as follows: After having fed bountifully on honey and pollen from the food cells a number of bees gather together at the top of the hive and there hang in a mass, usually buzzing the wings violently. After a while small drops of liquid wax ooze out on the under side of the body. There are

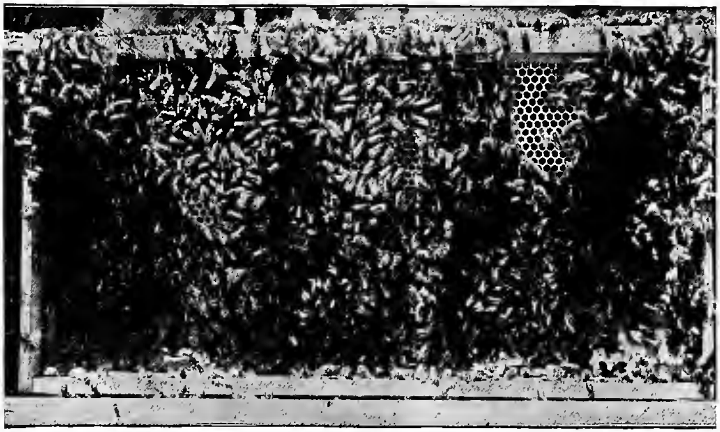


FIG. 242.—Honey-bees building comb. (From Benton.)

several pairs of small scale-like folds of the skin, called wax plates, on the under side of the hinder or abdominal body-rings. On these plates the wax spreads out and hardens into tiny thin sheets. After some of it has been made by a bee it leaves its wax-making companions and goes to the place where a new comb is to be builded or is building. Here it nips off its wax by means of its hind legs, which are furnished with a scissors-like arrangement, and with its broad, trowel-like jaws moulds it on the forming cells. Examine the "wax-shears" on the hind most legs of a dead bee and also the trowel-like jaws. Make drawings. Watch carefully the growth of the new comb. Of what shape are the new cells? Are they all of the same size? Is the bottom of each cell flat? How are those of the two opposite layers of which the comb is composed related to each other?

Note several bees standing in the covered entrance to the hive and steadily and rapidly vibrating their wings. They are "ventilating"—that is, making currents of air so that fresh air will constantly flow into the hive and foul air out. Ventilating bees may also be seen scattered through the hive. A movement of air through the comb is necessary for the honey-making as well as for ventilation. The nectar as it is gathered from flowers and poured out into cells from the crops of the food-gathering bees is too watery to be good honey, and must be partly evaporated. The ventilation assists largely in its evaporation. Touching the hand to the glass sides note that the interior of the hive is warmer on a cold day than the outer air. This is because the bees, when necessary, buzz violently to make themselves unusually warm and thus raise the temperature of the hive. When young bees are being reared the hive must always be kept warm. Note the bees clustering thickly over the brood-cells, i.e., the cells containing young.

Can you note any difference in the appearance of the various individuals? Are there some which do not work? Are all the cells filled with honey or pollen? If not, what is put into the other cells? The correct answer to these questions brings us to the consideration of the bees' development or life-history, and the make-up of the community. Some of the facts in the following brief account can be readily observed by the pupils, but some cannot. As many of the following statements as possible should be confirmed by observation.

A honey-bee community is made up of three kinds of individuals (fig. 243), namely, a single queen or mother which lays the eggs from which all the other bees are produced, several hundred drones or males, one of which becomes the royal consort, fertilizing the eggs, and from ten to forty thousand or more workers, which do all the work of the community, gathering food, making wax, building comb, ventilating the hive and caring for the young bees. The drones are larger, more robust, and more hairy than the workers, while the queen is longer, with a slender tapering abdomen. Certain combs are chosen as brood-combs (fig. 244), and beginning in the center of these and working outward the queen lays a tiny white elongate egg in the bottom of each cell. These eggs hatch in three days, and the young bees or larvæ appear as white, soft, footless, helpless, grubs. They are fed by certain worker bees called nurses (workers which have not yet learned to go out and gather pollen and honey), at first on a highly nutritious substance called bee-jelly, which the nurses make in their stomachs and regurgitate. After two or three days of bee-jelly diet they are given pollen and honey. A few days later a small mass of this new food is put into each cell, which is then "capped" or covered with wax. The larvæ after eating what is stored in their cell change into pupæ and lie quiescent for thirteen days when they become fully developed bees. They now

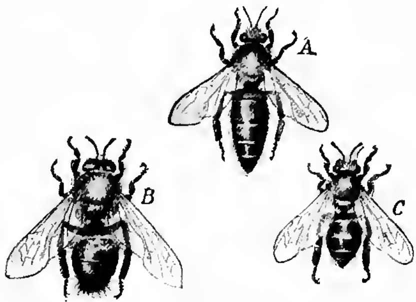


FIG. 243.—The honey-bee, *Apis mellifica*; *A*, queen; *B*, drone; *C*, worker. (From specimens.)

gnaw the caps away and come out into the hive ready to work.

Such is the life-history of the worker bee. It has been demonstrated that the eggs which produce workers and those which produce queens do not differ, but that if the workers desire to have a queen they tear down two or three cells around some one cell, enlarging it into a vase-shaped cavity (fig. 244). The larva that hatches in this large cell is fed for its whole larval life with rich bee-jelly. From its pupa issues not a worker but a new queen. The

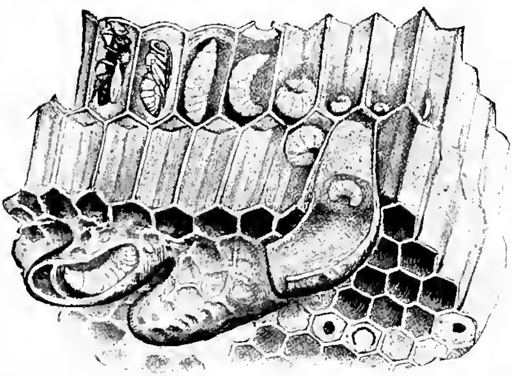


FIG. 244.—Worker brood and queen-cells of honey-bee; beginning at the right end of upper row of cells and going to the left is a series of egg, young larvæ, old larvæ, pupa, and adult ready to issue; the large curving cells below are queen-cells. (From Benton.)

eggs which produce drones or males differ from those which produce queens and workers in being unfertilized, the queen having the power to lay either fertilized or unfertilized eggs. When a new queen appears, or when several appear at once, there is great excitement in the community. If there are several they are believed to fight among themselves until only one survives. It is said that a queen never uses its sting except against another queen. The old queen now leaves the hive accompanied by many of the workers. She and her followers fly away together, finally alighting on some tree branch and hanging there in a dense mass. This is the familiar act of "swarming." Scouts leave the swarm to find a new home, to which they finally conduct the others. Thus is founded a new colony.

There are many more interesting things to be learned of the life in a honey-bee community; how it protects itself from the dangers of starvation, when food is scarce or winter comes on, by killing the useless drones and the immature bees in egg and larval stages; how the instinct of home-finding has been so highly developed that the worker may go miles away for honey and nectar, flying with unerring accuracy back to the hive; of the extraordinarily nice structural modifications which adapt the bee so perfectly for its complex and varied affairs; and of the tireless persistence of the workers until they fall exhausted and dying in the performance of their duties. The community, it is important to note, is a persistent or continuous one. The workers do not live long, the spring broods usually not over two or three months, and the fall broods not more than six or eight months; but new bees are hatching while the old ones are dying, and the community as a whole always persists. The queen may live several years, perhaps as many as five. She lays about one million eggs a year.

The honey-bees offer a splendid example of mutual aid instead of bitter war among individuals of a species. To be sure there is competition among different honey-bee communities for food, but among the thousands of individuals composing a single colony every one works for the benefit of the whole great family; the workers devote their whole life unceasingly for others.

Ants.—More than two thousand different kinds or species of ants are known, and all of them live in large communities or households and show a truly communal life. Ants, like honey-bees, may be kept in the school-room in a "formicary," and thus observed at home as well as when foraging in the fields. A "formicary" is simply an artificial nest in which an ant colony has been established. Professor Comstock gives the following directions for arranging a formicary:

"The principal materials needed for the construction of a nest of this kind are two panes of window-glass ten inches square, a sheet of tin eleven inches square, and a piece of plank one and a fourth inches thick, twenty inches long, and at least sixteen inches wide.

"To make the nest, proceed as follows: Cut a triangular piece about one inch long on its two short sides from one corner of one of the panes of glass. From the sheet of tin make a tray three-eighths of an inch in depth. This tray will be a little wider than the panes of glass and will contain them easily. On the upper side of the plank a short distance from the edge cut a deep furrow. This plank is to form the base of the nest, and the furrow is to serve as a moat, which is to be kept filled with water in order to prevent the escape of the ants. It is necessary to paint the base with several coats of paint to protect it from water and thus prevent its warping.

"To prepare the nest for use, place the tin tray on the base, put in the tray the square pane of glass, lay on the edges of the glass four strips of wood about one-half inch wide and a little thicker than the height of the ants which are to be kept in the nest, cover the glass with a layer of fine earth of the same thickness as the strips of wood, place upon this layer of earth and the strips of wood the pane of glass from which one corner has been cut, and cover the whole with a cover of the same size and shape as the upper pane of glass. In the nest figured the cover is made of blackened tin, and one-half of it is covered by a board. This gives a variation in temperature in different parts of the nest when it stands in the sunlight.

"The ants when established in the nest are to mine in the earth between the two plates of glass. The removal of one corner from the upper pane provides an opening to the nest. The thickness of the strips of wood between the edges of the two panes of glass determines the depth of the layer of earth in which the ants live. This should not be much thicker than the ants are high; for if it is the ants will be able to conceal themselves so that they cannot be observed

"The nest being prepared the next step is to transfer a colony of ants to it. The things needed with which to do this are a two-quart glass fruit-can, or some similar vessel that can be closed tightly, a clean vial, and a garden trowel. With these in hand find a small colony of ants, such as are common under stones in most parts of the country. Collect as many of the ants and of the eggs, larvæ, and pupæ as possible, and put them in the fruit-can, together with the dirt that is scooped up in collecting them with the trowel. Search carefully for the queen; sometimes she is found immediately beneath the stone covering the nest, but often it is necessary to dig a considerable distance in order to find her. She can be recognized by her large size. If the queen is not found, empty the contents of the can back into the nest, and take up another colony; without a queen the experiment will be a failure. When the queen is found place her in the vial so that she shall not be injured while being carried to the schoolroom.

"Having obtained a queen and a large part of her family, old and young, return to the schoolroom and empty the contents of the fruit-can on to the board covering the upper pane of glass, and place the queen there with her family. If much dirt and rubbish has been collected with the ants, remove some of it so that not more than half a pint of it remains. When this is done leave the ants undisturbed for a day or two. Of course the moat should be filled with water so that they cannot escape.

"Usually within twenty-four hours the ants will find the opening leading into the space between the two panes of glass and will make a mine into the layer of earth which is there, and will remove their queen and young to this place. This process can be hastened by gradually removing the dirt placed on the cover of the nest with ants.

"After the ants have made a nest between the panes of glass they can be observed when desired by merely lifting the board forming the cover of the nest.

"With proper care a colony can be kept in a nest of this kind as long as the queen lives, which may be several years. The food for the ants can be placed on the base of the nest anywhere within the moat, and may consist of sugar, minute bits of meat, fruits, etc. With a little care the kinds of food preferred by the colony can be easily determined. The pupæ of ants, which can be collected from nests in the field during the summer months will be greedily devoured. The soil in the nest should be kept from becoming too dry by putting a little water into one side of the tin tray from time to time."

The ant workers are specially distinguished in structure from the males and females by their lack of wings (fig. 245), and in numerous species there are two sizes or kinds, known as worker majors and worker minors. The life-history and communal habits of ants are not so thoroughly known as are those of the honey-bee, but they show even more remarkable specializations. The ant nest or formicary is, with most species, an elaborate system of underground galleries and chambers, special rooms being used exclusively for certain special purposes, as nurse-rooms, food-storage rooms, etc. The food of ants comprises many animal and vegetable substances, but the favorite kind with many species is the "honey-dew" secreted by the plant-lice (Aphididæ) and scale insects

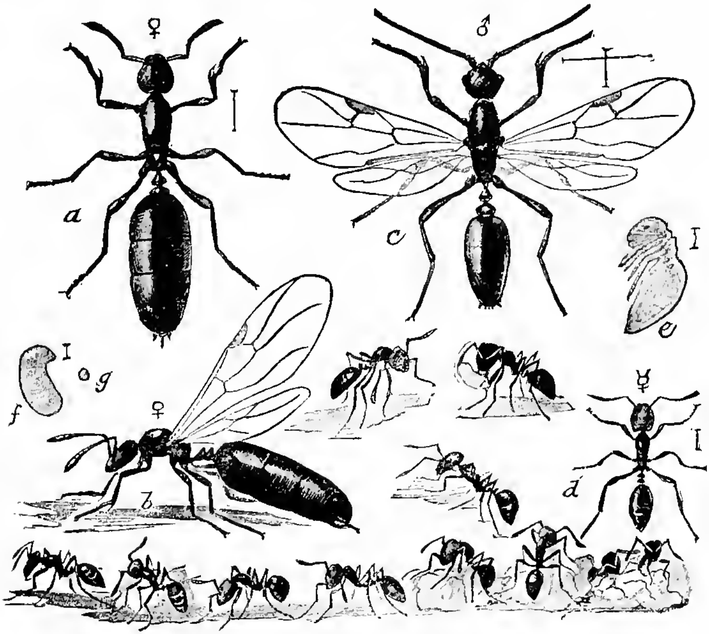


FIG. 245.—The little black ant, *Monomorium minutum*; *a*, female; *b*, female with wings; *c*, male; *d*, workers; *e*, pupa; *f*, larva; *g*, egg of worker, all enlarged. (From Marlatt.)

(Coccidæ). To obtain this honey-dew an ant strokes one of the aphids with its antennæ, when the fluid is excreted by the little insect and drunk by the ant. In order to have a certain supply of this food some species of ants care for and defend these defenseless aphids, which have been called their "cattle." In some cases they are even taken into the ants' nest and provided with food. In the Mississippi Valley a certain kind of plant-louse lives on the roots of corn. Its eggs are deposited in the ground in the autumn and hatch the following spring before the corn is planted. The common little brown ant also lives abundantly in the corn-fields, and is especially fond of the honey-dew secreted by the corn-root lice. So when they hatch in the spring before there are corn-roots for them to feed on, the ants with great solicitude carefully place them on the roots of a certain kind of knot-weed which grows in the field and there protect them until the corn germinates. They are then removed to the roots of the corn. In the arid lands of New Mexico and Arizona the ants rear scale insects on the roots of cactus.

Ants are among the most warlike of insects. Battles between communities of different species are numerous, the victorious community taking possession of the food-stores of the conquered. Some species of ants live wholly by war and robbery. In the case of the remarkable robber-ant (Eciton), found in tropical and sub-tropical regions, most of the workers are soldiers, and no longer do any work but fighting. The whole community lives exclusively by pillage. Some kinds go even farther than mere robbery of food-stores; they make slaves of the conquered ants. There are numerous species of these slave-making ants. They attack a nest of another species and carry home the eggs and larvæ and pupæ of the conquered community. When these come to maturity they have to act as slaves, collecting food, building additions to the nest, and caring for the young of the victors.

As in the case of the honey-bee the larval ants are helpless grubs and are cared for and fed by nurses. The so-called "ants' eggs"—the little white oval masses which we often see being carried in the mouths of ants in and out of nest—are not eggs, but are the pupæ, which are being brought out to enjoy the warmth and light of the sun or being taken back into the nest afterward.

Careful observation of the ants in the indoor nest, and of nests and individuals out of doors, will reveal many of the remarkable and interesting features of ant life, and almost surely things not now known to naturalists will be found out.

FIG. 246.—Bumble-bee at clover blossom. (From life.)

Wasps and bumble-bees.—The true wasps, commonly called yellow-jackets and hornets, and the bumble-bees, also live in communities; but among these forms each household lasts only from spring into autumn, new communities being formed the next spring by queens which live through the winter. The few bumble-bees which we see in winter-time, usually hiding in some sheltered place, are queens. In the spring each queen finds a deserted mouse's nest or other hole in the ground, gathers a mass of pollen, and lays some eggs on it. The larvæ, hatching, feed on the pollen, dig out irregular cells for themselves in it, pupate, and soon issue as workers or unfertile females.

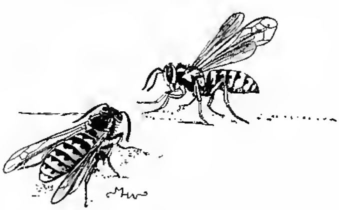


FIG. 247.—Yellow-jackets. (Natural size; from life.)

These workers gather more pollen, the queen lays more eggs, and several successive broods of workers are produced. Finally, late in the summer a brood containing males (drones) and fertile females (queens) is produced, mating takes place, and then before winter all the workers and drones and some of the queens die, leaving a few fertilized queens to hibernate and establish new communities in the spring.

The yellow-jackets (fig. 247) and hornets (Vespidæ), the so-called social wasps, have a life-history very like that of the bumble-bees. The communities of the social wasps are larger and their nests are often made above ground,

FIG. 248.—Nest of yellow-jackets (*Vespa*) cut open to show combs within. (About one-third natural size; photograph from specimen.)

being composed of several combs, one above the other, and all inclosed in a many-layered covering sac open only by a small hole at the bottom (fig. 248). This kind of nest hangs from the branch of a tree and is built of wasp-paper, which is a pulp made from bits of old wood chewed by the workers. The brood-cells are provisioned with killed and chewed insects, the larvæ of both solitary and social wasps living on animal food, while the larvæ of both solitary and social bees are fed on flower-pollen and honey. As with the bumble-bees, all the members of the community except a few fertilized females die in the autumn, the surviving queens founding new colonies in the spring. The queen then builds a miniature "hornet's nest" (fig. 249), lays an egg in each cell, and stores the cells with chewed insects. The first brood is composed of workers, which enlarge the nest, get more food, and relieve the queen of all labor except that of egg-laying. More broods of workers follow until the

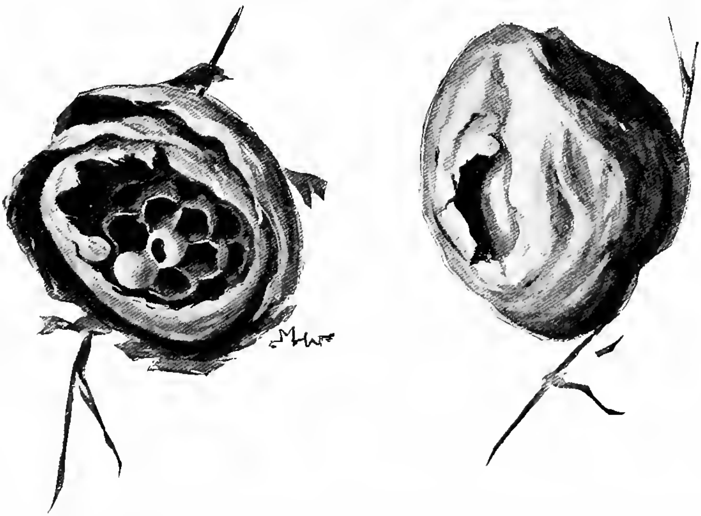


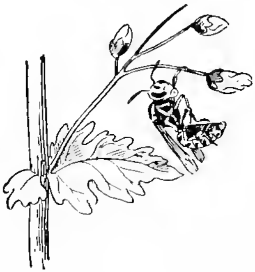
FIG. 249.—Queen-nest of yellow-jacket (*Vespa*). Specimen at right in normal condition; at left cut open to show brood-cells. (Natural size; from specimen.)

fall brood of males and females appears, after which the original process is repeated.

The nests of both bumble-bees and hornets are familiar to all country children, and in summer may be readily found and observed. In early spring the small "queen-nests" of hornets should be looked for, and in winter the hibernating queen bumble-bees and wasps should be sought under stones, in crevices of bark, or in other sheltered places.

Other social animals.—Besides bees, ants, and wasps there are many other animals which live together in more or less helpful association with each other. The beavers, which unite to build a dam in order to make a pond in which to build their houses; the prairie-dogs, which live in large "towns"; the bands of crows that post sentinels to watch for enemies while the others feed; the birds which migrate in great flocks following a few leaders; and the wolves, which hunt together in bands and are thus able to attack and pull down animals too large to be overcome by a single individual, are all examples of animals which display a certain degree of mutual aid. Let each pupil try to discover others among the animals familiar to him.

For detailed accounts of the honey-bee see Cowan's "Natural History of the Honey-bee," or Cook's "Bee-keepers' Guide," or Cheshire's "Bees and Bee-keeping." Maeterlinck's "The Life of a Bee" is most interesting. For a good account of the wasps and hornets see Ormerod's "British Social Wasps." "Ants and their Ways," by W. F. White, is good. For an interesting account of experiments to reveal the intelligence of ants, bees, and wasps, see Lubbock's "Ants, Bees, and Wasps." W. M. Wheeler has published in various numbers of the "American Naturalist" of 1902 accounts of his interesting studies on ants.



CHAPTER XXI

HOW ANIMALS ARE DISTRIBUTED OVER THE WORLD

Animals limited to particular regions.—We are used to seeing certain kinds of animals, such as rabbits, robins, field-mice, and garter-snakes in the particular region in which we live, and never seeing others, such as lions, elephants, birds-of-paradise, and boa-constrictors. We know, indeed, that these latter kinds do not live in our region nor even on our continent. But we are too likely to take such things for granted, and not inquire why it is that only certain particular kinds live in North America and certain others in Africa, while others still may be found all over the world.

As a matter of fact there are few things about animals more interesting to observe than their distribution over the world. Unfortunately in this matter we must depend for many of our facts upon the statements of other people; we can observe at first hand only a few of them. We can see for ourselves what kinds of animals live in our neighborhood, and that certain other kinds with which we are somewhat familiar from menageries or books do not. We can see that some animals, fishes for example, live always in water; and that some water animals live always in ponds, while others prefer the brooks. Many other water animals, on the contrary, can live only in the ocean (see Chapter X, on ocean animals), and of these some always keep near the bottom, where it is dark and cold, while many live on or near the surface. Again, some of the surface forms keep always near the shore, while others never or rarely come in sight of land. But most of the familiar animals about us cannot live in water

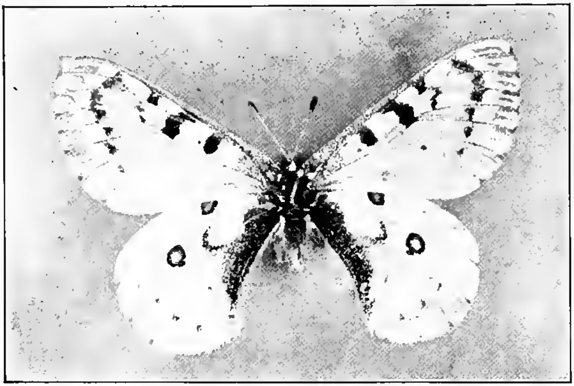


FIG. 250.—The Parnassian butterfly (*Parnassius smintheus*) which lives in the Rocky Mountains and Sierra Nevada, at an altitude of 5000 feet and above. (Natural size; from specimen.)

at all. They either burrow in the ground like moles and gophers, or live in trees like squirrels, or fly in the air like birds and butterflies.

Barriers.—Of land animals some can live only in tropical and sub-tropical regions, as the monkeys and most of the parrots, some live only in the snowy regions near the poles, as the polar bear and great walrus, while many prefer neither of these extremes but live in the temperate zones. Although the word "prefer" has been used, it is usually true that animals which live in arctic regions are not able to live elsewhere; they seem to be adapted solely for an arctic climate, so that the line around the earth south of which there is frost and freezing weather during a part of the year only is a sort of barrier beyond which they cannot safely venture. And, turning to the animals of the tropics, we find that most of them cannot endure any frost or freezing at all, the southernmost line of frost being to them a barrier north of which they cannot live. These barriers are raised by temperature. Similarly there are barriers made by differences in rainfall. The animals of the Eastern United States, accustomed to a large amount of moisture and to luxuriant vegetation, could not live on the arid, burning, sterile desert; but the lizards and desert rats and coyotes live there successfully.

But barriers more marked and more tangible are those such as oceans which surround continents and islands and thus limit the land animals of these regions to their respective districts. Similarly the land which surrounds a lake or pond limits the fishes in it to that particular lake or pond, although they would live quite as well in some other. And it is true that many animals could live elsewhere than in the place to which they are now restricted if they could only get there. Indeed they could live in any other region where the climate and general conditions are like their present home. So we say that the distribution of animals over the world is largely determined by barriers—barriers of temperature, of moisture, of water, of land, of high mountains, of deserts, of anything that the animal cannot cross.

How animals spread.—The ways in which animals spread are mostly easily understood. Birds can fly to new regions; quadrupeds can travel on foot for long distances; fishes can swim from one part of a river or lake or ocean to another. But although two rivers may empty into the ocean close together fishes cannot often easily get from one into the other. For most fresh-water fishes cannot live in salt water, so that even a small stretch of ocean is an effective barrier to them. Salmon, some eels, and a few other fishes, however, live part of the time in the ocean and part in streams. Many animals are transported long distances involuntarily. Rats and mice invading a ship from wharves at Liverpool sometimes get carried across the Atlantic Ocean to America. In fact the common black rats and brown rats of the houses and barns over this whole country are not native rats at all, but are descendants of European rats unintentionally brought across the ocean in ships. The same is true of many of the insect pests which trouble us; for example, the Hessian fly, which does great damage to wheat, the cockroaches of our houses and the carpet beetles or buffalo bugs which attack rugs and carpets. Sometimes a boring insect lying snugly in a log gets carried down a river, out into the ocean, and by means of ocean currents far away to some island where it may crawl out and lay eggs and so establish itself in a new country. Sometimes animals are intentionally imported by man from foreign countries. The introduction of the English sparrow into this country and the rabbits into Australia are examples of unfortunate experiments along this line.

Map showing the distribution of animals.—Zoologists have been studying the distribution of animals so long that they have been able to map out the range of many of the well-known kinds. On a map of the world they indicate, by shading, all those regions in which lions exist; all those in which elephants live, and all those in which humming-birds are found. Now this kind of map-making reveals many things of interest and throws much light on the relations of animals to climate, to geography, and to each other.

Such zoological map-making may be restricted to a limited locality, and is the best way for beginning students to study distribution. On a large sheet of strong paper a map of the region about the schoolhouse, say one or two miles square, should be made, with all the streams, ponds, swamps, pastures, woods, etc. Then search carefully for the haunts of certain kinds of animals which are known to occur in the mapped region, and mark them on the map. It will soon be found that the different kinds of animals are more or less limited to certain parts of the region. Attempt may next be made to find out why. Are there barriers? If so, of what nature? They cannot well be barriers of temperature or climate, unless a mountain is included in the region, but may be concerned with food, suitable hiding-places, proximity to man, necessity of water for breeding in, etc. This is a study, all of which must be made in the field, and where much ingenuity in observing and reasoning must be used.

For a reference-book on the subject of this chapter see Heilprin's the "Distribution of Animals," or Beddard's "Zoo-geography."

APPENDIX I

NOTE-BOOKS, DRAWINGS, AND REFERENCE BOOKS.

Note-books and drawings.—Each pupil should have a note-book of about 8 × 10 inches, opening at the end, in which both drawings and notes can be made. The paper should be unruled and of good quality (not too soft). Each pupil should make the drawings called for in connection with the study of the various animals considered in this book. These drawings should be in outline, and put in by pencil; the lines may be inked over if preferred. Each drawing and all the animal parts represented in it should be fully named. Notes should be made of any observations which cannot be represented in the drawings, for example, on the behavior of living animals. All notes referring to matters of life-history should be dated.

Scattered through this book will be found numerous suggestions for student field-work, for the observation of the life-history and habits and conditions of animals in nature. The initiation and direction of such work is left to the teacher. But its importance, both because of its instructiveness and its interest is great. Pupils should not only be incited to make individual observations whenever and wherever they can, but the teacher should make little field-excursions with the class, or with parts of it, at various times, to ponds or streams or woods, and "show things" to all. The life-history and feeding-habits of insects, the web-making of spiders, the flight, songs, nesting and care of young of birds, the haunts of fishes, the development of frogs, toads, and salamanders, the home-building and feeding-habits of squirrels, mice, and other familiar mammals are all (as has been called attention to at proper places in the book) specially fit subjects for field-observation.

Each pupil should keep a field note-book, recording from day to day, under exact date, any observations he may make. Let the most trivial things be noted; when referred to later in connection with other notes they may not seem so trivial. The field note-book should be smaller than the laboratory note- and drawing-book, small enough to be carried in the pocket. Notes should be made on the spot of observation; do not wait to get home. Sketches, even rough ones, may be advantageously put into the book. Students with photographic cameras can do some very interesting and valuable field-work in making photographs of animals, their nests and favorite haunts. Such photographic work is very effectively used now in the illustration of books about animals and plants (see the reproductions of photographs in this book). If the class is making a collection the collecting notes or data made in the field-books of the different pupil collectors should all be transferred to a common "Notes on Collections" book kept by the whole class.

Reference-books.—Throughout the preceding chapters exact references have been made to various books, as many of which as possible should be kept in the school library. Some of these references have been made with special regard to the teacher, but most with special regard to the pupil. All of the books referred to are included in the following list. For the convenience of the prospective buyer the names of the publishers and prices of the books are appended. In buying books it is, of course, not necessary to order from the various publishers.

A list of books desired may be handed to any book-dealer, who will order them, and who should in most cases be able to get them for a little less than publisher's list prices.

Bailey, Florence M. Handbook of Birds of the Western United States. 1902. Houghton, Mifflin & Co. $3.50.

Baskett, J. N. Story of the Fishes. D. Appleton & Co. $0.65.

—— The Story of the Birds. 1899. D. Appleton & Co. $0.65.

Beard, J. C. Curious Homes and their Tenants. D. Appleton & Co. $0.65.

Beddard, Frank. Animal Coloration. 1892. Macmillan Co. $3.50

—— Zoogeography. 1895. Macmillan Co. $1.60.

Bendire, Chas. Directions for Collecting, Preparing, and Preserving Birds Eggs and Nests. Distributed by the U. S. National Museum.

Bird-lore, an Illustrated Journal about Birds. Macmillan Co. $1.00 a year.

Chapman, Frank M. Handbook of the Birds of Eastern North America. 1899. D. Appleton & Co. $3.00.

—— Bird-life. 1900. D. Appleton & Co. $2.00

Cheshire, F. R. Bees and Bee-keeping. 1886. L. Upcott Gill.

Comstock, J. H. Manual for the Study of Insects. 1897. Comstock Publishing Co. $3.75.

—— Insect Life. 1901. D. Appleton & Co. $1.50.

—— **and Kellogg, V. L.** Elements of Insect Anatomy. 1901. Comstock Publishing Co. $1.00.

Cooke, W. W. Bird Migration in the Mississippi Valley. Distributed by the Division of Biological Survey, U. S. Dept. Agric.

Coues, Elliott. Key to North American Birds. 1890. Estes & Lauriat. $7.50.

Cowan, T. W. Natural History of the Honey-bee. 1890. London: Houlston. 1s. 6d.

Davie, Oliver. Methods in the Art of Taxidermy. 1894. Columbus, O. Oliver Davie & Co. $10.00 *net.*

Dickerson, Mary C. Moths and Butterflies. 1901. Ginn & Co. $1.50.

Dugmore, A. R. Bird Homes. Doubleday, Page & Co. $2.00.

Eckstrom, F. H. The Woodpeckers. Houghton, Mifflin & Co. $1.00.

Emerton, J. H. Spiders, their Structure and Habits. 1890. Knight E. Millet. $1.50 *net.*

—— Common Spiders. 1902. Ginn & Co.

Fabre, J. H. Insect Life. 1901. Macmillan & Co. $1.75.

Gage, S. H. Life History of the Toad. Teacher's Leaflets, No. 9, April, 1898. Prepared by College of Agriculture, Cornell University, Ithaca, N. Y.

Heilprin, A. The Distribution of Animals. 1886. D. Appleton & Co. $2.00.

Holland, W. J. The Butterfly Book. 1899. Doubleday & McClure Co. $3.00.

Hornaday, W. T. Taxidermy and Zoological Collecting. 1897. Chas. Scribner's Sons. $2.50 *net.*

Howard, L. O. Mosquitoes. 1901. McClure, Phillips & Co. $1.50 *net.*

—— The Insect Book. 1901. Doubleday, Page & Co. $3.00 *net.*

Huxley, T. H. The Crayfish; an Introduction to the Study of Zoology. D. Appleton & Co. $1.75.

Jordan, D. S. Manual of Vertebrate Animals of the Northern United States. 8th ed. 1899. A. C. McClurg & Co. $2.50.

—— **and Evermann, B. W.** Food and Game Fishes of North America. 1902. Doubleday, Page & Co. $3 00 *net.*

—— **and Kellogg, V. L.** Animal Life. 1900. D. Appleton & Co. $1.20.

Kellogg, V. L. Elementary Zoology. 1901. Henry Holt & Co. $1.20.

Long, Wm. J Ways of Wood Folk. 1901. Ginn & Co. $0.65.

—— Wilderness Ways. 1901. Ginn & Co. $0.65.

—— Secrets of the Woods. 1901. Ginn & Co. $0.65.

Lubbock, John. Ants, Bees, and Wasps. 1882. D. Appleton & Co. $2.00.

Maeterlinck, Maurice. The Life of a Bee. 1902. Dodd, Mead & Co.

McCarthy, Eugene. Familiar Fish. D. Appleton & Co. $1.50.

McCook, Henry. American Spiders and their Spinning Work. 3 vols. 1889–1893. H. C. McCook, Phila., Pa. $30.00.

Miall, L. C. The Natural History of Aquatic Insects. 1895. Macmillan Co. $1.75.

Needham, J. B. Outdoor Studies. 1898. American Book Co. $0.40.

Newbigin, M. I. Color in Nature. 1898. London: John Murray.

Ormerod, E. L. British Social Wasps. 1868. Longmans, Green, & Co., Reader, and Dyer.

Parker, T. J. Lessons in Elementary Biology. 1897. Macmillan Co. $2.65.

Peckham, George W. and E. J. On the Instincts and Habits of the Solitary Wasps. 1898. Sold by Des Forges & Co., Milwaukee, Wis. $2 00.

Poulton, E. B. The Colors of Animals. 1890. D. Appleton & Co. $1.75.

Ridgway, R. Directions for Collecting Birds. Distributed by U. S. National Museum.

Scudder, S. H. The Life of a Butterfly. 1893. Henry Holt & Co. $1.00.

—— Everyday Butterflies. 1899. Houghton, Mifflin & Co. $2.00.

Van Beneden, E. Animal Parasites and Messmates. 1876. D. Appleton & Co. $1.50.

White, W. F. Ants and their Ways. 1895. The Religious Tract Society.

APPENDIX II

REARING ANIMALS AND MAKING COLLECTIONS

MUCH good work in observing the behavior and life-history of some kinds of animals can be done by keeping them alive in the schoolroom under conditions simulating those to which they are exposed in nature. The growth and development of frogs and toads from egg to adult, as well as their feeding habits and general behavior, can all be observed in the schoolroom as explained in Chapter II. Harmless snakes are easily kept in glass-c vered boxes; snails and slugs are contented dwellers indoors; certain fish live well in small aquaria, and many other familiar forms can be kept alive under observation for a longer or shorter time. But from the ease with which they are obtained and cared for, the rapidity of their growth, the inexpensiveness of their live-cages, and the interesting character of their life-history and general habits, insects are, of all animals, the ones which specially commend themselves from the schoolroom menagerie. In the notes in chapter XII are numerous suggestions regarding the obtaining and care of certain kinds of insects which may be reared and studied to advantage in the schoolroom. In the following paragraphs are given directions for making the necessary live-cages and aquaria for these insects.

Live-cages and aquaria.—Prof. J. H. Comstock has so well described the making of simple and inexpensive cages and aquaria in his book, "Insect Life," that, with his permission, his account is quoted here.

Live-cages.—"A good home-made cage can be built by fitting a pane of glass into one side of an empty soap-box. A board, three or four inches wide, should be fastened below the glass so as to admit of a layer of soil being placed in the lower part of the cage, and the glass can be made to slide, so as to serve as a door (fig. 251). The glass should fit closely when shut, to prevent the escape of the insects.

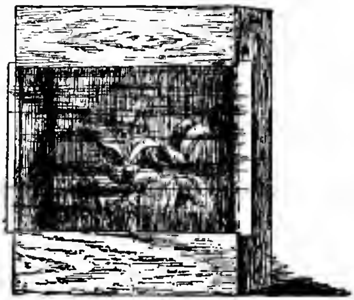


FIG. 251.—Soap-box breeding-cage for insects. (From Jenkins and Kellogg.)

"In rearing caterpillars and other leaf-eating larvæ, branches of the food-plant should be stuck into bottles or cans which are filled with sand saturated with water. By keeping the sand wet the plants can be kept fresh longer than in water alone, and the danger of the larvæ being drowned is avoided by the use of sand.

"Many larvæ when full-grown enter the ground to pass the pupal state; on this account a layer of loose soil should be kept in the bottom of a breeding-cage. This soil should not be allowed to become dry, neither should it be soaked with water. If the soil is too dry the pupæ will not mature, or if they do so the wings will not expand fully; if the soil is too damp the pupæ are liable to be drowned or to be killed by mold.

"It is often necessary to keep pupæ over winter, for a large proportion of insects pass the winter in the pupal state. Hibernating pupæ may be left in the breeding-cages or removed and packed in moss in small boxes. Great care should be taken to keep moist the soil in the breeding-cages, or the moss if that be used. The cages or boxes containing the pupæ should be stored in a cool cellar, or in an unheated room, or in a large box placed out of doors where the sun cannot strike it. Low temperature is not so much to be feared as great and frequent changes of temperature.

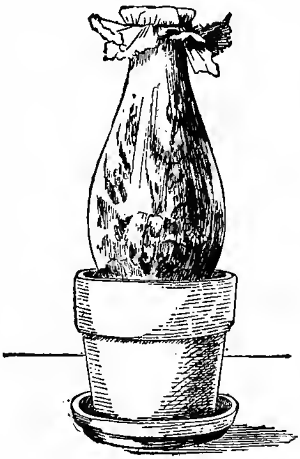


Fig. 252. — Lamp-chimney and flower-pot breeding-cage for insects. (From Jenkins and Kellogg.)

"Hibernating pupæ can be kept in a warm room if care be taken to keep them moist, but under such treatment the mature insects are apt to emerge in midwinter.

"An excellent breeding-cage is represented by fig. 252. It is made by combining a flower-pot and a lantern-globe. When practicable, the food-plant of the insects to be bred is planted in the flower-pot; in other cases a bottle or tin can filled with wet sand is sunk into the soil in the flower-pot, and the stems of the plant are stuck into this wet sand. The top of the lantern-globe is covered with Swiss muslin. These breeding-cages are inexpensive, and especially so when the pots and globes are bought in considerable quantities. A modification of this style of breeding-cage that is used by the writer differs only in that large glass cylinders take the place of the lantern-globes. These cylinders were made especially for us by a manufacturer of glass, and cost from six to eight dollars per dozen, according to size, when made in lots of fifty.

"When the transformation of small insects or of a small number of larger ones are to be studied, a convenient cage can be made by combining a large lamp-chimney with a small flower-pot.

"*The root-cage.*—For the study of insects that infest the roots of plants, the writer has devised a special form of breeding-cage known as the root-cage. In its simplest form this cage consists of a frame holding two plates of glass in a vertical position and only a short distance apart. The space between the plates of glass is filled with soil in which seeds are planted or small plants set. The width of the space between the plates of glass depends on the width of two strips of wood placed between them, one at each end, and should be only wide enough to allow the insects under observation to move freely through the soil. If it is too wide the insects will be able to conceal themselves. Immediately outside of each glass there is a piece of blackened zinc which slips into grooves in the ends of the cage, and which can be easily removed when it is desired to observe the insects in the soil.

"*Aquaria.*—For the breeding of aquatic insects aquaria are needed. As the ordinary rectangular aquaria are expensive and are liable to leak we use glass vessels instead.

"Small aquaria can be made of jelly-tumblers, glass finger-bowls, and glass fruit-cans, and larger aquaria can be obtained of dealers. A good substitute for these is what is known as a battery-jar (fig. 253). There are several sizes of these, which can be obtained of most dealers in scientific apparatus.

"To prepare an aquarium, place in the jar a layer of sand; plant some water-plants in this sand, cover the sand with a layer of gravel or small stones, and then add the required amount of water carefully, so as not to disturb the plants or to roil the water unduly. The growing plants will keep the water in good condition for aquatic animal life, and render changing of the water unnecessary, if the animals in it live naturally in quiet water. Among the more available plants for use in aquaria are the following:

"Waterweed, *Elodea canadensis*.

"Bladderwort, *Utricularia* (several species).

"Water-starwort, *Callitriche* (several species).

"Watercress, *Nasturtium officinale*.

"Stoneworts, *Chara* and *Nitella* (several species of each).

"Frog-spittle or water-silk, *Spirogyra*.

"A small quantity of duckweed, *Lemna*, placed on the surface of the water adds to the beauty of an aquarium.

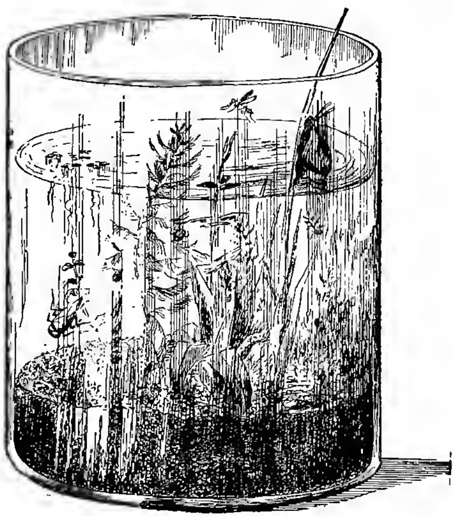


FIG. 253.—Battery-jar aquarium. (From Jenkins and Kellogg.)

"When it is necessary to add water to an aquarium on account of loss by evaporation, rain water should be used to prevent an undue accumulation of the mineral-water held in solution in other water."

Making collections.—Much is to be learned about animals by "collecting" them. But the collecting should be done chiefly with the idea of learning about the animals rather than with the notion of getting as many specimens as possible. To collect, it is necessary to find the animals alive; one learns thus their haunts, their local distribution, and something of their habits, while by continued work one comes to know how many and what different kinds or species of each group being collected occur in the region collected over. Collecting requires the sacrifice of life, however, and this will always be kept well in mind by the humane teacher and pupil. Where one set of specimens will do, no more should be collected. The author believes that school work in this line should be almost exclusively limited to the building up of a common school collection. Let a single set of specimens be brought together by the combined efforts of all the members of the class, and let it be well housed and cared for permanently. Each succeeding class will add to it; it may come in time to be a really representative exhibition of the local fauna.

The school collection should include not only adult specimens of the various kinds of animals, forming a systematic collection, as it is called, but also all kinds of specimens which illustrate the structure and habits of the animals in question and which will constitute a so-called biological collection. Specimens of the eggs and all immature stages; dissections preserved in alcohol or formalin showing the external and internal anatomy; nests, cocoons, and all specimens showing the work and industries of the various animals; in short, any specimen of the animal itself in embryonic or postembryonic condition, or any parts of the animal, or anything illustrating what the animal does or how it lives, all these should be collected as assiduously as the adult individuals. Each specimen in the collection should be labelled with the name of the animal, the date, and locality, and the name of the collector, with any particular information which will make it more instructive. If such special data are too voluminous for a label, they should be written in a general note-book called "Notes on Collections" (kept in the schoolroom with the collection), the specimen and corresponding data being given a common number so that their association may be recognized. In the following paragraphs are given brief directions for catching, pinning up, and caring for insects, for making skins of birds and mammals, and for the alcoholic preservation of other kinds of animals.

FIG. 251 —Insect killing-bottle; cyanide of potassium at bottom, covered with plaster of Paris. (From Jenkins and Kellogg.)

Insects.—For catching insects there are needed a net, a killing-bottle, a few small vials of alcohol, and a few small boxes to carry home live specimens, cocoons, galls, etc. For preparing and preserving the insects there are needed insect-pins, cork- or pith-lined drawers or boxes, and small wide-mouthed bottles of alcohol.

The net, about 2 feet deep, tapering and rounded at its lower end, is made of cheesecloth or bobinet (not mosquito-netting, which is too frail), attached to a ring, one foot in diameter, of No. 3 galvanized iron wire, which in turn is fitted into a light wooden or cane handle about three and a half feet long.

The killing-bottle (fig. 254) is prepared by putting a few small lumps (about a teaspoonful) of cyanide of potassium into the bottom of a wide-mouthed bottle holding about four ounces, and covering this cyanide with wet plaster of Paris. When the plaster sets it will hold the cyanide in place, and allow the fumes given off by its gradual volatilization to fill the bottle. Insects dropped into it will be killed in from two or three to ten minutes. Keep a little tissue paper in the bottle to soak up moisture and to prevent the specimens from rubbing. Also keep the bottle well corked. Label it "Poison," and do not breathe the fumes (hydrocyanic gas). Insects may be left in it over night without injury to them.

Butterflies or dragon-flies too large to drop into the killing-bottle may be killed by dropping a little chloroform or benzine on a piece of cotton, to be placed in a tight box with them. Larvæ (caterpillars, grubs, etc.) and pupæ (chrysalids) should be dropped into the vials of alcohol.

In collecting, visit flowers, sweep the net back and forth over the small flowers and grasses of meadows and pastures, look under stones, break up old logs and stumps, poke about decaying matter, jar and shake small trees and shrubs, and visit ponds and streams. Many insects can be collected in summer at night about electric lights, or a lamp by an open window.

When the insects are brought home or to the schoolroom they must be "pinned up." Buy insect-pins, long, slender, small-headed, sharp-pointed pins, of a dealer in naturalists' supplies. These pins cost ten cents a hundred. Order Klaeger pins, No. 3, or Carlsbaeder pins, No. 5. These are the most useful sizes. For larger pins order Klaeger No. 5 (Carlsbaeder No. 8); for smaller order Klaeger No. 1 (Carlsbaeder No. 2). Pin each insect straight down through the thorax (fig. 255) (except beetles, which pin through the right wing-cover near the middle of the body). On each pin below the insect place a small label with date and locality of capture. Insects too small to be pinned may be gummed on to small slips of cardboard, which should be then pinned up. Keep the insects in drawers or boxes lined on the bottom with a thin layer of cork, or pith of some kind. (Corn-pith can be used; also in the West, the pith of the flowering stalk of the century plant.) The cheapest insect-boxes and very good ones, too, are cigar-boxes. But

FIG. 255.—Insect properly "pinned up." (From Jenkins and Kellogg.)

unless well looked after they let in tiny live insects which feed on the dead specimens. For a permanent collection, therefore, it will be necessary to have made some tight boxes or drawers. Glass-topped ones are best, so that the specimens may be examined without opening them. A "moth-ball" (naphthaline) fastened in one corner of the box will help keep out the marauding insects.

Butterflies, dragon-flies, and other larger and beautiful-winged insects should be "spread," that is, should be allowed to dry with wings expanded. To do this spreading- or setting-boards (figs. 256 and 257) are necessary. Such a board consists of two strips of wood fastened a short distance apart so as to leave between them a groove for the body of the insect, and upon which the wings are held in position until the insect is dry. A narrow strip of pith or cork should be fastened to the lower side of the two strips of wood, closing the groove below. Into this cork is thrust the pin on which the insect is mounted. Another strip of wood is fastened to the lower sides of the cleats to which the two strips are nailed. This serves as a bottom and protects the points of the pins which project through the piece of cork. The wings are held down, after having been outspread with the hinder margins of the fore wings about at right angles to the body, by strips of paper pinned down over them.

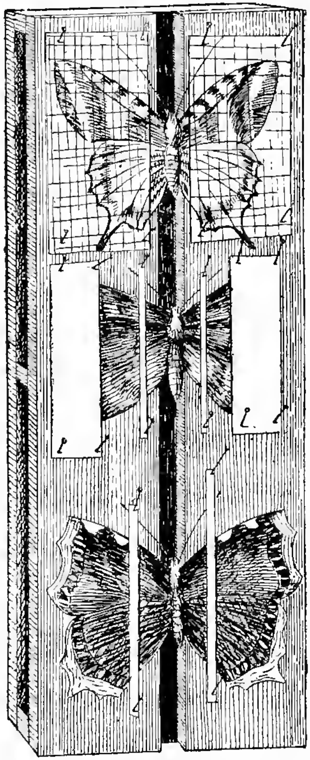


FIG. 256.—Setting-board with butterflies properly "spread." (After Comstock.)

"Soft specimens" such as insect larvæ, myriapods, and spiders should be preserved in bottles of alcohol (85 per cent). Nests, galls, stems, and leaves partly eaten by insects, and other dry specimens can be kept in small pasteboard boxes.

For a good and full account of insect-collecting and preserving, with directions for making insect-cases, etc., see Comstock's "Insect Life," pp. 284–314.

Birds. — In collecting birds, shooting is chiefly to be relied on. Use dust-shot (the smallest shot made) in small loads. For shooting small birds it is extremely desirable to have an auxiliary barrel of much smaller bore than the usual shotgun which can be fitted into one of the regular gun-barrels. In such an auxiliary barrel use 32-calibre shells loaded with dust-shot instead of bullets. Plug up the throat and vent of shot birds with cotton, and thrust each bird head downward into a cornucopia of paper. This will keep the feathers unsoiled and smooth.

Birds should be skinned soon after bringing home, after they have become relaxed, but before evidences of decomposition are manifest. The tools and materials necessary to make skins are scalpel, strong sharp-pointed scissors,

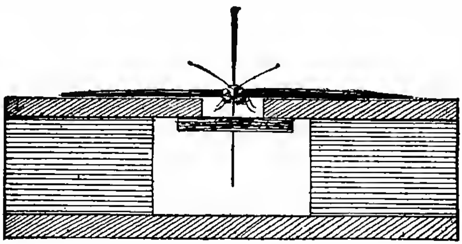


FIG. 257.—Setting-board in cross-section to show construction. (After Comstock.)

bone-cutters, forceps, corn-meal, a mixture of two parts white arsenic and one part powdered alum, cotton, and metric-system measure. Before skinning, the bird should be measured. With a metric-system measure carefully take the alar extent, i.e. spread from tip to tip of outstretched wings; length of wing, i.e. length from wrist-joint to tip; length of bill in straight line from base (on dorsal aspect) to tip; length of tarsus, and length of middle toe and claw.

To skin the bird, cut from anus to point of breast-bone through the skin only. Work skin away on each side to legs; push each leg up, cut off at knee-joint, skin down to next joint, remove all flesh from bone, and pull leg back into place; loosen skin at base of tail, cut through vertebral column at last joint, being careful not to cut through bases of tail-feathers; work skin forward, turning it inside out, loosening it carefully all around, without stretching, to wings; cut off wings at elbow-joint, skin down to next joint and remove flesh from wing-bones; push skin forward to base of skull, and if skull is not too large (it is in ducks, woodpeckers, and some other birds), on over it to ears and eyes; be very careful in loosening the membrane of ears and in cutting nictitating membrane of eyes; do not cut into eyeball; remove eyeballs without breaking; cut off base of skull, and scoop out brain; remove flesh from skull, and "poison" the skin by dusting it thoroughly with the powdered arsenic and alum mixture. Turn skin right side out, and clean off fresh blood-stains by soaking them up with corn-meal; wash off dried blood with water, and dry with corn-meal. Corn-meal may be used during skinning to soak up blood and grease.

There remains to stuff the skin. Fill orbits of eyes with cotton (this can be advantageously done before skin is reversed); thrust into neck a moderately compact, elastic, smooth roll of cotton about thickness of the natural neck; make a loose oval ball of size and general shape of bird's body and put into body-cavity with anterior end under the posterior end of neck-roll; pull two edges of abdominal incision together over the cotton, fasten, if necessary, with a single stitch of thread, smooth feathers, fold wings in natural position, wrap skin, not tightly, in thin sheet of cotton (opportunity for delicate handling here) and put away in a drawer or box to dry. Before putting away tie label to leg, giving date and locality of capture, sex and measurements of bird, and name of collector. Before bird is put into permanent collection it should be labelled with its common and scientific name.

The mounting of birds in lifelike shape and attitude is hard to do successfully; and a collection of mounted birds demands much more room and more expensive cabinets than one of skins. For instructions for the mounting of birds see Davie's "Methods in the Art of Taxidermy," pp. 39–57; or Hornaday's "Taxidermy and Zoological Collecting." For a more detailed account of making bird-skins, see also these books, or Ridgway's "Directions for Collecting Birds."

In collecting birds' nests cut off the branch or branches on which the nest is placed a few inches above and below the nest, leaving it in its natural position. Ground-nests should have the section of the sod on which they are placed taken up and preserved with them. If the inner lining of the nest consists of feathers or fur put in a "moth-ball" (naphthaline).

To preserve birds' eggs they should be emptied through a single small hole on one side by blowing. Prick a hole with a needle and enlarge with an egg-drill (obtain of any dealer in naturalists' supplies. Blow with a simple bent blowpipe with point smaller than the hole. After removing contents clean by blowing in a little water, and blowing it out again. After cleaning, place the egg, hole downward, on a layer of corn-meal to dry. Label each egg by writing on it near the hole a number. Use a soft pencil for writing. This number should refer to a record (book) under similar number, or to an "egg-blank," containing the following data: name of bird, number of eggs in set, date and locality, name of collector, and any special information about the eggs or nest which the collector may think advisable. The eggs may be kept in drawers or boxes lined with cotton, and divided into little compartments.

For detailed directions for collecting and preserving birds' eggs and nests, see Bendire's "Directions for Collecting, Preparing, and Preserving Birds' Eggs and

Nests" or Davie's "Methods in the Art of Taxidermy," pp. 74-78.

* *Mammals.*—Any mammal intended for a scientific specimen should be measured in the flesh, before skinning, and as soon after death as practicable, when the muscles are still flexible. (This is particularly true of larger species, such as foxes, wildcats, etc.) The measurements are taken in millimetres, a rule or steel tape being used. (1) Total length: stretch the animal on its back along the rule or tape and measure from the tip of the nose (head extended as far as possible) to the tip of the fleshy part of tail (not to end of hairs). (2) Tail: bend tail at right angles from body backward and place end of ruler in the angle, holding the tail taut against the ruler. Measure only to tip of flesh (make this measurement with a pair of dividers). (3) Hind foot: place sole of foot flat on ruler and measure from heel to tip of longest toe-nail (in certain small mammals it is necessary to use dividers for accuracy). The measurements should be entered on the label, along with such necessary data as sex, locality, date, and collector's name.

Skin a mammal as soon after death as possible. Lay mammal on back and with scissors or scalpel open the skin along belly from about midway between fore and hind legs to vent, taking care not to cut muscles of abdomen. Skin down on either side of the body by working the skin from flesh with fingers till hind legs appear. Use cornmeal to stanch blood or moisture. With left hand grasp a leg and work the knee from without into the opening just made; cut the bone at the knee, skin leg to heel and clean meat off the bone (leaving it attached of course to foot). In animals larger than squirrels skin down to tips

* The following directions for making skins of mammals were written for this book by Mr. W. K. Fisher of Stanford University, an experienced collector.

of toes. Do the same with other leg. Skin around base of tail till the skin is free all around so that a grip can be secured on body; then with thumb and forefinger hold the skin tight at base of tail and slowly pull out the tail. In small mammals this can be done readily, but in foxes it is often necessary to split the skin up along the under side and dissect it off the tail-bones. After the tail is free skin down the body, using the fingers (except in large mammals) till the fore legs are reached; treat the fore legs in the same manner as hind legs, thrusting elbow out of the skin much as a person would do in taking off a coat; cut bone at elbow; clean fore-arm bone. Skin over neck to base of ears. With scalpel cut through ears close to skull. With scalpel dissect off skin over the head (taking care not to injure eyelids) down to tip of nose, severing its cartilage and hence freeing skin from body. Sew mouth by passing needle through under lip and then across through two sides of the upper lip; draw taut and tie thread. Poison skin thoroughly. Turn skin right side out. Next sever the skull carefully from body, just where the last neck-vertebra joins the back of the skull. It is necessary to keep the skull, because characters of bone and teeth are much used in classification. Remove superfluous meat from the skull and take out brain with a little spoon made of a piece of wire with loop at end. Tag the skull with a number corresponding to that on skin, and hang up to dry. A finished specimen skull is made by boiling it a short time and picking the meat off with forceps, further cleaning it with an old tooth-brush, when it is placed in the sun to bleach. Care must be taken always not to injure bones or dislodge teeth.

Mammals are stuffed with cotton or tow; the latter is used in species from a gray squirrel up. Large mammals stuffed with cotton do not dry readily, and often spoil. Being much thicker-skinned than birds, mammals require more care in drying and ordinarily require a much longer period. Soft hay may be substituted for tow; never use feathers or hair. Roll a longish wad of cotton about the size of body and insert with forceps, taking care to form the head nearly as in life. Split the back end of the cotton and stuff each hind leg with the two branches thus formed. Roll a piece of cotton around end of forceps and stuff fore legs. Place a stout straight piece of wire in the tail, wrapping it slightly to give the tail the plump appearance of life. (If the cotton cannot be reeled on to the wire evenly, leave it off entirely.) Make the wire long enough to extend half way up belly. Sew up slit in belly. Lay mammal on belly and pin out on a board by legs, with the fore legs close beside head, and hind legs parallel behind, soles downward. Be sure the label is tied securely on right hind leg.

For directions for preparing and mounting skeletons of birds, mammals, and other vertebrates, see the books of Davie and Hornaday already referred to.

Fishes, batrachians, reptiles, and other animals.—The most convenient and usual way of preserving the other vertebrates (not birds or mammals) is to put the whole body into 85 per cent alcohol or 4 per cent formalin. Batrachians should be kept in alcohol not exceeding 60 per cent strength. Several incisions should always be made in the body, at least one of which should penetrate the abdominal cavity. Anatomical preparations are similarly preserved. By keeping the specimens in glass jars they may be examined without removal. Fishes should not be kept in formalin more than a few months, as they absorb water, swell, and grow fragile.

Of the invertebrates all, except the insects, are preserved in alcohol or formalin. The shells of molluscs can be preserved dry, of course, in drawers or boxes divided into small compartments.

APPENDIX III

CLASSIFICATION OF ANIMALS

As the animals referred to in this book are not taken up in a rigorous systematic or classificatory order, but are grouped together to some extent rather according to similarities of habit or habitat, all the different species of animals mentioned by either scientific or vernacular name are introduced into the following table of classification* of animals to branches and classes.

KINGDOM ANIMALIA.

BRANCH I. PROTOZOA.

Class I. **RHĪZŎP' ODA.**

Amœ'ba, sun animalcule, *Rosalī'na vă'rians*, For' minĭf'era.

Class II. **MYCĒTOZŌ' A.**

Class III. **MASTIGŎPH' ORA.**

Class IV. **SPŌROZŌ' A.**

Class V. **INFUSŌ' RIA.**

Paramœ'cium, *Vorticĕl'la*, bell animalcule, slipper animalcule, *Stĕn'tor*.

BRANCH II. PORĬF' ERA.

Class I. **PORIFERA.**

Grantia, glass sponge.

* The classification here used is that adopted by Parker and Haswell's Text-book of Zoology (1897).

BRANCH III. **CŒLĔN′TERĀ′TA** (sē lĕn′te rā′ta).

Class I. **HȲDROZŌ′A.**

Hȳ′dra, *Obē′lia*, sea-anemone, *Bunō′des californica*, jelly-fish, medusa, *Phȳsā′lia*, Portuguese man-of-war, *Gonionē′mus vertens.*

Class II. **SCȲPHOZŌ′A** (sī fō zō′ a).

Jelly-fish, medusa.

Class III. **ACTINOZŌ′A.**

Coral, polyp, *Madrĕp′ora cervicornis.*

Class IV. **CTĔNŎPH′ORA** (tĕn ŏph′o ra).

BRANCH IV. **PLĂTYHĔLMĬN′THES.**

Class I. **TURBELLĀ′RIA.**

Planā′ria.

Class II. **TRĔMATŌ′DA.**

Class III. **CĔSTŌ′DA.**

Tapeworm.

BRANCH V. **NĔMATHĔLMĬN′THES.**

Class I. **NĔMATŌ′DA.**

Vinegar-eel, *Anguillū′la*, *Trīchī′na spiralis*, hair worm, *Uncinā′ria.*

Class II. **ACANTHOCĔPH′ALA.**

Class III. **CHÆTŎG′NATHA** (kē tŏg′ na tha).

BRANCH VI. **TROCHELMĬN′THES.**

Class I. **ROTĬF′ERA.**

Class II. **DĪNOPHĬ′LEA.**

Class III. **GASTRŎT′RICHA.**

BRANCH VII. **MŎLLUSCOI′DA.**

Class I. **PŎLYZŌ′A.**

Class II. **PHŌRŎ′NIDA.**

Class III. **BRĂCHIŎP′ODA.**

BRANCH VIII. **ĔCHĬNŌDĔR′ MATA.**

Class I. **ASTEROI′ DEA.**

Starfish, *Asterī′na mineata*, *Astē′rias ocrā′cia.*

Class II. **OPHIUROI′ DEA.**

Class III. **ĔCHINOI′ DEA.**

Sea-urchin, *Strongylocĕntrō′tus franciscā′nus*, cake-urchin, sand-dollar.

Class IV. **HŎLOTHUROI′ DEA.**

Class V. **CRĪNOI′ DEA.**

Class VI. **CȲSTOI′ DEA.**

Class VII. **BLĂSTOI′ DEA.**

BRANCH IX. **ANNULĀ′ TA.**

Class I. **CHÆTŎP′ ODA** (kē tŏp′oda).

Earthworm.

Class II. **GĔPHYRĒ′ A** (jĕf e rē′a).

Class III. **ARCHI-ANNĔL′ IDA.**

Class IV. **HĬRUDĬN′ EA.**

Leech, *Clepsī′ne.*

BRANCH X. **ARTHRŎP′ ODA.**

Class I. **CRUSTĀ′ CEA.**

Crayfish, crab, lobster, pill-bug, water-flea, spider-crab, barnacle, kelp-crab, rock-crab, hermit-crab, oyster-crab, *Macrocheira*, *Bală′nus*, *Pollĭc′-ipes polymēnus*, *Brachyno′tus nudus*, *Căn′cer prodŭctus*, *Epialtus prodŭctus*, *Păg′arus samuelis*, damp-bug, wood-louse, *Cȳ′clops*, Isopod, *Sacculī′na*, *Copepod*, *Penĕl′la*, *Cochodĕr′ma virgā′tum.*

Class II. **ŎNYCHŎPH′ ORA.** (on y kŏf′o ra)

Class III. **MȲRĬĂP′ ODA.**

Thousand-legged worm, centiped, milliped, galley-worm, *Julus*, *Scolopĕn′dra*, *Scutĭg′era for′ceps.*

Class IV. **INSĔC′ TA.**

Mosquito, *Cū′lex*, silkworm, beetle, forest tent-caterpillar moth, violet-tip butterfly, *Clisiocăm′pa disstria*, *Clisiocăm′pa americā′na*, *Polygō′nia interrogātionis*, dragon-fly, damsel-fly, gall-fly, grasshopper, locust, cockroach, bee, tiger-beetle, squash-bug, sphinx-moth, May-fly, house-fly, midge, carrion-beetle, *Promē′thea*, *Melăn′oplus*, *Therioplĕc′tes*, horse-fly, *Ammŏph′ila*, digger-wasp, solitary wasp, plum curculio, *Conotrăch′elus nenuphar*, caddis-worm, case-worm, caddis-fly, case-fly, water-strider, *Hygrŏt′rechus*, predaceous diving-beetle, back-swimmer, water-scavenger-beetle, water-boatman, water-tiger, *Dўt′icus*, swallowtail butterfly, *Papĭl′io rū′tulus*, monarch butterfly, milkweed butterfly, cecropia moth, polyphemus moth, grapevine sphinx, *Ampe′lŏph′aga mȳ′ron*, ants, aphis-lion, peach-tree borer, *Sanninoidea exitiosa*, army-worm, *Leucā′nia unipuncta*, *Chrȳsō′pa*, rose-aphid, golden-eyed fly, lace-winged fly, *Cicā′da*, seventeen-year locust, harvest-fly locust, dog-day locust, *Cicā′da septendecim*, katydid, cricket, solitary bee, mining-bee, carpenter-bee, leaf-cutter bee, quince curculio, *Conotrăch′elus cratægi*, caterpillar, regal walnut moth, *Citherō′nia rĕg′alis*, hawk-moth, mantis, bag-worm, *Căl′igo*, owl-butterfly, *Tŏl′ype vĕl′leda*, *Căst′nia*, *Micrŏp′teryx aruncĕl′la*, *Lycæna*, *Grăp′ta*, walking-stick, *Diapherŏm′era fĕmorā′ta*, *Phȳl′lium*, *Kăl′lima*, viceroy-butterfly, *Anō′sia plĕx′ippus*, *Bāsilăr′chia archĭp′pus*, ichneumon, pigeon-horntail, *Trĕm′ex*, *Thalĕs′sa*, *Stylops*, bird-louse, *Nir′mus præstans*, *Vĕs′pa*, Vĕs′pidæ, yellow-jacket, hornet, bumble-bee, parnassian butterfly, *Parnăs′sius smĭn′theus*, Hessiăn fly, buffalo-bug, carpet-beetle.

Class V. **ARĂCH′NIDA.**

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BRANCH XI. MŎLLŬS′CA.

Class I. **PĔLECȲP′ODA.**

Oyster, *Ŏs′trea virginiāna*, *Phō′las*, *Chlorŏs′tomum funebrale*, clam.

Class II. **AMPHINEU′RA.**

Class III. **GASTRŎP′ODA.**

Snail, slug, *Ariolī′max călifornica*, nudibranch, *Dō′ris tuberculā′ta*, *Echinodoris*, *Triō′pha modesta*, *Pur′pura saxicola*, *Littorī′na scutulata*, *Acmara spectrum*, *Mȳt′ilus californianus.*

Class IV. **CĔPHALŎP′ODA.**

Squid, *Ommăs′trephes californica.*

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Class VI. **MAMMĀ'LIA.**

Cat, duck-bill, wood-rat, mole, pocket-gopher, prairie-dog, horse, dog, mouse, beaver, pig, sheep, rat, rabbit, man, cow, whale, dolphin, porpoise, shrew, camel, reindeer, lion, tiger, otter, wolf, moose, elk, deer, porcupine, armadillo, bear, fox, hare, fur-seal, *Callorhī'nus ursī'nus*, walrus, and all the animals referred to in Chapter XVI.

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