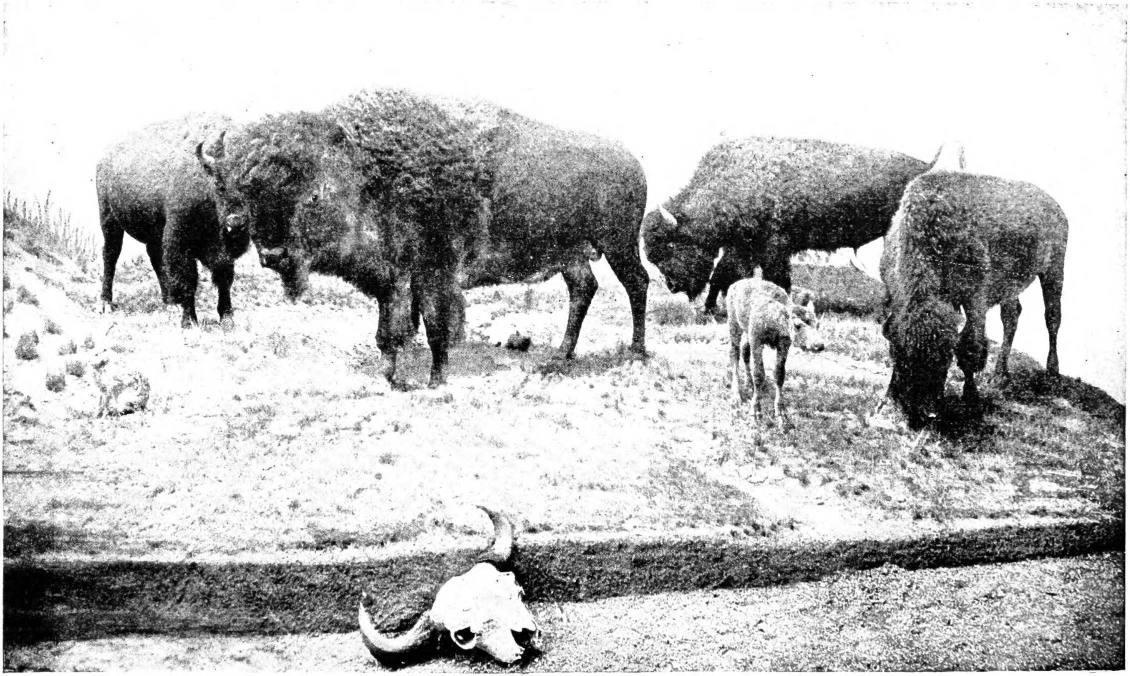
THE ANIMALS AND MAN

VERNON L. KELLOGG



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.)

THE ANIMALS AND MAN

AN ELEMENTARY TEXTBOOK OF ZOOLOGY AND HUMAN PHYSIOLOGY

BY

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PREFATORY NOTE

This book is a simple introduction to the study of the structure, physiology, behavior and classification of animals and to the study of the make-up and physiology of the human body. It makes use of some of what have been proved by experience to be the most useful parts—specially revised for this book—of the author's "Elementary Zoology" and "First Lessons in Zoology," to which have been added new chapters on human structure and physiology and on certain special relations between animals and man. The whole book has been written and arranged from the point of view of a biologist intent on making our knowledge of the make-up and life of the lower animals help in understanding human structure and physiology and in contributing to human welfare. I believe that this point of view need not militate in the least against the disciplinary or informational value of a text-book of zoology. I believe, indeed, that it will enhance these values.

Chapters XXI to XXVIII, on human structure and physiology, were written by Assistant Professor Isabel McCracken of this University, and to that extent Miss McCracken is joint author of the book.

I wish to acknowledge my indebtedness to those numerous zoologists who have accorded me permission to use illustrations original with them. The sources of these repeated illustrations are indicated in the captions of the pictures. The drawings for the figures original with me have mostly been made by Miss Mary Wellman and Mr. Sekko Shimada to both of whom I am under obligation for their intelligent and skilful help.

V. L. K.

STANFORD UNIVERSITY, January, 1911.

CONTENTS

PART I

THE PARTS OF ANIMALS AND HOW THEY ARE USED

PART II

THE LIFE-HISTORY OF ANIMALS

PART III

DIFFERENT KINDS OF ANIMALS, THEIR CLASSIFICATION, HABITS AND SPECIAL RELATION TO MAN

PART IV

HUMAN STRUCTURE AND PHYSIOLOGY

(Chapters XXI–XXVIII by Isabel McCracken)

PART V

ANIMALS IN RELATION TO EACH OTHER, TO PLANTS, AND TO THE OUTSIDE WORLD

APPENDICES

THE ANIMALS AND MAN

The Animals and Man

PART I

THE PARTS OF ANIMALS AND HOW THEY ARE USED

CHAPTER I

THE GRASSHOPPER AND THE SNAIL

An animal's body composed of parts.—The body of every animal, even 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 in special ways. That is, the

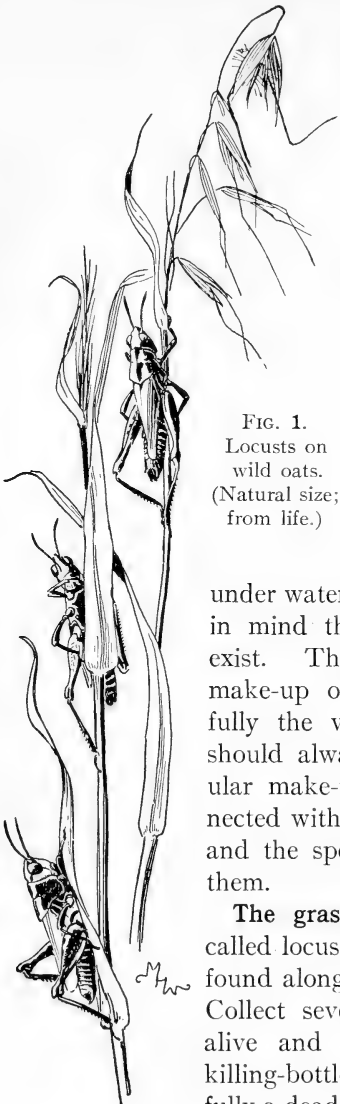


FIG. 1. Locusts on wild oats. (Natural size; from life.)

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. 1). Collect several specimens, keeping some alive and dropping the others into the killing-bottle (see p. 472). 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 fore 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 wings cover and protect the plaited delicate hind wings 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 fig. 2), 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? Note that the soft skin of the neck is well protected by the projecting 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 continua-

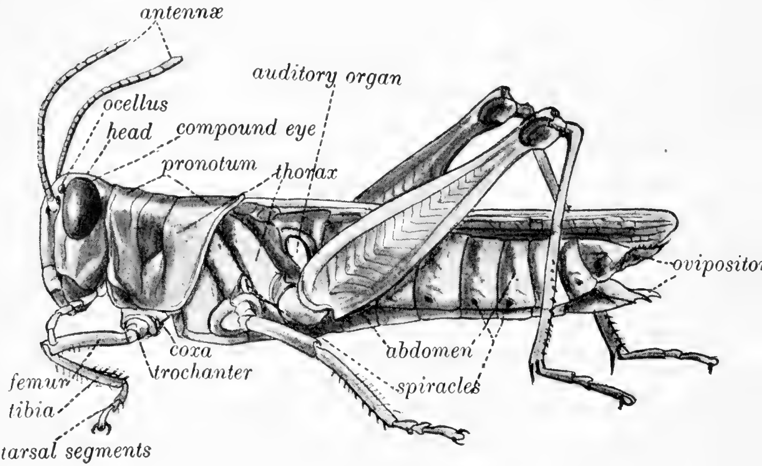


FIG. 2. Locust, with external parts named.

tions of the exo-skeleton projecting internally and these are sometimes called the endo-skeleton.)

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 vesicle and nerve-ganglion on the inside from which a nerve 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 which open into a system of internal tubes that carry the air to all parts of the body. The locust does not take in air through nostrils on the head nor through the mouth, but by means of these many lateral openings in the body-wall. There is 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.

(A more detailed study of the external structure of the locust can easily be arranged for by reference to Comstock and Kellogg's "Elements of Insect Anatomy," 5th ed.)

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. 3). They should be fed pieces of lettuce or cabbage leaves. Observe the habits of the snails; 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, as the locust, 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.

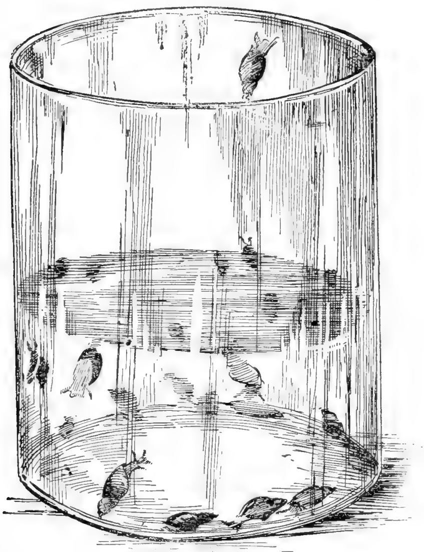


FIG. 3. Pond snails in a battery jar aquarium. (One-third natural size; from life.)

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 II

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. 4).—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 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

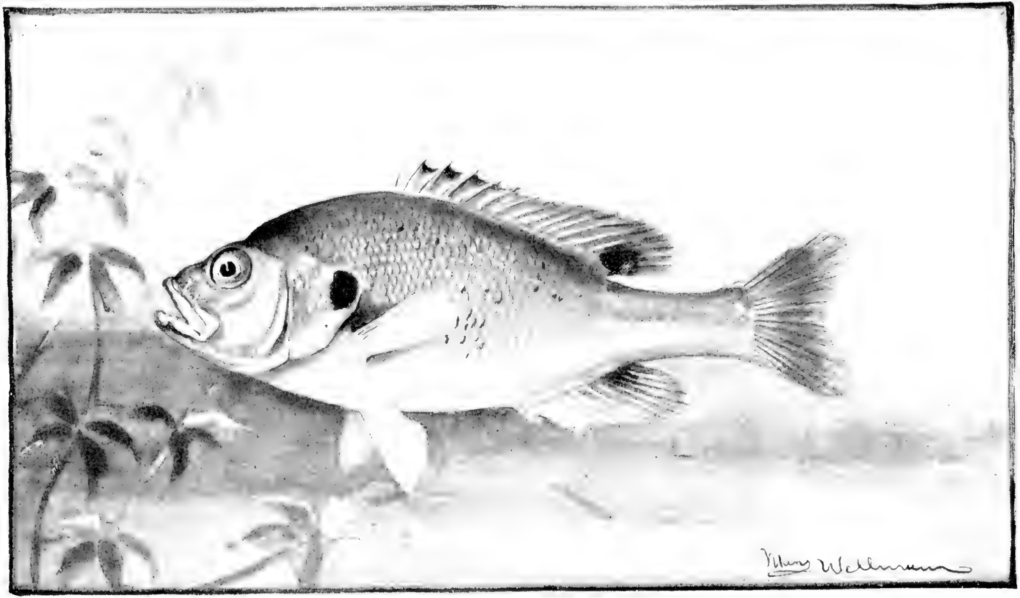


FIG. 4. A sunfish, *Eupomotis* sp. (One-half natural size.)

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 carbon 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 float 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."

Sunfishes eat insects, shellfish, spawn of other fishes, but not other fishes themselves.

The females lay their eggs in shallow saucer-like depressions on the stream bed, which are scooped out and cleared of pebbles by the males. After laying her eggs the female departs, leaving the nest to the exclusive care of the male. The males are very active and pugnacious, defending the nest with great bravery. This attention lasts, however, only until the eggs hatch, which happens in a week or more, depending on the temperature. The young fry are left to care for themselves.

The English sparrow (fig. 5).—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 or in the school yard.

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

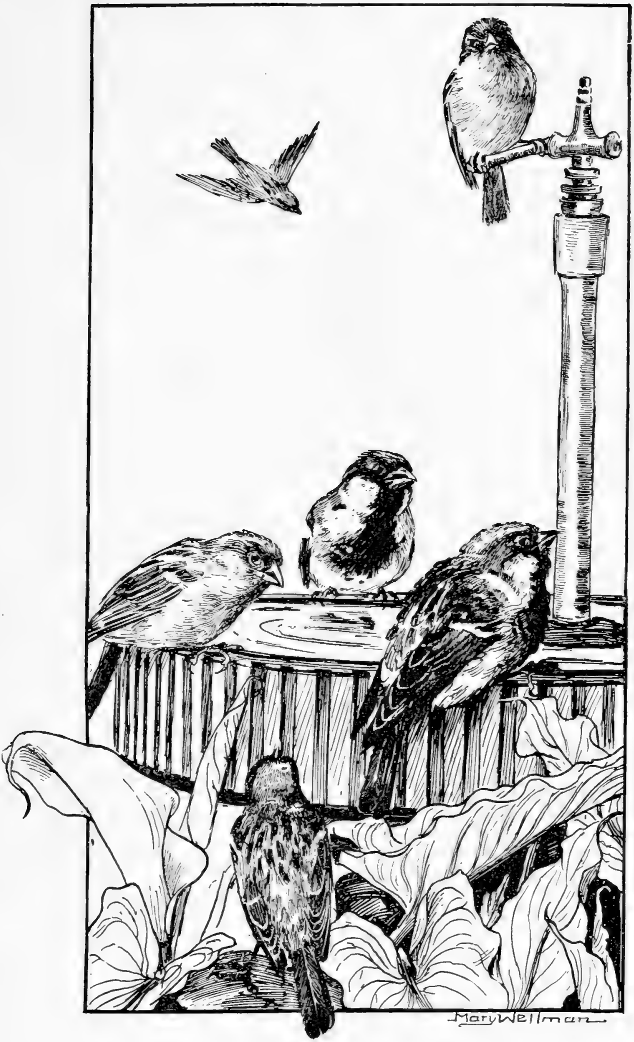


FIG. 5. English sparrows; note the black cheeks and throat which distinguish the males. (One-half natural size; from life.)

and the horny covering of bill and feet are simply modified 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 thin bare stem and small terminal tuft of branches, are called thread feathers or filoplumes.

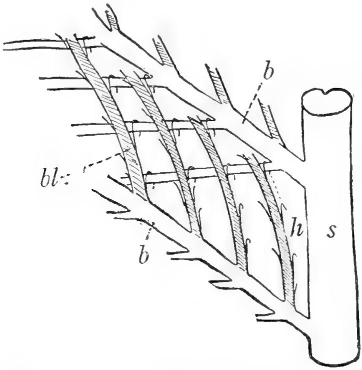


FIG. 6. Bit of bird's feather, greatly magnified; *s*, shaft; *b*, barb; *bl*, barbule; *h*, hamule.

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. 6), 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 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. 7 the names of them 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. 7.

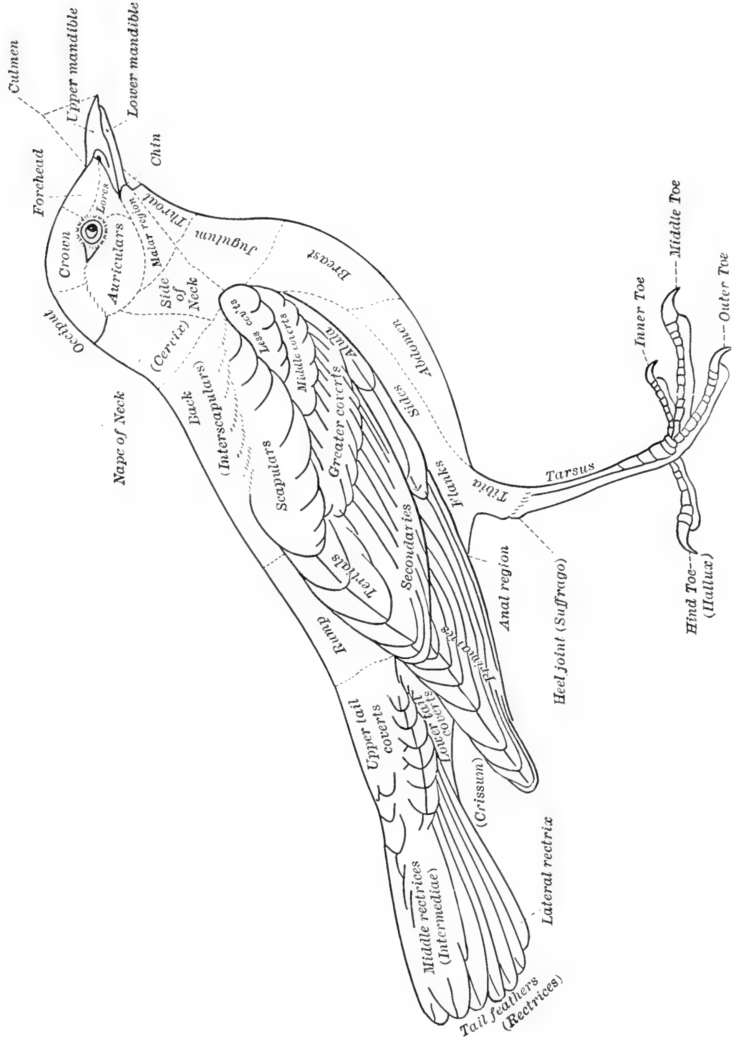


FIG. 7. Outline of bird's body, with names of external parts and regions.

Examine a wing; determine by reference to fig. 7 what feathers compose the primaries, secondaries, tertiaries, 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. 7.

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.

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

CHAPTER III*

THE GARDEN TOAD (*Bufo lentiginosus*)

TECHNICAL NOTE.—Although this description is written for the toad it will fit for the dissection of the frog. It will be found, after casting aside a few ungrounded prejudices, that the toad is the better for class dissection. Toads are best collected about dusk, when they can be picked up in almost any garden in town or in the country. During the spring many can be found in the ponds where they are breeding. To kill the toad place it in an air-tight vessel with a piece of cotton or cloth saturated in chloroform or ether. When the toad is dead, wash off the specimen and put in a dissecting-pan for study. Several specimens should be placed in a nitric acid solution for a day or so (for directions for preparing, see p. 25) to be used later for the study of the nervous system. Also several specimens should be injected for the better study of the circulatory system. With an injecting mass made as directed in Appendix I, introduce through a small canula into the ventricle of the heart. This will inject the arterial system, and with increased pressure the injecting mass may be forced through the valves of the heart, thus passing into the auricles and throughout the venous system. After injecting use the specimen fresh or after it has been preserved in 4% formalin.

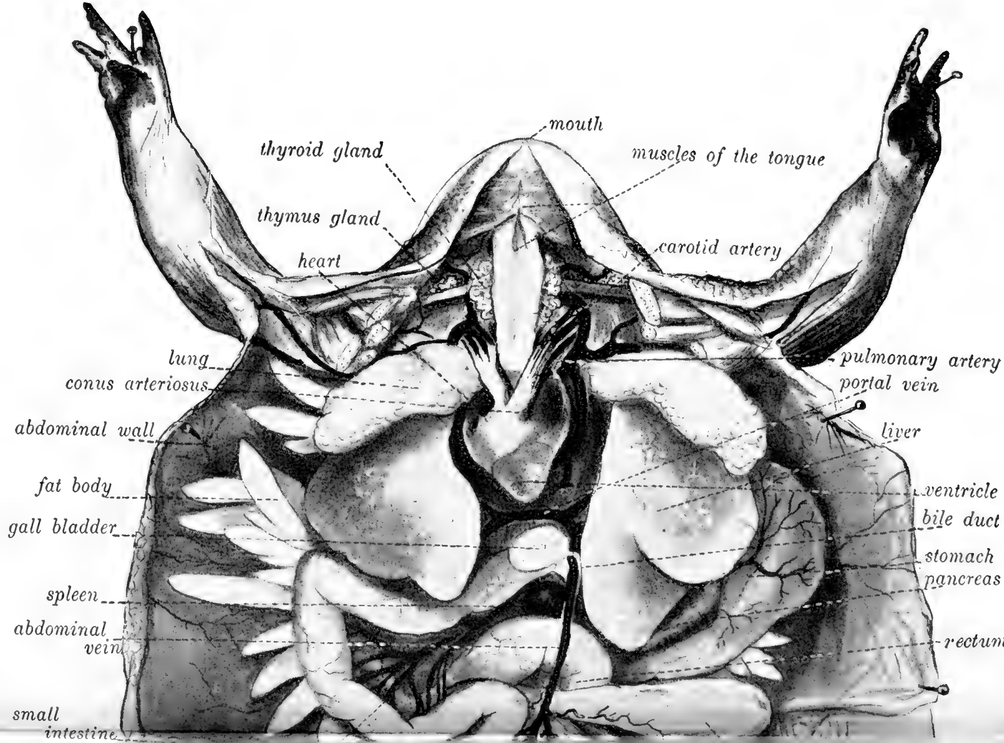
External structure.—Note that the body of the toad is divided into several principal regions or parts, corresponding to those of the human body. Indeed, all through the study of the toad's anatomy a general correspondence of the body-parts and their arrangement with the parts of the human body and their arrangement will be manifest. The toad and ourselves belong to the same great animal branch.

*If preferred, or the school is not equipped for dissections by pupils, the teacher may substitute demonstrations of already dissected specimens for the dissections by students called for by this and the following chapter.

As you look at the toad note the similarity of the parts on one side to those of the other, as right leg corresponding to left leg, right eye to left eye, etc. This arrangement of the body in similar halves among animals is known as *bilateral symmetry*. As a rule animals which show bilateral symmetry move in a definite direction. The part that moves forward is the *anterior end*, while the opposite extremity is the *posterior end*. In most animals we note two other views or aspects; that which is called the "back" and with most animals is, under ordinary conditions, uppermost is called the *dorsum* or *dorsal aspect*, while that which lies below is the *venter* or *ventral aspect*. When referring to a view from one side we speak of it as a right or left *lateral aspect*. These terms hold good for most of the animals that we shall study.

Note on the head of the toad the wide, transverse *mouth*. What other openings are on the head? Note the two large *eyes*, the organs of sight. Just back of each eye find an elliptical, smooth membrane. This is the tympanum of the outer *ear*, and through this membrane the vibrations produced by sound-waves are transferred to the inner ear, which receives sensations and transmits them to the brain. Open the mouth by drawing down the lower jaw. Note just within the angle of the lower jaw the *tongue*. How is it attached to the wall of the mouth? On the tongue are a great many fine *papillæ* in which is located the sense of taste. It has now been seen that most of the special senses of the toad have their seat in the head. Pass a straw or bristle into one of the nostrils. Where does it come out? These internal openings to the nose are the *inner nares*. Note in the roof of the mouth just posterior to each of the eyeballs an opening. These are the internal openings to the wide *Eustachian tubes*, which lead to the mouth from the chamber of the ear behind the tympanum.

Note far back in the mouth an opening through which food passes. This is the *œsophagus* or *gullet*. Note just


mouth
thyroid gland
muscles of the tongue
thymus gland
carotid artery
heart
lung
conus arteriosus
abdominal wall
fat body
gall bladder
spleen
abdominal vein
small intestine
pulmonary artery
portal vein
liver
ventricle
bile duct
stomach
pancreas
rectum

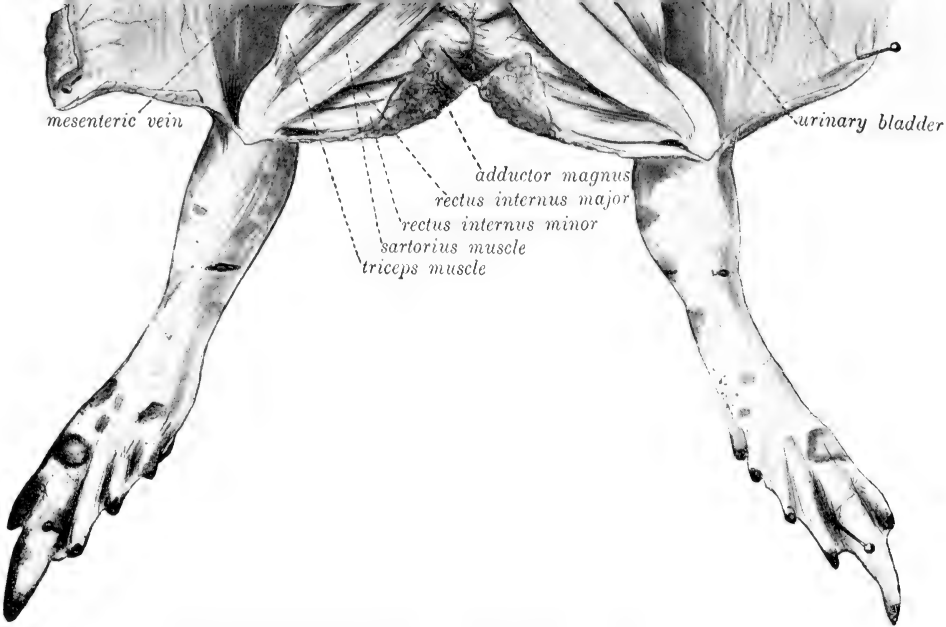


FIG. 8. Dissection of the garden toad, *Bufo lentiginosus.*

below this gullet an elevation in which is a perpendicular slit, the *glottis.* This is the upper end of the *laryngotracheal chamber,* and the flaps within on either side of the slit are the *vocal cords.*

Note at the posterior end of the body in the median line an opening. This is the *anal opening* or *anus.* Note the general make-up of the toad. How do its arms compare with our own? How do its fore feet (hands) differ from its hind feet? Note that the body is covered by a tough enveloping membrane, the *skin.* In the skin are many glands which by their excretion keep it soft and moist.

Internal Structure.—TECHNICAL NOTE.—With a fine pair of scissors make a longitudinal median cut through the skin of the venter from the anal opening to the angle of the lower jaw. Spread the cut edges apart and pin back in the dissecting-pan.

Note the complex system of *muscles* which govern the movements of the tongue. Observe a number of pairs of muscles overlying the bones which support the arms. These are attached to the *pectoral* or *shoulder-girdle.* Note the large sheet of muscles covering the ventral aspect of the toad. These are the *abdominal muscles,* which consist of two sets, an outer and an inner layer. Note that posteriorly the abdominal muscles are attached to a bone. This is the *pubic bone* of the *pelvic girdle* which supports the hind legs.

TECHNICAL NOTE.—With the scissors cut through the muscles of the body-wall at the pubic bone and pass the points forward to the shoulder-girdle. Separate the bones of the shoulder-girdle and pin out the flaps of skin and muscle to right and left in the dissecting-pan (see fig. 8). Cover the dissection with clear water or weak alcohol.

Note two large conspicuous soft brown lobes of tissue. These form the *liver,* an organ which produces a secretion that assists in the process of digestion. Note just anterior to the liver and extending between its two lobes a pear-shaped organ, the *heart.* The lower end or apex of the heart, *ventricle*, undergoes a contraction, forcing blood out into the *blood-vessels*. This is followed by a relaxation of the apex and a contraction of the basal portion, the *auricle*. The heart is surrounded by a delicate semi-transparent sac, the *pericardium*. The pericardium is filled with a watery fluid, *body-lymph*, which bathes the heart. Note between the lobes of the liver a small bladder-shaped transparent organ of a pinkish color. This is the *gall-bladder*, a reservoir for the *bile*, the secretion from the liver. Separate the lobes of the liver and note, beneath, the long convoluted tube which fills most of the body-cavity. This is part of the *alimentary canal*. The most anterior portion of the canal, the *gullet* or *œsophagus*, leads to a large U-shaped enlargement, the *stomach*. From the lower end of the stomach there extends a long, slender, very much convoluted tube, the *small intestine*, which is followed by a much larger one, the *large intestine*. This large intestine after one or two turns passes directly back into the *rectum*, which opens at last to the exterior through the anus. Note just ventral to the rectum a large thin-walled membranous sac. This is the *urinary bladder* which acts as a reservoir for the secretion from the *kidneys*. Notice a many-branched yellow structure with a glistening appearance, the *fat-body* (*corpus adiposum*). Now push liver and intestine to one side and note the pinkish sac-like bodies (perhaps filled with air), the *lungs*. The lungs are paired bodies which open into the laryngotracheal chamber. The toad takes air into its mouth through its nostrils, and then forces it, by a kind of swallowing action, through the laryngotracheal chamber into the lungs.

Now lift the stomach and note in the loop between its lower end and the small intestine a thin transparent tissue. This is a part of the *mesentery*, which will be found to suspend the whole alimentary canal and its attached organs to the dorsal wall of the body. Note in the loop of the stomach in the mesentery an irregular pinkish glandular structure which leads by a small duct into the intestine. This gland is the *pancreas*, and the duct is the *pancreatic duct*. From it comes a secretion which aids in the digestion of food. Near the upper end of the pancreas note a round nodular structure, generally dark red. This is the *spleen*, a ductless gland, the use of which is not altogether known.

Make a drawing which will show as many of the organs noted as possible.

TECHNICAL NOTE.—Pass two pieces of thread under the rectum near the pubic bone. Tie these threads tightly a short distance apart and then cut the rectum in two between the threads. Now carefully lift up the alimentary canal with attached organs (liver, etc.), and cut it off near the region of the heart.

How is the heart situated with regard to the lungs? The heart consists of a lower chamber with thick muscular walls, the tip, called the *ventricle*, and two upper thin-walled chambers, the *right* and *left auricles*. Can you make out these three chambers? The purified blood from the lungs flows into the left auricle, while the venous blood from all over the body laden with its carbon dioxid enters the right auricle. From these two chambers the blood enters the ventricle. Here the pure and impure blood are mixed. From the ventricle the blood enters a large muscular tube on the ventral side of the heart. This is the *conus arteriosus*, which gives off three branches on each side; the anterior ones, the *carotid arteries*, supply the head, the next ones, the *systemic arteries*, or *aortæ*, carry blood to the rest of the body, while the posterior vessels, the *pulmonary arteries*, go directly to the lungs and there break up into fine vessels (*capillaries*) where the carbon dioxid is given off and oxygen is taken from the air. From the lungs the blood returns through the *pulmonary vein* to the left auricle. Meanwhile the blood which has passed through the systemic arteries and body capillaries is collected again into other vessels going back to the heart; these are the *veins*, which empty into a large thin-walled reservoir, the *sinus venosus*, which in turn connects with the right auricle of the heart. Three large veins enter the sinus venosus, namely, two *pre-caval veins* at the anterior end, and a single *post-caval vein* at the posterior end. Trace out the larger arteries and veins from the heart to their division into or origin from the smaller vessels.

TECHNICAL NOTE.—Carefully remove the heart together with the lungs. The lungs may be inflated by blowing into them through the laryngotracheal chamber with a quill and tying them tightly, after which they should be left for several days to dry. When perfectly dry, sections may be cut through them in various places with a sharp knife, and by this means a very good idea of the simple lung structure of the lower backboned animals can be obtained. With a sharp knife cut the heart open, beginning at the tip (ventricle) and cutting up through the conus arteriosus and the two auricles. Note the valves in the heart which separate the different compartments.

Note on either side of the median line in the dorsal region a pair of reddish glandular bodies, *the kidneys*. Attached to the kidneys of the male are two white ovoid glandular masses. These are the reproductive organs. From each kidney trace a tube, *ureter*, posteriorly toward the region of the anus. The kidneys are the principal excretory organs of the body. The blood which flows through the delicate blood-vessels in the kidney gives up there much of its waste products. These pass out through small tubules of the kidneys into the ureters, which carry the wastes toward the anus. Along one side of each kidney may be seen a yellowish glistening mass, the *adrenal body*.

In some of the specimens studied, the body cavity may be filled with thousands of little black spherical bodies. These are undeveloped *eggs* lying in the female reproductive organs situated on each side of the post caval vein. They are deposited by the mother toad in the water in long strings of transparent jelly, which are usually wound around sticks or plant-stems at the bottom of the pond near the shore.

From these eggs the young toads hatch as tadpoles and in their life-history pass through an interesting metamorphosis. (See Chapter IX.)

TECHNICAL NOTE.—The teacher should be provided with several well-cleaned skeletons of the toad in order that the bones may be carefully studied. Boil in a soap solution a toad from which most of the muscles and skin have been removed (see Appendix I). Leave in this solution until the muscles are quite soft and then pick off all bits of muscles and tissue from the bones. If this is carefully done, the ligaments which bind the bones will be left intact and the skeleton will hold together.

Note that the *skeleton* (fig. 9) consists of a head portion which is composed of many bones joined together to form a bony box, the *skull;* of a series of small segments, the *vertebræ*, forming the *vertebral column*, which with the skull forms the *axial skeleton;* and of the *appendicular skeleton*, consisting of the bones of the fore and hind limbs. Note that the skull is composed of many bones joined together, some by *sutures*, while others are fused. The anterior limbs (arms) articulate with the *pectoral* or *shoulder-girdle*. The arms will be seen to be made up of a number of bones placed end to end. Note that the uppermost, the *humerus*, is attached to the pectoral girdle, while at its lower end it articulates with the *radio-ulna*. At the lower end of the radio-ulna is a small series of *carpal* bones which afford attachments for the slender finger-bones, the *phalanges* or *digital* bones. The bones of the leg are articulated with a closely fused set of bones, the *pelvic girdle*. The leg-bones, proceeding from the pelvic girdle, are named *femur*, *tibio-fibula*, *tarsal* bones, and *phalanges* or *digits*. To what bones of the arm do these correspond? Determine the other principal bones of the skeleton by reference to figure 9.

TECHNICAL NOTE.—In a specimen which has been macerated for some time in 20% nitric acid dissect out the nervous system. Place the specimen in a pan, ventral side uppermost, and pin out. Carefully pick away the vertebræ and the roof of the mouth-cavity, thereby exposing the central nervous system, which will appear light yellow.

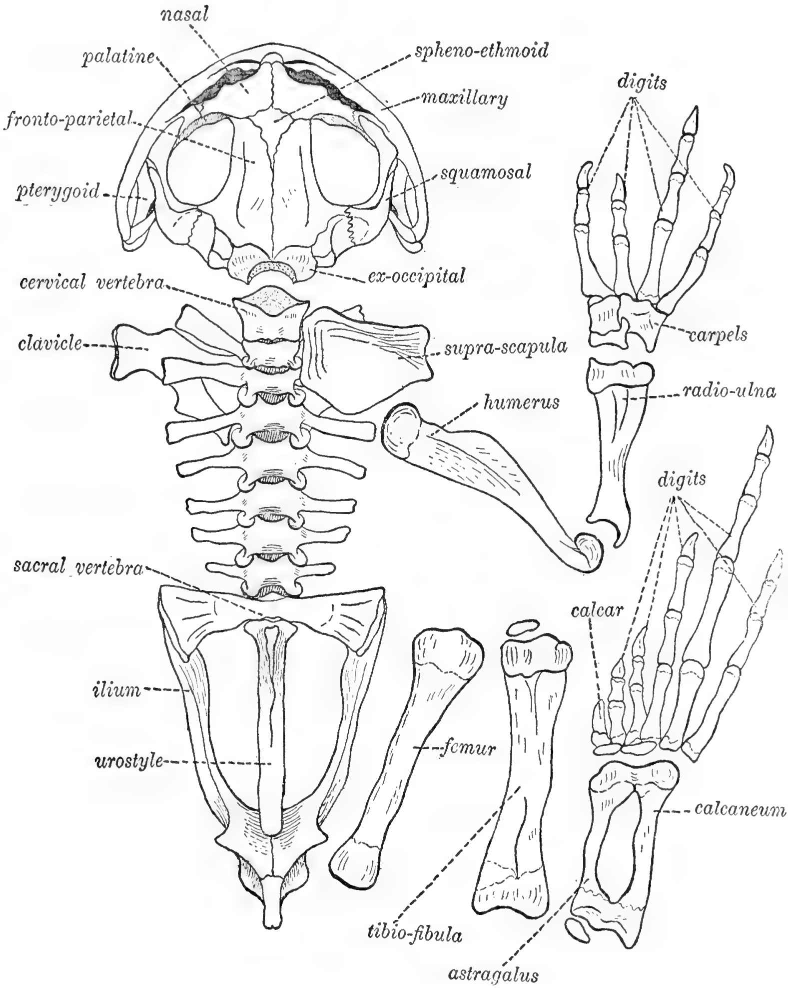


FIG. 9. Skeleton of the garden toad.

Examine the *brain*. In front of the true brain are the *olfactory lobes*, the nervous centre for the sense of smell. The brain itself is composed of several parts. The anterior portion consists of two elongated parts, the *cerebral hemispheres;* just back of these are the optic lobes or *midbrain*, consisting of two short lobes, which are followed by the small *cerebellum*, which in turn is followed by a long part, the *medulla oblongata*, which runs imperceptibly into the long dorsal nerve, the *spinal cord*. Note the large *optic nerves* running out to each eye. How far backward does the spinal cord extend? Note the many pairs of nerves given off from the brain and spinal cord. These nerves branch and subdivide until they end in very fine fibres. Some end in the muscle-fibres, and through them the central nervous system innervates the muscles. These are *motor endings*. Still others pass to the surface and receive impressions from the outside. These last are *sensory endings*. Note that the *spinal nerves* arise from the spinal cord by two roots, an *anterior* or *ventral*, and a *posterior* or *dorsal root*. Trace the principal spinal nerves to the body-parts innervated by them. These nerves are numbered as first, second, etc., according to the number of the vertebræ (counting from the head backward) from behind which they arise.

For a more detailed account of the anatomy of the toad (frog) the student may refer to Parker and Haswell's Textbook of Zoology, Vol. II.

CHAPTER IV

THE CRAYFISH (*Cambarus* sp.)

TECHNICAL NOTE.—The crayfish, or crawfish, is found in most of the fresh-water ponds and streams of the United States. (It is not found east of the Hoosatonic River, Mass. In this region the lobster may be used. On the Pacific coast the crayfishes belong to the genus *Astacus.*) Crayfishes may be taken by a net baited with dead fish, or they may be caught in a trap made from a box with ends which open in, and baited with dead fish or animal refuse of any sort. This box should be placed in a pond or stream frequented by crayfish. If possible the student should study the living animal and observe its habits. Crayfish which are to be kept alive should be placed in a moist chamber in a cool place. They will keep for a longer time in a moist chamber than in water. Some fresh specimens should be injected by the teacher for the study of the circulatory system. A watery solution of coloring matter or, better, of an injecting mass of gelatine (see Appendix I) is injected into the heart through the needle of a hypodermic syringe. For the purpose of injecting, a small bit of the shell may be removed from the cephalothorax above the heart. Specimens which are to be kept for some time should be placed in alcohol or 4% formalin.

External structure (fig. 10).—Place a specimen in a pan for study. Note that the body, which of course differs much in shape from that of the toad, is also unlike that of the toad in being covered by a hard calcareous *exo-skeleton*, which acts as a covering for the soft parts and also as a place of attachment for the muscles, just as the internal skeleton does in the case of the toad. The body is composed of an anterior part, the *cephalothorax*, and a posterior part, the *abdomen*. The cephalothorax is covered above and on the sides by the *carapace*, which is divided into parts corresponding to the head and thorax of the toad by the transverse

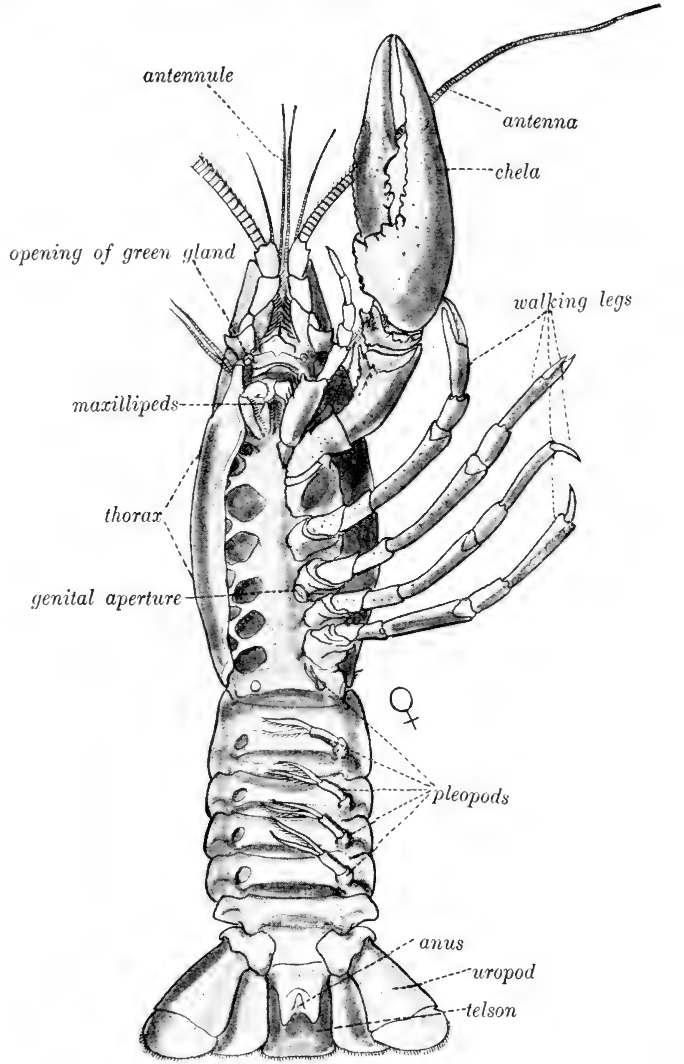


FIG. 10. Ventral aspect of crayfish, *Cambarus* sp. with the appendages of one side disarticulated.

cervical suture. The abdomen is composed of segments. How many? The flattened terminal segment is called the *telson.* Is the cephalothorax composed of segments? Where is the mouth of the crayfish? Where is the anal opening?

At the anterior end of the cephalothorax note a sharp projection, the *rostrum.* Where are the eyes? Remove one of them 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 facets is the external window of an eye element or *ommatidium.* An eye composed in this way is called a *compound eye.* In front of the eye 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 slit 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. This bag-like structure is believed to be an auditory organ. The longer pair of appendages are the *antennæ,* and the sense of smell is believed to be located in the fine hair-like projections upon the joints. Thus it is seen that the sense-organs of the crayfish, like those of the toad, are located on the head. 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.*

Make a drawing of the surface of part of an eye; also of an antennule; and of an antenna.

Technical Note.—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*, or swimming feet. How many pairs are there? Each is composed of a basal part, the *protopodite*, and two terminal segments, an inner one, the *endopodite*, and an outer, the *exopodite*. In the males the first and second pleopods of the abdomen are larger and less flexible than the others. In the female the pleopods serve to carry the eggs and the first two pairs are very small or absent. Note the last set of abdominal appendages. These are the *uropods*, which together with the telson form the tail.

Make a drawing of the pleopods of one side.

Examine the appendages of the cephalothorax. Like the appendages of the abdomen the typical composition of each includes a protopodite, an exopodite and an endopodite, but some of these appendages are much modified, and show a loss of one of these parts, or the addition of an extra part. The cephalothoracic appendages may be divided into three groups, an anterior group of three pairs of mouth-parts (belonging to the head) of which the first pair is the *mandibles* and the others are 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 first maxillæ are small and also lack the exopodite; the second maxillæ have a large paddle-like structure which extends back over the gills on each side within the space, the *branchial chamber*, above the gills. 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. Each pair of walking-legs except the last bears *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 sides of the gill and thence into the fine vessels in the little leaf-like lamellæ. At the same time the air which is mixed with the water bathing the gills passes freely through the thin membranous walls of these lamellæ and blood-vessels, and the blood gives off its carbon dioxide to the water and takes up oxygen from the air in the water. Thus it will be seen that the office of the gill is like that of the lung in the toad, namely, to act as an organ for the elimination of carbon dioxide and the taking up of oxygen.

Note the pincer-like appendages of the first pair of legs. These pincers are the *chelæ*, with which food is torn into bits and placed in the mouth. In the basal segment of each of the last pair of legs of the male note the *genital pore*. In the female the *genital pores* are in the basal segments of the next to last pair of legs. Is the crayfish bilaterally symmetrical? Note the repetition of parts in the crayfish, that is, the recurrence of similar parts in successive segments. This serial repetition of parts among animals is called *metamerism*.

Internal Structure (fig. 11).—TECHNICAL NOTE.—With a pair of scissors cut through the dorsal wall of the cephalothorax into the body-cavity. Cut the body-wall away from both sides and remove the middle portion.

At the anterior end of the cephalothorax note the large membranous sac, the *stomach*. Attached to each end of this are sets of muscles which control its movements. To the right and left of the stomach notice attached to the shell large muscles which connect by stout ligaments at their lower ends with the mandibles. Note a yellow fringe-like structure, the *digestive gland*, which fills most of the region about the stomach. It connects by a pair of small tubes, the *bile-ducts*, with the alimentary canal. Within the posterior portion of the cephalothorax note a pentagonal sac, the *heart*, contained within a delicate membrane, the *pericardium*. Remove the pericardium and note a pair of dorsal openings into the heart, called *ostia*. (There are also two

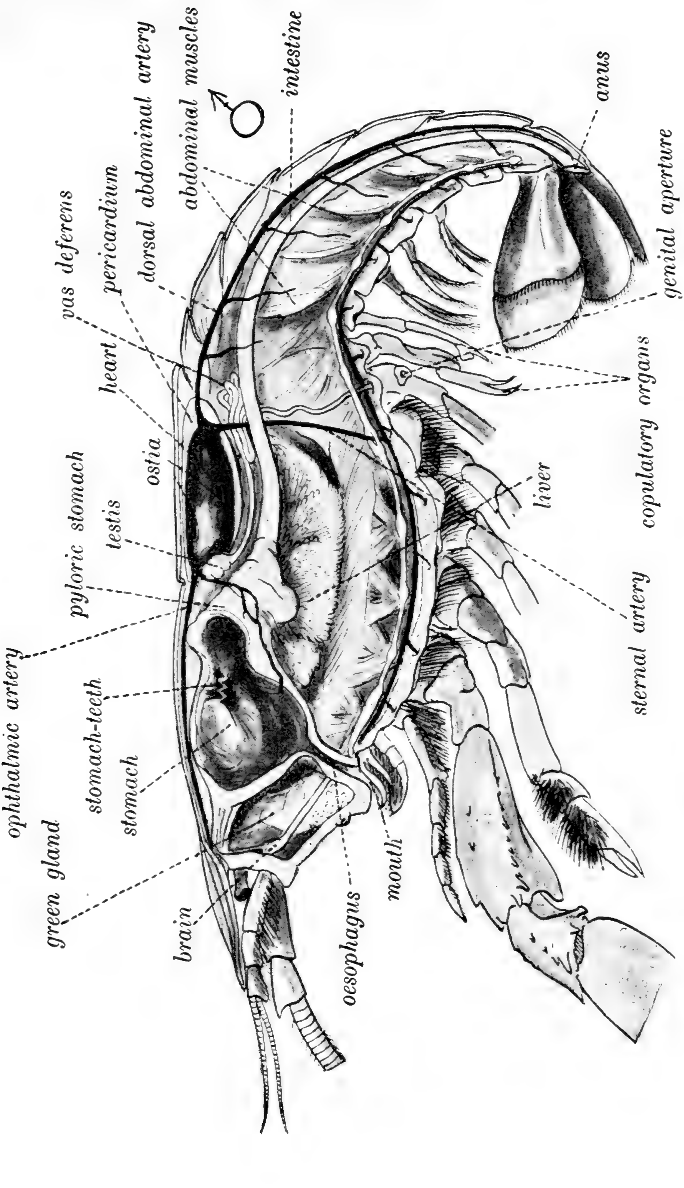


FIG. 11. Diagram of median longitudinal section of crayfish, *Cambarus* sp.

lateral pairs and a ventral pair of ostia.) Note passing anteriorly from the heart along the median line to the eyes a blood-vessel, the *ophthalmic artery*. Arising from the anterior portion of the heart are the *antennary arteries*, running to the antennæ. Yet another pair running anteriorly from the heart to the stomach and digestive glands are called the *hepatic arteries*. From the posterior end of the heart arises the *dorsal abdominal artery*, running back to the telson. Below this arises the *sternal* artery, which will be seen later.

In the region below the heart are located the reproductive organs. They are whitish glandular masses from each of which runs a tube which opens at the base of the last pair of walking-legs in the male, and at the base of the third pair of walking-legs in the female.

TECHNICAL NOTE.—Cut longitudinally through the dorsal wall of the abdomen on either side of the median line and remove the piece of shell.

Note the powerful *muscles* within which flex and extend the abdomen. By a rapid contraction of these muscles the tail is brought beneath the body, propelling the animal strongly backwards. When the crayfish crawls it generally goes forward, but in swimming it reverses this direction.

Make a drawing showing, in their natural position, the internal organs which have been studied.

Examine the alimentary canal for its whole length. Note that the large bladder-shaped stomach is attached to the mouth-opening by a short tube. What part of the canal is this? From the posterior end of the stomach is a short thick-walled part, the *small intestine*, followed by a long straight tube, the *large intestine*, which opens to the exterior through the *anus*.

TECHNICAL NOTE.—Remove the alimentary canal, detaching it from the anal end first, and working forward.

Cut the stomach open. Note an interior portion, the *cardiac chamber*, and a smaller posterior portion, the *pyloric chamber*. Examine its inner surface. What do you find here? This structure is called the *gastric mill*. Food, which for the most part consists of any dead organic matter, is chewed by the "stomach-teeth" into fine bits, and is then passed into the pyloric chamber. It is here that the digestive glands empty their secretion into the food. These glands have the same office as have the liver and pancreas combined in the toad, and so they are often called the *hepato-pancreas*. When the stomach has been removed there will be noted in the anterior portion of the body paired, flattened bodies, already mentioned, which connect with openings at the base of each of the antennæ by means of wide thin-walled sacs, the *ureters*. These organs are the *kidneys*, or *green glands*. Their office is similar to that of the kidneys in the toad, namely, the elimination of waste from the body.

Technical Note.—Carefully remove all of the alimentary canal, digestive glands, and reproductive organs. This process will expose the floor of the cephalothorax. Now cut away from either side the horny floor or bridge at the bottom of the cephalothorax. If the specimen has not already been immersed, place it in clear water for further dissection.

The foregoing dissection will expose the *central nervous system*. It extends as a series of paired *ganglia* connected by a double nerve-cord along the ventral median line from the œsophagus to the last segment of the abdomen. From what points do the lateral nerves arise? Anteriorly the double nerve-cord divides, the two parts passing upward on each side of the œsophagus, where they again meet to form the *supra-œsophageal ganglion* or *brain*. Where do the nerves run which rise from the brain? What is the difference between the position of the central nervous system in the crayfish and in the toad?

Make a drawing of the nervous system.

Just beneath the nerve-cord note a blood-vessel extending the length of the body. This is the *sternal artery*, which arises from the posterior end of the heart and passes ventrally at one side of the alimentary canal and between the nerve-cords. Here the sternal artery divides into an anterior and a posterior branch, from which lesser branches are given off to each one of the appendages. The various arteries running to all parts of the body finally pour out the blood into the body-cavity, where it flows freely in the spaces among the various tissues and organs. After the blood has bathed the body tissues it flows to the gills on either side passing up the outer side of the gill through delicate thin-walled vessels, where it is oxygenated as has already been described. From the gills the purified blood flows back on the inner side through a large chamber, *sinus*, into the pericardium, through the ostia of the heart, whence it is driven into the arteries once more. This sort of a circulatory system in which the blood in places is not enclosed in a definite vessel is known as an *open system*. In the toad we find the blood in a *closed system*, i.e., arteries leading into capillaries which in turn lead into veins, in no case allowing the blood to pass freely through the spaces of the body.

For a detailed account of the life and structure of the crayfish see Huxley's "The Crayfish: an Introduction to the Study of Zoology."

CHAPTER V

AMŒBA, PARAMŒCIUM AND VORTICELLA

Amœba.—TECHNICAL NOTE.—*Amœbæ* are found in stagnant pools of water on the dead leaves, sticks and slime at the bottom. To obtain them, collect slime and water from various puddles in separate bottles and take them to the laboratory. Place a small drop of slime on a slide under a cover-glass. Examine under the low power first and note any small transparent or opalescent objects in the field. Examine these objects with the higher power and note that some are mere granular jelly-like specks, which slowly (but constantly) change their form. These are *Amœbæ.*

A teacher of zoology recommends the following method of obtaining a large supply of *Amœbæ:* "For rearing *Amœbæ* place two or three inches of sand in a common tub, which is then filled with water and placed some feet from a north window; three or four opened mussels, with merest trace of the mud from the stream in which they are taken, are partially buried in the sand and a handful of *Nitella* and a couple of crayfish cut in two are added; as decomposition goes on a very gentle stream is allowed to flow into the tub, and after from two to four weeks abundant *Amœbæ* are to be found on the surface of the sand and in the scum on the sides of the tub; small *Amœbæ* appear at first, and later the large ones."

Having found an *Amœba* (fig. 12) note its irregular shape, and if it moves actively observe its method of moving. How is this accomplished? The viscous, jelly-like substance which composes the whole body of an *Amœba* is called *protoplasm.* The little processes which stick out in various directions are the "false feet" (*pseudopodia*). Note that the outer portion, the *ectosarc*, of the protoplasmic body is clear, while the inner, the *endosarc*, is more or less granular in structure. Has *Amœba* a definite body-wall? Do the pseudopodia protrude only from certain parts of the body?

Within the endosarc 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 within the endosarc. These are food-particles

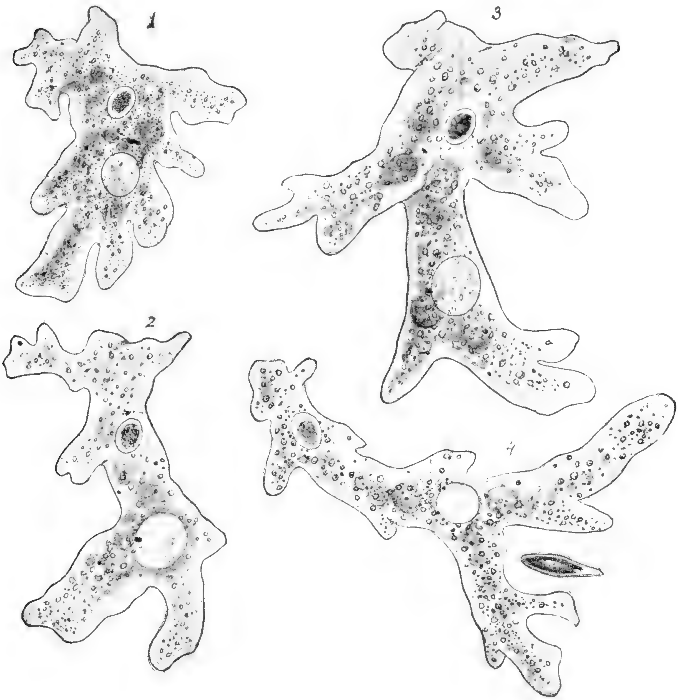


Fig. 12. An Amœba, showing forms assumed by a single individual in four successive changes. (Greatly magnified; from life.)

which have been taken in through the body-wall. Note how pseudopodia flow about food-particles in the water and how these are digested by the protoplasm. If an *Amœba* comes into contact with a particle of sand, note how it at once retreats. Note within the endosarc an oval transparent body which shows no pulsations. This is the *nucleus*, a very complex little structure of great importance in the make-up of *Amœba*.

Note that *Amœba* has no mouth or alimentary canal; no nostrils or lungs, no heart or blood-vessels, no muscles, no glands. It is an animal body not made up of numerous distinct organs and diverse tissues. Its whole body is a minute speck of protoplasm, and forms a single animal cell. But it takes in food, it moves, it excretes waste matter from the body, is sensitive to the touch of surrounding objects, and, as we may be able to see, it can reproduce itself, i.e., produce new *Amœbæ*. *Amœba* is one of the simplest living animals.

It is only rarely that we can find an *Amœba* actually reproducing. The process, in its gross features, is very simple. First the *Amœba* draws in all of its pseudopodia and remains dormant for a time. Next, certain changes take place in the nucleus, which divides into equal portions, one part withdrawing to one end of the protoplasmic body, the other to the opposite end. Soon the body protoplasm itself begins to divide into two parts, each part collecting about its own half of the nucleus. Finally the two halves pull entirely away from each other and form two new *Amœbæ*, each like the original, but only half as large. This is the simplest kind of reproduction found among animals.

Amœbæ continue to live and multiply as long as the conditions surrounding them are favorable. But when the pond dries up the *Amœbæ* in it would be exterminated were it not for a careful provision of nature. When the pond begins to dry up each *Amœba* contracts its pseudopodia and the protoplasm 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 some new pond.

The Slipper Animalcule (*Paramœcium* sp.).—TECHNICAL NOTE.—*Paramœcia* can be secured in most pond-water where leaves or other vegetation are decaying. However, if specimens are not readily secured place some hay or finely cut dry clover in a glass dish, cover with water and leave in the sun for several days. In this mixture specimens will develop by thousands. Place a drop of water containing *Paramœcia* on a slide with cover-glass over it. Using a low power, note the many small animals darting hither and thither in the field. Run a thin mixture of cherry gum in water under the cover-glass. In this mixture they can be kept more quiet and be better studied.

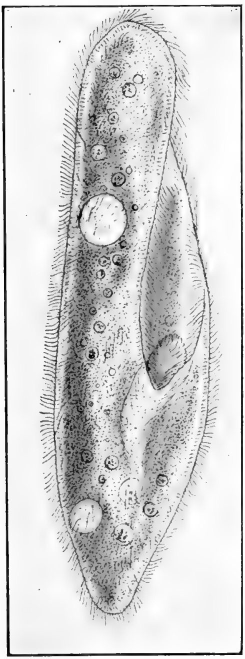


FIG. 13. *Paramoecium* sp.; note the body-wall, cilia, buccal groove, gullet, contractile vacuoles and nuclei. (Greatly magnified; from life.)

How does *Paramœcium* (fig. 13) differ from *Amœba* in form and movement? Has the body an anterior and a posterior end? The delicate, short, thread-like processes, on the surface of the body, which beat about very rapidly in the water are called *cilia*, and they are simply fine prolongations of the body protoplasm. What is their function? Note a fine *cuticle* covering the body. Note also many minute oval sacs lying side by side in the ectosarc. These are called *trichocysts* and from each a fine thread can be thrust out.

Note on one side, beginning at the anterior end, the *buccal groove* leading into the interior through the *gullet*. Observe also that by the action of the cilia in the buccal groove food-particles are swept into the gullet. Rejected or waste particles are ejected from the body occasionally. Where? Note about midway of the *Paramœcium* an ovoid body with a smaller oval one attached to its side, the former being the *macronucleus*, the latter the *micronucleus*. Note that there are two contractile vacuoles in the *Paramœcium;* also that the food-vacuoles have a definite course in their movement inside the endosarc.

Make a drawing of a *Paramœcium*.

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 the ingress of food, the two nuclei, the fixed cilia, and the definite cell-wall giving a fixed shape to the body, are all specializations which make *Paramœcium* more complex than *Amœba*. But the whole body is still composed of a single cell, and there is, as in *Amœba*, no differentiation of the body-substance into different tissues, and no arrangement of body-parts as systems of organs.

Paramœcium may occasionally be found reproducing. This process takes place very much as in *Amœba*. The animal remains dormant for a while, the micronucleus then divides, the macronucleus elongates and finally divides in two, the protoplasm of the body becomes constricted into two parts, each part massing itelf about the withdrawn halves of the macro- and micronuclei, and lastly the whole breaks into two smaller organisms which grow to be like the original. After multiplication or reproduction has gone on in this way for numerous generations (from one to two hundred), a fusion of two *Paramœcia* seems necessary before further divisions take place. (This is probably true of *Amœba* also.) This process of fusion, called *conjugation*, may be noted at some seasons. Two *Paramœcia* unite with their buccal grooves together, part of the macronucleus and micronucleus of each passes over to the other, and the mixed elements fuse together to form a new macro- and micronucleus in each half. The conjugating *Paramœcia* now separate, and each divides to form two new individuals.

The Bell Animalcule (*Vorticella* sp.).—TECHNICAL NOTE.—Specimens of *Vorticella* may usually be found in the same water with *Amœba* and *Paramœcium*. The individuals live together in colonies, a single colony appearing to the naked eye as a tiny whitish mound-like tuft or spot on the surface of some leaf or stem or root in the water. Touch such a spot with a needle, and if it is a Vorticellid colony it will contract instantly. Bring bits of leaves, stems, etc., bearing Vorticellid colonies into the laboratory and keep in a small stagnant-water aquarium (a battery-jar of pond-water will do).

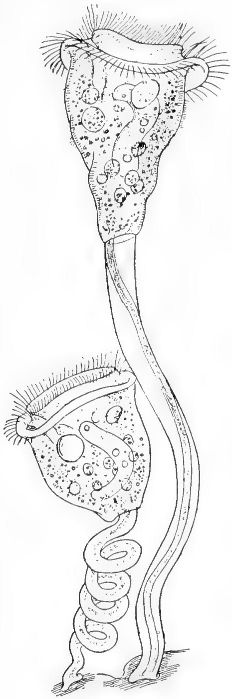


FIG. 14. *Vorticella* sp.; one individual with stalk coiled and one with stalk extended; note the peristome, epistome, vestibule, nucleus, contractile vesicle, food particles, etc. (Greatly magnified; from life.)

Examine a colony of *Vorticella* in a watch-glass of water or in a drop of water on a glass slide under the microscope. Note the stemmed bell-shaped bodies which compose the colony. Each bell and stem together form an individual *Vorticella* (fig. 14). How are the members of the colony fastened together? Tap the slide and note the sudden contraction of the animals; also the details of contraction in the case of an individual. Watch the colony expand; note the details of this movement in the case of an individual.

Make drawings showing the colony expanded and contracted.

With higher power examine a single individual. Note the thickened, bent-out, upper margin of the bell. This margin is called the *peristome*. With what is it fringed? The free end of the bell is nearly filled by a central disk, the *epis-*

tome, with arched upper surface and a circlet of *cilia*. Between the epistome and peristome is a groove, the *mouth* or *vestibule*, which leads into the body. Study the internal structure of the transparent, bell-shaped body. Note the differentiation of the protoplasm comprising the body into an inner transparent colorless *endosarc* containing various dark-colored granules, vacuoles, oil-drops, etc., and an outer uniformly granular *ectosarc* not containing vacuoles. Is the stalk formed of ectosarc or endosarc or of both? Note the curved *nucleus* lying in the endosarc. (This may be difficult to distinguish in some specimens.) Note the nu-numerous large circular granules, the food particles. Note the *contractile vesicle*, larger and clearer than the food vacuoles. Note the thin *cuticle* lining the whole body externally. A high magnification will show fine transverse ridges or rows of dots on the cuticle.

Make a drawing showing the internal structure.

Observe a living specimen carefully for some time to determine all of its movements. Note the contraction and extension of the stalk, the movements of the cilia of peri-stome and epistome, the flowing or streaming of the fluid endosarc (indicated by the movements of the food particles), the behavior of the contractile vesicle.

Make notes and drawings explaining these motions.

Specimens of *Vorticella* may perhaps be found dividing, or two bell-shaped bodies may be found on a single stem, one of the bodies being sometimes smaller than the other. These two bodies have been produced by the longitudinal division or fission of a single body. In this process a cleft first appears at the distal end of the bell-shaped body, and gradually deepens until the original body is divided quite in two. The stalk divides for a very short distance. One of the new bell-shaped bodies develops a circlet of cilia near the stalked end. After a while it breaks away and swims about by means of this basal circlet of cilia. Later it settles down, becomes attached by its basal end, loses its basal cilia and develops a stalk.

"Conjugation occurs sometimes, but it is unlike the conjugation of *Paramœcium* in two important points: Firstly, the conjugation is between two dissimilar forms; an ordinary large-stalked form, and a much smaller free-swimming form which has originated by repeated division of a large form. Secondly, the union of the two is a complete and permanent fusion, the smaller being absorbed into the larger. This permanent fusion of a small active cell with a relatively large fixed cell, followed by division of the fused mass, presents a striking analogy to the process of sexual reproduction occurring in higher animals."

The single-celled body.—The study of *Amœba*, *Paramœcium* and *Vorticella* has made us acquainted with a type of animal body very different from that of the toad or the crayfish. These extraordinarily minute animals have a body so simple in its composition, compared with the toad's, that if the toad's body be taken for the type of the animal body, *Amœba* might readily be thought not to be an animal at all. The body of *Amœba* is not composed of organs, each with a particular function or work to perform. Whatever an *Amœba* does is done, we may say, with its whole body. But as we learn the things that this formless viscid speck of matter does, we see that it is truly an animal; that it really does those things which we have learned are the necessary life-processes of an animal. *Amœba* takes up and digests food composed of organic particles; it has the power of motion; it knows when its body comes in contact with some external object, that is, it can feel or has the power of sensation. *Amœba* takes in oxygen and gives out carbon dioxide, and it can produce new individuals like itself, that is, it has the power of reproduction. But for the performance of these various life-processes or functions it has no widely differing special parts or organs, no mouth or alimentary canal, no lungs or gills, no legs, no special reproductive organs. We have here to do with one of the "simplest animals." With a minute, organless, soft speck of viscous matter called protoplasm for a body, the simplest structural condition to be found among living beings, *Amœba* nevertheless is capable of performing in the simplest way in which they may be performed, those processes which are essential to animal life.

Paramœcium has a body a little less simple than *Amœba.* The food-particles are taken into the body always at a certain spot; this might be spoken of as a mouth. And the body has some special locomotory organs, if they may be so called, in the presence of the cilia. The body, too, has a definite shape or form. But, as in *Amœba*, there is no alimentary canal, nor nervous system, nor respiratory system, nor reproductive system. The whole body feels and breathes and takes part in reproduction.

A long jump has been made from the toad and crayfish to *Amœba* and *Paramœcium;* from the complex to the simplest animals. But, as will later be seen, the great difference between the bodies of these simplest animals and those of the highly complex ones is only a difference of degree; there are animals of all grades and stages of structural condition connecting the simplest with the most complex. When animals are studied systematically, as it is called, we begin with the simplest and proceed from them to the slightly complex, from these to the more complex, and finally to the most complex. There are hundreds of thousands of different kinds of animals, and they represent all the degrees of complexity which lie between the extremes we have so far studied.

The cell.—The characteristic thing about the body of *Amœba* and *Paramœcium* and the other "simplest animals" —for there are many members of the group of "simplest animals," or Protozoa—is that it is composed, for the animal's whole lifetime, of a single cell. A cell is the structural unit of the animal body. The bodies of all other animals except the Protozoa, the simplest animals, are composed of many cells. These cells are of many kinds, but the simplest kind of animal cell is that shown by the body of an *Amœba*, a tiny speck of viscous, nearly colorless protoplasm without fixed form. The protoplasm composing the cell is differentiated to form two parts or regions of the cell, an inner denser part, called the nucleus, and an outer clearer part, called the cytoplasm. Sometimes, as in the *Paramœcium*, the cell is enclosed by a cell-wall which may be simply a denser outer layer of the cytoplasm, or may be a thin membrane secreted by the protoplasm. Thus the cell is not what its name might lead us to expect, typically cellular in character; that is, it is not (or only rarely is) a tiny sac or box of symmetrical shape. While the cell is composed essentially of protoplasm, yet it may contain certain so-called cell-products, small quantities of various substances produced by the life-processes of the protoplasm. These cell-products are held in the protoplasmic body-mass of the cell, and may consist of droplets of water or oil or resin, or tiny particles of starch or pigment, etc. The cell cannot be said to be composed of organs, because the word organ, as it is commonly used in the study of an animal, is understood to mean a part of the animal body which is composed of many cells. But the single cell can be somewhat differentiated into parts or special regions, each part or special region being especially associated with some one of the life-processes. In *Paramœcium*, for example, the food is always taken in through the so-called mouth-opening; the fine protoplasmic cilia enable the cell to swim freely in the water, the waste products of the body are always cast out through a certain part, and so on. But this is a very simple sort of differentiation, and the whole body is only one of those structural units, the cells, of which so many are included in the body of any one of the complex animals.

Protoplasm.—The protoplasm, which is the essential living substance of the typical animal cell and hence of the whole animal body, is a substance of very complex chemical and physical make-up. The most important thing about the chemical constitution of protoplasm is that there are always present in it certain complex albuminous substances called proteids which are never found in inorganic bodies, although the elements that compose these substances as well as all the rest of the protoplasm are the familiar ones, carbon, nitrogen, hydrogen, oxygen, sulphur, phosphorus, potassium, sodium, etc. The atoms in a single proteid molecule often number more than a thousand, and the molecules are very large. But chemists have yet to find out a great deal about these complex albuminous compounds.

In addition to the proteids protoplasm usually contains certain native albumins and certain other characteristic compounds known as carbohydrates and fats (which differ essentially from the albuminous substances in lacking nitrogen as a composing element). There are also various salts and gases and always water to be found in living substances. Water is absolutely necessary to the physical condition of half fluidity which gives to protoplasm its essential capacity for motion on itself. The commoner salts found in living substances are compounds of chlorine as well as the carbonates, sulphates, and phosphates of the alkalies and alkali earths, especially common salt (sodium chloride), potassium chloride, ammonium chloride, and the carbonates, sulphides, and sulphates of sodium, potassium, magnesium, ammonium, and calcium. The gases found in living matter are oxygen and carbon dioxide. These, when not in chemical combination, are almost always dissolved in water, although rarely they may be in the form of gas bubbles.

The physical constitution of protoplasm seems to be that of a viscous liquid containing many fine globules of a liquid of different density. It is a sort of liquid foam. Some naturalists however, believe the fine globules to be solid granules while still others believe that numerous fine threads of dense protoplasm lie coiled and tangled in the clearer viscous protoplasm. The difficulty in determining the physical structure is due to the limitations of the microscope. The ultimate structure of protoplasm is ultra-microscopic.

What little is known of the chemistry and physics of protoplasm certainly is far from explaining its wonderful properties. It should be held clearly in mind also that the full life capacity of protoplasm is realized only when it is in that differentiated and organized condition typical of the structural unit or cell. The essential thing about the cell is not that it has a definite shape or size or that it is truly cell- or sac-like, but that it is a tiny but definitely organized mass of protoplasm with various substances secreted by or held in it. The protoplasm itself is differentiated into at least two parts, an inner, denser, smaller part called the nucleus, and an outer surrounding, usually larger, portion called the cytoplasm. Such a differentiated or organized protoplasmic unit can perform all of the essential functions of life and persist in this performance indefinitely unless destroyed by extrinsic causes. The cell itself may not have an indefinite existence as a unit, but it will be the progenitor of an indefinitely prolonged series of cells. A single part of this cell, that is, a bit of protoplasm either of the nucleus or the cytoplasm, or the whole of either can perform for a while most of the activities of life; but such a part always lacks the capacity for reproduction, that is, for persistence as living matter.

CHAPTER VI

ANIMAL PHYSIOLOGY

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 usual difference between animals and plants is the possession by the former of the organs of motion and their nerves. True, plants have the

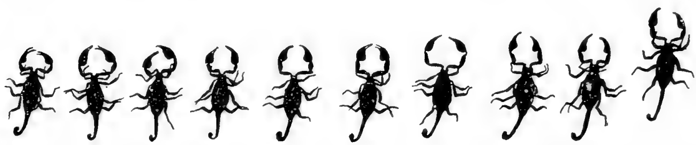


FIG. 15. Scorpion walking, showing the successive positions of body and legs. (After instantaneous photographs by Marey.)

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.

There are three different ways in which locomotion takes place, namely, 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 only now succeeded in making a beginning toward achieving a mechanism for it.

The simplest and what may be called the most imperfect modes of locomotion are shown by the simplest animals. These modes we have already studied in Amœba, Paramœcium, and Vorticella. The living elements in the body of the higher animals are the many individual cells, and they show many kinds of movement. But motion in the higher animals is produced chiefly by the contraction of muscles, each of which is made up of contractile fibres which may be thought to be modifications of such a fibre as exists in the stalk of Vorticella.

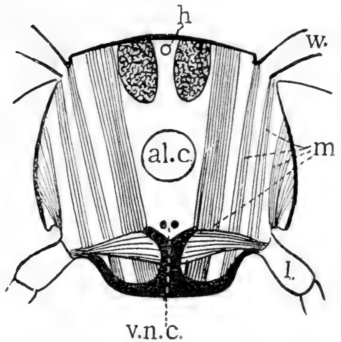


FIG. 16. Diagram of cross-section through the thorax of an insect to show the exo-skeleton and the leg and wing muscles attaching to it; *h*, heart; *al. c*, alimentary canal; *v. n. c*, ventral nerve cord; *w*, wing; *l*, leg; *m*, muscles. (Much enlarged; after Graber.)

The muscles require firm points of attachment to pull against and the complex movements of most animals require also rigid levers and fulcra. These firm solid parts of an animal's body compose its skeleton.

The skeleton of a backboneless or invertebrate animal differs from that of a backboned or vertebrate animal (as we have seen in comparing the frog and crayfish) 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 (fig. 16). It is therefore called an exo-skeleton.

In the vertebrates the skeleton is mainly developed from tissues within the body and is called in consequence the endo-skeleton. Even more than in the invertebrates it is a system (fig. 17) 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.

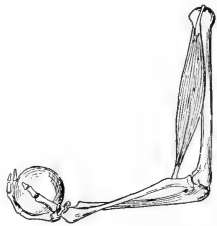


FIG. 17. Skeleton of arm of man, with biceps muscle; to show how bones and muscle act as levers. (After Jenkins.)

To illustrate the use of the skeleton of a vertebrate we may examine the bones of the hind legs of a cat (fig. 18). 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 is 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 makes a joint with a

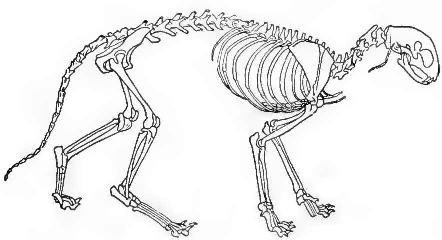


FIG. 18. Skeleton of cat. (After Reighard and Jennings.)

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 forms the skeleton of each toe. 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 such movements the toes rest on the solid ground, the body is lifted and thrown forward. There are several 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. 19. Muscles on side of fore leg of cat. (After Reighard and Jennings.)

Fig. 19 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 hipbone 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.

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 tnat 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.

Respiration.—Respiration is the name commonly used in books for the process of obtaining oxygen. The process has, however, another object in addition to procuring oxygen. When oxygen combines with carbon a poisonous gas, 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 from the body as for oxygen to be supplied to it. Carbon dioxide, like oxygen, is soluble in water. Blood, which is composed largely of water, can carry off carbon dioxide as well as bring oxygen. Also, since carbon dioxide is made by a combination with oxygen it arises just where it can be carried away by the very means that brings the necessary oxygen. Thus the respiratory, aided by the circulatory apparatus manages both the bringing of a supply of oxygen and the disposal of the 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 great 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, as we have seen, 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. However, such animals have only sluggish and weak motions. Much increase in size and activity make certain demands on the surface of the body which unfit it for respiraton. The hard covering of insects, crabs, and other animals necessary in connection with locomotion and for protection from injuries illustrates 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 the higher vertebrates the exterior skin surface is not at all 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 net-work of capillary blood-vessels. Through the walls of these small sacs the oxygen and carbon dioxide pass.

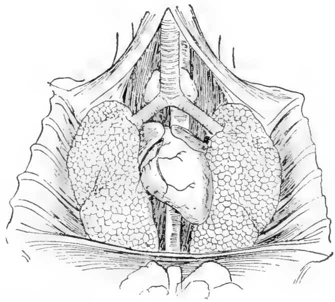


Fig. 20. Tracheal tube, lungs, heart and diaphragm of a mouse.

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. 20), 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 go, 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 necessary movements. It is to be kept in mind, however, that the respiratory apparatus 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.—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 XIII), 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.

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 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.

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 very 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. In the polyps and jelly-fishes (see Chapter XIII), this cavity is extended, the digestive surface being much increased by partitions, tubes, etc. Worms, 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. All this variety depends much on the nature of the food of the individual animal, and the processes necessary to turn it into body material.

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 disposed of in some other way. 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. Also a large amount of waste substance is produced which must be removed. In such animals 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. 21), only part of the circulatory system consists of definite tubes; these open into loose ill-defined spaces in the body-cavity. In these spaces the blood moves 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 "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 crustaceans 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.

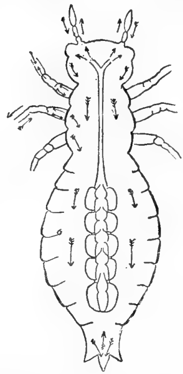


FIG. 21. Diagram of circulatory system of a young dragon-fly; in the middle is the chambered dorsal vessel with single artery; the arrows indicate the direction of blood-currents. (After Kolbe.)

In vertebrates the blood circulates in a definite system of tubes through which it is pumped by a heart. The fishes (fig. 22) 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

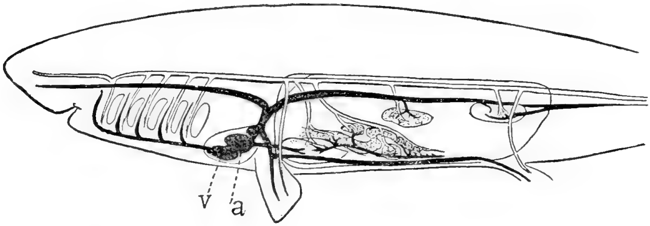


FIG. 22. Diagram of the circulatory system of a fish; *v*, ventricle; *a*, auricle. (After Parker and Haswell.)

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 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.

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 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.

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

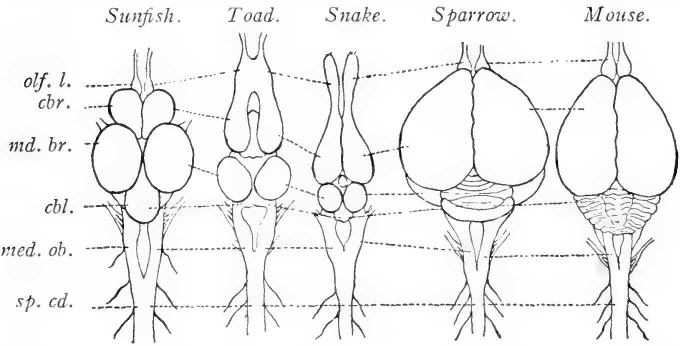


FIG. 23. Diagram of brains of vertebrates; *olf. l.*, olfactory lobes; *cbr.*, cerebrum; *md. b.*, midbrain (optic lobes); *cbl.*, cerebellum; *med. ob.*, medulla oblongata; *sp. cd.*, spinal cord.

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 connected with the muscles by means of the nervous system. Through this connection light, heat, sound, etc., guide muscular action.

The nervous system of a vertebrate (fig. 24), consists of a central portion, the brain (figs. 23, 25), 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,

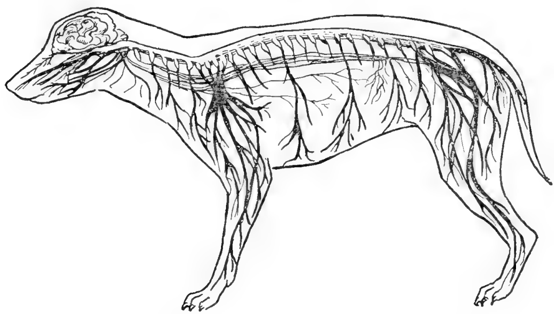


Fig. 24. Central nervous system of a dog. (After Ritzema-Bos.)

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.

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 (fig. 26) 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 nervous system any more than we do of a muscular or bony system. 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.

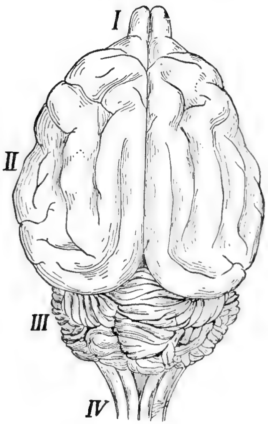


FIG. 25. Brain of a cat, dorsal surface; I, olfactory bulbs; II, cerebral hemispheres, III, cerebellum; IV, medulla oblongata. (After Reighard and Jennings.)

In recent years a great deal of careful observation and experimentation has been done on the behavior of the simplest animals. The conclusions of the naturalists who have done this work are not yet in sufficient harmony to make possible any satisfactory generalizations, but it seems certain that much of the behavior of the simpler animals is determined and controlled by agencies outside of the body.

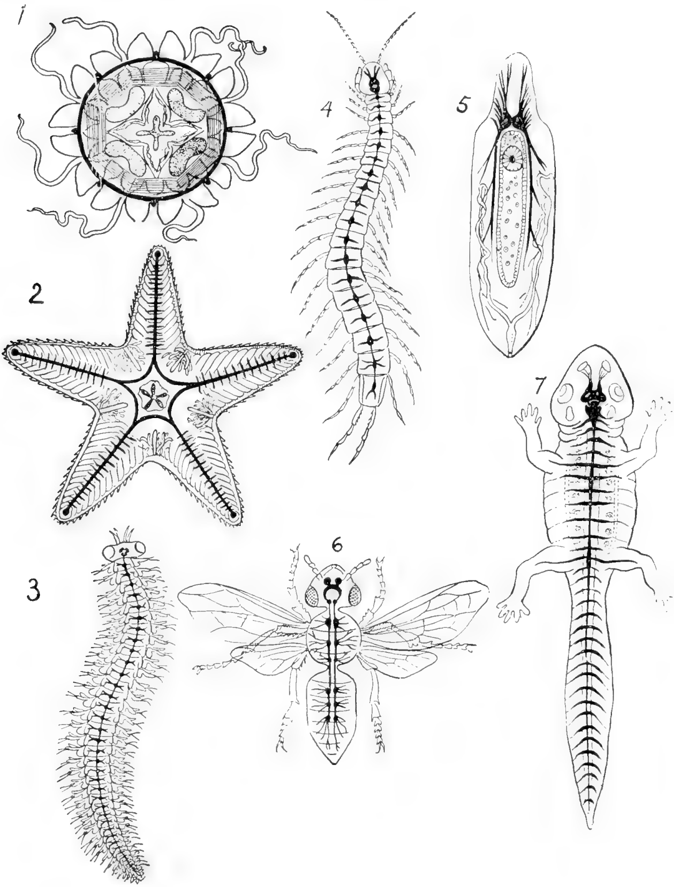


FIG. 26. Diagrams showing fundamental structure of types of several animal phyla: 1, sea-anemone; 2, starfish; 3, worm; 4, centiped; 5, clam; 6, honeybee; 7, salamander. In each figure the central nervous system is indicated by the black lines. (After Haeckel.)

Light, for example, has always a definite influence on certain simple animals compelling them to move in certain ways and to continue moving until they have arranged their bodies in a fixed position with regard to the direction of the light rays. Certain chemical substances, as well as gravitation, magnetism and other external agencies exert similarly definite influences. These externally controlled movements are called tropisms. Various other animal motions are of such a definite character, always recurring in exactly the same way under the same conditions of stimulation, that they are called reflexes; and these also go to show, as do the tropisms, that much of the behavior of the simpler animals, and even more or less of that of the higher animals, is beyond the control of the animal itself.

As we proceed upward in the animal scale we find a gradual grouping into 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 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 the names 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. 27) 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 especially supplied, in certain tailed monkeys the tip of the tail, and in hogs the end of the snout.

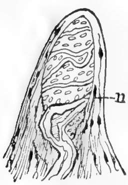


FIG. 27. Tactile corpuscle of the skin of man; *n*, nerve. (Greatly magnified; after Kölliker.)

The taste organs are much like the tactile organs except that the special taste cell must be exposed or covered only by a thin osmotic membrane, so that small particles of the substance to be tasted can come into actual contact with it. The taste organs (fig. 28) 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 or a sense akin to it is used not only to test food substances but also the chemical character of the fluid medium in which they live.

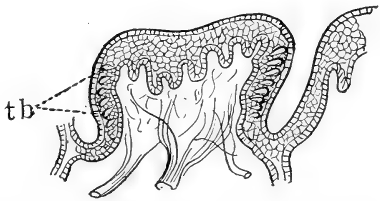


FIG. 28. Papilla with taste buds (*t. b.*) from the tongue of a calf. (Greatly magnified; after Loven.)

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. 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. 29), 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.

FIG. 29. The antenna of a carrion beetle, with the terminal three segments enlarged and flattened and bearing many "smelling-pits." (Much enlarged; photo-micrograph by Geo. O. Mitchell.)

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 organs, which transmit this stimulation along the auditory nerve to the brain, or nerve ganglion, 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. 30), 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

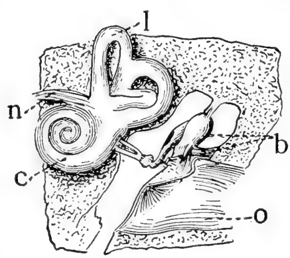


FIG. 30. Diagram of the internal part of the human ear; *o*, external opening; *b*, bones of the ear; *l*, labyrinth; *c*, cochlea or "snail shell"; *n*, auditory nerve. (After Headly.)

—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.

In most animals the auditory organs show the common characteristic of being wholly composed of, or having,

FIG. 31. 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. A spiracle at the side of the tympanum allows air to pass into a chamber behind the tympanum so that the air pressure is the same on both outer and inner surfaces of the tympanum. (Greatly magnified; photo-micrograph by Geo. O. Mitchell.)

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

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.

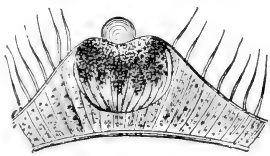


FIG. 32. Simple eye of a jellyfish. (Greatly magnified; after Hertwig.)

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. 32).

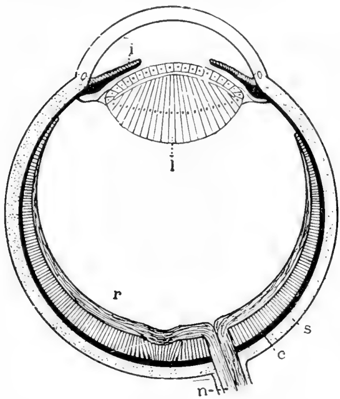


FIG. 33. Diagram of vertebrate eye; *c*, choroid; *i*, iris; *l*, lens; *n*, optic nerve; *r*, retina; *s*, sclerotic. (From Kingsley.)

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 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

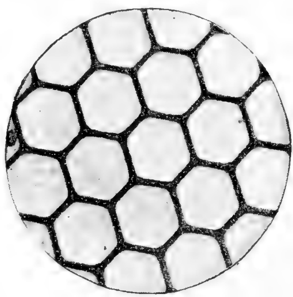


FIG. 34. Part of cornea, showing facets, of the compound eye of a horse-fly. (Greatly magnified; photo-micrography by Geo. O. Mitchell.)

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. 33) are organs of extreme structural complexity and of high development, although some of the other vertebrates have undoubtedly a keener and more highly perfected sight.

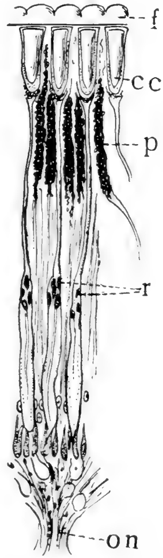


FIG. 35. Section through a few facets and eye elements (ommatidia) of the compound eye of a moth; *f*, corneal facets; *c. c*, crystalline cones; *p*, pigment; *r*, retinal parts; *o. n.*, optic nerve. (Greatly magnified; after Exner.)

The crustaceans and insects have eyes of a peculiar character called compound eyes (figs. 34 and 35). 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 largely 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 II

THE LIFE-HISTORY OF ANIMALS

CHAPTER VII

MULTIPLICATION AND DEVELOPMENT

Multiplication.—We know that any living animal has parents; that is, has been produced by other animals which may still be living or be now dead or, as with *Amœba*, may have changed, by division, into new individuals. Individuals die, but before death, they produce other individuals like themselves. If they did not, their kind or species would die with them. This production of new animals constantly going on is called the reproduction or multiplication of animals. The process is well called multiplication, because each female animal normally produces more than one new individual. She may produce only one at a time, one a year, as many of the sea-birds do or as the elephant does, but she lives many years. Or she may produce hundreds, or thousands, or even millions of young in a very short time. A lobster lays 10,000 eggs at a time. Nearly nine millions of eggs have been taken from the body of a thirty-pound female codfish. As a matter of fact but very, very few of these eggs produce new animals which reach maturity. From the 10,000 eggs produced by the lobster each year an average of but two new mature lobsters is produced. There is always a struggle for food and for place going on among animals, for many more are produced than there are food and room for, and so of all the new or young animals which are born the great majority are killed before they reach maturity. In a later chapter more attention will be given to this great struggle for life.

In the preceding paragraph it has been stated that "we know that any living animal has parents; that is, has been produced by other animals which may still be living or be now dead." This is a statement, however, which has found complete acceptance only in modern times. It is a familiar fact that a new kitten comes into the world only through being born; that it is the offspring of parents of its kind. But we may not be personally familiar with the fact that a new starfish comes into the world only as the production of parent starfish, or that a new earthworm can be produced only by other earthworms. But naturalists have proved these statements. All life comes from life; all organisms are produced by other organisms. And new individuals are produced by other individuals of the same kind. That these statements are true all modern observations and investigations of the origin of new individuals prove. But in the days of the earlier naturalists the life of the microscopic organisms like *Amœba* and *Paramœcium*, and even that of many of the larger but unfamiliar animals, was shrouded in mystery. And various and strange beliefs were held regarding the origin of new individuals.

Spontaneous generation.—The ancients believed that many animals were spontaneously generated. The early naturalists thought that flies arose by spontaneous generation from the decaying matter of dead animals. Frogs and many insects were thought to be generated spontaneously from mud, and horse-hairs in water were thought to change into water-snakes. But such beliefs were easily shown to be based on error, and have been long discarded by zoologists. But the belief that the microscopic organisms, such as bacteria and infusoria, were spontaneously generated in stagnant water or decaying organic liquids was held by some naturalists until very recent times. And it was not so easy to disprove the assertions of such believers. If some water in which there are apparently no living organisms, however minute, be allowed to stand for a few days, it will come to swarm with microscopic plants and animals. Any organic liquid, as a broth or a vegetable infusion, exposed to the air for a short time becomes foul through the presence of innumerable microscopic organisms. But it has been certainly proved that these organisms are not spontaneously produced in the water or organic fluid. A few of them enter the water from the air, in which there are always greater or less numbers of spores of microscopic organisms. These spores germinate quickly when they fall into water or some organic liquid, and the rapid succession of generations soon gives rise to the hosts of bacteria and one-celled animals which infest all standing water. If all the active organisms and inactive spores in a glass of water are killed by boiling the water, and this sterilized water be put into a sterilized glass, and this glass be so well closed that germs or spores cannot pass from the air without into the sterilized liquid, no living animals will ever appear in it. We know of no instance of the spontaneous generation of animals, and all the animals whose life-history we know are produced by other animals of the same kind.

Simplest multiplication and development.—The simplest method of multiplication and the simplest kind of development shown among animals are exhibited by such simple animals as *Amœba* and *Paramœcium*. This method we have already studied. The production of new individuals is accomplished by a simple division or fission of the body (a single cell) into two practically equivalent parts. The only change necessary for the young or new *Amœba* to become like its parent, is that of simple growth to a size about twice its present size. The development here is reduced to a minimum. Just as the simplest animals perform the other life-processes, such as taking and digesting food, breathing and feeling, in an extremely primitive simple way, so do they perform the necessary life-process of reproduction or multiplication in the simplest way shown among animals.

In the case of *Paramœcium* the process of multiplication is slightly more complex than that of *Amœba* in the fact that sometimes before the simple fission of the body takes place the interesting phenomenon of conjugation occurs. If the two conjugating individuals differ at all—and they always do differ, because no two individual animals, although belonging to the same species, are exactly alike—the new individual, made up of parts of each of them, will differ slightly from both. Nature seems intent on making every new individual differ slightly from the individual which precedes it. And the method of multiplication which Nature has adopted to produce the result is the method which we have seen exhibited in its simplest form in the case of *Paramœcium*—the method of having two individuals take part in the production of a new one.

The development of the new *Paramœcia* is a little more complex than that of *Amœba*. Not only must the new *Paramœcium* grow to the size of the original one, but it must develop those slight, but apparent, modifications of the parts of its body which we can recognize in the full-grown, fully developed *Paramœcium* individual. A new mouth-opening must develop on the new individual formed of the hinder half of the original *Paramœcium* and new cilia must be developed. And the recent studies of a careful naturalist have shown that altogether the new Paramœcia undergo considerable change during their growth to full size. Thus there is a slight advance in complexity of development, just as there is in complexity of structure in *Paramœcium* as compared with *Amœba*. In the many-celled animals this complexity of development is carried to an extreme.

Birth and hatching.—When a young animal is born alive, it usually resembles in appearance and structure the parent, although of course it is much smaller, and requires always a certain time to complete its development and become mature. A young kangaroo or opossum is carried for some time after its birth in an external pouch on the mother's body and is a very helpless animal. A young kitten is born with eyes not yet opened and must be fed by the mother for several weeks. On the other hand young Rocky Mountain sheep are able to run about swiftly within a few hours after birth.

Most animals appear first as eggs laid by the mother. This is true of the birds, the reptiles, the fishes, the insects, and most of the hosts of invertebrate animals. This egg may be cared for by the parent as with the birds, or simply deposited in a safe place as with most insects, or perhaps dropped without care into the water as with most marine invertebrates. The young animal which issues from the egg may at the time of its hatching resemble the parent in appearance and structural character (although always much smaller) as with the birds, some of the insects, and many of the other animals. Or it may issue in a so-called *larval* condition, in which it resembles the parent but slightly or not at all, as is the case with the gill-bearing, legless, tailed tadpole of the frog or the crawling, wingless, wormlike caterpillar of the butterfly, or the maggot of the house-fly.

Life-history.—Any animal which hatches from an egg has undergone a longer or shorter period of development within the egg-shell before hatching. The development of an animal from first germ-cell to the time it leaves the egg, for example, the development of the embryo chick from the first cell to time of hatching, is called its *embryonic* development; and the development from then on, for example, that of the chick to adult hen or rooster, or that of tadpole to frog, is called the *post-embryonic* development. Beginning students of animals cannot study the embryonic development (*embryology*) of animals readily, but they can in many cases easily follow the course of the post-embryonic development, and this study will always be interesting and valuable.

CHAPTER VIII

MOSQUITOES AND CATERPILLARS

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 to-

*Most of the work outlined in this chapter, as also that of the succeeding chapter, can be done only in the spring or summer, so that this part of the book although devoted to a subject which should logically be treated immediately after,—if indeed not before—the structure and general physiology, may be postponed until after the next part (classification) is studied.

gether 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. 36). 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 observation 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 denser 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 most 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 gills of most mosquito larvæ are too undeveloped, and therefore they have to come occasionally to the surface to breathe.

FIG. 36. A mosquito, *Culex* sp.; showing eggs (on surface of the water), larvae (long and slender, in the water), pupa (large-headed at surface), and adult (in the air). (About three times natural size; from living specimens.)

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 for many kinds.

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 mouthless pupa takes no food 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 Appendix I), 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. 37) 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 as in the females. What are the large black spots on the head? Make a drawing of a mosquito, showing and naming these parts.

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.

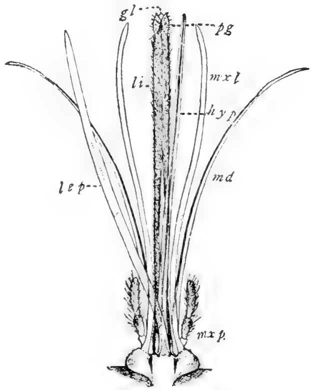


FIG. 37. Beak of female mosquito, dissected to show the piercing needle-like parts and their sheath; *mx. p.*, the maxillary palpi, or feelers of the mouth. (Greatly magnified.)

Distribution of mosquitoes.—Mosquitoes are distributed all over the world, being found in enormous numbers in arctic regions and on high moutain ranges as well as in the tropics, and in swamps and marshy valleys. About four hundred and fifty species, or different kinds, of mosquitoes are known, nearly seventy 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 germs of malarial fever (see Chapter XII). Only certain kinds of mosquitoes, however, are malaria-carriers. These all belong to the genus Anopheles; they may be distinguished by the possession of spotted wings, as most of 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. The malaria-bearing kinds have the maxillary palpi long in both male and female, while in the other kinds the females have short palpi (fig. 37). Other kinds of mosquitoes are 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 and especially so just after a moult.

For full accounts of the life of mosquitoes see "Mosquitoes," by Dr. L. O. Howard or "Mosquito Life" by Evelyn G. Mitchell.

CATERPILLARS

Caterpillars are the larvæ of moths and butterflies. While larva is the entomologist's name for the young of any kind of insect that has a complete metamorphosis, most persons call the larvæ of different kinds of insects by different names, as grubs for the larvæ of beetles, maggots for those of many flies, wrigglers for those of mosquitoes, slugs for those of saw-flies and caterpillars for those of moths and butterflies.

Most caterpillars are readily distinguishable by the five pairs of short, blunt, fleshy abdominal legs which they possess in addition to the three pairs of jointed thoracic legs.

The different kinds also are often easily recognizable by well-marked color patterns, or by coverings of colored hair or the presence of conspicuous tubercles and the like.

They may be found from late spring to early fall usually busily feeding in their favorite plants. "The best hunting grounds are the sides of country roads, the edges of woods,

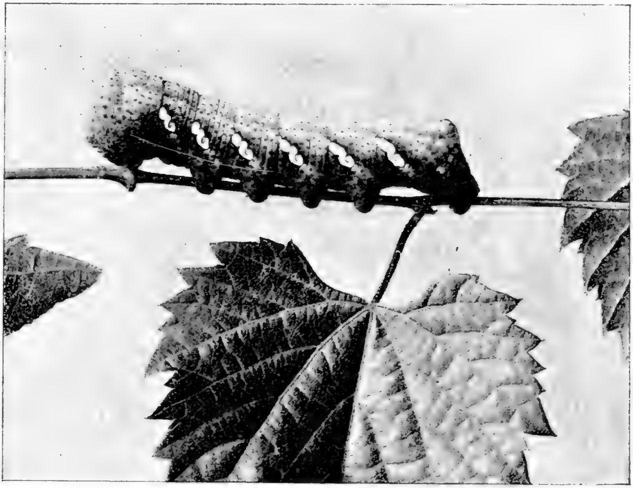


FIG. 38. Larva of the achemon sphinx moth, *Philampelus achemon*. (Natural size; after Lugger.)

half-cleared fields and gardens. Low fresh second growths of oak, poplar or elm will pay investigation. . . . A low growth of wild cherry is almost sure to yield a harvest." Virginia creeper, sassafras, bayberry, hop-vines, appletrees, nettles, milkweeds and wild carrot are all favorite feeding grounds of butterfly caterpillars.

The important thing to note at the time of collecting a live caterpillar, which you wish to rear indoors, is the kind of plant it is feeding on. For these are the best leaves to bring in to it. Indeed some kinds of caterpillars will eat the leaves of only certain few kinds of plants. Indoors the live caterpillars should be kept in clean cages (see Appendix II for directions for making cages) and given plenty of fresh food. They will then eat, grow, moult, pupate and finally turn into perfect moth or butterfly.

The observations to be made on the caterpillars are of

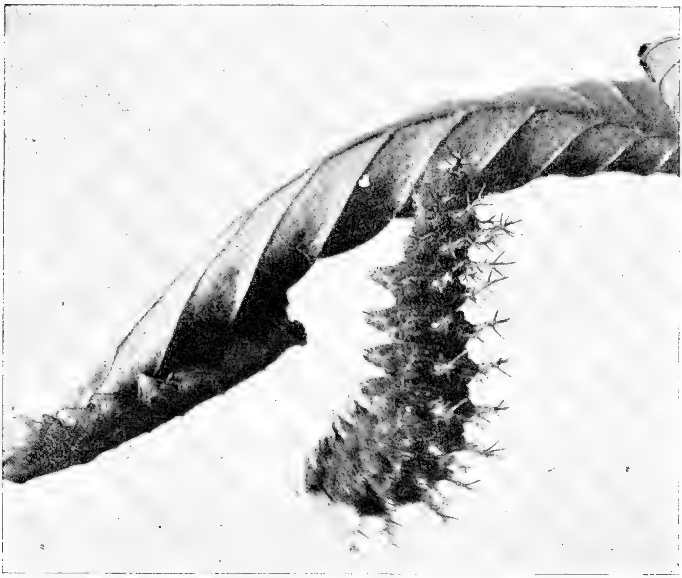


FIG. 39. Larva of the violet-tipped butterfly, *Polygonia interrogationis*, pupating. (Slightly enlarged; photograph from life by the author.)

two general categories: (1) observations of structure; (2) observations of behavior. To record the first make drawings; for the second make notes.

Of structural characteristics note the segmental make-up of the body and number of the segments; number, position and character of the legs, the mouth-parts, eyes and antennæ on head; presence and arrangement of hairs or tubercles, and position and number of spiracles (breathing pores).

All of these points may be shown in a single drawing. A colored drawing should be made showing the colors and color pattern.

Among the characteristics of behavior to be noted are the manner of walking, manner of eating, attitudes when disturbed or frightened, and the processes of moulting and pupating.

If an inch worm (caterpillar of a Geometrid moth) can be found, note its different methods of walking and the difference in the number of legs. Is there a relation between the different number of legs and the different mode of walking?

Some caterpillars go into the ground to pupate, some spin silken cocoons, some simply attach themselves freely exposed. The spinning of cocoons should be watched closely and described fully in the notes.

A fully spun cocoon should be cut open several days after it is made, in order to see the chrysalid within. If some caterpillars have burrowed into the ground one or two should be dug up after several days in order to see what has happened. If the chrysalid has been made freely exposed note whether its colors and patterns are such as would tend to conceal it if it were hanging against bark or among leaves.

Make a drawing of the chrysalid showing and naming all the parts that can be observed. Look for spiracles and for the wings, legs, mouth-parts and antennæ of the future moth or butterfly.

Make drawings and notes describing in detail the issuance of the moth or butterfly from the chrysalid case. Pay special attention to the unfolding and expanding of the wings. By what means does this expansion probably take place?

Make drawings of the fully expanded moth or butterfly showing not only its general shape but all of its parts. Note all of the details in which it differs from the caterpillar. These include number, character and arrangement of the segments, number and character of the legs, presence of the wings, difference of the wings, difference in antennæ, eyes and mouth-parts, clothing of scales over wings and body, color and color patterns, etc.

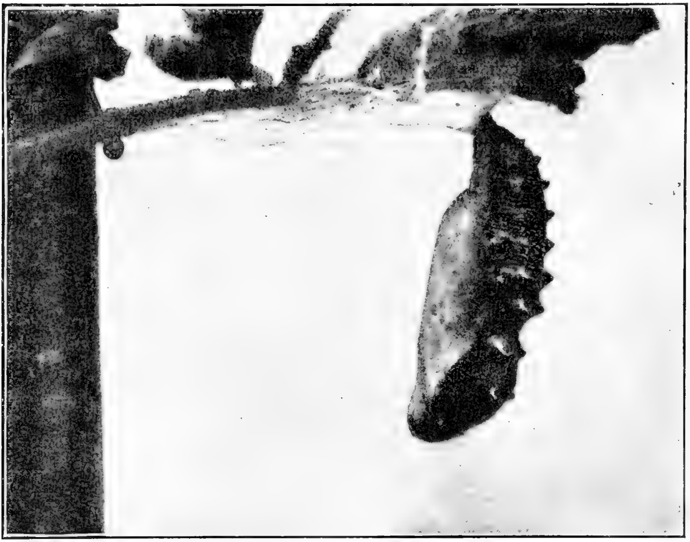


FIG. 40. Pupa or chrysalid of the violet-tipped butterfly, *Polygonia interrogationis*. (Slightly enlarged; photograph from life by the author.)

There is no limit to the possibilities of pleasure and interest in the field study and collecting of moths and butterflies. The study should include observations on their flight, their resting attitudes, their feeding habits, their play with each other, and their mating and egg-laying.

Directions for collecting and preserving these and other insects will be found in Appendix II.

Butterflies can be named by referring to some such book as Comstock's "How to Know the Butterflies," Holland's "The Butterfly Book," or Scudder's "Everyday Butterflies." The more common and conspicuous moths can be named from Holland's "The Moth Book."

CHAPTER IX

FROGS AND BIRDS

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 birdlike 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.

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. 42).

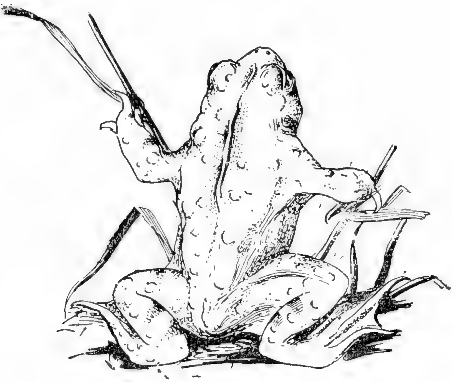


Fig. 41. Garden toad.

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 sucessfully 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 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

FIG. 42. Tadpoles. (Photograph from life by Cherry Kearton; permission of Cassell and Co.)

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?

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, cray-fish, small turtles, and fish, and may also occasionally capture small birds. A few grown-up toads and frogs should be kept in the school-room 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. 43. Garden toad.

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 into 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.

BIRDS

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 moth or butterfly, although she never eats leaves herself, always lays her eggs on the plants or trees where the young, on hatching, can find at hand their proper leaf food. Such is the habit of all moths and butterflies. Some of them indeed take no food in their adult stage; others do, 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."

FIG. 44. Nest of humming-bird, made of sycamore down. (One-half natural size.)

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 female? What does the other do? How long before the eggs hatch? Do they all hatch at the same time?

After hatching the care of the fledglings should be well

FIG. 45. 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.)

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. 45), 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.

See Chapters XVII–XXI in Baskett's "The Story of the Birds," and Chapter VI in Chapman's "Bird-life."

PART III

DIFFERENT KINDS OF ANIMALS, THEIR CLASSIFICATION, HABITS AND SPECIAL RELATION TO MAN

CHAPTER X

THE CLASSIFICATION OF ANIMALS

Basis and significance of classification.—It is the common knowledge of all of us that animals are classified: that is, that the different kinds are arranged in the mind of the zoologist and in the books of natural histroy, in various groups, and that these various groups are of different rank or degree of comprehensiveness. A group of high rank or great comprehensiveness includes groups of lower rank, and each of these includes groups of still lower rank, and so on, for several degrees. For example, we have already learned that the toad belongs to the great group of back-boned animals, the Vertebrates, as the group is called. So do the fishes and the birds, the reptiles and the mammals or quadrupeds. But each of these constitutes a lesser group, and each may in turn be subdivided into still lesser groups.

In the early days of the study of animals and plants their classification or division into groups was based on the resemblances and the differences which the early naturalists found among the organisms they knew. At first all of the classifying was done by paying attention to external resemblances and differences, but later when naturalists began to dissect animals and to get acquainted with the structure of the whole body, the differences and likenesses of inner parts, such as the skeleton and the organs of circulation and respiration, were taken into account. At the present time and ever since the theory of descent began to be accepted by naturalists (and there is practically no one who does not now accept it), the classification of animals, while still largely based on resemblances and differences among them, tells more than the simple fact that animals of the same group resemble each other in certain structural characters. It means that the members of a group are related to each other by descent, that is, genealogically. They are all the descendants of a common ancestor; they are all sprung from a common stock. And this added meaning of classification explains the older meaning; it explains why the animals are alike. The members of a group resemble each other in structure because they are actually blood relations. But as their common ancestor lived ages ago, we can learn the history of this descent, and find out these blood-relationships among animals only by the study of forms existing now, or through the fragmentary remains of extinct animals preserved in the rocks as fossils. As a matter of fact we usually learn of the existence of this actual blood-relationship, or the fact of common ancestry among animals, by studying their structure and finding out the resemblances and differences among them. If much alike we believe them closely related; if less alike we believe them less closely related, and so on. So after all, though the present-day classification means something more, means a great deal more, in fact, than the classification of the earlier naturalists it is still largely based on and determined by resemblances and differences just as was the old classification. Sometimes the fossil remains of ancient animals tell us much about the ancestry and descent of existing forms. For example, the present-day one-toed horse has been clearly shown by series of fossils to be descended from a small five-toed horse-like animal which lived in the Tertiary age.

Importance of development in determining classification.—A very important means of determining the relationships among animals is by studying their development. If two kinds of animals undergo very similar development, that is, if in their development and growth from egg-cell to adult they pass through similar stages, they are nearly related. And by the correspondence or lack of correspondence, by the similarity or dissimilarity of the course of development of different animals much regarding their relationship to each other is revealed. Sometimes two kinds of animals which are really nearly related come to differ very much in appearance in their fully developed adult condition because of the widely different life-habits the two may have. But if they are nearly related their developmental stages will be closely similar until the animals are almost fully developed. For example, certain animals belonging to the group which includes the crabs, lobsters, and crayfishes, have adopted a parasitic habit of life, and in their adult condition live attached to the bodies of certain kinds of true crabs. As these parasites have no need of moving about, being carried by their hosts, they have lost their legs by degeneration, and the body has come to be a mere sac-like pulsating mass, attached to the host by slender root-like processes, and not resembling at all the bodies of their relatives, the crabs and crayfishes. If we had to trust, in making out our classification, solely to structural reremblances and differences, we should never classify the *Sacculina* (the parasite) in the group Crustacea, which is the group including the crabs and lobsters and crayfishes. But the young *Sacculina* is an active free-swimming creature resembling the young crabs and young shrimps. By a study of the development of *Sacculina* we find that it is more closely related to the crabs and crayfishes and the other Crustaceans than to any other animals, although in adult condition it does not at all, at least in external appearance, resemble a crab or lobster.

Scientific names.—To classify animals then, is to determine their true relationships and to express these relationships by a scheme of groups. To these groups proper names are given for convenience in referring to them. These proper names are all Latin or Greek, simply because these classic languages are taught in the schools and colleges of almost all the countries in the world, and are thus intelligible to naturalists of all nationalities. In the older days, indeed, all the scientific books, the descriptions and accounts of animals and plants, were written in Latin, and now most of the technical words used in naming the parts of animals and plants are Latin. So that Latin may be called the language of science. For most of the groups of animals we have English names as well as Greek or Latin ones and when talking with an English-speaking person we can use these names. But when scientific men write of animals they use the names which have been agreed on by naturalists of all nationalities and which are understood by all of these naturalists. These Latin and Greek names of animals laughed at by non-scientific persons as "jaw-breakers," are really a great convenience, and save much circumlocution and misunderstanding.

AN EXAMPLE OF CLASSIFICATION.

Technical Note.—There should be provided a small set of bird-skins which will serve just as well as freshly killed birds, and which may be used for successive classes, thus doing away with the necessity of shooting birds. The birds suggested for use are among the commonest and most easily recognizable and obtainable. They may be found in any locality at any time of the year. The skins can be made by some boy interested in birds and acquainted with making skins, or by the teacher, or can be purchased from a naturalists' supply store, or dealer in bird skins. The skins will cost about 25 cents each. This example or lesson in classification can be given just as well of course with other species of birds, or with a set of some other kinds of animals, if the teacher prefers. Insects are especially available, butterflies perhaps offering the most readily appreciated resemblances and differences.

Species.—Examine specimens of two male downy woodpeckers (the males have a scarlet band on the back of the head). (In the western States use Gardiner's downy woodpecker.) Note that the two birds are of the same size, have the same colors and markings, and are in all respects alike. They are of the same kind; simply two individuals of the same kind of animal. There are hosts of other individuals of this kind of bird, all alike. This one kind of animal is called a *species*. The species is the smallest* group recognized among animals. No attempt is made to distinguish among the different individuals of one kind or species of animal as we do in our own case.

Examine a specimen of the female downy woodpecker. It is like the male except that it does not have the scarlet neck-band. But despite this difference we know that it belongs to the same species as the male downy because they mate together and produce young woodpeckers, male and female, like themselves. There are thus two sorts of individuals,† male and female, comprised in each species of animal. A *species* is a group of animals comprising similar individuals which produce new individuals of the same kind usually after the mating together of individuals of two sexes which may differ somewhat in appearance and structure.

Examine a male hairy woodpecker and a female; (in western States substitute a Harris's hairy woodpecker). Note the similarity in markings and structure to the downy. Note the marked difference in size. Make notes of meas-

*The lesser group called *variety*, or subspecies, we may leave out of consideration for the present.

†Some species of animals are not represented by male individuals; and in some all the individuals are hermaphrodites.

urements, colors and markings, and drawings of bill and feet, showing the resemblances and the differences between the downy woodpecker and the hairy woodpecker. These two kinds of woodpeckers are very much alike, but the hairy woodpeckers are always much larger (nearly a half) than the downy woodpeckers and the two kinds never mate together. The hairy woodpeckers constitute another species of bird.

Genus.—Examine now a flicker (the yellow-shafted or golden-winged flicker in the East, the red-shafted flicker in the West). Compare it with the downy woodpecker and the hairy woodpecker. Make notes referring to the differences, also the resemblances. The flicker is very differently marked and colored and is also much larger than the downy woodpecker, but its bill and feet and general make-up are similar and it is obviously a "woodpecker." It is, however, evidently another species of woodpecker, and a species which differs from either the downy or the hairy woodpecker much more than these two species differ from each other. There are two other species of flickers in North America which, although different from the yellow-shafted flicker, yet resemble it much more than they do the downy and hairy woodpeckers or any other woodpeckers. We can obviously make two groups of our woodpeckers so far studied, putting the downy and hairy woodpeckers (together with half a dozen other species very much like them) into one group and the three flickers together into another group. Each of these groups is called a *genus*, and genus is thus the name of the next group above the species. A genus usually includes several, or if there be such, many, similar species. Sometimes it includes but a single known species. That is, a species may not have any other species resembling it sufficiently to group with it, and so it constitutes a genus by itself. If later naturalists should find other species resembling it they would put these new species into the genus with the solitary species. Each genus of animals is given a Greek or Latin name, of a single word. Thus the genus including the hairy and downy woodpeckers is called *Dryobates;* and the genus including the flickers is called *Colaptes.* But it is necessary to distinguish the various species which compose the genus *Colaptes,* and so each species is given a name which is composed of two words, first the word which is the name of the genus to which it belongs, and, second, a word which may be called the species word. The species word of the yellow-shafted flicker is *auratus* (the Latin word for golden), so that its scientific name is *Colaptes auratus.* The natural question, Why not have a single word for the name of each species? may be answered thus: There are already known more than 500,000 distinct species of living animals; it is certain that there are no less than several millions of species of living animals; new species are being found, described and named constantly; with all the possible ingenuity of the wordmakers it would be an extremely difficult task to find or to build up enough words to give each of these species a separate name. This is not attempted. The same species word is often used for several different species of animals, but never for more than one species belonging to a given genus. And the names of the genera are never duplicated. (There are, of course, much fewer genera than species, and the difficulty of finding words for them is not so serious.) Thus the genus word in the two-word name of a species indicates at once to just what particular genus in the whole animal kingdom the species belongs, while the second or species word distinguishes it from the few or many other species which are included in the same genus. This manner of naming species of animals and plants (for plants are given their scientific names according to the same plan) was devised by the great Swedish naturalist Linnæus in the middle of the eighteenth century and has been in use ever since.

Family.—Examine a red-headed woodpecker (*Melanerpes erythrocephalus*) and a sapsucker (*Sphyrapicus varius*) and any other kinds of woodpeckers which can be got. Find out in what ways the hairy and downy woodpeckers (genus *Dryobates*), the flickers (genus *Colaptes*), and the other woodpeckers resemble each other. Examine especially the bill, feet, wings and tail. These birds differ in size, color and markings, but they are obviously all alike in certain important structural respects. We recognize them all as woodpeckers. We can group all the woodpeckers together, including several different genera, to form a group which is called a *family*. A family is a group of genera which have a considerable number of common structural features. Each family is given a proper name consisting of a single word. The family of woodpeckers is named *Picidæ*.

We have already learned that resemblances between animals indicate (usually) relationship, and that classifying animals is simply expressing or indicating these relationships. When we group several species together to form a genus we indicate that these species are closely related. And similarly a family is a group of related genera.

Order.—There are other groups* higher or more comprehensive than families, but the principle on which they are constituted is exactly the same as that already explained. Thus a number of related families are grouped together to form an *order*. All the fowl-like birds, including the families of pheasants, turkeys, grouse and quail, all obviously related, constitute the order of gallinaceous birds called *Gallinæ*. The families of vultures, hawks and owls constitute the order of birds of prey, the *Raptores*, and the families of the thrushes, wrens, warblers, sparrows, black-birds,

*Each of these higher groups has a proper name composed of a single word. In the case of no group except the species is a name-word ever duplicated. Each genus, family, order, or higher group has a name-word peculiar to it, and belonging to it alone.

and many others constitute the great order of perching birds (including all the singing birds) called the *Passeres*.

Class and branch.—But it is evident that all of these orders, together with the other bird orders, ought to be combined into a great group, which shall include all the birds, as distinguished from all other animals, as the fishes, insects, etc. Such a group of related orders is called a *class*. The class of birds is named *Aves*. There is a class of fishes, *Pisces*, and one of frogs and salamanders, *Batrachia*, one of snakes and lizards called *Reptilia*, and one of the quadrupeds which give milk to their young called *Mammalia*. Each of these classes is composed of several orders, each of which includes several families and so on down. But these five classes of Pisces, Batrachia, Reptilia, Aves and Mammals agree in being composed of animals which have a backbone or a backbone-like structure, while there are many other animals which do not have a backbone, such as the insects, the starfishes, etc. Hence these five backboned classes may be brought together into a higher group called a *branch* or *phylum*. They compose the branch of backboned animals, the branch *Vertebrata* (now usually looked on as a sub-branch of the great branch *Chordata*), all the animals like the star-fishes, sea-urchins and sea-lilies which have the parts of their bodies arranged in a radiate manner compose the branch *Echinodermata;* all the animals like the insects and spiders and centipedes and crabs and crayfishes, which have the body composed of a series of segments or rings and have legs or appendages each composed of a series of joints or segments, make up the branch *Arthropoda*. And so might be enumerated all the great branches or principal groups into which the animal kingdom is divided.

TABLE OF BRANCHES AND CLASSES 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, the following table of classification* of animals to branches and classes is introduced to show the relationships of the various large groups.

KINGDOM ANIMALIA.

Branch I. PRŌTOZŌ′A.

Class I. *Rhīzŏp′oda.*
Class II. *Mycētozō′a.*
Class III. *Mastigŏph′ora.*
Class IV. *Spōrozō′a.*
Class V. *Infusō′ria.*

Branch II. PORĬF′ERA.

Class I. *Porifera.*

Branch III. CŒLĔN′TERĀ′TA (sē-lĕn-te-rā-ta).

Class I. *Hȳdrozō′a.*
Class II. *Scȳphōzōa* (sī-fō-zō′-a).
Class III. *Actĭnozō′a.*
Class IV. *Ctĕnŏph′ora* (tĕn-ŏph′-o-ra).

Branch IV. PLĂTYHĔLMĬN′THES.

Class I. *Turbella′ria.*
Class II. *Trĕmatō′da.*
Class III. *Cĕstō′da.*

Branch V. NĔMATHĔLMĬN′THES.

Class I. *Nĕmatō′da.*
Class II. *Acanthocĕph′ala.*
Class III. *Chætŏg′natha* (kē-tŏg′-na-tha)

Branch VI. TROCHELMĬN′THES.

Class I. *Rotĭf′era.*
Class II. *Dīnŏphĭ′lea.*
Class III. *Gastrŏt′richa.*

Branch VII. MŎLLUSCOI′DA.

Class I. *Pŏlyzō′a.*
Class II. *Phōrŏ′nida.*
Class III. *Brăchiŏp′oda.*

*The classification here used is that adopted by Parker and Haswell's Text-book of Zoology (1897).

BRANCH VIII. ECHĬNŌDĔR′MATA.

Class I. *Asteroi′dea.*
Class II. *Ophiuroi′dea.*
Class III. *Ĕchinoi′dea.*
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′o-da).
Class II. *Gĕphyrē′a* (jĕf-e-rē′-a).
Class III. *Archi-annĕl′ida.*
Class IV. *Hĭrudĭn′ea.*

BRANCH X. ARTHRŎP′ODA.

Class I. *Crustā′cea.*
Class II. *Ŏnychŏph′ora* (ŏn-y-kŏf′-o-ra).
Class III. *Mȳrĭăp′oda.*
Class IV. *Insĕc′ta.*
Class V. *Arăch′nida.*

BRANCH XI. MŎLLŬS′CA.

Class I. *Pĕlecȳp′oda.*
Class II. *Amphineu′ra.*
Class III. *Gastrŏp′oda.*
Class IV. *Cĕphalŏp′oda.*

BRANCH XII. CHORDĀ′TA.

Sub-branch I. Adĕlochor′da.
Class *Adĕlochor′da.*
Sub-branch II. Urochor′da.
Class *Urochor′da.*
Sub-branch III. Vertebra′ta.
Division A. *Acrā′nia.*
Class *Acrā′nia*
Division B. *Crāniā′ta.*
Class I. *Cȳclostŏm′ata.*
Class II. *Pĭsces* (pĭs-sēz).
Class III. *Amphĭb′ia.*
Class IV. *Reptĭl′ia*
Class V. *Ā′ves.*
Class VI. *Mămmāl′ia.*

CHAPTER XI

THE SIMPLEST, OR ONE-CELLED, ANIMALS (PROTOZOA)

Besides the *Amœba, Paramœcium* and *Vorticella* (described in Chapter V) there are thousands of other kinds of Protozoa. Most of them live in water, but a few live in damp sand or moss, and some live inside the bodies of other animals as parasites. Of those which live in water some are marine, while others are found only in fresh-water streams and lakes.

Form of body.—The Protozoa all agree in having the body composed for its whole lifetime of a single cell, * but they differ much in shape and appearance. Some of them are of the general shape and character of *Amœba*, sending out and retracting blunt, finger-like pseudopodia, the body-mass itself having no fixed form or outline but constantly changing. Others have the body of definite form, spherical, elliptical, or flattened, enclosed by a thin cuticle, and having a definite number of fine thread-like or hair-like protoplasmic prolongations called flagella or cilia. Many of the familiar Protozoa of the fresh-water ponds always have two whiplash-like flagella projecting from one end of the body. By means of the lashing of these flagella in the water the tiny creature swims about. Others have many hundreds of fine short cilia scattered, sometimes in regular rows, over the body-surface. The Protozoan swims by the vibration of these cilia in the water.

There is no stagnant pool, no water standing exposed in

*In some Protozoa a number of similar cells temporarily unite to form a colony, but each cell may still be regarded as an individual animal.

watering-trough or barrel which does not contain thousands of individuals of the one-celled animals. And in any such stagnant water there may always be found several or many different kinds or species. A drop of this water examined with the compound microscope will prove to be a tiny world

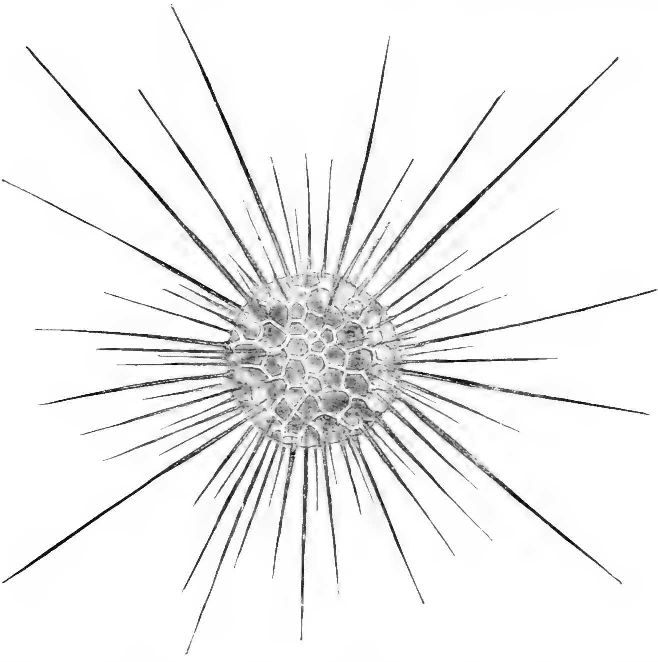


FIG. 46. Sun animalcule, a fresh-water Protozoan with a siliceous skeleton and long thread-like protoplasmic prolongations. (From life.)

(all an ocean) with most of its animals and plants one-celled in structure. A few many-celled animals will be found in it preying on the one-celled ones. There are sudden and violent deaths here, and births (by fission of the parent) and active locomotion and food-getting and growth and all of the businesses and functions of life which we are accustomed to see in the more familiar world of larger animals.

Marine 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, and the herring, and the mackerel. Those who have been on the seashore will recall the sea-urchins and starfishes and the sea-anemones which live in the tide-pools. On the beach there are the innumerable shells, too, each representing an animal which has lived in the ocean. But more abundant than all of these, and in one way more important than all, are the myriads of the marine Protozoa.

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 ocean (especially in the southern seas) a microscopical examination of this water 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 in all the water from the surface to a great depth below it. In a pint of this ocean-water there may be millions of these minute animals. In the oceans of the world the number of them is inconceivable. And these myriads of Protozoa represent a great host of different species grouped in various families and orders. All of this wealth of animal life was unknown to the earlier naturalists, for but few of the Protozoa are visible without the aid of the microscope.

Among all these ocean Protozoa none are more interesting than those belonging to the two orders Foraminifera (fig. 48) and Radiolaria. The many kinds belonging to these orders secrete a tiny shell (of lime in the Foraminifera, of silica in the Radiolaria) which encloses most of the one-celled body. These minute shells present a great variety of shape and pattern, many being of the most exquisite symmetry and beauty. The shells 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.

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 the ocean floor. Large areas of the bottom of the Atlantic Ocean are covered with this slimy ooze, called Foraminifera ooze or Radiolaria ooze, depending on the kinds of animals which have formed it. Nor is it only in present times that there has been a forming of such beds by the marine Protozoa. All over the world there are thick rock strata composed almost exclusively of the fossil shells of these simplest animals. The chalk-beds and cliffs of England, and of France, Greece, Spain, and America, were made by Foraminifera. 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 Barbadoes earth from the island of Barbadoes are composed of the shells of ancient Radiolaria.

FIG. 47. *Stentor* sp.; a Protozoan which may be fixed, like *Vorticella*, or free-swimming, 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. (From life.)

It is thus evident that the Protozoa are an ancient group of animals. As a matter of fact zoologists are certain that it is the most ancient of all animal groups. All of the animals of the ocean depend upon the marine Protozoa and the marine Protophyta, one-celled plants, for food. Either they feed on them directly, or prey on animals which in turn prey on these simplest organisms. A well-known zoologist has said: "The food-supply of marine animals consists of a few species of microscopic organisms which are inexhaustible and the only source of food for all the inhabitants of the ocean. The supply is primeval as well as inexhaustible, and all the life of the ocean has gradually taken shape in direct dependence on it." The marine Protozoa are the only animals which live independently; they alone can live or could have lived in earlier ages without depending on other animals. They must therefore be the oldest of marine animals. By oldest is meant that their kind appeared earliest in the history of the world, and as it is certain that ocean life is older than terrestrial life—that is, that the first animals lived in the ocean—it is obvious that the marine Protozoa are the most ancient of all animal groups.

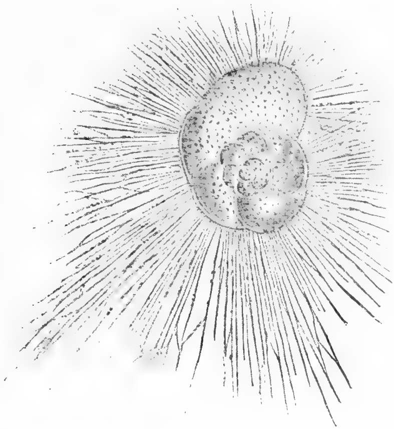


FIG. 48. *Rosalina varians*, a marine Protozoan (Foraminifera) with calcareous shell. (After Schultz.)

As already learned in the examination of examples of one-celled animals, it is evident that life may be successfully maintained without a complex body composed of many organs performing their functions in a specialized way. The marine Protozoa illustrate this fact admirably. Despite their lack of special organs and their primitive way of performing the life-processes, that they live successfully is shown by their existence in such extraordinary numbers. They outnumber all other animals. The conditions of life in the surface-waters of the ocean are easy and constant, and a simple structure and simple method of performing the necessary life-processes are wholly adequate for successful life under these conditions.

CHAPTER XII

HUMAN DISEASES CAUSED BY ONE-CELLED ANIMALS

Long ago when it was first discovered that various parasitic worms lived in our bodies and were the causes of pain and injury and even certain diseases physicians rapidly came to believe that all our ills were in some way caused by such parasites, known or unknown. Later there came a reaction against this belief as the search for the supposed parasites causing various diseases was unsuccessful in revealing them; but again with the later discovery, by means of perfected microscopes and methods of investigation, of bacterial germs in the body tissues the parasite or germ theory of disease was rehabilitated, and this time to endure.

These first known and first studied "germs" were all bacteria, which are extremely small, simple, one-celled plants. They are indeed probably the simplest of all living plants. But with the continued study of germs and contagious and infectious diseases it was found that certain of these diseases were produced not by bacteria or bacilli but by one-celled microscopic animals, organisms belonging to the branch Protozoa, or simplest animals. So today just as we recognize that typhoid, cholera and tuberculosis are diseases caused by the presence and growth in our body of bacteria, we recognize that malaria, sleeping sickness, relapsing fever and other related diseases are caused by the presence and growth of Protozoa.

A marked difference between the bacteria-caused and the Protozoa-caused diseases is the manner of the development and of the inoculation of the disease germs. While bacteria have a very simple sort of life-history, the disease-producing Protozoa have usually a very complicated life-history and one that requires two kinds of hosts for its completion. The bacteria or bacilli that cause typhoid fever for example, multiply in the body by simple division repeated indefinitely, forming generation after generation of bacilli all alike and of the same habits. The Protozoa that cause malaria multiply for a number of generations in the body, somewhat as the bacteria do, but then gradually cease multiplying and either die or lie more or less inert in the blood until they are sucked up with some of this blood into the stomach of a mosquito when they renew their active life and their process of multiplication but in a way very different from their former way. The very shape and appearance of the germs become so changed that they could not be recognized as belonging to the same kind if the actual process of the changes had not been clearly observed.

In the mosquito's stomach some of the little round inactive bodies suddenly put forth five or six long slender lash-like processes that break off and go swimming about like little snakes. These find some of the inactive bodies which have become somewhat swollen and fuse with them and the new body formed by this fusion becomes active and moves toward the wall of the stomach and there burrows into this wall as far as its outer coating. Here the parasite comes to rest and begins to grow rapidly until it forms a little nodule on the outer surface of the stomach. Inside this nodule the body stuff of the parasite divides into many hundred minute spindle-shaped bodies. Finally the walls of the nodule, which now projects into the body-cavity of the mosquito, break and the hundreds of new active germs escape into the blood of the insect which flows freely all through its body-cavity. From the blood they migrate forward into the neck and head and finally lodge in the salivary glands where they remain.

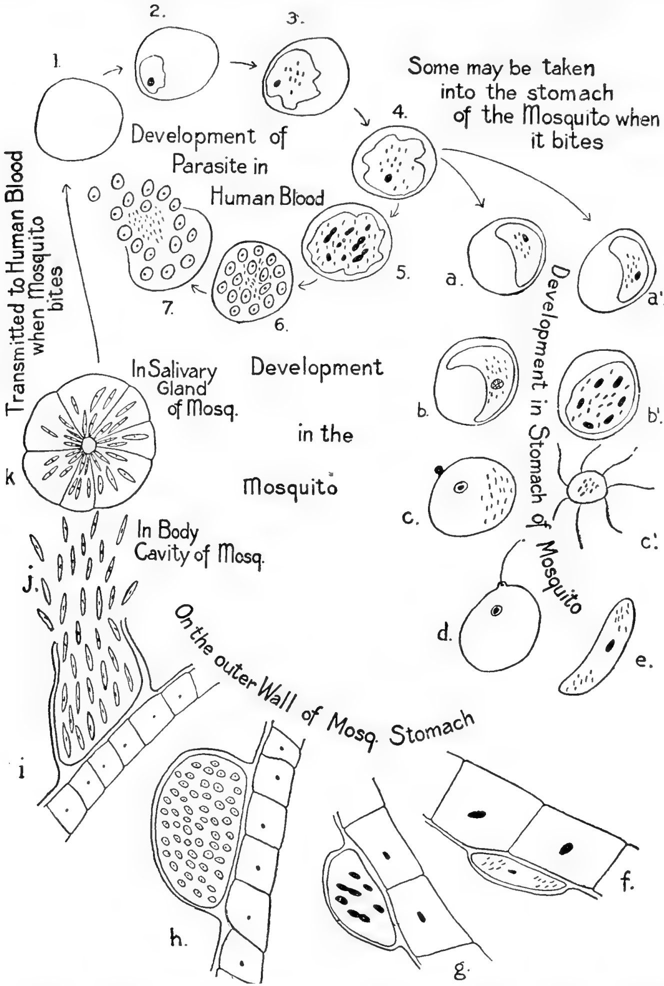


FIG. 49. Diagram to illustrate the life-history of the malarial parasite. 1 is a red blood-corpuscle, 2 to 7 shows the development of the parasite in the corpuscle, *a b c d* and *a′ b′ c′* and *e* the development of the parasite in the stomach of the mosquito, *f g h i* the development in the capsule on the outer wall of the stomach of the mosquito, *k* in the salivary gland.

When a mosquito "bites," that is, pierces the skin with its needle-like mouth-parts, so as to suck blood, it always pours a little of the fluid from the salivary glands into the wound. The reason for this is not certainly known, but the fluid, perhaps, keeps the blood from coagulating and thus from refusing to flow. However, one of the results of this habit is to inoculate the bitten person with the germs of

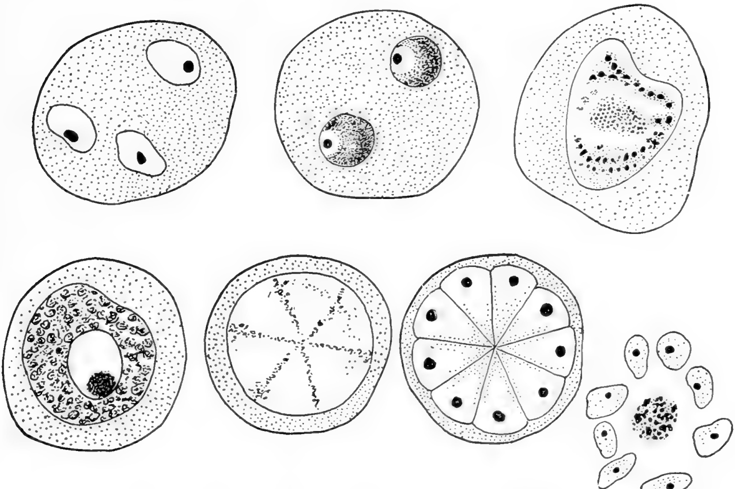


FIG. 50. Diagrammatic figure of stages in the development of the malaria-producing *Haemamoeba* (*Plasmodium*) in a red blood-corpuscle of the human body.

malaria, for some of the many quiet little spindle-shaped germs flow into the blood with the salivary fluid.

As soon as they enter the blood they become active and attach themselves to the red blood-corpuscles and burrow into them. As they work their way into the corpuscles they change their shape gradually, getting shorter and thicker, until by the time a germ is well lodged within a blood-corpuscle it is nearly spherical.

The germ now feeds and grows at the expense of the corpuscle. It may become nearly as large as the whole corpuscle. Then its body stuff divides into about six parts, the corpuscle breaks down, and the six new germs escape

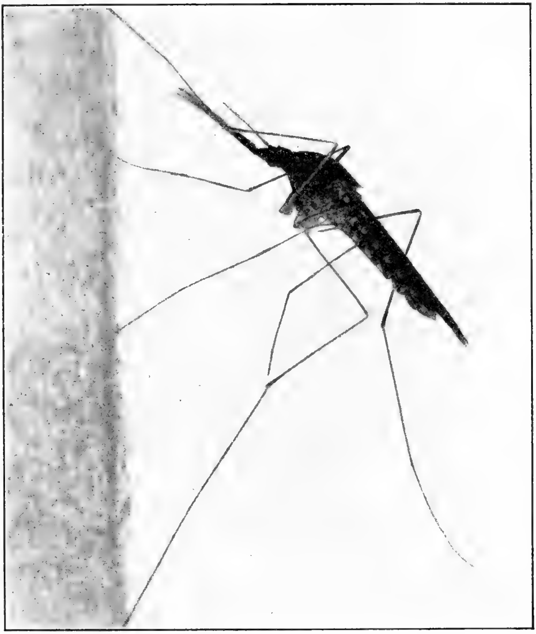


FIG. 51. Malarial mosquito, *Anopheles maculipennis*, on the wall. (Photograph from life by R. W. Doane.)

into the blood to find new blood-corpuscles to attack.

This kind of simple multiplying goes on for a number of generations but ceases after a while, and the germs of the last generation lie inert in the blood until they can be taken into a mosquito's body. Then a new life-cycle is started, according to the processes already described.

This, in brief and most general terms, is the story of the relation of the minute Protozoan animals called *Hæmatozoa*, or, popularly, malarial germs, with man and the mosquito. Not all kinds of mosquitoes—and over a hundred species of mosquitoes live in the United States—carry malaria germs. In only a few kinds, certain ones belonging to the spotted-winged genus *Anopheles*, can the malarial germs live and multiply. But it is difficult for the non-expert to tell one kind of mosquito from another and as the malaria-spreading kinds are scattered over the whole country, all mosquitoes should be avoided or fought. How mosquitoes live is told in Chapter VIII and how to fight them in Chapter XV.

The way in which quinine cures malaria is by its power of killing the germs when they are in our blood. But we do not know that they are there until a great many have been produced by their rapid method of multiplication, and then it takes some time for the quinine to make headway against them. We should be saved much suffering by preventing their getting a lodgment into the body at all.

As the germs are not created in the mosquito's body but only get into it by the sucking up of blood by the insect from some person already suffering from the disease, another way of fighting malaria is to prevent mosquitoes from having access to malarial patients, in other words to isolate and quarantine *from mosquitoes* any person suffering from malaria.

While malaria in America is not looked on as a fatal disease—although in fact about 10,000 persons die each year from its effects—elsewhere in the world, as in the Mediterranean countries and especially in India, it is a very terrible disease indeed, carrying off hundreds of thousands, even millions of victims every year. In some of these countries, notably in Italy, mosquito fighting is done on a large scale under governmental control and expense.

The malarial fevers are the principal diseases which in our own country are produced by one-celled animals living in our bodies. But elsewhere in the world other even more serious diseases are caused by Protozoan germs. The terrible sleeping sickness of Africa is one of these and, as with malaria, the germs are spread from man to man by a blood-sucking insect. This is not the mosquito but a larger heavier fly called the *tse-tse*, which is rather like a small horse-fly in general appearance.

Yellow fever is also almost certainly caused by a Protozoan parasite, which is distributed exclusively by mosquitoes. Several infectious diseases of domestic animals are caused by Protozoa. The best known of these in this country is the Texas or splenic cattle fever, the germs of which pass part of their life in the bodies of ticks and are distributed by them from animal to animal. These germs, called *Piroplasma*, have the interesting power of entering the eggs in the body of the female tick so that when the young ticks hatch from these eggs, which are laid on the ground when the old ticks drop off from the cattle upon which they have been holding while sucking their blood, these young ticks are already inoculated with germs. When cattle are attacked by these young ticks they become inoculated with the fever by the escape of the germs from the bodies of the ticks into their blood.

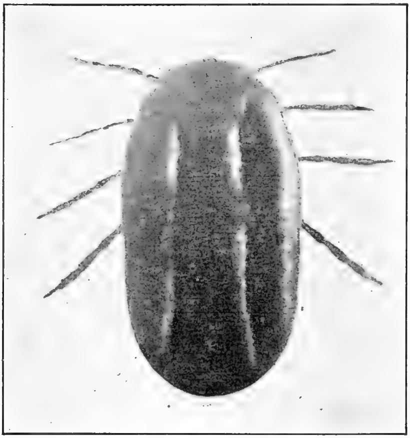


FIG. 52. Texas fever tick, *Margaropus annulatus;* young adult not fully gorged. (After Doane.)

The characteristic common to all these Protozoa-caused diseases that they are disseminated by insects in whose bodies the germs live for part of their life and undergo a special part of their multiplication is one that distinguishes them from the diseases caused by bacteria. However, several of the bacterial diseases are undoubtedly partly spread by insects, as cholera and typhoid fever by house-flies, plague by fleas, etc. But the germs do not have to live in the insects' bodies in order to complete their life-history. However, the germs of some bacterial diseases can be, and are, taken into the stomachs of the insects and passed out of the body alive and virulent. The bacilli of both typhoid fever and cholera have been found in "flyspecks," which are the excrement from the alimentary canal of the fly.

CHAPTER XIII

THE INVERTEBRATES

The invertebrate or backboneless animals include all of the great branches, or phyla, into which the animal kingdom is divided, except one, the branch Chordata. According to our table of animal classification (see pp. 116, 117) there are twelve of these invertebrate branches, one of which, the Protozoa, or one-celled animals, we have already briefly discussed. Included in the other eleven branches are all the sponges, sea-anemones, corals and jellyfishes, all the animals we commonly know as worms and a host of less familiar worm-like others, all the starfishes, sea-urchins and sea-cucumbers, the crabs, the centipedes, the insects and spiders and all the shell-fish and other creatures grouped together as molluscs. The backboneless animals outnumber by far in species and in individuals the backboned animals. The insects alone, which compose but a single class, the Insecta, of the great branch Arthropoda, include a greater number of kinds than all the other animal classes and branches together. But just the same the interest of most of us is held more by the backboned animals, the fishes, batrachians, reptiles, birds and animals; those animals with which our own bodies may be most readily compared and among whom we find our most valuable and entertaining and friendly companions and aids in life.

However, the five hundred thousand known species, more or less, of invertebrate animals now living include a host of kinds whose lives are of great interest and of great immediate importance to us. Some of them help build islands on which men live; others live parasitically in our bodies to our great discomfort and danger; many are persistent enemies of our crops and domestic animals. Finally, all in their structure, their physiology, their development and growth, their extraordinary adaptations to the conditions of their life, their marvelous modes of distribution, their beauty of color and pattern, and symmetry of outline, appeal to that inborn love of knowledge in us, as subjects to study, admire and enjoy.

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 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. 53). 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

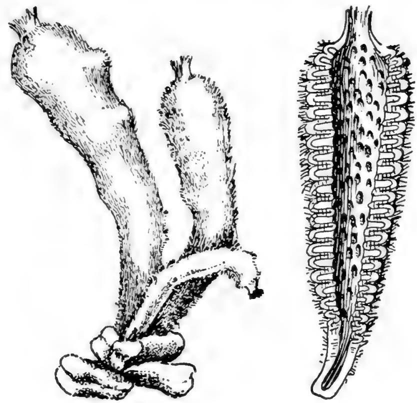


FIG. 53. A simple sponge, *Grantia* sp.; at right a longitudinal section, showing the simple body-cavity. (One-half natural size; after Jordan and Kellogg.)

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. 54. The skeleton of a glass sponge, composed of siliceous spicules; from Japan. (Natural size.)

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. 54). All the sponges compose the animal branch called *Porifera*.

Hydra.—One of the most interesting of the simple animals found in fresh-water ponds is Hydra (fig. 55). 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 watchglass, under the low power of a compound microscope, or with a good magnifier.

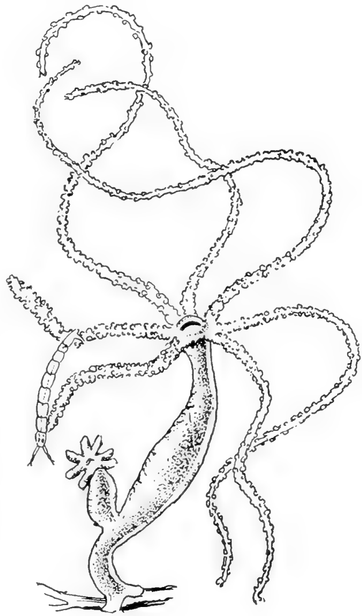


FIG. 55. Hydra; note two tentacles catching an insect larva; note the budding young Hydra. (Natural size, one sixth of an inch high; from life.)

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. Sometimes Hydra may be seen with another much smaller one growing out from it (fig. 55). 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.

Sea-anemones, corals and jellyfishes.—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, but are much larger. When the tide is out, exposing the dripping seaweed-covered rocks, and the little 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. 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 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, or long coral reefs fringing the shores of continents, formed by the skeletons of millions of polyps. For as they live closely 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 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. 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.

By walking along the sea-beach soon after a storm one may find many shapeless masses of a clear and 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. 56), around the edge of which are disposed numerous threads or tentacles (corresponding to the tentacles of the polyp). The mouth-opening is at the end of a longer or shorter projection which hangs from the middle of the under side of the umbrella,

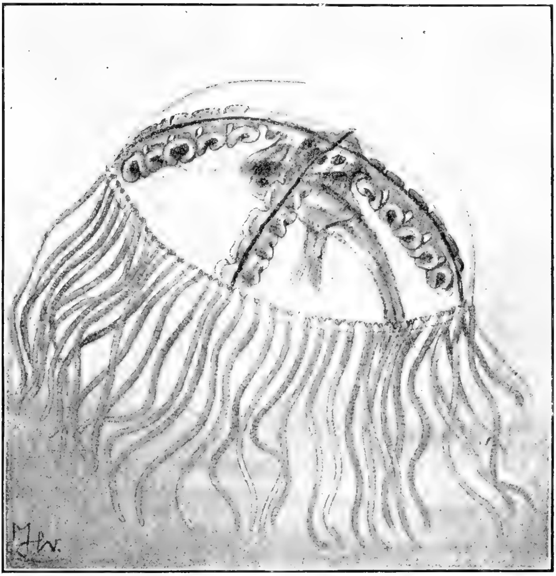


Fig. 56. A jellyfish or medusa, *Gonionema vertens*, eating two small fishes. (Natural size.)

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" 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.

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*. Although these animals do not look at all alike, the starfishes having a body composed of

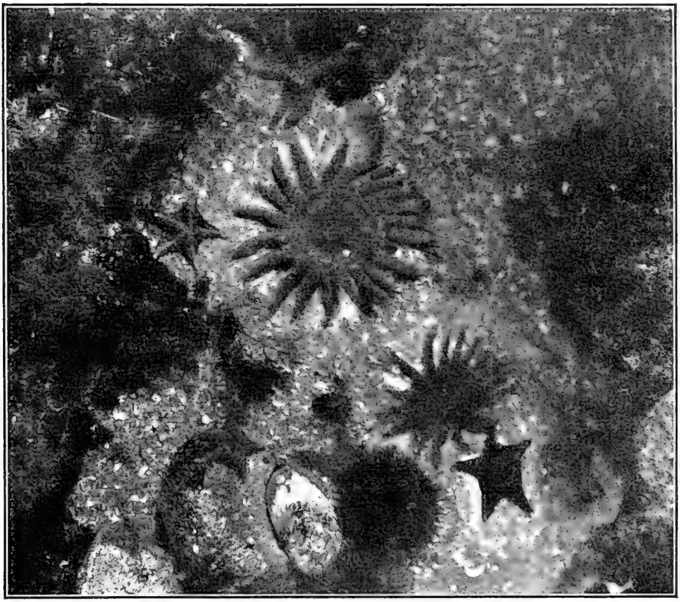


FIG. 57. Starfishes of various kinds in a tide-pool on the Bay of Monterey, California; note two with five rays, three pentagonal, and two with many rays. (Photograph by the author, from living specimens *in situ*.)

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 structure, the mouth being in 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 be had for examination, note that the body is covered by a

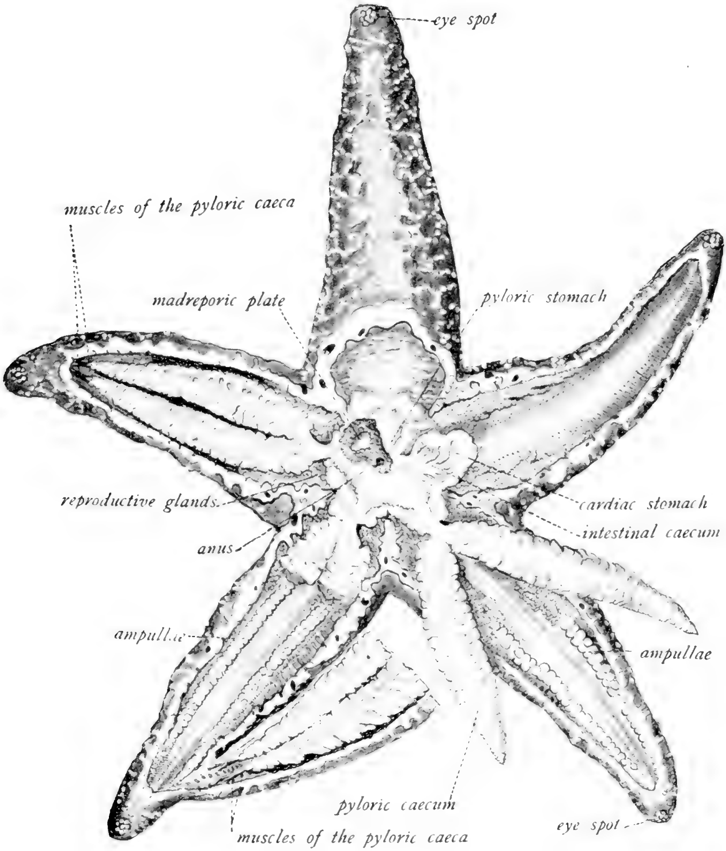


FIG. 58. Dissection of a starfish (*Asterias* sp.).

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 starfishes 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 secrets fluids which kill the prey, after which the soft parts are digested.

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. 57). Some have the spaces between the rays filled out nearly to the tips of the arms, making the animal 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!

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.

The sea-urchins, 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. 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 together 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 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.

Worms.—In the older classifications the branch Vermes included all the animals which are now divided into four branches of terrible names (Platyhelminthes, Nemathelminthes, Trochelminthes and Annulata). Vermes were worms; that was easy to remember. But with the discovery of many new worm-like creatures and of new things about some of the old ones called worms naturalists have decided that the old easy grouping was not a correct one. Hence the new one.

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

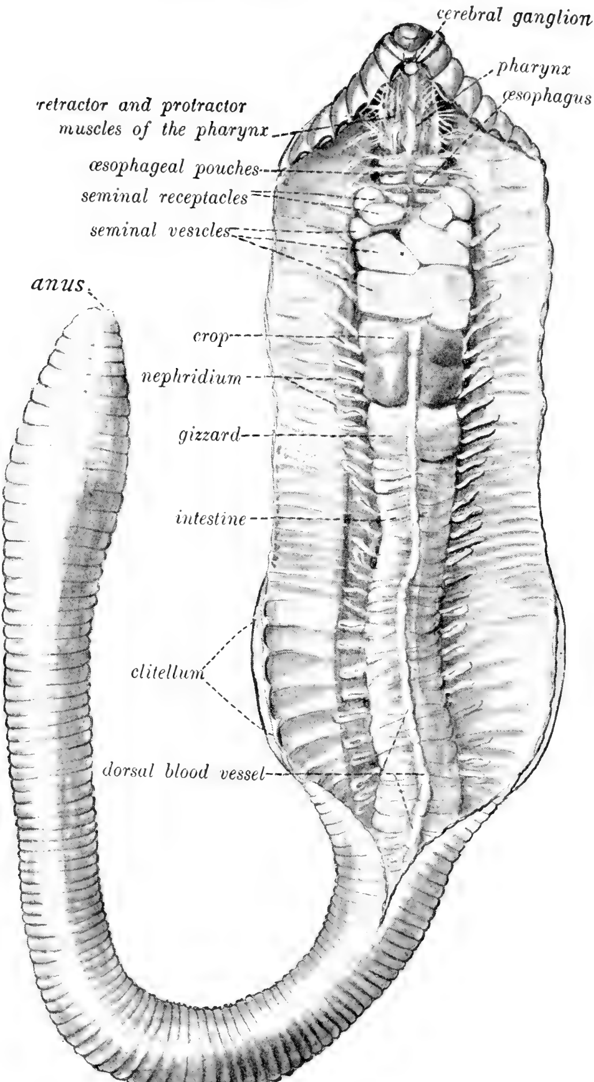


FIG. 59. Dissection of the earthworm, *Lumbricus* sp.

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 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 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.

The group of roundworms, so called from their slender, smooth, cylindrical bodies, contains some interesting animals. Familiar examples are the vinegar-eels, which can be found in mouldy vinegar, and the hairworms or horsehair 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 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. 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 such a case the cysts being dissolved by the digestive juices, the worms escape, develop reproductive organs and produce young, which then migrate

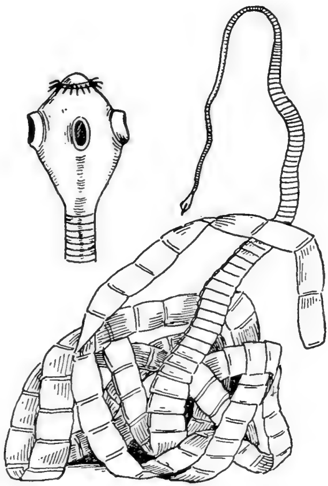


FIG. 60. Tapeworm; head, magnified, at left; the whole worm may be several yards long. (After Leuckart.)

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.

CHAPTER XIV

THE INVERTEBRATES (*continued*): ARTHROPODS AND MOLLUSCS

The jointed-legged animals.—None of the invertebrates we have studied so far has any organs which are really of the nature of legs, in the meaning commonly ascribed to the word. In fact the animals of only one out of the eleven invertebrate branches have organs which show any analogy with the jointed legs of our own body and of the other terrestrial vertebrates. This branch is that of the Arthropoda which includes in its five classes a great host of familiar

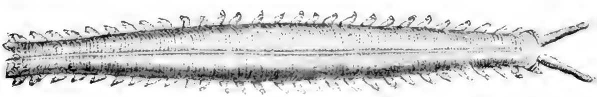


FIG. 61 *Peripatus eiseni.* Mexico.)

animals, namely, all the crabs, shrimps, sand-fleas, barnacles, etc., (class *Crustacea*); the thousand-legged worms (bad name; they are not worms at all) and centipeds (class *Myriapoda*); all the insects (class *Insecta*); the scorpions, spiders, mites and ticks (class *Arachnida*); and one other class, the *Onychophora*, containing but a single genus (*Peripatus*) of curious half worm-like, half centipede-like animals found in the tropics which seem to be a sort of connecting link between the true worms and the myriapods. All of these animals agree in possessing legs composed of several distinct articulated segments.

The crayfish, or crawfish (whose structure is described in Chapter IV) is a good example of the Crustaceans. It 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 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.

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 enclosed 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 exo-skeleton, 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 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. 62) 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 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

FIG. 62. 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 of the species *Pollicipes polymenus;* the largest crab (upper left-hand) is *Brachynotus nudus;* the one in left lower corner is a young rock-crab, *Cancer productus;* the one in the seaweed at the right is a kelp crab, *Epialtus productus;* while the two in snail-shells in the right 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.)

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 enclosed 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. The hermit crabs all 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.

Crustaceans which at first glance are hardly recognizable as such are the stalked or sessile barnacles (fig. 62), which live fixed in great numbers on the rocks between tide lines, or on the piles supporting wharves, or on the bottom of ships or even on the bodies of whales. The body of the stalked barnacle is enclosed in a sort of bi-valved shell formed by a fold of the skin and stiffened by five calcareous plates. The legs of which there are usually six pairs are long and feathery and divided nearly to the base. These feathery feet project from the opened shell when the animal is undisturbed and, waving about in the water, catch small animals which serve as the barnacle's food. The acorn barnacle has no stalk but looks like a low bluntly pointed pyramid, this appearance being due to the convergence of the six calcareous plates in its body-wall. Barnacles have no heart nor any blood-vessels and show other degenerate features. This degeneration is due to their fixed life. The young barnacles when hatched from the egg are free-swimming larvæ as with most other Crustaceans.

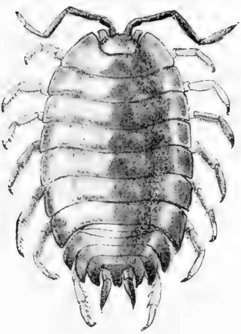


Fig. 63. A damp-bug, Isopod. (Four times natural size.)

Pill-bugs, wood-lice, or damp-bugs (fig. 63), 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 Crustacea, that class of animals which includes the crayfish, lobster, and crabs. 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 the 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.

Millipeds and centipeds (class Myriapoda).—The Myriapoda are land-animals breathing by means of tracheæ like the insects. In them the body-segments are nearly uniform in character with the exception of the head, which, as in the insects, bears the mouth-parts and antennæ. There is no grouping of the body-segments into regions except as the head is distinct from the rest of the body. (In a few myriapods there are indications of a division of the hind body into thorax and abdomen.) The presence of true legs on all the segments of the hinder region of the body and the lack of the three-region division of the body are the principal external structural characteristics which distinguish myriapods from insects. The internal anatomy corresponds in general character with that of insects.

FIG. 64. A galley-worm (milliped) *Julus* sp.

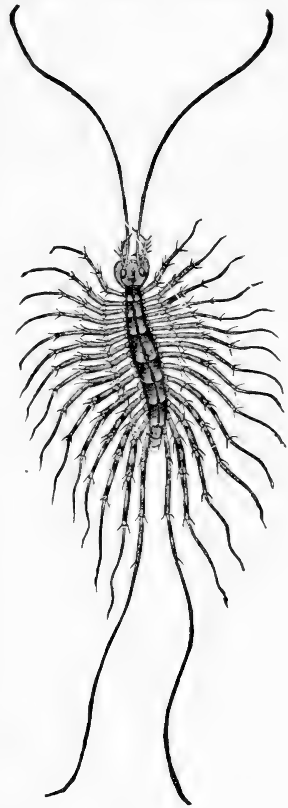


FIG. 65. The skein centiped, *Scutigera forceps*, common in houses and conservatories. (Natural size; after Marlatt.)

The most familiar myriapods are the millipeds, and the lithobians and centipeds. The millipeds are cylindrical in shape, have two pairs of legs on most of the body-segments and are vegetable feeders, though some may feed on dead animal matter. The galley-worms (*Julus*) (fig. 64), large, blackish, cylindrical millipeds found under stones and logs and leaves and in loose soil, are familiar forms. They crawl slowly and when disturbed curl up and emit a malodorous fluid. They can easily be kept alive in shallow glass vessels with a layer of earth in the bottom, and their habits and life-history may thus 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 60 to 100 eggs at a time. The eggs of this species hatch in about twelve days.

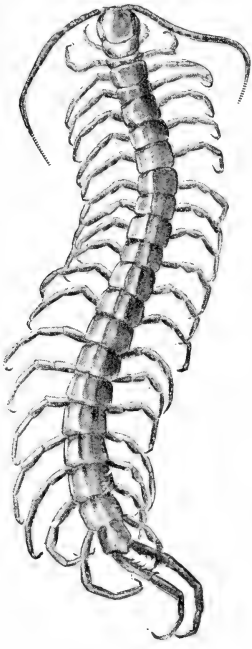


Fig. 66. A centiped, *Scolopendra* sp. (Natural size.)

The lithobians and centipeds are flattened and have but a single pair of legs on each body-ring. They are predaceous in habit, catching and killing insects, snails, earthworms, etc. They can run rapidly, and 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 (*Scutigera forceps*) (fig. 65) is yellowish and has fifteen pairs of legs, long 40-segmented antennæ, and nine large and six smaller dorsal segmental plates. The true centipeds (*Scolopendra*) (fig. 66) have twenty-one to twenty-three body-rings, each with a pair of legs, and the antennæ have seventeen to twenty joints. 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 even dangerous to man. The popular notion that a centiped "stings" with all of its feet is fallacious. It is recorded by Humboldt that centipeds are eaten by some of the South American Indians.

Insects (class Insecta).—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, dragon-flies, 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 grasshopper, mosquito, and caterpillars have already made us acquainted with the elementary facts concerning insect body-form, structure, and life-history, and elsewhere in this book are accounts of the special relations of insects to flowers, to other animals and also to man.

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. A good way to begin the study of the kinds and classifications of insects is to make a collection. Directions for this are given in Appendix II.

Books of insect classification are Comstock's "Manual of Insects" and Kellogg's "American Insects."

Insects live both on land and in water, 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 the tide-lines.

Among the most interesting insects to study in the field and to keep alive and observe in the schoolroom are the water-bugs and beetles to be found in almost any brook or pond. Collect various kinds alive and keep in the schoolroom aquarium (Appendix II). 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. 67).

Fig. 67. A water-strider, *Hygrotrechus* sp., adult. (Twice natural size.)

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

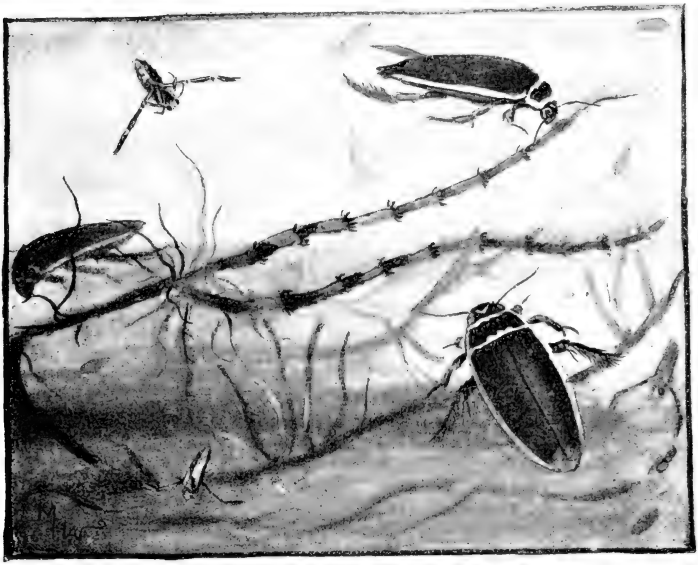


Fig. 68. Predaceous diving beetles, *Dyticus*, and back-swimmers, *Notasecta*. (Slightly less than natural size; from living specimens.)

is the extra pair situated? Note the peculiar shape of the legs. What are the legs specially fitted for?

Swimming about below the surface may sometimes be found large, shining, black beetles (fig. 68) 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 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 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.

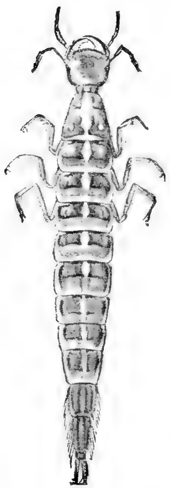


FIG. 69. Water-tiger, the larva of the predaceous water-beetle, *Dyticus* sp. (Natural size.)

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. 68), which swim with under side uppermost, and have the back black with large creamy patches, the other called water-boatmen (fig. 70), 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 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.

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 nymphs, i. e., young (fig. 71), 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 can easily be kept alive in the school aquarium (see Appendix II).

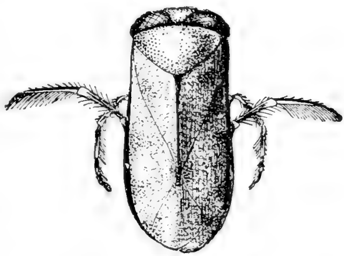


FIG. 70. Water-boatman, *Corisa* sp. (Twice natural size; after Jenkins and Kellogg.)

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 beating 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 takes no food and lives only a few hours, or at most a few days. The Mayflies have the shortest adult stage of all insects. The female drops her eggs into the water.

Moths and butterflies are among the most attractive and instructive insects to collect and classify and to rear as caterpillars and chrysalids in the schoolroom or at home. Some of the most beautiful butterflies and largest and most striking moths 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 Appendix II) in the schoolroom. Directions for the study of caterpillars have already been given in Chapter VIII.

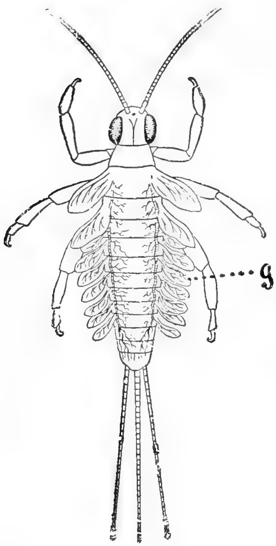


FIG. 71. Young (nymph) of a Mayfly, showing (*g*) tracheal gills. (Three times natural size; after Jenkins and Kellogg.)

Scudder's "Every-day Butterflies," Mary Dickerson's "Moths and Butterflies," and Eliot and Soule's "Caterpillars and their Moths," are admirable 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. Comstock's "How to Know the Butterflies," and Holland's "The Butterfly Book," are finely illustrated manuals of butterfly classification.

Scorpions, spiders, mites, and ticks (**class Arachnida**).—The class Arachnida is composed of Arthropods whose body-segments are grouped into two regions, a cephalothorax bearing the mouth-parts, eyes, and legs, and an abdomen. The

FIG. 72. Swallow-tail butterflies, *Papilio rutulus*. (One-half natural size; drawn from life.)

segments composing each of these two parts are so fused that, except in the scorpions, they are usually indistinguishable. There are no antennæ, the eyes are simple, the mouth-parts fitted for biting, and there are four pairs of legs. In their internal anatomy the arachnids show in some forms a peculiar modification of the respiratory organs, the tracheæ being flat and leaf-like and massed together in a few groups rather than being tubular and ramifying through the body.

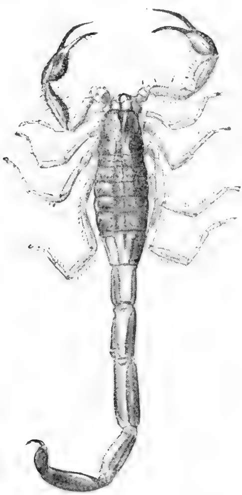


FIG. 73. A scorpion, (*Centrurus* sp., from California. (Natural size.)

The dorsal vessel or heart usually has a few blood-vessels or arteries running from it. This class is divided into three orders, the Arthrogastra, or scorpions, the Acarina, or mites and ticks, and the Araneina, or spiders.

The scorpions (fig. 73) have the posterior six segments of the abdomen much narrower than the seven anterior segments and forming a tail which bears at its tip a poison-fang or sting. This sting is used to kill prey, such as insects and other small animals. The tail can be darted forwards over the body to strike prey which has been previously seized by the large pincer-like maxillary palpi. Scorpions are common in warm regions, about twenty species being known in southern North America. Their sting though painful is not dangerous to man. The young are born alive and are carried about by their mother for some time after birth.

The mites (fig. 74) and ticks (fig. 75) are mostly small obscure animals, which live more or less parasitically. The common red spider of house-plants as well as the sugar- and cheese-mites, the dreaded itch-mite and the chigger are familiar examples of these degraded arachnids, and the wood-ticks, dog- and chicken-ticks are common examples of the larger blood-sucking forms. The body in both mites and ticks is very compact, the two body-regions, cephalothorax and abdomen, being closely fused. Various species of ticks have been proved to be the carriers of the germs of certain diseases of human beings and domesticated animals (see Chapter XII).

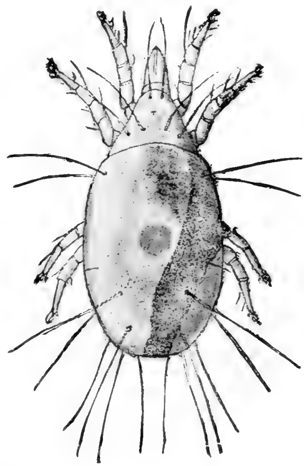


FIG. 74. The cheese-mite, *Tyroglyphus siro*. (Greatly enlarged; after Berlese.)

The spiders have the abdomen distinctly set off from the cephalothorax. The eyes (fig. 76) vary in number and arrangement, the mandibles are large, each being composed of two parts, a basal hair-covered part, the falx, and a terminal smooth, shining, slender, sharp-pointed part, the fang, which is movably articulated with the falx (fig. 76). In the falx is a poison-sac from which poison flows through the hollow fang and out at its tip. The legs vary in relative length in different spiders, and each is made up of seven joints. The spinnerets (fig. 77), which are situated at the tip of the abdomen, are six in number (a few spiders have only four), and are like little short fingers. They have at their tips many fine little spinning-tubes from each of which a fine silken thread issues when the spider is spinning. These many fine threads fuse as they issue to form a single strong cable or sometimes a flat rather broad band. The spinnerets are movable, and by their manipulation the desired kind of line is produced. The silk comes from many silk-glands in the abdomen, from each of which a fine duct runs to a spinning-tube.

The spiders may be divided into two groups according to

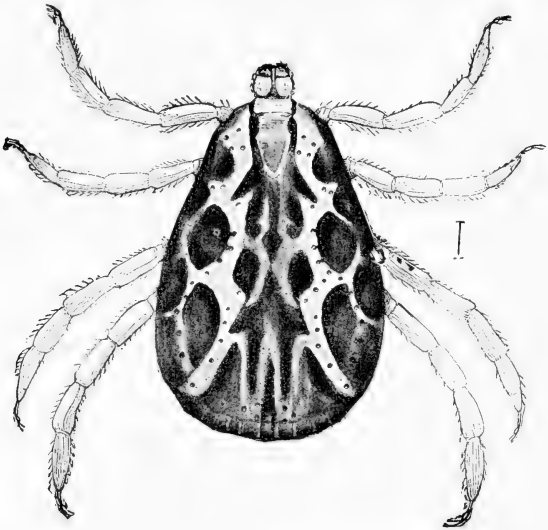


Fig. 75. The dog- or wood-tick, *Dermacentor americanus*, male, the most abundant tick in the Northern States. (Natural size indicated by line; after Osborn.)

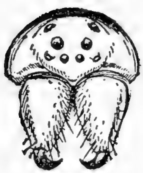


Fig. 76. The eyes and mandibles of a spider. (Much enlarged; after Jenkins and Kellogg.)

their habits, viz., the wandering or hunting spiders, which do not spin webs to catch their prey, and the sedentary or web-weaving spiders, which spin snares to catch their prey. The wandering spiders can spin silk, however, and often do so to line their burrows, to make nests, or to make egg-sacs. The hairy tarantulas and the trap-door spiders of similar appearance are among the most interesting of the hunting spiders. They live in vertical burrows or tunnels in the ground which are lined with silk, and which in the case of the trap-door spider are covered with a door or lid made of silk and soil. The top of this door is always covered with soil or bits of leaves or twigs so that it is nearly indistinguishable from the surface of the ground about it.

The common rather large swift black spiders found under stones and boards are hunting spiders, belonging to the family Lycosidæ and are called the running spiders. They live in burrows in the ground, coming out to stalk and chase their prey. The eggs are laid in globular egg-sacs which are often carried about, attached to the spinnerets, by the female (fig. 79). The young spiderlings after hatching, in some species, climb on to the mother's back and are carried by her for some time. Other kinds of wandering or hunting spiders are the crab-spiders (Thomisidæ) (fig. 80), which run sidewise or backward as well

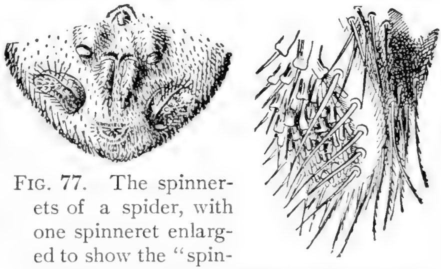


FIG. 77. The spinnerets of a spider, with one spinneret enlarged to show the "spinning spools" or tubes. (Much enlarged; after Jenkins and Kellogg.)

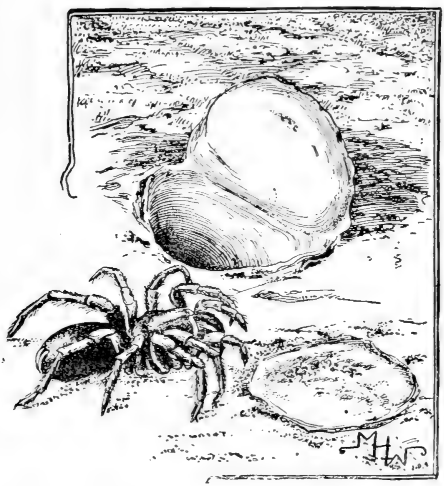


FIG. 78. Trap-door spider (California), and two burrows, one with door open, one with door closed. (Natural size; from living spider in field.)

as forward, and the black and red, fierce-eyed, stout-bodied little jumping spiders (Attidæ) (fig. 81), which leap on their prey.

The sedentary or web-weaving spiders are of various kinds. They may be grouped according to their spinning habits into cobweb weavers (Therididæ), small slim-legged spiders which make the familiar unsymmetrical cobwebs of houses and outbuildings; funnel-web weavers (Agalenidæ), larger long-legged spiders of meadow and field which spin a flat or concave horizontal web in the grass with a silken tube leading down to the ground; the curled-thread weavers (Dictynidæ), which use in addition to the usual lines peculiar broad lines made of waved or curled threads in their irregular webs made in fence-corners and on plants; and finally orb-weavers (Epeiridæ) (fig. 82), the host of variously colored and patterned stout-bodied garden-spiders which spin the beautiful symmetrical circular webs familiar to all. If a complete uninjured orb web be examined it will be found to consist of a small central hub either open or closed,

FIG. 79. A female running spider (Lycosid), carrying its egg-sac attached to its spinnerets. (Slightly enlarged; after Jenkins and Kellogg.)

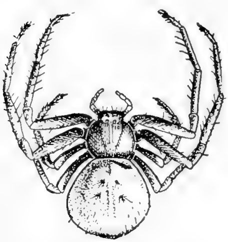


FIG. 80. A crab-spider (Thomisid). (Slightly enlarged; after Jenkins and Kellogg.)

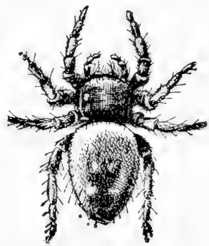


FIG. 81. A jumping spider (Attid). (Slightly enlarged; after Jenkins and Kellogg.)

from which run radii to the outer edges of the web. Around the hub is an open or free zone, and farther out a spiral zone, so called because a line running in close spiral turns fills in the space between the radii. This is the real prey-catching part of the snare, and the silken line here is sticky, while the radii and some other parts of the web are made of silk that is not sticky. The web is supported by strong foundation-lines, attached to leaves, stems, or whatever is firm in the neighborhood of the web. The spider either rests on the web usually in the centre, or lies concealed in a nest or tent near at hand from which a special path-line runs to the centre of the web. The building of one of these orb webs is a great work, and is done with extraordinary nicety of manipulation by the use of feet and spinnerets.

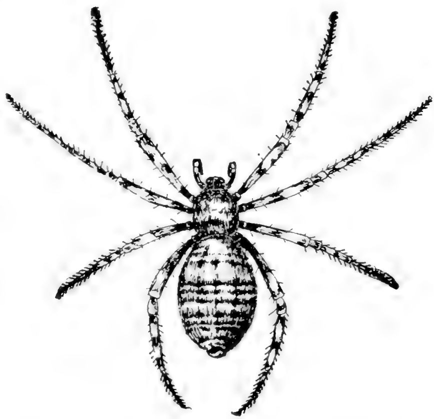


FIG. 82. *Argiope* sp., a large orb-weaver (Epeirid). (Natural size; after Jenkins and Kellogg.)

For an account of web-making, etc., see McCook's "American Spiders and their Spinning Work."

The habits and instincts of spiders in connection with the care of the young, the building of webs and nests, ballooning by means of silken lines, the active stalking and catching of prey, etc., are very interesting and offer a good field for independent observation and study by the student. McCook's book will be the best guide for this study.

Mussels, oysters, snails, "sea shells" and cuttlefish (Branch Mollusca).—The molluscs are not to be mistaken for any other of the lower animals; they have a structure peculiarly their own. In them the body is not articulated or segmented as with the worms and arthropods, nor radiate as in the echinoderms, nor plant-like as with the sponges and polyps. Where the typical molluscan body is well developed it is composed of four principal parts: a head, with the mouth, feelers, eyes, and other organs of special sense; a trunk containing the internal organs; a foot which is a muscular mass not at all foot- or leg-like in shape, but which is the organ of locomotion by means of which the mollusc crawls; and a mantle which is a fold of the skin enclosing most of the body and which produces the shell. Such a typical molluscan body is possessed by most of the snails. But in most of the other molluscs one or more of these four body-regions are so fused with some other region as to be indistinguishable. In the mussels and clams the head is not at all set off from the rest of the body, the cuttle-fishes and octopi have no foot, the slugs have no shell. In the case of some of the molluscs without external shell there are inside the body the rudiments or vestiges of a shell.

With regard to the internal organs we note the constant presence of three pairs of ganglia, viz., the brain, lying above the pharynx, which sends nerves to the feelers, eyes, and auditory organs; the pedal ganglion, which sends nerves to the foot, and the visceral ganglion, which sends nerves to the viscera. This is a condition of the nervous system characteristic of all molluscs. The heart is a well-developed pulsating sac in the upper part of the body, composed of either two or three chambers, and there is a well-defined closed system of arteries and veins, specially complete in the cuttlefishes and octopi. This highly developed condition of the circulatory system also distinguishes the molluscs from the other invertebrates.

The shell is composed of carbonate of lime and may be in two pieces, bivalved as in the oyster and clams, or in one piece, univalved, as in the usual spiral snail and sea shell type. The eggs are usually laid in a mass held together by a gelatinous substance. In most species the young mollusc on hatching from the egg does not resemble its parents, but is a free-swimming larva called a *veliger*. It is provided with cilia for organs of locomotion. It must undergo a radical change in order to reach the adult stage. Thus metamorphosis occurs in this branch as well as among the Arthropods and Echinoderms. In the development of some molluscs, however, there is little or no metamorphosis, the young being hatched in a condition much resembling, except in size, the parent.

The branch Mollusca is divided into five classes, three of which include the more familiar kinds. These three classes are the Pelecypoda, including the mussels, cockles, clams, scallops, oysters, etc., molluscs with a shell composed of two pieces, one on each side of the body and hinged together; the Gastropoda, including the snails, slugs, periwinkles, whelks, and a host of other univalved shell-fish, that is, molluscs which have a shell composed of a single piece; and the Cephalopoda, including the squids, cuttle-fishes, octopi, and the pearly nautilus.

Clams show a range in size from the little fresh-water *Cyclas* about 1 cm. long to the giant clam of the Indian and Pacific islands "which is sometimes 60 cm. (2 feet) in length and 500 pounds in weight." They show also some variety in the form and appearance of the shell, but not anything like the degree of variety shown by the shells of the Gastropods.

The edible clams are of several different species. The hard-shell clam (*Venus mercenaria*), or "quohog" as it is often called, is 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 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 shells of this edible clam are white. The soft-shell clam (*Mya arenaria*), "the clam *par excellence*, which figures so largely in the celebrated New England clam-bake, is found in all the northern seas of the world. . . .

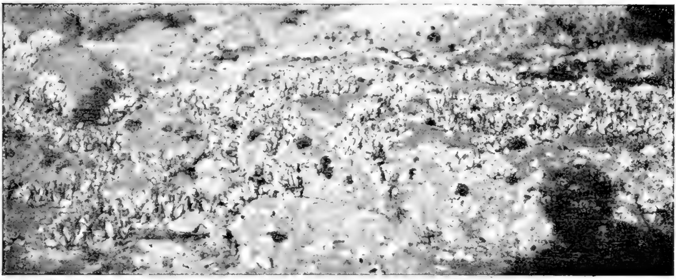


FIG. 83. California mussels and barnacles on rocks, exposed at low tide. (Photograph by the author.)

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 beneath the surface. When the flats are covered with water his clamship extends his long siphons 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 fœcal refuse is forced out of the other siphon. When the tide ebbs the siphons are closed and partly withdrawn." Ocean clams and mussels have furnished food for man for ages, and along coasts are found here and there great mounds made of heaps of clam-shells which have become covered over with soil and vegetation. Such mounds are the old feasting-places of the early coast inhabitants, and the archæologist often finds in these "kitchen-middens," as they are called, various relics of the early natives of the continent.

Even more widely known than the clams are the oysters (*Ostrea virginiana*), also members of this class of mol-

FIG. 84. An Eastern oyster, *Ostrea virginiana*. (After photograph by W. H. C. Pynchon.)

luscs. The oyster is carefully cultivated by man in many countries. It has its two shells or two shell-halves dissimilar, one valve being hollowed out to receive the body, while the other is nearly flat. The oyster is attached to the sea-bottom by the outside of the hollowed-out valve. When first hatched the young oyster swims freely 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 "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 3,000 acres, and produce an annual crop of 25,000,000 bushels."

The "pearl-oyster" is not a true oyster, that is, not a member of the family to which the edible oysters belong, but it is a member of the same class, that is, it is a bivalve

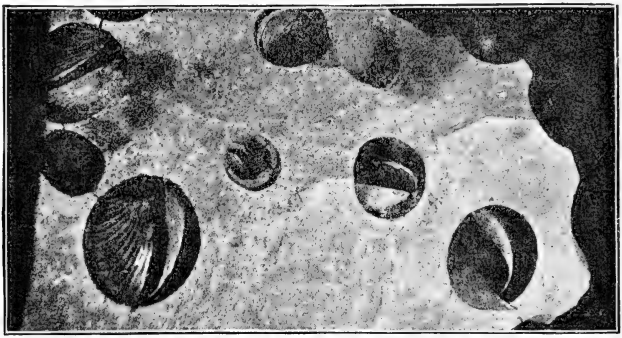


FIG. 85. *Pholas* sp., a mollusc burrowing in sandstone. (Photograph by C. H. Snow; permission of the American Society of Civil Engineers.)

mollusc. Pearls are obtained from a number of different "pearl-oysters," but the finest pearls and mother-of-pearl come from the tropical species *Meleagrina margaritifera*. This pearl-oyster has an extensive distribution, being found in Madagascar, the Persian Gulf, Ceylon, Australia, Philippine Islands, South Sea Islands, Panama, West Indies, etc. Mother-of-pearl is simply the inner lining of the shell, which is composed of numerous thin layers of carbonate of lime so arranged that the edges of the successive layers produce many fine striæ very close together. The beautiful iridescence of this inner shell-lining is caused by the complicated diffraction and reflection (interference effects) of the light by the fine striæ and the translucent superposed thin plates of shell material. Pearls are simply isolated deposits of shell material usually around some particle of foreign substance which has found lodging in the mantle-cavity. Sometimes small objects are purposely introduced into the shell in order to stimulate the formation of pearls. The pearl-fishers go out in boats and

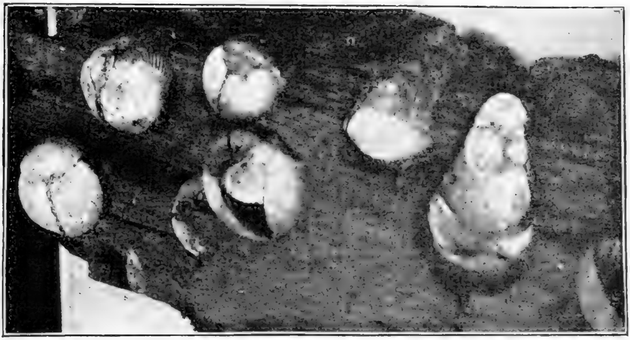


FIG. 86. *Martesia xylophaga*, a Pholad, burrowing in Panama mahogany. (Photograph by C. H. Snow; permission of the American Society of Civil Engineers.)

dive to the bottom, filling baskets with pearl-oysters. These are piled up in a bin and left to die and decompose. When the flesh is pretty thoroughly disintegrated, it is washed away with water, great care being taken that none of the pearls loose in the flesh are lost. When the washing is concluded the shells themselves are examined for pearls which may be attached to the interior of the valves. The principal pearl-fishery is that on the coast of Ceylon; pearl-fishing has been carried on here for over 2000 years.

The ship-worm (*Teredo*) is an interesting member of this class of bivalve molluscs, because of its unusual habits, and strangely modified body form. The teredo is long and worm-like in general appearance, with a small bivalve shell at one end and two elongated siphons at the other. The young teredo is a free-swimming ciliated embryo like the young of the other bivalve molluscs, but it soon settles on a piece of submerged wood, usually the pile of a wharf, or the bottom of a ship, and burrows into this wood. As it grows it enlarges and deepens its tube-like burrow, and lines it with a calcareous deposit. The burrow may be a foot long or longer, and when thousands of teredos attack a pile or the bottom of a ship, the wood soon becomes riddled with holes.

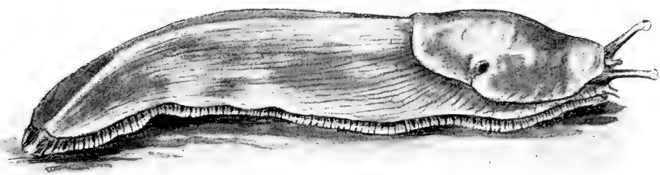


FIG. 87. The giant yellow slug of California, *Ariolimax californica*. This slug reaches a length of twelve inches. (From life.)

These boring molluscs do great damage to wharves and ships. In Holland where they were first discovered they caused such injuries to the piles and other submerged wood which supported the dikes and sea-walls that they seriously threatened the safety of the country.

Perhaps one-half of all the known species of molluscs are snails and slugs (fig. 87). Snails are either aquatic or terrestial in habit, but in either case they (the true pulmonate snails) breathe not by means of gills, as do most of the other molluscs, but by means of a so-called "lung." This lung is a sac with an external opening on the right side of the body and with its inner surface richly furnished with fine blood-vessels. The exchange of gases between the blood and the outer air takes place through the thin walls of the blood-vessels. Most snails which live in the water, as the pond-snails and the river-snails, have to come occasionally to the surface to breathe. These fresh-water and land-molluscs which possess a lung-sac instead of gills constitute the order Pulmonata. The pulmonate pond- and land-snails and slugs are vegetable feeders, and where they occur in large numbers do much injury to vegetation. While the common pond-snails have but one pair of feelers, at the base of which are found the eyes, most of the land-snails and slugs have two pairs of "horns," the eyes being on the tips of the second pair.

There are other snails common in ponds, also called, like the pulmonate forms, pond-snails, which have gills and no lung-sac. These pond-snails belong to a different order of molluscs, and live on the bottom of the pond, crawling about in the soft mud and feeding on animal instead of vegetable food.

The shells of the various kinds of snails vary much. In many of the land-snails the spiral is not spire-shaped or conical, but is flat. In some the whorls of the spiral run from left to right (dextral) when the shell is looked at with apex held toward one, while in others the whorls run from right to left (sinistral).

Of the hosts of marine Gastropods we can notice only a few kinds. The nudibranchs are a group of beautiful forms in which the shell is wholly wanting and the mantle is usually absent. The gills are thus exposed and are usually in the shape of delicate freely projecting tufts arranged in rows along the back. The body is often strikingly and variedly colored. These soft, naked "sea-slugs" live near the shore, creeping about among the rocks and seaweeds. About a thousand species of nudibranchs are known.

Among the shell-forming marine Gastropods there is 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 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. The "oyster-drills" are Gastropods with odd spiny shells

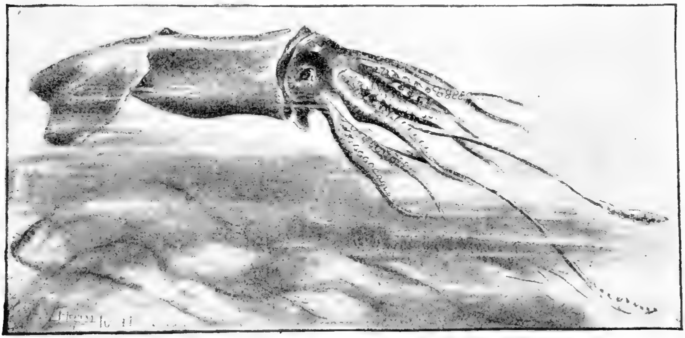


FIG. 88. The giant squid, *Ommatostrephes californica.* (From specimen with body, exclusive of tentacles, four feet long, thrown by waves on the shore of the Bay of Monterey, Calif.)

which do much harm in oyster-beds 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.

There are two principle groups of Cephalopods, namely the Decapods and the Octopods. The decapods, as their name indicates, have ten feet or arms surrounding the mouth, and the body is usually elongate and containing a horny "pen" or calcareous "bone." This group includes the cuttle-fishes or sepias, from which is obtained sepia ink and the cuttle-fish bone used to feed canary birds. The ink is a secretion which the cuttle-fish discharges when attacked, to create a cloud in the water and thus escape unperceived. The squids commonly used as bait by fishermen also belong to the decapods.

The octopods have a short sac-like body and neither an external nor internal shell. To this group belong the famous devil-fishes (octopus) whose strange and terrifying appearance combined with their frequently great size, has furnished the basis for many a weird tale of the sea. Devil-fishes having tentacles more than thirty feet in length have been found.

The pearly nautilus is a cephalopod of four gills instead of two as with the octopods and decapods, and is the only existing member of what was in the early times of earth's history a large group of animals. They make a many-chambered, spiral shell with its inner surface lined with beautiful pearly nacre.

CHAPTER XV

FIGHTING INSECT PESTS

Experts estimate that insects rob us each year of $400,000,000 worth of crops and $100,000,000 worth of forest trees and lumber. Besides this monetary loss insects also disseminate disease among our domesticated animals and, worst of all, among ourselves. It is no wonder then that the United States takes a lively interest in fighting insects.

This fighting is done both by the Federal government through its large and very effective Bureau of Entomology—by far the largest and best such governmental bureau in the world—and through the offices of state entomologists and state agricultural colleges and experimental stations. Besides, millions of farmers, fruit-growers and stock-raisers are doing a good deal of insect-fighting on their own account. The fighting includes first of all the acquiring of a thorough knowledge of the kinds of insects doing injury and their life-history and habits. Only with this knowledge can the most effective and economical means be devised for checking them. Hence much of the work of the governmental and state bureaus of entomology is the careful scientific study of insect life in general. It is a direct outcome of such study, for example, that the present widespread and successful use of insect parasites as natural remedies for insect pests has been developed. This method of insect fighting, which is simply the encouragement and assistance of Nature, promises soon to be the most important of all modes of lessening the losses due to our insect enemies.

In 1868 some young lemon and orange trees were brought to Menlo Park, California, from Australia. These little trees were unfortunately infested by a few small degenerate sap-sucking insects called, from the curious white waxen egg-masses which they produce, cottony cushion scale insects. These insects evidently found California and its orange orchards congenial in climate, rich in food and devoid of enemies for them, because by 1880 the cottony cushion scales were so abundant and wide-spread as to be a serious pest. By another ten years they had become a menace to the whole

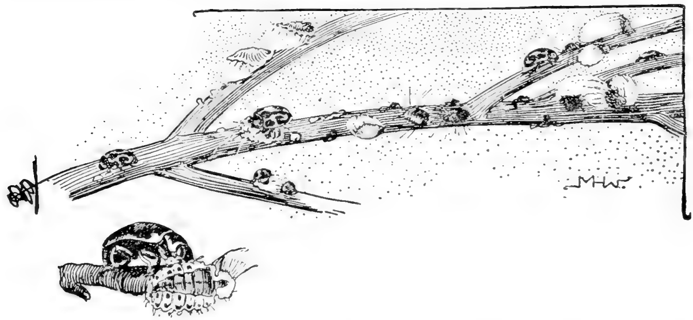


FIG. 89. The cottony cushion scale, *Icerya purchasi*, attacked by the Australian lady-bird beetle, *Novius cardinalis*. (Upper figure slightly enlarged, lower figure much enlarged; drawn from life.)

orange industry of the state.

In 1888 an entomologist was sent to Australia to hunt for native natural enemies of the cottony cushion scale. He found a very small red and black lady-bird beetle, called *Novius cardinalis*, feeding on the cottony cushion scales, and doing this so effectively that the scale insects were kept within safe numbers in Australia. Almost all the lady-bird beetles are "beneficial insects" in that their food consists chiefly of other insects and mostly such injurious kinds as plant lice and scale bugs.

The entomologist collected a few of the little black and red lady-bird beetles and sent them to California where they were enclosed under netting with orange branches infested by cottony cushion scales. The beetles began their beneficent work, increased in numbers and were later distributed in scale-infested orange orchards. In a few years they had practically relieved the California orange growers of all anxiety concerning cottony cushion scales. And now they are the standard and easily and cheaply applied remedy for scale insects of this kind.

This is so far the most successful case of the introduction and establishing in America of one insect species to attack and keep in check another insect species. But numerous other introductions have been made both of predaceous insects (lady-bird beetles, etc.), and parasitic insects (kinds that lay their eggs in or on other kinds so that the hatching young feed on the living bodies of the hosts). Among the most conspicuous examples of this modern way of fighting insect pests is the work now being done, chiefly under governmental control, in connection with the gypsy moth plague in New England.

In 1869 an astronomer and amateur naturalist living in Medford, Mass., was experimenting in cross breeding various silk-producing moths trying to produce a hardier silk maker than the Chinese mulberry silkworm. He caused to be sent to him from Europe the eggs and larvæ of various cocooning moths and among them those of the gypsy. In some way eggs or young of this moth, which has long been known as a pest of shade and forest trees in Europe, escaped from the experimenter's rooms and found congenial growing and breeding places in the neighborhood. The naturalist gave public notice of the escape but not until ten or twelve years after was the new settler noticed as abundant enough to be a nuisance and a menace, and not until 1889 was its spread sufficiently wide to attract general attention. In 1890 a town meeting appropriated $300 to exterminate the pest. These $300 did not do much exterminating and from that time until today it has been a constant struggle between moth and the people of New England backed by the United

States government. More than a million dollars have been expended, a score of professional entomologists aided by hundreds of paid helpers have been employed, and all the means known to scientific insect fighting have been tried. The most interesting feature of the great struggle is the importation from Europe and Japan of various natural insect enemies of the moth. Already more than fifty kinds have been introduced and experimented with, and it is for the discovery of some kind that will prove as efficacious against the soft winged gypsy as the Australia lady-bird beetle against the cottony cushion scales of California that the entomologists and New Englanders are working and praying. The gypsy moth if not fought against would probably ruin all the trees of New York and New England in a very few years.

But all this fighting of insects by the use of other insects, bug versus bug, as a Californian entomologist describes it, is but a small and, so far, a very small part of the war waged against insect pests in our country. There are indeed many entomologists who hold that the older ways of fighting, the use of so-called "artificial" remedies, as poisonous sprays, preventive and repellent bands and washes, traps and means of burning and crushing, and last but by no means least the high culture and strengthening of the attacked plants are ways that will never be satisfactorily replaced by the newer so-called "natural" remedies.

Among these artificial remedies the most conspicuous, widespread and generally applicable are the poisonous sprays. These are of two general categories, just as injurious insects are of two general categories. Insects are either of sucking mouth, taking liquid food, plant sap, or animal juices, by thrusting a sharp beak through the outer covering of leaf or twig or fruit or animal body and sucking up the sap or blood, or they are of biting mouth, nipping off and chewing bits of plant or animal tissue and swallowing solid particles. Now according as an injurious insect feeds by one or the other of these ways, the poisonous spray or *insecticide* must be specially chosen. For those plant attacking insects that have chewing mouth-parts and bite off and swallow bits of leaf or fruit or twig—all beetles, caterpillars, slugs, locusts, etc., are of this category—some

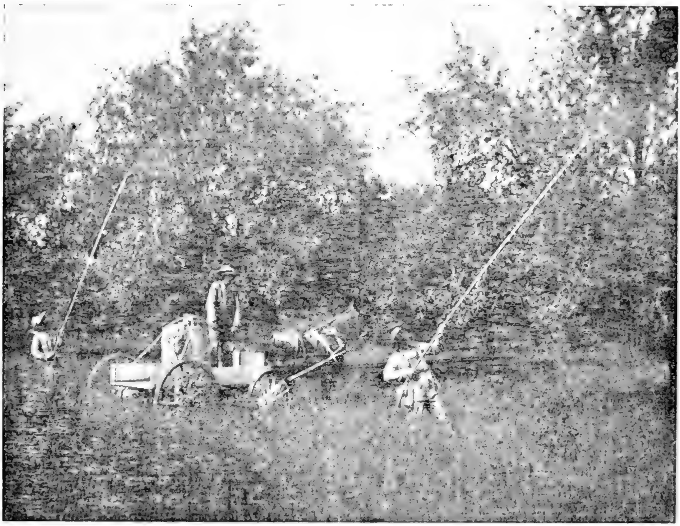


FIG. 90. Spraying an arsenical poison on apple trees against the codlin moth. (Photograph by Dudley Moulton.)

arsenical spray should be used. Paris green or London Purple thoroughly mixed with water, 1lb. to 200 gallons, or a mixture of 4 ounces of arsenate of soda and 11 ounces of acetate of lead in 100 gallons of water, are the best of such sprays. They should be so put on as to cover the attacked foliage thoroughly with a thin coating of poison. Then when the beetles or caterpillars bite off and swallow bits of leaf they will at the same time swallow enough poison to kill themselves.

If, however, the insect pest is one with sucking mouth-parts, obtaining its liquid food underneath the covering tissue of leaf, fruit or twigs—all plant-lice, scale insects, squash bugs, stink bugs and sucking bugs generally are of this category—the poisonous spray must be one that will kill by contact. It must be what is called an external irritant. The most available and effective of these external irritants is kerosene. As, however, the raw oil is also very irritating and dangerous to plant tissue as well as to insects it must be made into an emulsion before being sprayed on to the insect-infested foliage. The emulsion may be made as follows: Dissolve one-half pound of hard soap shaved finely in one gallon of boiling water. Add this to two gallons of kerosene aud churn the mixture with a force pump for a few minutes until it becomes a soft butter-like mass. This stock emulsion should be mixed with water whenever it is desired to make up the spray, in the proportion of one part of stock to ten parts of water.

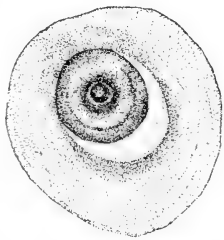


FIG. 91. A San Jose scale insect underneath its waxen covering. (Much enlarged.)

Other insecticides that kill by contact are mixtures of whale oil soap and water in the proportion of about one pound of whale oil to six gallons of water; also pyrethrum powder and water in the proportion of one pound of powder to thirty gallons of water.

For scale insects, which are so covered and protected by their waxen shell as to be very difficult to kill by contact, washes made of unslacked lime 50 lbs., sulphur 25 lbs., salt 18 lbs., and water sufficient to make 100 gallons; or resin 20 lbs., caustic soda (70% strength) 5 lbs., fish oil 3 lbs., and water sufficient to make 100 gallons, may be used.

Lime alone is a very good insecticide; the best way to prepare it is to add just water enough to stone- or shell-lime to dry-slack thoroughly; then sift and apply as a powder as soon as possible.

A method of insect killing which is available for use against either biting or sucking insects but which requires a good deal of special preparation and apparatus is that of fumigating with hydrocyanic gas. By covering the tree with a tent and then generating the gas under it by adding one ounce of pure potassium cyanide to one ounce of sulphuric acid in three fluid ounces of water, all insect life on the tree will be killed. The quantities of cyanide, acid, and water above given suffice to make gas to fill 150 feet of tent space. Hydrocyanic gas is deadly not only to insect but also to every other form of animal life.

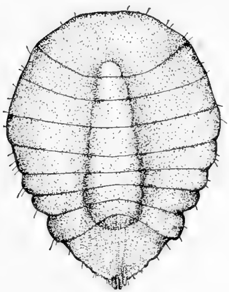


FIG. 92. San Jose scale insect removed from its waxen under covering. (Much enlarged.)

The vapor of bisulphide of carbon is a very effective insecticide. The bisulphide of carbon can be bought as a liquid in drug stores and a little of it poured into an open saucer which can be placed in a closed closet, or bin or trunk or even in a tight room. It volatilizes rapidly and the fumes are deadly. As the fumes are heavier than air the saucer should be placed in the upper part of the closet or bin. One dram of the liquid will suffice for each cubic foot of space in the receptacle. The vapor is inflammable and explosive and cannot be used where it can come into contact with fire. This remedy is very convenient and effective for clothes' moths.

For some kinds of insects simple methods of killing by attracting them to light or to poisoned food can be used.

Preventive remedies for insects such as the screening of windows, the covering of special plants with netting, or the encircling of tree trunks with bands of some sticky substance to prevent the crawling up of wingless insects have their place in insect fighting.

There still remains one other class of the so-called artificial remedies to be mentioned. They are really, however natural remedies. These are all those included under the general term of clean farming and high cultivation. The result of their use is to make the plant better fitted to withstand the attacks of their insect enemies. In nature almost all plants have to sustain more or less severe insect attacks. It is naturally the weakest plants that succumb first. Where man has gathered together many plant individuals of one kind and has by that very act invited all the kinds of insects that normally feed on these kinds of plants to come and feast, he is, we might say, morally bound to protect his plant wards from the too serious appetites of their guests. At least he will be prudent if he recognizes this obligation.

Insect pests of even more importance than those that attack our crops and our forests, our clothes and our domestic animals are those that bring suffering and death to our own bodies by breeding and disseminating the germs of human disease.

The role played by insects in breeding and distributing these animal disease germs, as well as bacterial (plant) germs, has already been pointed out in Chapter XII. To fight successfully these disease spreading insects, which is the most effective way of fighting the insect-spread infectious diseases, much has to be known of the structure, life-history and general habits of the particular insect kinds involved. The two most important kinds in our country are mosquitoes, which breed and disseminate malaria and yellow fever, and house flies, which spread typhoid and other bacterial diseases. The fleas, which disseminate plague, are also of great importance.

The very best way to fight house-flies is to destroy their favorite breeding-places, which are manure piles and privy vaults. The eggs are laid on fresh manure or excrement and hatch in from eight to twelve hours into footless maggots that reach their full growth in as few as eight days. Then they change to pupæ from which the adult flies issue in from eight to eighteen days. The length of life in the

FIG. 93. Foot of house-fly showing claws, hairs, pulvilli and the minute clinging hairs on the pulvilli. (Photograph by R. W. Doane.)

different stages, egg, larva, and pupa, varies with temperature and other conditions. All manure should be removed from barnyards at least once a week and spread out to dry. The flies cannot breed in dry manure. If the manure cannot be removed and spread out it should be kept in a fly-tight bin. Outdoor privy vaults and cesspools must be attended to. Cesspools should be kept covered and all pit privies replaced by dry-earth closets. Finally garbage cans and rubbish heaps should be cared for. Of course, any room or house can be kept free from flies, or nearly so, by screens; but neighborhood and community effort toward abolishing the breeding places is by far the most effective means of fighting the deadly housefly.

To fight mosquitoes the same advice applies; destroy the breeding places. Mosquitoes breed in puddles and ponds;

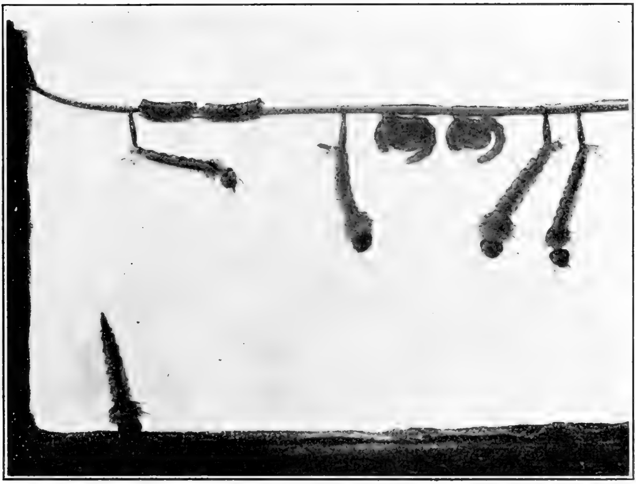


FIG. 94. Eggs, larvæ and pupæ of mosquitoes, *Theobaldia incidens*. (Photograph by R. W. Doane.)

in open barrels and tins of water; in marshes and lily-ponds; in fresh or slightly salt water anywhere that is not flowing. Mosquitoes mostly do not fly far; if the pests are abundant in or about a house look for a near-by breeding place. If this is a small puddle or pond that cannot be readily drained pour kerosene on its surface. The oil will spread out forming a thin coating over the water that will prove fatal to winged mosquitoes coming to lay their eggs, and to larvæ (wrigglers) coming up to the surface to breathe, as well as to the pupæ that normally float on the surface and to the adults trying to issue from the pupal shells. About one pint of kerosene will effectively cover fifteen square feet of water. Old cans or pails or casks in which rainwater collects should be removed; garden water taps should not be allowed to leak; water troughs should be kept running or be emptied every few days.

If the mosquitoes come from a marsh or large pond community efforts at drainage are in order. Certain little fishes called "millions" or "top minnows" (*Fundulus* species) are great mosquito-wriggler eaters, and a pond well stocked with these, or indeed almost any kind of top feeding fishes, will not produce many mosquitoes.

There are no very satisfactory ways of killing or driving away the winged flies. Smudges and pyrethrum powder do some good. Ill-smelling oils like pennyroyal smeared on hands and face may be helpful, but they are very disagreeable to most persons. The real way in which to rid a region or community of mosquitoes—which is equivalent to ridding it of all danger from malarial fevers—is to abolish the breeding places or keep them covered with oil through the mosquito breeding season.

An excellent recent book about injurious insects and the ways to fight them is "Our Insect Friends and Foes," by J. B. Smith.

CHAPTER XVI

THE VERTEBRATES

The backboned animals or vertebrates, comprising the fishes, salamanders, frogs and toads, lizards, crocodiles, turtles and snakes, birds, and all the quadrupeds or mammals, belong to the great branch Chordata which includes also a few small unfamiliar ocean animals which do not look at all like the backboned animals, but which agree with them in possessing a peculiar structure called the notochord. This notochord consists of a series or cord of cells extending longitudinally through the body from head to tail, above the alimentary canal and below the spinal nerve-cord. In all the vertebrates excepting a few low forms, the notochord although present in the young, is replaced in the adult by a segmented bony or cartilaginous axis, the spinal or vertebral column. But in the ascidians or sea-squirts (called also tunicates) it persists throughout life. In addition to this characteristic notochord, nearly all the Chordata are marked by the presence, either in embryonic or larval stages only, or else persisting throughout life, of a number of slits or clefts in the walls of the pharynx which serve for breathing, and which are called gill-slits.

Structure of the vertebrates.—As the backboned or vertebrate animals make up almost the whole of the branch Chordata, and as the few other chordates are animals the special structures of which we shall not undertake to study in this book, we may note here some of the other more obvious structural characteristics of the true vertebrates. The possession of a backbone or bony (sometimes cartilaginous) spinal column is the characteristic by which we distinguish them from the invertebrate or backboneless animals. Furthermore, all of the vertebrates possess an internal skeleton which is in most cases composed of bone, and is firm and strong. In some of the lower fishes, as the sharks and sturgeons, the skeleton is made up of cartilage, tough but not hard. The vertebrate skeleton consists typically of an axial portion comprising the spinal column and head, and of two pairs of appendages or limbs, variously developed as fins, wings, legs and arms. In some vertebrates these limbs are represented by mere rudiments, and in the lowest fish-like forms, the lancelets and lampreys, there is not the slightest trace of limbs. A part of the central nervous system, the spinal cord, runs longitudinally through the body on the dorsal side of the alimentary canal; the circulatory system is closed, the blood being always confined in the heart and in vessels called arteries, veins, and capillaries, and the blood is red in color owing to the presence of numerous red corpuscles or blood-cells. The nervous system is highly developed, with a large brain in all the typical forms, and with complex and usually highly efficient special sense-organss. Respiration is carried on by means of external gills, or by internal lungs which communciate with the outside through the mouth and nostrils. To the lungs and gills the blood is brought to be "purified," i.e., to give up its carbon dioxide and to take up oxygen.

Classification.—The Chordata are variously divided by zoologists into eight or ten classes, of which (in the eight-class system) the five classes* Pisces (fishes), Batrachia (batrachians), Reptilia (reptiles), Aves (birds), and Mammalia (mammals), belong to the true vertebrates. These classes will be considered in the following chapters.

*The animals included by some zoologists in the single class Pisces, are held by other zoologists to constitute three distinct classes, thus making a subdivision of the branch into ten classes.

The remaining three classes include a number of strange marine forms which until recent years were considered as worms, but which are now known to be the nearest living allies of the earliest or primitive vertebrates. The relationship of these forms to vertebrates is manifest, not in the appearance or structure of the adult stage, but only during embryonic or larval stages.

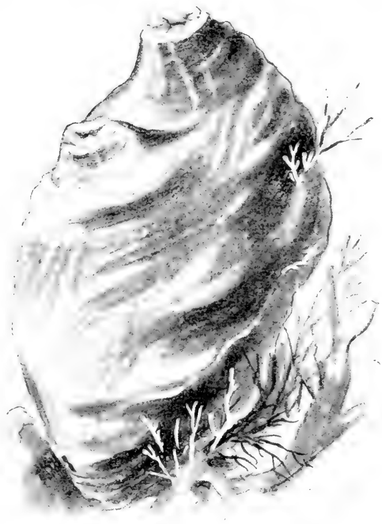


Fig. 95. An ascidian, or sea-squirt, from the coast of California. (Natural size; after Jordan and Kellogg.)

The ascidians.—The sea-squirts, or Ascidians, common on the seashore, compose one class of these primitive chordate animals. They possess a simple, sac-like body (fig. 95), fastened to the rocks by one end, the other being provided with two openings, one for the ingress and the other for the exit of water, a strong current of which flows constantly through the body. By means of this current the ascidian obtains food. Usually sea-squirts live together in large colonies, and in some cases a number of individuals enclose themselves in a common gelatinous mass, forming what is called a compound ascidian.

The ascidian when born is a tiny, free-swimming, tadpole-like creature with a slender finned tail. It swims about freely for only a few hours, however, soon attaching itself to a rock, and in its further development becoming degenerate.

It loses its tail and with it the short notochord possessed by the larva; the eye and the auditory organ are lost, and the nervous system and alimentary canal become much reduced and simplified. Sea-squirts in their adult stage are very simple degenerate animals, with low functional development, yet their embryonic and larval conditions show a considerable degree of structural specialization, and the presence of the notochord in these early stages reveals their affinity with the backboned animals.

The fishes.—We have already studied (Chapter II) 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 scooped out in the gravel over which the male 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. 96), 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

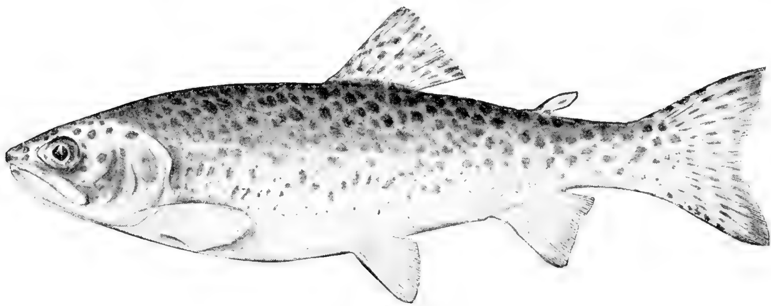


FIG. 96. The rainbow-trout, *Salmo irideus.*

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 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. Cod-fishes 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. 97). The members of the great mackerel tribe swim in the open sea,

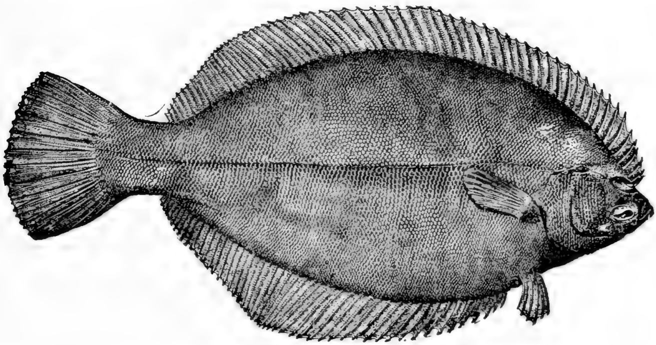


FIG. 97. The winter flounder, *Pseudopleuronectes americanus*. (After Goode.)

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. 98) 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, 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 can 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.

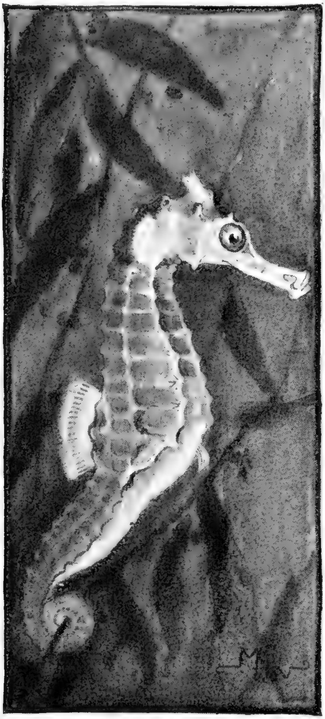


Fig. 98. A sea-horse, *Hippocampus kelloggi*. (Natural size, 8 inches long; after Jordan and Snyder.)

The rays and skates are peculiar ocean fishes, which lie at the bottom of shallow-water shores. They feed on crabs, molluscs, and bottom-fishes. The small common skates, "tobacco-boxes", 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-ray 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, 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.

Food-fishes and fish-hatcheries.—Most fishes are suitable for food, though not all. Some are too small to be worth catching or too bony to be worth eating. Some of the larger ones, especially the sharks, are tough and rank. A few are bitter and in the tropics a number of species feed on poisonous coelenterates about the coral reefs, becoming themselves poisonous in turn. But a fish is rarely poisonous or unwholesome unless it takes poisonous food. Where fishes of a kind specially used for food gather in great numbers at certain seasons of the year, fishing is carried on extensively and with an elaborate equipment. Such fisheries, some of which have been long known, are scattered all over the world. Along the shores of the Mediterranean Sea, and on the coasts of Norway, France, the British Isles and Japan are numerous great fishing-places. But "nowhere are there found such large fisheries as those along the northern Atlantic coasts of our own continent, extending from Massachusetts to Labrador. Especially on the banks of Newfoundland are codfish, herring, and mackerel caught." Among our fresh-water fisheries the great salmon fisheries of the Penobscot and Columbia rivers and of the Karluk and other rivers of Alaska are the best known. The whitefish of our Great Lakes is also one of the important food-fishes of the world.

In many places fishes are raised in so-called hatcheries, not usually for immediate consumption but for the purpose of stocking ponds and streams either in the neighborhood of the hatchery or in distant waters which the special species cultivated has not been able naturally to reach. The eggs of some fishes are large and non-adherent, two features which greatly favor artificial impregnation and hatching. In the hatcheries the eggs are put first into warm water, where development begins; they are then removed into cool water, which arrests development without injury, making shipment possible. The eggs of salmon and trout in particular can be sent long distances to suitable streams or ponds. The eggs of the shad have been thus carried from the East to the streams of California, and trout have been distributed to many streams in our country which by themselves they could never have reached.

The salmon is a conspicuous example of those fishes which can be artificially propagated. The eggs of the salmon are large, firm, and separate from each other. If the female fish be caught when the eggs are ripe and her body be pressed over a pan of water the eggs will flow out into the water. By a similar process the milt or male sperm-cells can be procured and poured over the eggs to fertilize them. The young after hatching are kept for a few days or weeks in artificial pools, till the yolk-sacs are absorbed and they can take care of themselves. They are then turned into the stream, where they drift tail foremost with the current and pass downward to the sea. All trout may be treated in similar fashion, but there are many food-fishes which cannot be handled in this way. In some the eggs are small or soft, or viscid and adhering in bunches. In others the life-habits make artificial fertilization impossible. Such species are artificially reared only by catching the young and taking them from one stream to another. To this type belong the black bass, the sunfish, the catfish and other familiar forms.

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 toad and frog (Chapters III and IX). 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 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

FIG. 99. The southwestern tree-frog, *Hyla arenicolor*. (After Dickinson.)

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 true tree-frogs, or tree-toads, constitute a family especially well represented in tropical America. They have little 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 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.

"The Frog Book" by Mary Dickerson is a well-illustrated and complete account of the frogs and toads of this country.

The salamanders (figs. 100 and 101) are batrachians, with the body not short and tailless as in the frogs and toads,

FIG. 100. The Western brown eft, or salamander, *Diemyctylus torosus.* (From life.)

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. The little green triton or eft of the Eastern States, or its larger brown-backed congener (fig. 100) 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

FIG. 101. The tiger salamander. (After Jenkins and Kellogg.)

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 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 serpentine 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

FIG. 102. The giant land-tortoise of the Galapagos Islands, *Testude* sp. These tortoises attain a length of four feet. (Photograph from life by Geo. H. Coleman, of a specimen brought to Stanford University by Snodgrass and Heller.)

skin. With 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 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

FIG. 103. A lizard in the grass. (Photograph from life by Cherry Kearton; permission of Cassell & Co.)

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.

FIG. 104. The blue-tailed skink, *Eumeces skeltonianus*. (From life.)

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. 103) is a very large one, about fifteen hundred species being known in the world, but it is represented in the United States by comparatively few kinds. Specimens of some species of the common 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 thought 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

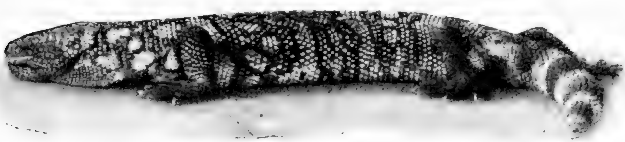


FIG. 105. The Gila monster, *Heloderma horridum*. (One fourth natural size; photograph from life by J. O. Snyder.)

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 resembles 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. 105), 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

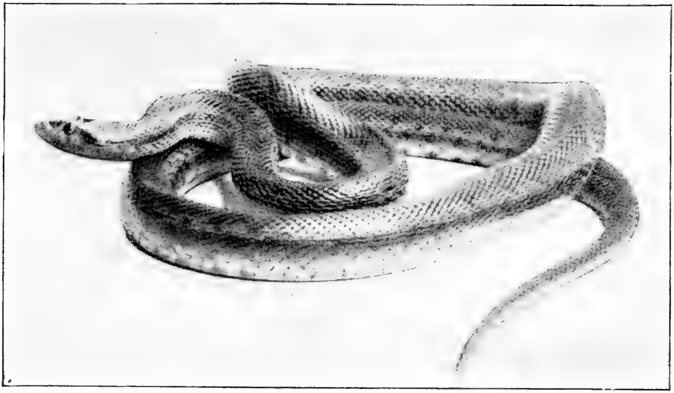


FIG. 106. The gopher-snake, *Pituophis bellona*. (Photograph from life, by J. O. Snyder.)

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 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

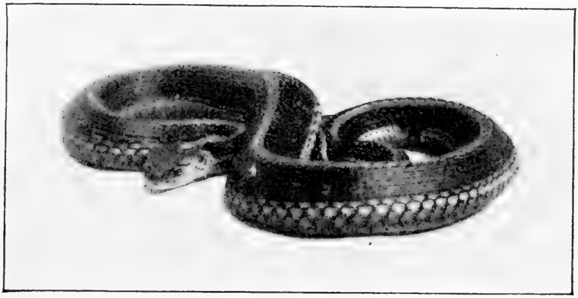


FIG. 107. A garter-snake, *Thamnophis parietalis*. (Photograph from life by J. O. Snyder.)

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 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.107), 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 king-snake (fig. 108) of the Central States are beautiful, lustrous, black-and-yellow-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.

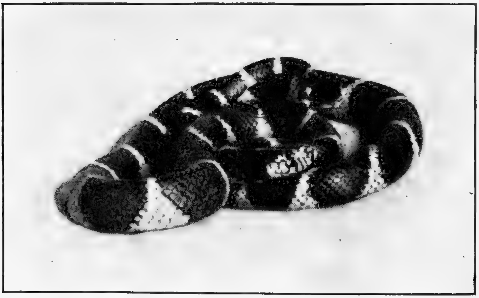


FIG. 108. A king-snake, *Lampropeltis boyli*. (Photograph from life, by J. O. Snyder.)

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 rattle-snakes 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. 109. 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-

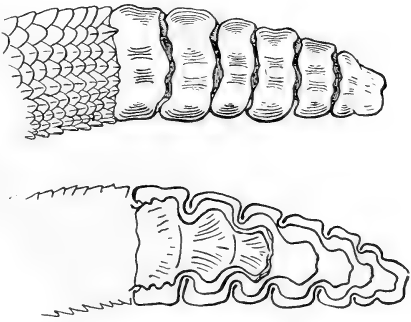


Fig. 109. The rattles of the rattle-snake; the lower figure shows a longitudinal section of the rattle. (Natural size.)

shaped darker blotches on the sides, and seldom exceeds three feet in length. It occurs in the 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. 110. 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.

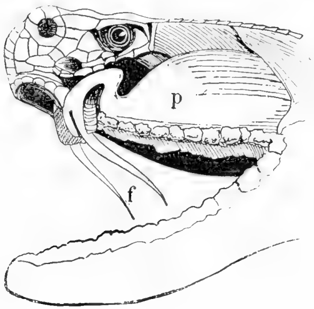


FIG. 110. Dissection of the head of a rattle-snake; *f*, poison fangs; *p*, poison-sac.

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 XVII

THE VERTEBRATES (*continued*): BIRDS

Birds are readily and unmistakably distinguishable from all other kinds of animals by their feathers. They are further distinguished from the reptiles on one hand by their possession of a complete double circulation and by their warm blood (normally of a temperature of from 100–112° F.), and from the mammals on the other by the absence of milk-glands. There are about 10,000 known species of living birds; they occur in all countries, being most numerous and varied in the tropics.

Body form and structure.—The general body form and external appearance of a bird are too familiar to need description. The covering of feathers, the modification of the fore limbs into wings, and the toothless, beaked mouth are characteristic and distinguishing external features. The feathers, although covering the whole of the surface of the body, are not uniformly distributed, but are grouped in tracts called *pterylæ*, separated by bare or downy spaces called *apteria*. They are of several kinds, the short soft plumules or down-feathers, the large stiffer contour-feathers, whose ends form the outermost covering of the body, the quill-feathers of the wings and tail, and the fine bristles or vibrissæ about the eyes and nostrils called thread-feathers. The fore limbs are modified to serve as wings, which are well developed in almost all birds. However, the strange Kiwi or Apteryx of New Zealand with hair-like feathers is almost wingless, and the penguins have the wings so reduced as to be incapable of flight, but serving as flippers to aid in swimming underneath the water. The ostriches and cas-

FIG. 111. Cardinal grosbeak, or red bird, *Cardinalis cardinalis*. (One-half natural size; from life.)

sowaries also have only rudimentary wings and are not able to fly. Legs are present and functional in all birds, varying in relative length, shape of feet, etc., to suit the special perching, running, wading, or swimming habits of the various kinds. Living birds are toothless, although certain extinct forms, known through fossils, had large teeth set in sockets on both jaws. The place of teeth is taken, as far as may be, by the bill or beak formed of the two jaws, projecting forward and tapering more or less abruptly to a point. In most birds the jaws or mandibles are covered by a horny sheath. In some water and shore forms the mandibular covering is soft and leathery. The range in size of birds is indicated by comparing a humming-bird with an ostrich.

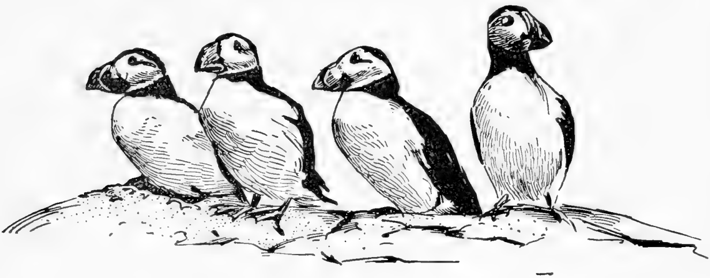


FIG. 112. Puffins. (Drawn from a photograph from life.)

Many of the bones of birds are hollow and contain air. The air-spaces in them connect with air-sacs in the body, which connect in turn with the lungs. Thus a bird's body contains a large amount of air, a condition helpful of course in flight. The breast-bone is usually provided with a marked ridge or keel for the attachment of the large and powerful muscles that move the wings, but in those birds like the ostriches, which do not fly and have only rudimentary wings, this keel is greatly reduced or wholly wanting. The fore limbs or wings are terminated by three "fingers" only; the legs have usually four, although a few birds have only three toes and the ostriches but two.

As birds have no teeth with which to masticate their food, a special region of the alimentary canal, the gizzard, is provided with strong muscles and a hard and rough inner surface by means of which the food is crushed. Seed-eating birds have the gizzard especially well developed, and some birds take small stones into the gizzard to assist in the grinding. The lungs of birds are more complex than those of batrachians and reptiles, being divided into small spaces by numerous membranous partitions. They are not lobed as in mammals, and do not lie free in the body-cavity, but

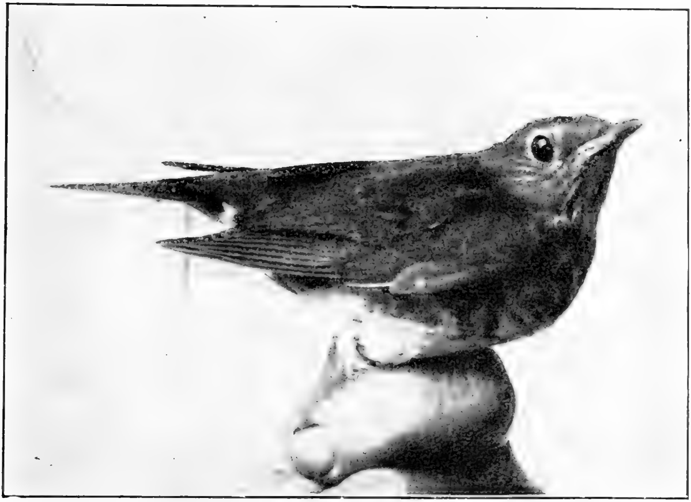


FIG. **113**. Russet-backed thrush, *Turdus ustulatus*. (Photograph from life by Eliz. and Jos. Grinnell.)

are fixed to the inner dorsal region of the body. Connected with the lungs are the air-sacs already referred to, which are in turn connected with the air-spaces in the hollow bones. By this arrangement the bird can fill with air not only its lungs but all the special air-sacs and spaces, and thus greatly lower its specific gravity. The vocal utterances of birds are produced by the vocal cords of the syrinx or lower larynx, situated at the lower end of the trachea just where it divides into the two bronchial tubes, the tracheal rings being here modified so as to produce a voice-box containing two vocal cords controlled by five or six pairs of muscles. The air passing through the voice-box strikes against the vocal cords, the tension of which can be varied by the muscles. In mammals the voice-organ is at the upper or throat end of the trachea.

The heart of birds is composed of four distinct chambers, the septum between the two ventricles, incomplete in the Reptilia, being complete in this group. There is thus no mixing of arterial and venous blood in the heart. The systemic blood-circulation being completely separated from the pulmonic, the circulation is said to be double. The circulation of birds is active and intense; they have the hottest blood and the quickest pulse of all animals. In them the brain is compact and large, and more highly developed than in batrachians and reptiles, but the cerebrum has no convolutions as in the mammals. Of the special senses the organs of touch and taste are apparently not keen; those of smell, hearing, and sight are well developed. The optic lobes of the brain are of great size, relatively, compared with those of other vertebrate brains, and there is no doubt that the sight of birds is keen and effective. The power of accommodation or of quickly changing the focus of the eye is highly perfected. The structure of the ear is comparatively simple, there being ordinarily no external ear, other than a simple opening. The organs of the inner ear, however, are well developed, and birds undoubtedly have excellent hearing. The nostrils open upon the beak, and the nasal chambers are not at all complex, the smelling surface being not very extensive. It is probable that the sense of smell is not, as a rule, especially keen.

Development and life-history.—All birds are hatched from eggs, which undergo a longer or shorter period of incubation outside the body of the mother, and which are, in most cases, laid in a nest and incubated by the parents.

The eggs are fertilized within the body of the female, the mating time of most birds being in the spring or early summer. Some kinds, the English sparrow, for example, rear numerous broods each year, but most species have only one or at most two. The eggs vary greatly in size and color-markings, and in number from one, as with many of the Arctic ocean

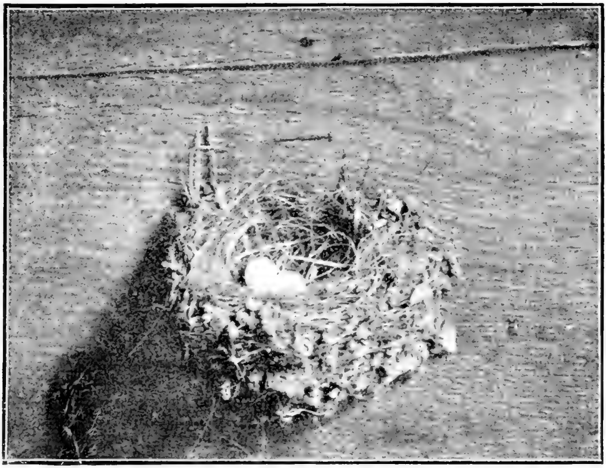


FIG. 114. The nest and eggs of the black phoebe, *Sayornis nigricans*. (Photograph by J. O. Snyder.)

birds, to six or ten, as with most of the familiar song-birds, or from ten to twenty, as with some of the pheasants and grouse. The duration of incubation (outside the body) varies from ten to thirty days among the more familiar birds, to nearly fifty among the ostriches. The temperature necessary for incubation is about 40° C. (100° F.). Among polygamous birds (species in which a male mates with several or many females) the males take no part in the incubation and little or none in the care of the hatched young; among most monogamous birds, however, the male helps to build the nest, takes his turn at sitting on the eggs, and is active in bringing food for the young, and in defending them from enemies. The young, when ready to hatch, break the egg-shell with the "egg-tooth," a horny pointed projection on the upper mandible, and emerge either blind and almost naked, dependent upon the parents for food until able to fly (altricial young), or with eyes open and with body cov-

FIG. **115**. Western chipping sparrow, *Spizella socialis arizonae*. (Photograph from life by Eliz. and Jos. Grinnell.)

ered with down, and able in a few hours to feed themselves (precocial young).

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 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.

There are many good "bird books" to enable students to learn the different kinds. For Western birds Florence Merriam Bailey's "Handbook of Birds of the Western United States" will be the most useful. For Eastern birds Frank Chapman's "Handbook of the Birds of Eastern North America" may be recommended.

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

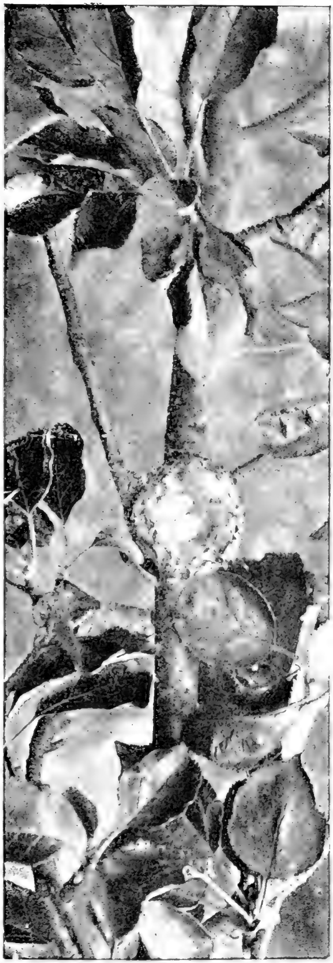


FIG. 116. Nest and eggs of the ruby-throat humming-bird, *Trochilus colubris*, seen from above, in an apple-tree. (Photograph by E. G. Tabor, permission of The Macmillan Co.)

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 IX. 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? The field-study of the birds of a given locality will comprise much observation bearing directly on their distribution or special habitat. Certain birds will be found to be limited to

FIG. 117. Razorbill auk and egg. (Drawn from photograph made from life.)

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. Dis-

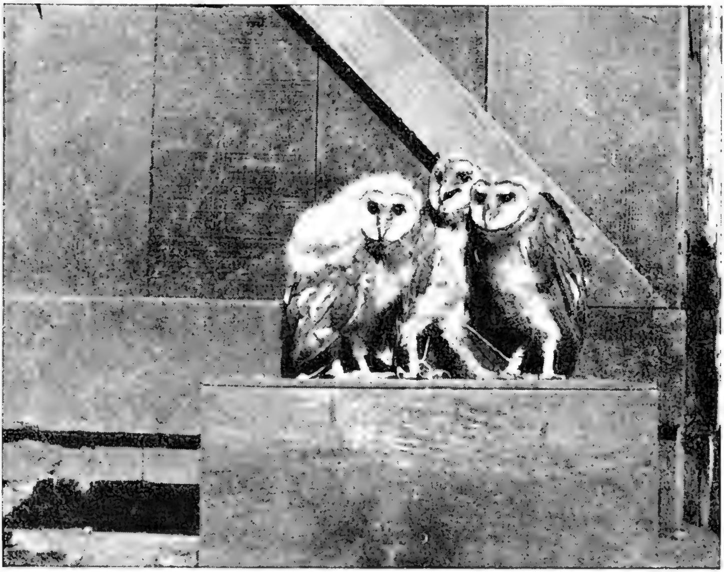


FIG. 118. Young barn-owls. (Photograph from life by Geo. Towne; permission of The Condor.)

tinguish 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

FIG. 119. Nest of the buff-breasted fly-catcher, *Empidonax fulvifrons pygmaeus*, on the cone of a pine-tree. (Photograph by R. D. Lusk; permission of The Condor.)

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 in the 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 kept by the school, 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 the South again in the autumn. Notes on the kinds of days, as stormy, clear, cold, warm, 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 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 XXXIII. 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. 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.

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.

FIG. 120. Ostriches on ostrich-farm at Pasadena, California. (Photograph from life.)

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 semi-palmate, where the web runs out only about half-way. 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-

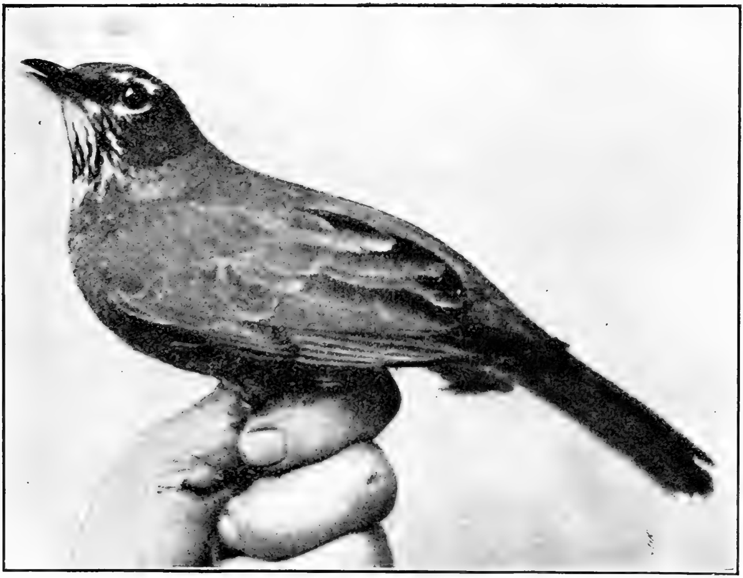


FIG. 121. Western robin, *Merula migratoria propinqua.* (Photograph from life by Eliz. and Jos. Grinnell.)

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 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

Fig. 122. Young ostriches just from egg, at ostrich-farm at Pasadena, California. (Photograph from life.)

and strain their food from it. Note the firm, chisel-like bill (fig. 123) 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 humming-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

FIG. 123. The yellow-hammer, *Colaptes auratus*. (Photograph from life by W. E. Carlin; permission of G. O. Shields.)

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 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 speed of flight of some birds is enormous, the passenger-pigeon having been estimated to

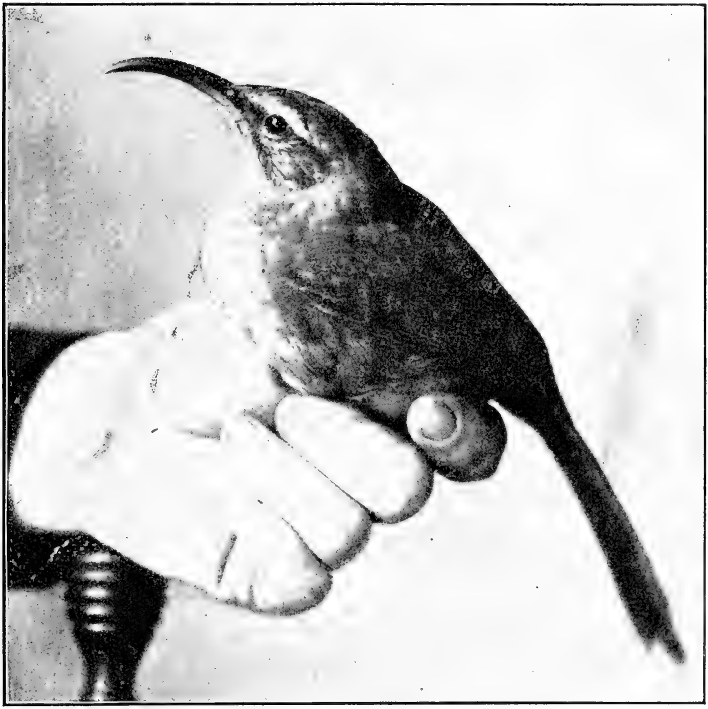


FIG. 124. Sickle-billed thrasher, *Harporhynchus redivivus*. (Photograph from life by Eliz. and Jos. Grinnell.)

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

FIG. 125. Gulls soaring. (Photograph by O. H. von Bargen, on San Francisco Bay; permission of *Camera Craft*.)

of the tongue and tail (fig. 123) 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.

FIG. 126. Horned larks, *Otocoris alpestris*, and snowflakes, *Plectrophenax nivalis*. (Photograph by H. W. Menke; permission of The Macmillan Co.)

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 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 XVIII

THE VERTEBRATES (*continued*): MAMMALS

The mammals constitute the highest group of animals, including man, the monkeys and apes, the quadrupeds, the bird-like bats and fish-like seals and whales; in all about 2500 species. They are found everywhere except on a few small South Sea islands. Only a few species, however, have a world-wide distribution. The name Mammalia is derived from the mammary or milk glands with which the females are provided and by the secretion of which the young of this class, born free in all but a few of the lowest forms, are nourished for some time after birth. 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, which 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 the greater portion of the animal food of many human races, likewise a large amount of their clothing. Horses,

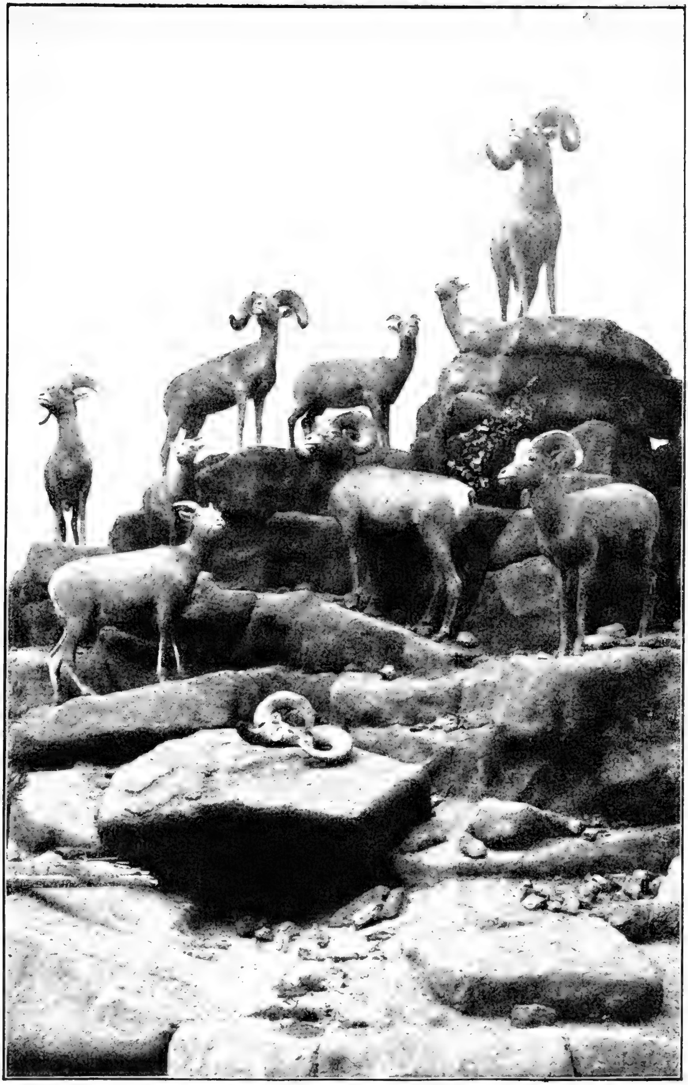


FIG. 127. A group of Rocky Mountain Sheep, *Ovis canadensis*. (Photograph of specimens mounted by L. L. Dyche.)

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 various purposes.

Body form and structure.—The mammalian body varies greatly. Its variety of form and general organization is explained by the facts that, although most of the species live on the surface of the earth, some are burrowers in the ground, some flyers in the air, and some swimmers in the water. Mammals never have more than two pairs of limbs; in most cases both pairs are well developed and adapted for terrestrial progression. In the aerial bats the fore limbs are modified into organs of flight; among the aquatic seals, sea-lions, walruses, and whales both sets are modified to be swimming flippers or paddles. In many of these aquatic forms the hind limbs are greatly reduced or even completely wanting.

Most mammals are externally clothed with hair, which is a peculiarly modified epidermal process. Each hair, usually cylindrical, is composed of two parts, a central pith containing air, and an outer more solid cortex; each hair rises from a short papilla sunk at the bottom of a follicle lying in the true skin. In some mammals the hairs assume the form of spines or "quills," as in the porcupine. The hairy coat is virtually wanting in whales and is very sparse in certain other forms, the elephant, for example, which has its skin greatly thickened. The claws of beasts of prey, the hooves of the hoofed mammals, and the outer horny sheaths of the hollow-horned ruminants are all epidermal structures.

The bones of mammals are firmer than those of other vertebrates, containing a larger porportion of salts of lime. Among the different forms the spinal column varies largely in the number of vertebræ, this variation being chiefly due to differences in length of tail. Apart from the caudal vertebræ their usual number is about thirty. The mammalian skull is very firm and rigid, all the bones composing it, excepting the lower jaw, the tiny auditory ossicles, and the slender bones of the hyoid arch, being immovably articulated together. The correspondence between the bones of the two sets of limbs is very apparent. The number of digits varies in different mammals, and also in the fore and hind limbs of a single species. Among the Ungulates the reduction in the number of digits is especially noticeable; the forefoot of a pig has four digits, that of the cow two, and that of the horse one. The two short "splint" bones in the horse are remnants of lost digits. The teeth are important structures in mammals, being used not only for tearing and masticating food, but as weapons of offence and defence. A tooth consists of an inner soft pulp (in old teeth the pulp may become converted into bone-like material) surrounded by hard white dentine or ivory, which is covered by a thin layer of enamel, the hardest tissue known in the animal body. A hard cement sometimes covers over as a thin layer the outer surface of the root, and may also cover the enamel of the crown. The teeth in most forms are of three groups: (*a*) the incisors, with sharp cutting edges and simple roots, situated in the centre of the jaw; (*b*) the canines, often conical and sharp-pointed, next to the incisors; (*c*) next the molars, broad and flat-topped for grinding, and divided into premolars and true molars. There is great variety in the character and arrangement of these structures in mammals, their variations being much used in classification. The number and arrangement of the teeth is expressed by a dental formula, as, for example, in the case of man:

$$i\frac{2-2}{2-2},\quad c\frac{1-1}{1-1},\quad p\frac{2-2}{2-2},\quad m\frac{3-3}{3-3} = 32.$$

The mouth is bounded by fleshy lips. On the floor of the mouth is the tongue, which bears the taste-buds or papillæ, the organs of taste. The œsophagus is always a simple straight tube, but the stomach varies greatly, being usually simple, but sometimes, as in the ruminants and whales, divided into several distinct chambers. The intestine in vegetarian mammals is very long, being in a cow twenty times the length of the body. In the carnivores it is comparatively short—in a tiger, for example, but two or three times the length of the body.

The blood of mammals is warm, having a temperature of from 35° C. to 40° C. (95° F. to 104° F.). It is red in color, owing to the reddish-yellow, circular, non-nucleated blood-corpuscles. The circulation is double, the heart being composed of two distinct auricles and two distinct ventricles. Air is taken in through the nostrils or mouth and carried through the windpipe (trachea) and a pair of bronchi to the lungs, where it gives up its oxygen to the blood, from which it takes up carbon dioxide in turn. At the upper end of the trachea is the larynx or voice-box, consisting of several cartilages attaching by one end to the vocal cords and by the other to muscles. By the alteration of the relative position of these cartilages the cords can be tightened or relaxed, brought together or moved apart, as required to modulate the tone and volume of the voice.

The kidneys of mammals are more compact and definite in form than those of other vertebrates. In all mammals except the Monotremes they discharge their product through the paired ureters into a bladder, whence the urine passes from the body by a single median urethra. Mammary glands, secreting the milk by which the young are nourished during the first period of their existence after birth, are present in both sexes in all mammals, though usually functional in the female only.

The nervous system and the organs of special sense reach their highest development in the mammals. In them the brain is distinguished by its large size, and by the special preponderance of the forebrain or cerebral hemispheres over the mid- and hind-brain. Man's brain is many times larger than that of all other known mammals of equal bulk of body, and nearly three times as large as that of the largest-brained ape. In man and the higher mammals the surface of the forebrain is thrown into many convolutions; among the lowest the surface is smooth. Of the organs of special sense, those of touch consist of free nerve-endings or minute tactile corpuscles in the skin. The tactile sense is especially acute in certain regions, as the lips and end of the snout in animals like hogs, the fingers in man, and the under surface of the tail in certain monkeys. All the other sense-organs are situated on the head. The organs of taste are certain so-called taste-buds located in the mucous membrane covering certain papillæ on the surface of the tongue. The organ of smell, absent only in certain whales, consists of a ramification of the olfactory nerves over a moist mucous membrane in the nose. The ears of mammals are more highly developed than those of other vertebrates both in respect to the greater complexity of the inner part and the size of the outer part. A large outer ear for collecting the sound-waves is present in all but a few mammals. A tympanic membrane separates it from the middle ear in which is a chain of three tiny bones leading from the tympanum to the inner ear, composed of the three semi-circular canals and the spiral cochlea. The eyes have the structure characteristic of the vertebrate eye, consisting of a movable eyeball composed of parts through which the rays of light are admitted, regulated, and concentrated upon the sensitive expansion, retina, of the optic nerve lining the posterior part of the ball. The eye is protected by two movable lids. In almost all mammals below the Primates there is a third lid, the nictitating membrane. In some burrowing rodents and others the eye is quite vestigial and even concealed beneath the skin.

Development and life-history.—All mammals except the Monotremes give birth to free young. The two genera of Monotremes produce their young from eggs hatched outside the body; *Tachyglossus* lays one egg which it carries in an external pouch, while *Ornithorhynchus* deposits two eggs in its burrow. The embryo of other mammals develops in the lower portion of the egg-tube, to the walls of which it is intimately connected by a membrane called the placenta. (In the kangaroos and opossums, Marsupialia, there is no placenta.) Through this placenta blood-vessels extend from the body of the mother to the embryo, the young developing mammal thus deriving its nourishment directly from the parent.

The duration of gestation (embryonic or prenatal development in the mother's body) varies from three weeks with the mouse, eight weeks with the cat, nine months with the stag, to twenty months with the elephant. Like the birds, the young of some mammals, the carnivores for example, are helpless at birth, while those of others, as the hoofed mammals, are very soon able to run about. But all are nourished for a longer or shorter time by the milk secreted by the mammary gland of the mother.

Habits, instinct, and reason.—Despite the wonderful examples of instinct and intelligence shown by many insects and by the other vertebrates, especially the birds, it is among mammals that we find the highest development of these qualities and of reason. In the wary and patient hunting for prey by the carnivora, in the gregarious and altruistic habits of the herding hoofed mammals, in the highly developed and affectionate care of the young shown by most mammals, and in the loyal friendship and self-sacrifice of dogs and horses in their relations to man, we see the culmination among animals of the development of the functions of the nervous system. In the characteristics of intelligence and reason man of course stands immensely superior to all other animals, but both intelligence and reason are too often shown by many of the other mammals not to make us aware that man's mental powers differ only in degree, not in kind, from those of other animals.

Pure instinct is hereditary, and purely instinctive actions are common to all the individuals of a species. Those actions which the individual could not learn by teaching, imitation, or experience are instinctive. The accurate pecking at food by chicks just hatched from an incubator is purely instinctive. Purely instinctive also is the laying of eggs by a butterfly on a certain species of plant which may have to be sought for over wide acres, so that the caterpillars when hatched shall find themselves on their own special food-plant. Yet the butterfly never ate of this plant and will never see its young. Such elaborate instincts as these have been developed from the simplest manifestations of sensation and nervous function, just as the complex structures of the body have been developed from simple structures.

The feeding and domestic habits and the whole general behavior of animals are extremely interesting subjects of observation and study. And such observation intelligently pursued will be of much value. The point to be kept ever in mind is that all animal habits are connected with certain conditions of life; that in every case there is an answer to the question "why." This answer may not be found; in many cases it is extremely difficult to get at, but often it is simple and obvious and can be found by the veriest beginner.

Classification.—The mammals of North America represent eight orders. Three additional mammalian orders, namely, the Monotremata, including the extraordinary duck-bills (*Ornithorhynchus*) and a species of *Tachyglossus* in Australia and Tasmania; 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 (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 best known of the foreign marsupials. After birth the young are transferred to an external pouch, the marsupium, on the ventral surface of the mother, in which they are carried about and fed. 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. 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 the 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 States, but shows some variation in the different regions. There are several species of jack-rabbit, 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 a few inches 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. 128) and ground-squirrels are commonly known rodents found all over the country. They are the terrestrial members of the squirrel family, the best known

FIG. 128. Chipmunk. (Permission of *Camera Craft.*)

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

Fig. 129. The hoary bat, *Lasiurus cinereus*. (Photograph from life, by J. O. Snyder.)

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. 129), order Chiroptera, differ from all other mammals in having the fore limbs modified for flight by the elongation of the forearms and especially of four of the fingers, 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 Eastern 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, reaching 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, 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 rhinocerus, 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 belong to the Ruminants, so called because of 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

FIG. 130. Male elk, or wapiti, *Cervus canadensis*. (Photograph of a specimen mounted by L. L. Dyche.)

and Central States and the white-tailed, black-tailed, and mule deers of the West, the great-antlered elk or wapiti (*Cervus canadensis*) (fig. 130), the great moose (*Alce americana*), 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. 131) common on the Western plains also sheds its horns, which,

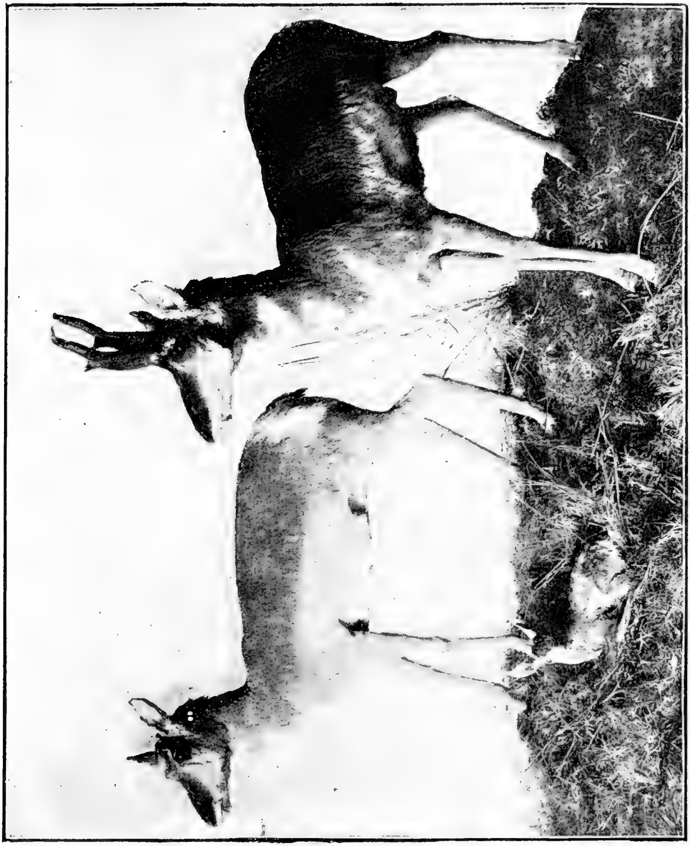


Fig. 131. Antelope, male, female, and young, *Antilocapra americana*. (Photograph of specimens mounted by L. L. Dyche.)

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*) (frontispiece), the big-horn or Rocky Mountain sheep (*Ovis canadensis*) (fig. 128), and the strange pure-white Rocky Mountain goat (*Oreamnos montanus*). The buffalo was once abundant on the Western plains,

FIG. 132. A buffalo, *Bison bison*, killed for its skin and tongue on the plains of Western Kansas, forty years ago. (Photograph by J. Lee Knight.)

travelling in enormous herds. But so relentlessly has this fine animal been hunted for its skin and flesh that it is now practically exterminated (fig. 132). 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 enclosing 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 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 walruses 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. 133) live gregariously in great rookeries on the Pribilof or Fur Seal Islands, and the Commander Islands in Bering Sea.

The bears are represented in North America by nine species, of which the best known are the wide-spread brown, or black bear (*Ursus americanus*) and the huge grizzly bear (*U. horribilis*). 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

FIG. 133 The Lukanin rookery of fur seals, *Callorhinus alascanus*, on St. Paul Island, Pribilof group, Bering Sea. (Photograph from life, by the Fur Seal Commission.)

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, include 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 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 particular 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,

FIG. 134. "Bob," a monkey of the genus *Cercopithecus*. (Photograph from life by D. S. Jordan.)

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.

CHAPTER XIX

DOMESTICATED ANIMALS

The animals that we call domestic while sometimes of kinds and appearance very different from any wild animals that we know are yet certainly all descended from kinds that are or were originally wild. There are wild pigs, wild goats, wild doves, wild ducks, wild silkworms! There are no wild dogs nor probably any longer any true wild horses but it is easy for us to see from what wild animals our tame dogs and horses have been derived.

It is certain from the records of history, of ancient pictures and carvings and still more ancient bones and relics, that man has had domesticated animals for the last ten thousand years. How long before that he made a practise of taming and using and perhaps breeding his animal companions of pre-historic times we may never know. In the caves where are found the bones and rude implements of early man, that primitive man of the Glacial epoch, there are also found the bones of various animals, but these seem to be the remains of kinds that were either his victims or his conquerors in the raw struggle for existence of those ancient times. However, when the pre-historic Egyptians emerged from the Stone Age into the earliest light of history they appear with cattle, sheep, donkeys and dogs already fully domesticated.

The domestication of animals is the result of several different factors. First, there may be the simple capture and taming and using of individuals of a wild species. Then comes the rearing in captivity of young of this species, and the easier taming of these home-reared individuals because of their earlier acquaintanceship with man.

But in this rearing in captivity a new element enters almost at once. That is the choosing or selection of certain of these young to be allowed to grow up, and again the choosing among these when grown up of those to be the parents

FIG. 135. Assyrian hunters with great dogs. From an Assyrian wall relief of 668 B.C., now in the British Museum. (After Keller.)

of more young. This selection may be almost unconsciously done, or it may be made intentionally and carefully, so as to preserve the most desirable individuals and have them give birth to others like themselves.

Then there comes the crossing of special individuals or the hybridizing with other races in the hope of adding or combining in the offspring the desirable qualities of both kinds of parents. It is this careful selecting and crossing that are

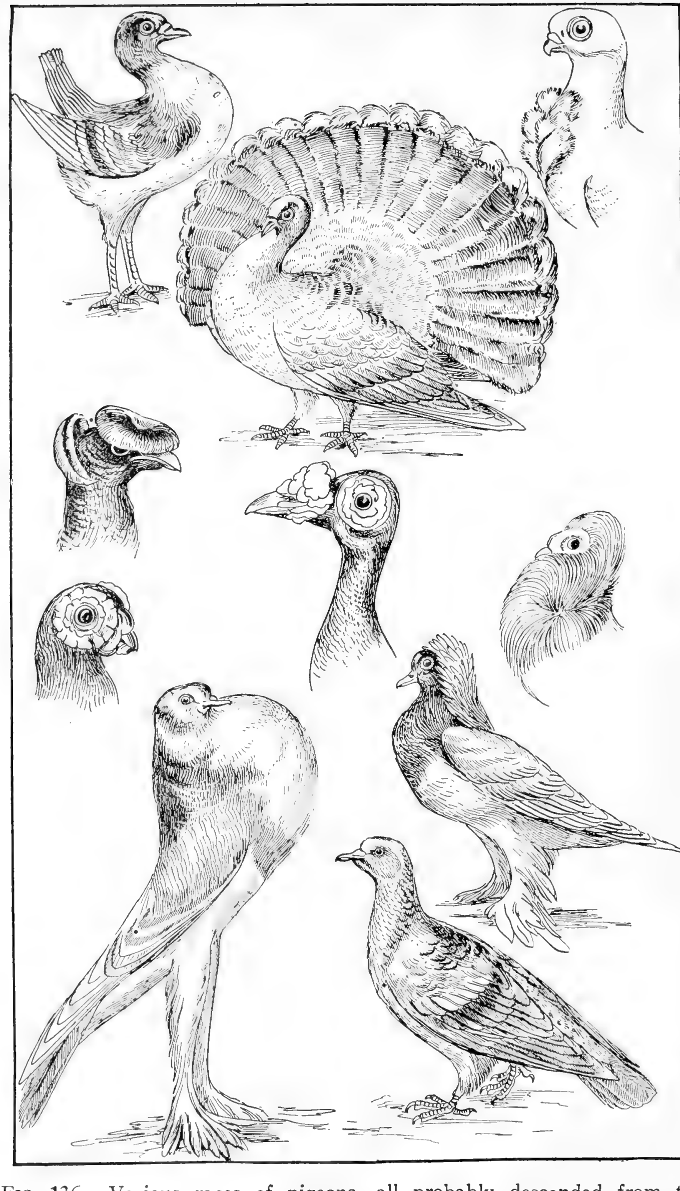


FIG. 136. Various races of pigeons, all probably descended from the European rock dove, *Columba livia*, shown in lower right hand corner. (After Haeckel.)

usually meant when animal breeding is spoken of. And our modern hosts of kinds or races of domesticated animals, the scores of sorts of dogs and cats and cows and pigeons and ducks have all been produced by "breeding." The acts of choosing and hybridizing and choosing again and rearing from these chosen offspring and again from each following generation until a form is arrived at very different in appearance or habit from the original ancestor are called also artificial selection. It was largely on a basis of his observations of the methods and results of artificial selection that Charles Darwin founded his great theory of natural selection, which, is, simply, that Nature unconsciously chooses or selects among animal and plant individuals and kinds through the survival and producing of young by those types born with traits advantageous in the struggle for existence, this struggle being inevitable on account of the geometrical ration by which animals multiply.

The art of the animal breeder has reached in these later days, the days since Darwin particularly, a very high stage of development. It is becoming a science, because the breeders are studying the laws of variation and heredity and making their hybridizations on a basis of the scientific knowledge of these laws.

There is in our country a large association of animal and plant breeders known as the American Breeders' Association, the reports of whose meetings with the discussions and prefaced papers presented at them are books of true science. Such men as Luther Burbank have given the science of breeding a popular fame and familiarity that was not known a half century ago.

An important thing to note in connection with animal breeding and artificial selection is that the selecting and modifying is all made to change the animals along lines wholly determined by man; lines that make the animals more useful or pleasing or curious to us but not better fitted to survive in Nature. In fact most of these artificially induced changes tend to unfit the animal for success in life unaided by man; they are mostly degenerative changes. The loss of flight, the shortening of legs, the over-development of fat, the production of crests and plumes and ruffs, the loss of horns, the sluggishness and helplessness that characterize the domesticated animals of different kinds, are all characters and conditions of degeneration.

FIG. 137. Thibet wolf, *Canis niger*, one of the wild ancestors of dogs. (After Sclater.)

As an outcome of this modern great interest and activity in the methods and results of producing new races and types of domesticated animals, the history of the origin of many of the more wide-spread and useful of these animal races has been unraveled, and the following paragraphs give in briefest possible form some interesting facts about the origin of our more familiar animal companions.

There seems to be no doubt that the dog is the oldest domesticated animal as he is also the closest and the most universal. From among the crudest of living human races to the most civilized and cultivated, the dog is everywhere always man's companion, serving him as faithful helper in the chase, in caring for his flocks and home, and as companion of his table and fireside. The Bushmen of Australia, the Esquimaux of the Arctic, the Indians of the prairie and pampas, the cannibals of the scattered Pacific Islands as well as the Caucasians of the world's great capitals have their dog companions. And as is inevitable under such many and different conditions and civilization stages of human existence the kinds of dogs are many and very different. How many dog races and types there now are I do not know; hundreds, at least. There are many long books filled with the descriptions and illustrations of these manifold varieties, from the tiny, toy dogs of Paris, that a lady can carry in her muff, to the great Danes and St. Bernards that stand three feet high and weigh one hundred and fifty pounds.

The origin of all these dog races is not to be found in any one wild species of doglike animal but in several. These wild ancestors of the dogs are certain wolves and jackals of various lands. Dogs are descended from at least seven such wild species, namely the jackal (*Canis aureus*) of western Asia, the landga (*Canis pallipes*) of India, the jackal wolf (*Canis anthus*) of northeast Africa, the walgie (*Canis simensis*) of Ethiopia, the black Thibet wolf (*Canis niger*) of Thibet, and the coyote (*Canis latrans*) and dun-gray wolf (*Canis occidentalis*) of North America.

The house cats, on the contrary, as various and as widely distributed as they are, seem to be all descended from a single wild species. This is the dun wild cat (*Felis maniculata*) of northeast Africa. All of the present races of house cats trace their lineage back to Egypt. That the Egyptians were much given to the possession and care of cats the numerous cat mummies of their graves show. Cats were a sacred animal for them under the special protection of the Goddess *Bast*, a goddess introduced into Egypt by Semitic influence.

The horses of modern times can be traced back to two wild ancestors, namely *Equus przewalskii* of northern Asia, from which all the Oriental, Mongolian, Arabian, North African and East European races have sprung; and *Equus caballus fossilis*, or the diluvial horse, of Europe, from which the German, Norman, English and West European horses generally have arisen. In America fossil horses have

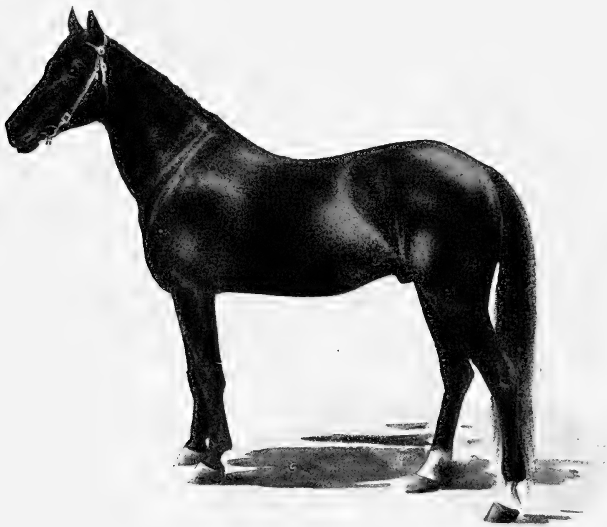


FIG. 138. Arion, a record-holding American trotting horse. (After Plumb.)

been found back through a series of geologic ages as far as the beginning of the Tertiary age forming a connected series from the small *Eohippus* of the Lower Eocene period, about the size of a fox, and with four toes and splint of the first digit on the front feet and three toes and splint of the fifth digit on each hind foot; through *Protorohippus* and *Orohippus* of the Middle Eocene, about 14 inches high, with four toes on front feet and three toes on hind feet, and no splints; through *Mesohippus* of the Oligocene, about the size of a coyote, and with three toes on all its feet; through *Protohippus* and certain other kinds of the Middle Miocene, about as large as Shetland ponies and with three toes on all feet but with the side toes not touching the ground; to *Equus*, which first appeared in the Pleistocene with only one developed toe and splints of the 2d and 4th on each foot.

FIG. 139. Restoration of the four-toed horse; based on a mounted skeleton, 16 inches high, in the American Museum of Natural History. (After a water-color by C. R. Knight.)

The color of the prehistoric horse is not known but it was probably dun with more or less well-defined stripes like a zebra. The bones of human beings have been found associated with those of prehistoric horses in South America and in Europe. Remains of horses are associated in Europe with human relics of the Bronze Age.

Donkeys have been derived from two wild species, the Nubian Desert donkey, *Equus tæniopus*, and the onager, *Equus onager* of eastern Asia. Tame donkeys are figured in the earliest of Egyptian and Assyrian drawings and carvings.

The races of domesticated hogs are also descended from two wild races, the European wild boar, *Sus scrofa*, and another species, *Sus vittatus*, from eastern Asia. From this latter the swine of China and those of the Romans and indeed most of the European races have descended. The lake dwellers of Switzerland had domesticated hogs, and pig

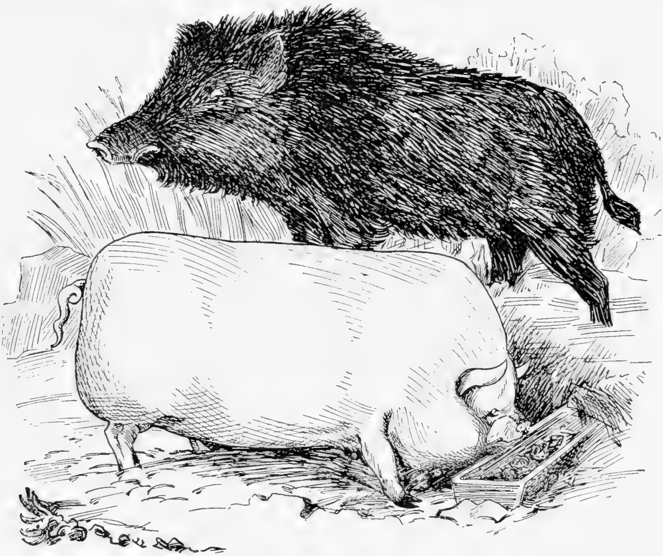


FIG. 140. Wild boar contrasted with the modern domestic pig. (After Romanes.)

remains have been found with prehistoric relics in Denmark. China has had domesticated swine for thousands of years.

The many races of cattle all trace back to two sources, the wild Banteng, *Bos sondaicus*, of Java and South Asia, from which are derived the zebus, the old Egyptian long-horns, and many of the races of Europe, such as the Spanish, Albanian, Sardinian, Polish and brown Alpine cattle; and the primitive wild ox of Europe, *Bos primigenius*, from which have descended most of the English, North German, and Holland races. This wild species persisted in Germany until the 12th century and in Poland up to the 18th century. A few persons in America have tried to create a hybrid race by crossing domestic cattle with the buffalo but probably no permanent result has been reached. It is a pity that our American bison could not have left us more of a heritage than a shameful memory.

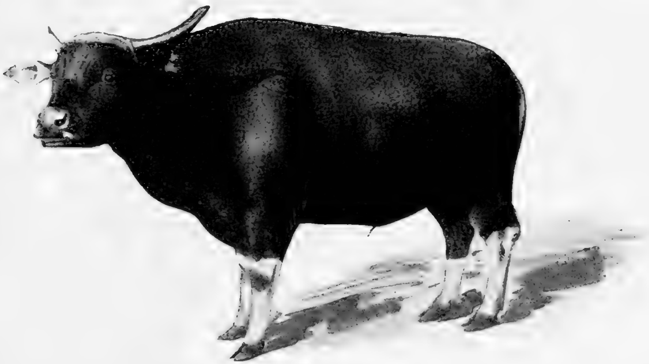


FIG. 141. The Banteng, *Bos sondaicus*, or wild ox of Java and South Asia. (After Keller.)

The domesticated races of sheep seem to have had three original wild sources, the *Ovis musimon* of South Europe, the *Ovis arkal* of Western Asia and the *Ovis tragelaphus* of North Africa. Most of our present European and American races come from the second named of these wild kinds. The earliest certain remains of tame sheep appear in the Stone Age. In the Bronze Age sheep domestication was well developed. The oldest of Assyrian drawings picture domesticated sheep, among which the still persisting fat-tailed race appears. The Egyptians had domesticated sheep in pre-Pharaonian times.

Our goats also are descended from three wild races, namely *Capra aegagrus* of Western Asia, *Capra falconeri*

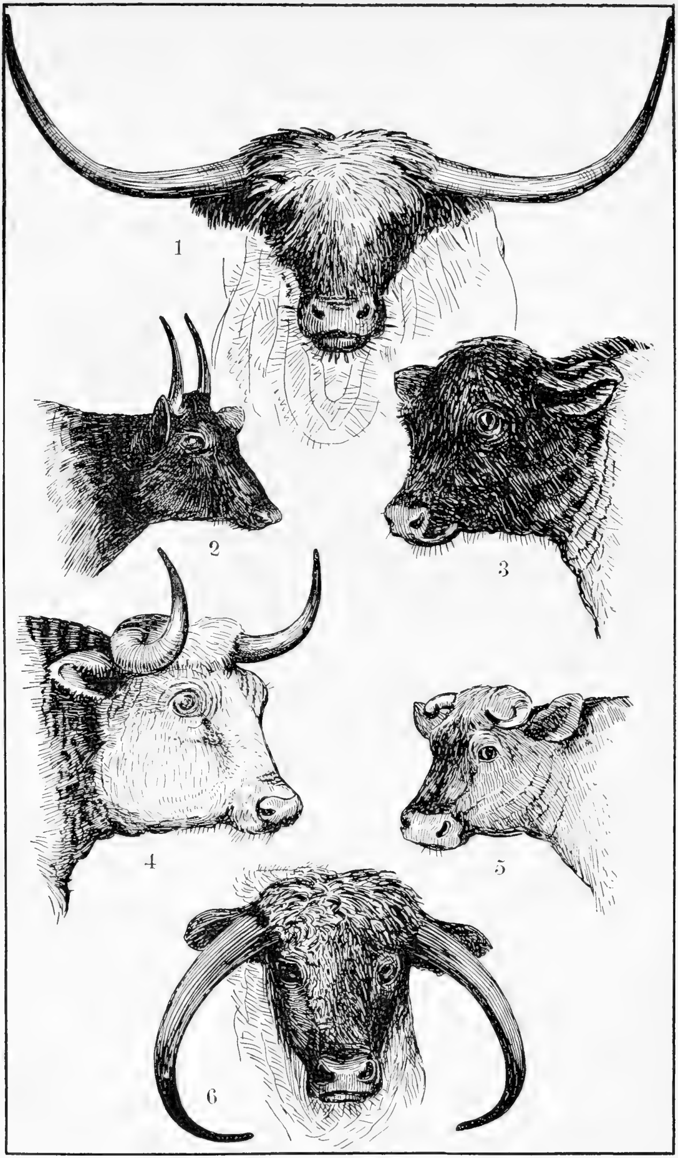


FIG. 142. Heads of various British breeds of domestic cattle, showing variations in shape of head and condition of horns: 1 Highland Scot; 2, Irish Kerry; 3, Aberdeen Angus; 4, Hereford; 5, Jersey; 6, Long-horned Midland. (After Romanes.)

and *Capra jemlaica* of the Himalayas. The earliest prehistoric indications of tame goats come from the times of the Lake-dwellers. In the Bronze Age they were common.

Other mammals that are represented by domestic races are the camel, the elephant, the water buffalo, the rabbit, the ferret, the reindeer, the lama and alpaca, the guinea-pig, the mouse, the rat, etc. But excepting with the rabbit the

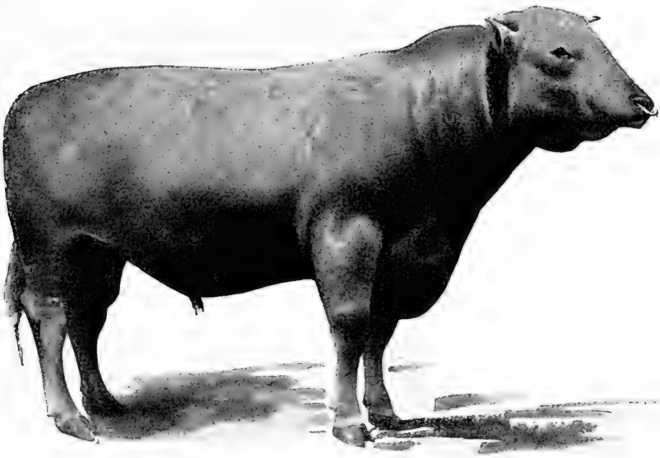


FIG. 143. White Hall Sultan, a Shorthorn prize bull. (After Plumb.)

domesticated forms of these animals are only wild species tamed and reared under man's hand but not much modified by breeding. There are several well-marked races of domesticated rabbits all of which probably trace their lineage back to a wild species native to Spain and Southern France.

Of birds there are domesticated races of doves, chickens, turkeys, ducks, geese, swans, pea-fowls, pheasants, canary birds, ostriches, cormorants and others. Of these the doves and chickens are represented by the most varieties. Brown, an English authority on domesticated birds, lists more than seventy races of chickens now living, thirteen races of ducks, ten of geese and eight of turkeys. Of pigeons there must be nearly as many domestic races as there are of chickens. And yet all of them, with all their extraordinary variety of crests, and ruffs, and tails and plumage pattern, and all their various special manners such as tumbling, dancing,

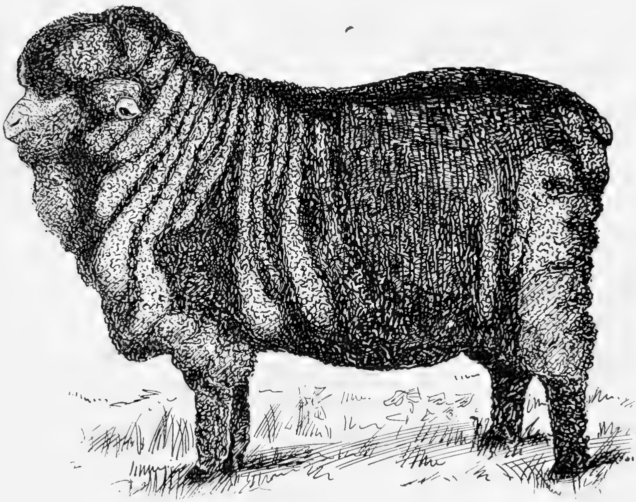


FIG. 144. Typical American Merino ewe, a highly specialized breed of sheep, with fine, close-set wool. (After Shaw.)

and the like, are descended from a single wild species, the common rock dove, *Columba livia*, of Europe, Asia and North Africa (fig. 136).

The domestic races of chickens are by some naturalists also held to be descended from a single wild species, the jungle fowl, *Gallus bankivus*, which ranges from Hindukoosh to the Chinese island of Hainau and through most of the Indonesian islands. But other naturalists believe that one or two other wild species of fowl are concerned in the ancestry of our barnyard hen.

The domestic ducks are derived from the wild duck *Anas boschas*, and have evidently originated from this ancestor independently both in China and in Europe. The domestic geese seem to have an older origin than the ducks; in fact geese are probably the oldest of domesticated birds. The ancestor of our races is the wild species *Anas cinereus*. The Chinese races however, are descended from *Anas cygmoides*, and the early Egyptians seem to have tamed and used the Nile goose, *Chenalopex egyptiaca*.

FIG. 145. The wild sheep of the Trans-Caspian steppes, *Ovis arkal*. (After Keller.)

The domesticated peacocks are descended from the wild species of India, *Pavo cristatus*. The turkeys trace their ancestry to the wild *Meleagris gallopavo* of North America. The swans are really only tamed wild kinds. Common species are the white swan of Europe, *Cygnus olor*, the black swan of New Holland, *Cygnus atratus*, and the black-necked swan of South America, *Cygnus nigricollis*. The pheasants also are so far practically only partially tamed wild species, whose eggs however, are usually hatched under turkeys. Most of the kinds kept are from the Orient.

Canary birds are descended from the wild species, *Fringilla canariensis* of the Canary Islands. But there has been some crossing of them with other species of wild birds, especially certain sparrow and finch kinds. There are now numerous domesticated races which vary structurally in color-pattern as well as in voice. Many of the characters resemble the ruffs, crests, and other plumage eccentricities of pigeons. The principal place of canary bird breeding at present is in the Harz Mountains of Germany.

Tamed cormorants are used by the Chinese and Japanese as fishing birds, somewhat as falcons were used in days of

FIG. 146. Wild jungle fowls, *Gallus bankiva*, of India. (After Brown.)

old as hunting birds. Indeed in these same days cormorants were used for sport. Charles I of England had a "master of the cormorants." Nowadays, however, cormorant fishing is a practical means of gaining food. A ring is placed about the neck of each bird so as to prevent it from swallowing the fish it catches. Several different species of cormorants are thus used.

The ostrich is the most recent addition to the ranks of domesticated birds. The tamed species is derived directly from the widely distributed African ostrich, *Struthio camelus*.

Besides mammals and birds two or three species of fish, such as the carp and goldfish, may be called domesticated.

This is certainly true of the goldfish which is a product of Chinese animal breeding. Some most bizarre forms have been produced in the thousand or more years in which this fish has been a subject of selection and hybridization.

There are also finally at least two species of insects that have a right to be called domesticated animals, namely, the honeybee and the mulberry silkworm. The honeybee, *Apis mellifica*, has been long used by man to obtain honey from, but only in modern times has the species been the subject of true "breeding." However, already several distinct races have been produced. The bee is native to Europe and Asia, and "wild" honeybees in America are only communities established by wandering swarms from hives, or from other "wild" communi-

FIG. 147. Silver-laced Wyandotte cockerel.

FIG. 148. White-crested black Polish cock.

ties which have descended from such escaped swarms.

The silkworm, *Bombyx mori*, has on the contrary been an artificially bred animal for five thousand years, and scores of races, with differently colored and shaped cocoons exist. The actual wild species from which the domesticated races are descended is not known, but it is most likely some one of the several wild species of Northern India. The cocoons of certain of these wild Indian species are today still collected for the silk and sold under the commercial name of "Tussoor" silk. The ancient breeding and care of silkworms was mostly done in China and Japan. Today it is carried on even more extensively in France and Italy.

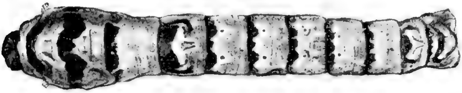


FIG. 149. Tiger-banded variety of the Bagdad silkworm race. (Natural size.)

CHAPTER XX

FOSSIL ANIMALS

Not all the animal kinds that have lived on this earth still live on it. Indeed those that now exist, as many hundred thousands or millions as they may be, are certainly only a small part of all that have existed. The earth has had a history of life as varied and nearly as old as the history of its own liquid and solid self. As soon as it had cooled and contracted from a great gaseous mass to a smaller compacter liquid and solid one it began to be a possible abode of life. And sometime after its temperature had got below the coagulation or killing point for protoplasm—which is the basic substance of every living thing—life appeared. Whence it came or how it came to be produced are great questions that science has yet no answer for and may never have. The speculations about it are various: such as that living germs reached the earth from other planets in meteorites or as "cosmic dust," or that it originated spontaneously under the peculiar chemical and physical conditions of the earth's surface in those ancient dim days of the first hardening and cooling. And there are even some biologists who think that such spontaneous generation of life from non-living substances may be going on today. But no one of them has been able to prove this. "All life from previous life" is the dictum of most naturalists of today. And this poses the problem of the origin of the first life as one far beyond present scientific knowledge.

If, however science knows nothing about the origin of life in the early days of the earth's history it does know something

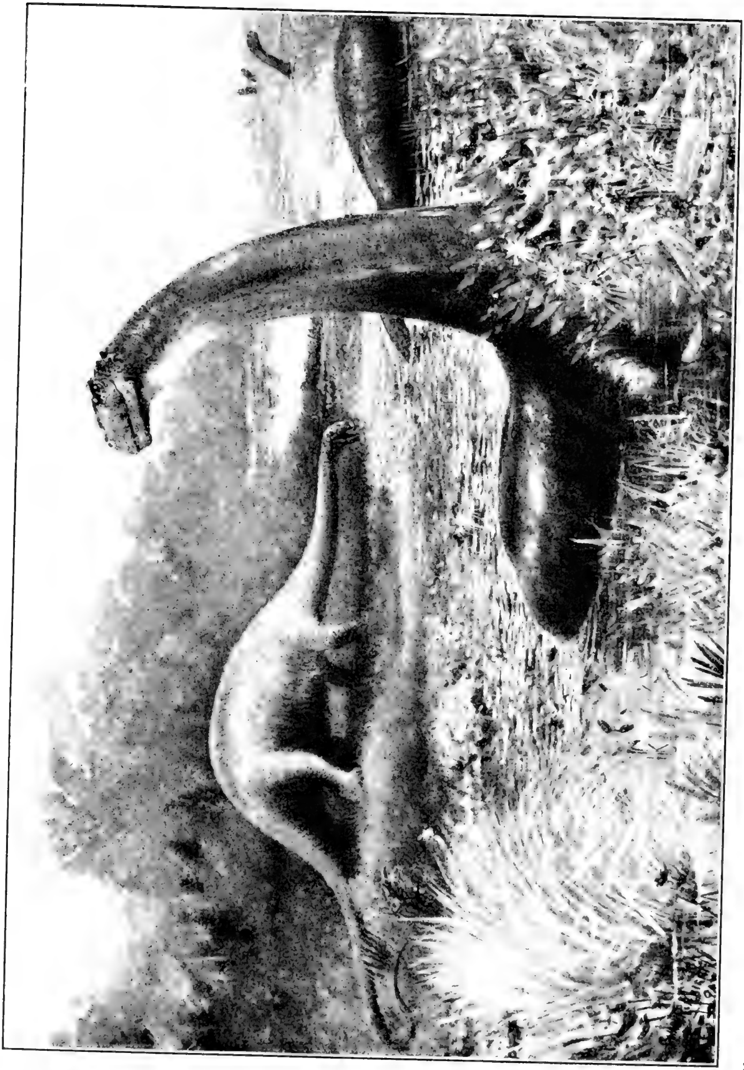


FIG. 150. *Brontosaurus*, or Thunder Lizard. Restoration by Osborn and Knight. (After Sternberg; from painting in the American Museum of Natural History.)

about what kinds of living creatures, both plants and animals lived in those and succeeding ages. It knows this by virtue of the preservation of parts of some of these animals and plants as fossils.

Animal fossils are the actual remains of bones or shells or other (usually hard) parts of the body preserved intact in soil or rock; or else, and more commonly, are parts of animals which have been turned into stone by slow replacement of these parts by rock particles; or else, finally, are parts of which stony casts have been made. Examples of these three kinds of fossil are (1) extinct insects preserved in amber, teeth of ancient sharks, tusks of mammoths, shells of various molluscs; (2) petrified bones, corals, crinoids shells, etc.; (3) casts of insect wings, etc.

Huxley said that "fossils are only animals and plants which have been dead rather longer than those which died yesterday." This "rather longer" may mean anywhere from a few thousand to several million years. Geologists estimate the age of the habitable earth—the time, that is, since life could have existed on the surface—as being from fifteen million to seventy million years. This enormous time is divided into certain periods of various lengths each period being characterized by a certain set of geologic, geographic and life conditions, and these conditions determining in some measure the kinds of plants and animals living during the period. The geologic history of the earth, which is a very broken and partial one, is read by the geologists from the kind and succession of rocks and fossils which form the outer crust. Only in certain rocks, those that have been slowly deposited in water as small (usually soil) particles and have become compacted and hardened into layers or strata, one above the other, do fossils occur. Hence only water-inhabiting animal kinds, or those land kinds whose dead bodies might get into lakes or oceans, are represented by fossil remains. Also, sedimentary or stratified rocks

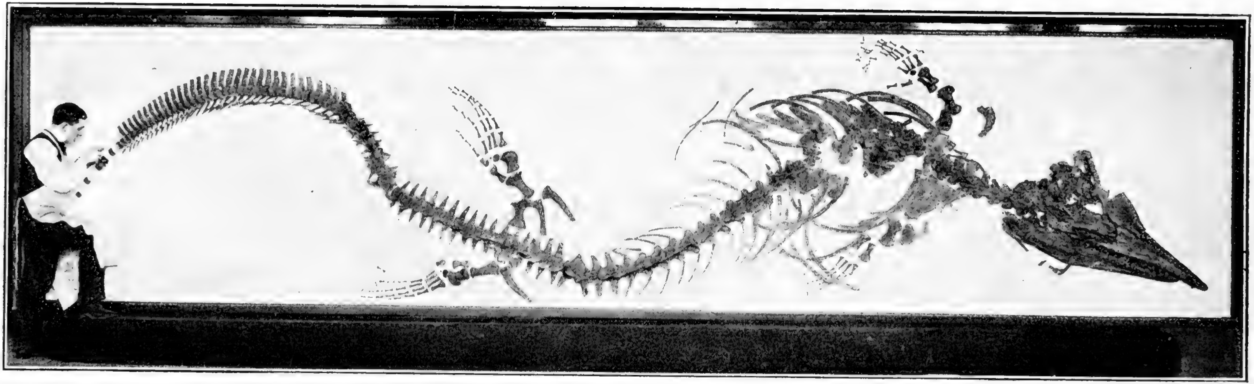


FIG. 151. Skeleton of Ram-nosed Tylosaur, *Tylosaurus dyspelor*. (In the American Museum of Natural History; after Sternberg)

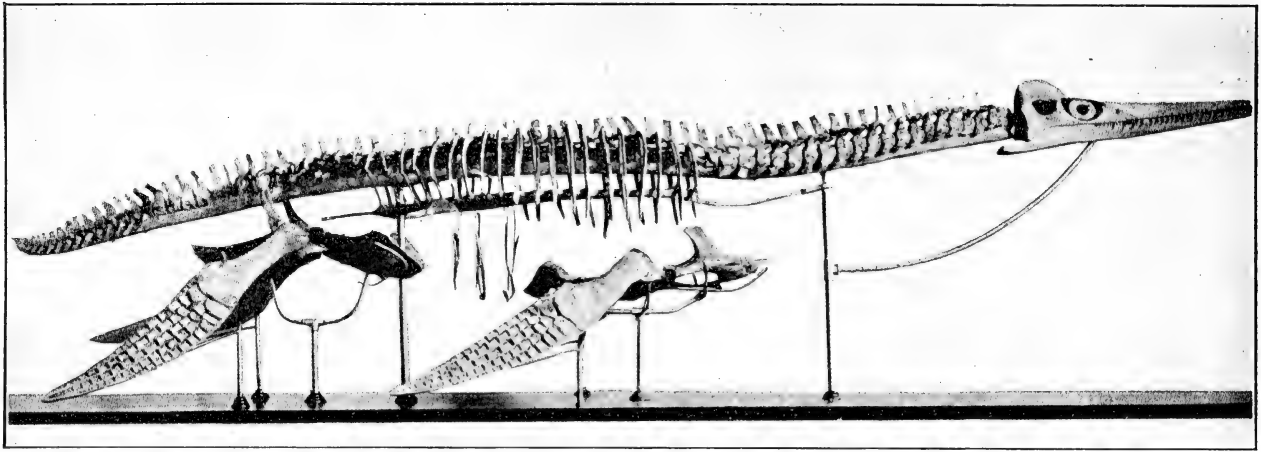


Fig. 152. Skeleton of the Plesiosaur, *Dolichorhynchus osborni.* (In the Museum of the University of Kansas; after Williston and Sternberg.)

form only a part of the earth's crust. Rocks that are cooled and solidified from a molten condition, such as volcanic and other igneous kinds, and even stratified rocks that have been highly heated, contain no fossils. Hence the record or history of the life of the long geologic ages before our present one is most incomplete. But it is one of extraordinary interest and value in any study of biology.

Only a very few words can be said about the interesting kinds of earlier creatures, now extinct, that inhabited our earth in ancient times. In the very oldest fossil bearing rocks are found only remains of the simpler kinds of animals as the one-celled kinds, and the sponges, corals, jelly-fishes, etc. In the next oldest strata there are still only simple invertebrate animals but more kinds than in the older rocks. The first vertebrates appear next and these are all fishes. Amphibians are found only in more recent strata, reptiles in still more recent and mammals and birds in still younger strata. That is, it is plain from the record of the rocks that the animal types have appeared in succession beginning with the simpler kinds and advancing towards the most complex or higher types by regular stages. This fact is one of the most important that has been learned about life, for it is very strong evidence for the belief of most naturalists that animal kinds are descended from each other, the complex or higher ones from simpler or lower ones.

The table or diagram on the next page shows the order of the appearance of various kinds of animals in geologic time.

One must not believe that with the advent of new types of animal life all of the old types became extinct. It is not at all true. Although hundreds of thousands of animal species have become extinct and are known to us only through their fossil remains, or are not known at all, some

Eras or Periods.	Ages or Systems.	Animals Especially Characteristic of the Era or Age.
Cenozoic. Era of Mammals.	Quaternary or Pleistocene (age of man and recent mammals)	Man; mammals, mostly of species still living.
	Tertiary: Pliocene, Miocene, Eocene	Mammals abundant; belonging to numerous extinct families and orders.
Mesozoic. Era of Reptiles.	Cretaceous	Birdlike reptiles; flying reptiles; toothed birds; first snakes; bony fishes abound; sharks again numerous.
	Jurassic	First birds; giant reptiles; ammonites; clams and snails abundant.
	Triassic	First mammals (a marsupial); sharks reduced to few forms; bony fishes appear.
Paleozoic. Era of Invertebrates.	Carboniferous (age of amphibians)	Earliest of true reptiles. Amphibians; lung fishes; fringe fins; first crayfishes; insects abundant; spiders; fresh-water mussels.
	Devonian (age of fishes)	First amphibians (froglike animals); sharks; ostracophores; first land shells (snails); molluscs abundant; first crabs.
	Silurian (age of invertebrates)	First truly terrestrial or air-breathing animals; first insects; corals abundant; mailed fishes.
	Ordovician or Lower Silurian	First known fishes, ostracophores, mailed and with cartilaginous skeleton; brachiopods; trilobites, molluscs, etc.
	Cambrian	Invertebrates only.
Archean.	Algonkian. Laurentian.	Simple marine invertebrates.

species of all the great groups from simplest to higher are living today. Most of these species are however modern in their origin. The original or first species in all the great

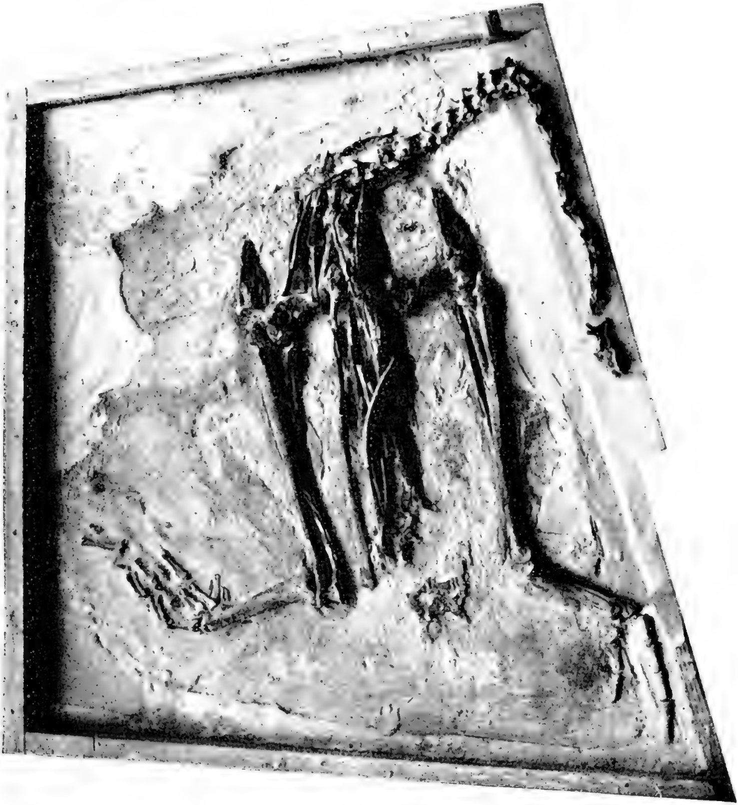


FIG. 153. Skeleton of *Hesperornis regalis*, the Giant Toothed Bird of the Kansas Cretaceous. (In the American Museum of Natural History; after Sternberg.)

groups are gone; and some whole families and orders of species are extinct. For example in the class of reptiles there existed in the Mesozoic era many enormous kinds called Dinosaurs, Ichthyosaurs, Pterodactyls, etc., of which no living representatives are left. Some of these reptiles had wings (Pterodactyls) and seem more like great birds than true reptiles. In the bird class, too, there were, in the same era, various enormous kinds now extinct, some of which had teeth.

An interesting example of the geologic succession of related animals and one often referred to in books about extinct animals, is that of the horse series. In lower Eocene rocks is found an animal called *Eohippus*, about the size of a fox, with four hoofed toes and the rudiment of a fifth on forefeet and three hoofed toes on hind feet. This is the first of a series of similar but always differing and ever-more horse-like forms that are found in the rock strata successively younger and higher, representing Miocene, Pliocene and Quaternary periods. The hoofed toes disappear one by one, the size of the whole animal is ever larger, and the teeth are more and more like horse's teeth as we examine the successively younger (more recent) members of the series, until in the rocks of our present epoch we find the bones of an animal which is essentially identical with the horse as we know it today.

Similar ancestral series have been discovered for the deer, for certain pond snails, for the ammonites, for many other kinds of animals, indeed. The first deer in the early Miocene had no antlers. In the middle Miocene are found small deer with small two-pronged antlers. In the upper Miocene and lower Pliocene there are larger deer with three-pronged, larger antlers. In the later Pliocene occur four and five-pronged antlers, while in the Pleistocene are remains of deer with branching antlers like those of the living species.

The fossil fishes of the earlier geologic periods are all of the simpler, more primitive families of which none or but few representatives occur today. Of the 12,000 known

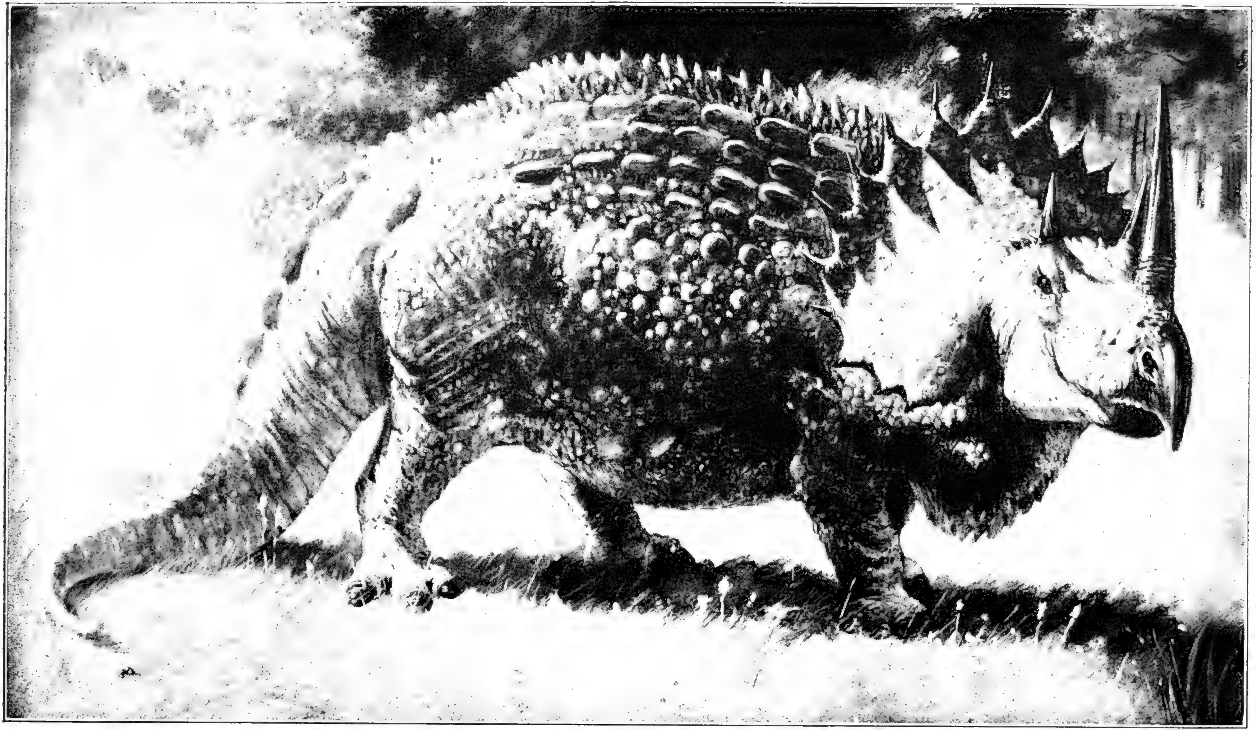


FIG. 154. Three-toed Dinosaur, *Triceratops* sp. Restoration by Osborn and Knight. (After Sternberg; from painting in the American Museum of Natural History.)

living species of fishes 11,500 belong to the great group of Teleostomi or bony fishes, of which the first representatives are found only in Triassic strata. But fossil fishes are known from all the geologic periods from the Silurian on up. All the fishes of these earlier millions of years were of more primitive shark-like families. Many of these families are now wholly extinct and of the others only a few persisting species remain. Even those early families of the true bony fishes of the Triassic and Jurassic rocks are mostly now extinct. Most modern families date from Cretaceous times.

The question may be asked: Are there any fossil men known? The answer is yes. But man is very young, geologically speaking. No indubitable human bones or relics have been found in rocks earlier than those of the present great epoch, the Quaternary. But this epoch is certainly already many thousand years old. Man existed in Glacial times. Remains of the mammoth, the cave-lion, cave-bear, and other extinct animals have been found in the same caves with human bones. So man has a certain geologic history; one at least of 20,000 years; probably much longer.

PART IV

HUMAN STRUCTURE AND PHYSIOLOGY

(Chapters XXI to XXVIII, inclusive, by ISABEL McCRACKEN)

CHAPTER XXI

INTRODUCTION

The study of physiology and its purpose.—We have found in our study of animals that they are made up of many parts or structures arranged in definite ways. To see many of the parts it was necessary to dissect the animals that we have studied most carefully, as the frog and crawfish. This study of the structure of animals is called the study of anatomy. We must know something of the anatomy of the animal body to understand what it can do.

We have learned that each part has its special function and that these various functions constitute the processes which, added together, are life itself.

The study of the functions of the various structures of the body is called the study of physiology.

Since the study of physiology is the study of the parts of the living body in action, the study of human physiology at first hand is very difficult. We can dissect the lower animals easily, and find out at first hand what their parts are and how they are put together, but elementary students cannot dissect the human body. They must depend upon the statements of physicians, surgeons, and trained physiologists for most of their knowledge of human anatomy and human physiology.

The health of the human body depends upon the right performance of its proper function by each part of the body. The laws of health or of hygiene are merely those rules that have been proved by experience and experimentation to be best adapted for maintaining the body in its best working condition.

Our chief purpose in studying human physiology is therefore to understand the working of the human body as a self-regulated, working machine, that we may know how to give it the protection and care necessary to preserve it as such.

Structural units of the living body and division of labor.—In a lifeless mechanism like a watch, we find many individual parts, and these parts so nicely adjusted one to the other that they all work together successfully as a whole. So it is in the living mechanism.

Our study of the amœba (Chapter V) made us acquainted with a living, feeding and moving animal whose body is composed of a single cell. Our study of the structure of the toad (Chapter III) showed us that the life-functions are performed in this animal by certain large systems of organs; that these organs are made up of groups of tissues formed of masses of similar cells, each cell performing its own special kind of work. The cell is therefore the structural and physiological unit of the body. Each cell does its share of the work of that tissue of which it is a part, and each tissue does its share of the work of the organ of which it is a part. In the same way each organ works in harmony with all the other parts in its system, and all the systems work together to maintain life.

The living substance of the cell and metabolism.—In Chapter V it was explained that while the cells of the body may differ very much in appearance and function, they are alike in being chiefly made up of the one substance protoplasm. This is the living substance of the cell. The life and activity of the body depend upon the life and activities of the protoplasm of the many cells of the body that make up the various organs. A diseased condition of body means a diseased condition of the protoplasmic cells of the body.

Metabolism.—In their functional activity, the cells of the body provide *heat* and do some kind of *work*. This work is done by reason of the *energy* generated by the cell. In providing energy the cell itself wears out or wastes away. It has, however, the power of self-renewal or self-repair. This double process of "waste and repair" is known as *metabolism.*

The *air* we breathe, the *water* we drink and the *food* we eat supply the cells of the body with the three essentials for their metabolism.

Protoplasm is a very complex substance built of simpler substances. The foods we eat are first reduced to simple substances. Each protoplasmic cell acts as a little chemical laboratory in laying hold of these simple food substances, and recombining their elements into its own complex substance. It then reverses the process and, with the aid of oxygen, breaks up this complex substance into simple substances. These are then thrown out of the cell as waste products.

The whole problem of the body, as a mechanism, is, therefore, to obtain air, water, and food and to carry these to the cells; then to carry the waste away from the deep-seated cells, and eliminate it from the body.

It is to this end that all the systems of the body work together.

Systems of the human body and their functions.—In the human body, as in the higher animals already studied, there is a *digestive system,* consisting of the alimentary canal and all of its parts. This system supplies the body with food and prepares the food for the use of the tissues. A *circulatory system*, consisting of heart, blood-vessels, capillaries, and lymphatics, transports the prepared food and oxygen to the cells of the body. The *muscular and skeletal systems*, consisting of the muscles and bones of the body and their attachments, enable the body to do all the things requiring motion. The *respiratory system*, consisting of the air passages of the nose, throat or pharynx, larynx, the bronchial tubes and minute air sacs forming the large respiratory surface, is employed in supplying the blood with oxygen which is to be carried to the cells. An *excretory system*, consisting of the kidneys and their ducts, and certain glands in the skin known as sweat glands, take up the waste from the blood and remove it from the body. The *nervous system*, consisting of the brain, spinal column and innumerable nerves, puts all the parts of the body into communication so that they may work in harmony. The *sense-organ system*, intimately connected with the nervous system and functioning with it, comprises the organs for seeing, hearing, smelling, tasting, feeling, etc. They put the inside of the body into communication with the outside world.

All of these systems work together to maintain life, that is, to maintain the metabolism of the cells. If any system fails to fulfill its function the whole body suffers and disease sets in. It is our business to provide the body with good food, fresh air, pure water and daily exercise so that each system may be kept in the best condition possible for its work.

The chemistry of the body.—The chemist tells us that, in all the world, there are only about seventy simple or *elementary* substances. All the gases, liquids and solids that we know of, are formed by uniting these simple elements in many ways. Thus the simple element oxygen united with the simple element hydrogen forms the water we drink. A mixture of pure oxygen, nitrogen, hydrogen and a few other gases forms the air we breathe.

The cells of the body are made up of certain chemical substances, compounds of the simple elements, sulphur, phosphorus, carbon, oxygen, hydrogen and nitrogen and a few other substances (potassium, chlorine, calcium and magnesium). Comparatively few elements, therefore, are found in the animal tissues. These are, however, united in many ways to form many different compounds.

Chemical compounds of the body.—The chemical compounds found in the body are *proteids*, *carbo-hydrates*, *fats*, *acids*, and *salts*.

Proteids contain carbon, oxygen, hydrogen, and nitrogen. These are called the nitrogenous compounds.

Carbo-hydrates contain carbon, hydrogen and oxygen, the former predominating.

Fats contain also chiefly oxygen, carbon and hydrogen, the latter predominating. The carbo-hydrates and fats are known as non-nitrogenous substances.

Since these are the chief substances that the body is built up of, they must also be the chief substances in the foods we eat.

OBSERVATION OF A FEW SIMPLE CHEMICAL ELEMENTS

Oxygen, the properties of.—The most necessary element in all the world is oxygen. Neither plant nor animal can live without it. Fire cannot burn without it. It forms about one-fifth of the atmosphere. It is a colorless, odorless and tasteless gas. Most of the other simple elements will combine with it, especially at a high temperature.

Oxidation and combustion.—Oxidation is the union of oxygen with any other substance. We say that a substance is oxidized if it has taken up oxygen. Thus carbon, when it takes up oxygen, is oxidized and becomes carbon-dioxide. When oxidation is rapid or accompanied by light or great heat it is called combustion. When a match is rubbed on a surface, the heat produced by friction causes the phosphorus and other substances at the match tip to take up oxygen rapidly, causing combustion. Phosphorus is thus oxidized and the combustion that arises from its rapid oxidation sets the match on fire and consumes it.

Rust is oxidized iron or iron-oxide.

It is the nature of organic substances (compounds containing carbon) to unite easily with oxygen. That is, oxygen has a great affinity for these compounds. It combines easily with other elements.

To obtain oxygen.—The simplest way to obtain pure oxygen is to heat some compound containing it. The heat breaks up the compound and sets its elements free. The oxygen thus escaping may be collected.

Experiment 1.—Place some oxide of mercury in a test tube and heat it. It gradually disappears from view. The oxygen and the mercury of the compound have separated. The oxygen has become an invisible gas, the mercury has become vaporized. Drops of pure mercury will soon condense on the sides of the glass.

If, while the experiment is in progress, a live coal on the end of a stick, be inserted into the mouth of the test tube the coal will glow with a greater brilliancy. This means that oxygen in its pure state unites more freely with the carbon of the wood and makes a more brilliant glow than did the oxygen of the air, mixed as it was with other gases.

Potassium chlorate gives up oxygen rapidly when heat is applied to it, so rapidly indeed as to cause an explosion. If an equal quantity of black oxide of manganese be mixed with potassium chlorate, the oxygen is given off more slowly and without danger of explosion, and may then be collected in jars as follows:

Arrange an apparatus as in fig. 155. First fill the jar with water and invert it over the pan of water. Partly fill the test tube with the mixture of potassium chlorate and black oxide of manganese (equal parts). Fit the test tube with a tightly fitting cork and a bent glass delivery rod. Before placing the delivery tube in the water move the alcohol flame along the test tube so as to drive out the air and warm the tube, that no moisture may form on the tube and break the glass.

Then heat the mixture gradually, beginning at the top and working toward the bottom. After a few seconds gas will come off. The delivery tube may then be placed under water beneath the opening of the jar, and soon the bubbles of oxygen coming off will displace the water in the jar.

Caution.—After collecting a jar of oxygen (or several jars) lift the end of the delivery tube out of the water before removing the lamp, otherwise the water will rush back into the delivery tube and crack it.

Insert the live coal of a splinter into the jar. It will burst into flame.

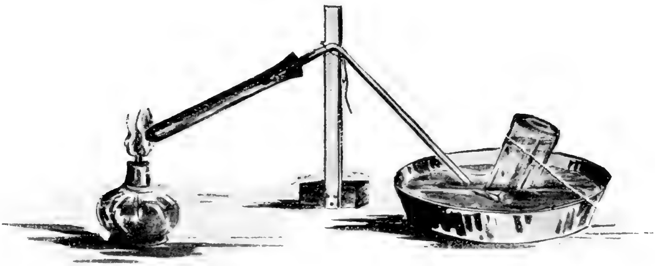


FIG. 155. Apparatus for collecting oxygen. (After Jenkins and Kellogg.)

Or heat the end of a piece of picture wire and insert the red-hot wire into the oxygen. It will burn with a bright flame, thus showing again that oxygen "supports combustion."

Other experiments with oxygen may be found in books on elementary chemistry.

Properties of Carbon.—Carbon is the chief solid element in wood, muscle, fat, sugar, starch, etc., in fact in every substance that is or has been living. For this reason, substances containing carbon are called *organic substances.* It is found in coal, showing that coal was once a living substance. A special branch of chemistry, called "Organic Chemistry," is devoted to the study of the carbon compounds.

The black substance, or charcoal, left after the splinter was burned is almost pure carbon. It is without taste or odor. When carbon is cold it has little affinity for other elements. When it is heated, however, it takes up oxygen, or becomes oxidized, as we have seen in our oxygen experiment. The gas formed by oxidized carbon is carbon dioxide. It is colorless but may be readily detected on account of its power to turn lime water milky.

Carbon dioxide is constantly formed in our bodies and given off in the breath. If we breathe through a straw or glass tube into a jar of lime water, the water in the jar will soon take on a milky appearance due to the union of the carbon and lime. In the formation of carbon dioxide, as in other oxidations (or formation of other oxides), heat is generated.

This principle is made use of in the cells of the body for the generation of heat and energy.

Oxidation in the body.—The oxygen of the air is taken into the lungs and passed into the blood. The blood carries it to the cells. The carbon of the living cell derived from the food takes up oxygen, that is, becomes oxidized. Heat is produced, and the energy, by means of which the work of the body is done, is liberated.

Phosphorus.—Phosphorus in its pure state is a yellowish waxy substance. With calcium and oxygen it forms a large part of our bones. The affinity of pure phosphorus for oxygen is so great that it must be kept under water or else combustion will take place.

Sulphur.—Pure yellow sulphur is familiar to all of us. When sulphur is oxidized it gives off suffocating fumes. Muscle is largely a compound of sulphur and other elements. The disagreeable odor given off by decaying flesh is caused chiefly, by the sulphur fumes. In eating an egg with a silver spoon the sulphur of the egg forms with the silver a blackish compound.

FOODS AND NUTRITION

Food nutrients.—Those substances needed by the cells for their metabolism and their growth are called food nutrients. The nutrient or food value of any substance therefore depends upon its composition or the amounts and kinds of nutrients present. It must contain one or more of the following substances, proteids, carbohydrates, fats, water and inorganic salts.

The following table shows approximately the average composition of some of those substances commonly used as food.

Composition of Foods.*

(In 100 parts)	Water H_2O	Proteid	Fat	Carbohydrate		Inorganic Salts
				Digestible Starch and Sugar	Cellulose	
Meat	76.7	20.8	1.2	.3		1.3
Eggs	73.7	12.6	12.1			1.1
Cheese	36–60	25–33	7–30	3–7		3–4
Cow's milk	87.5	3.4	3.2	4.8		.7
Wheat flour	13.3	10.2	.9	74.8		.5
Wheat bread	35.6	7.1	.2	55.5	.3	1.1
Rye flour	13.7	11.5	2.1	69.7	.3	1.4
Rye bread	42.3	6.1	.4	49.2	1.6	1.5
Rice	13.1	7.0	.9	77.4	.5	1.0
Corn	13.1	9.9	4.6	68.4	.6	1.5
Macaroni	10.1	9.0	.3	79.0	2.5	.5
Peas, beans, lentils	12–15	23–26	1½–2	49–54	.3	2–3
Potatoes	75.5	2.	.2	20.6	4–7	1.
Carrots	87.1	1.	.2	9.3	.7	.9
Cabbages	90.	2–3	.5	4–6	1.4	1.3
Mushrooms	73–91	4–8	.5	3–12	1–2	1.2
Fruit	84	.5		10.	1–5	.5
Butter	15		83.		4.	

*Howell's Physiology, p. 676 (with slight additions).

Uses of nutrients (proteids, carbohydrates, fats, salts, and water).—The exact use of each kind of nutrient to the body is a subject upon which there has been much careful experimentation. Two things are positively known, and they have already been stated. First, the nutrients furnish the cells with materials for growth and metabolism, and second, their oxidation in the cells results in the production of energy, in the form of heat or motion; that is, they furnish the body with building material and fuel.

The proteid compounds are best fitted for this purpose, though each food nutrient has its value.

We may now consider each of the food nutrients separately, and the place of each in our diet.

Proteids or nitrogenous compounds (albumins, etc.).—While the exact composition of proteid is unknown the substances forming it are known to be carbon, oxygen, hydrogen, nitrogen, sulphur and other elements. Such foods as white of egg, lean meat, milk curd and the gluten of wheat, contain large amounts of proteid. The proteid food stuffs are the only food stuffs supplying nitrogen to the body. This nitrogen is being constantly eliminated *from* the cells and hence must be constantly restored *to* the cells.

Proteids have been called flesh-producers or tissue-formers because they possess all the elements for forming tissues and cells, as muscles, nerves, etc.

Plants manufacture proteid from sugars and certain mineral salts, the former supplying the carbon, hydrogen, and oxygen, the latter supplying nitrogen, sulphur, and other elements. Plants are therefore the original source of supply for proteid food. While carnivorous animals obtain their proteid by eating the flesh of other animals, these have obtained it from plants.

Tests For Proteid.

a. Xanthoproteic Test.—Boil the substance to be tested in strong nitric acid (80%); a lemon yellow appears. Wash in water and add enough ammonia to neutralize the acid. If the color changes to deep orange proteid is present.

b. Millon's Test.—Pour Millon's reagent (solution of mercury in nitric acid) over the substance to be tested and bring slowly to a boiling point. If proteid is present the solution becomes rose red.

Proteid burns with the odor of burning leather.

Carbohydrates (starches, sugars, etc.).—Carbohydrates contain carbon, oxygen and hydrogen. The green parts of plants are, with the aid of sunlight, the manufacturers of starch. The materials used are carbon dioxide (CO_2) obtained from the air by the leaves, and water obtained by the roots. Thus vegetables and fruits supply the carbohydrate foods.

Starch forms the chief carbohydrate food of the world.

Carbohydrates unaided could not, however, form living cells because they lack the element nitrogen, therefore, they could not take the place of proteids.

The carbohydrates, with the fats, have been called the heat and energy producers because their compounds, in becoming split up and oxidized, produce energy for the performance of the body movements, and heat to maintain the temperature of the body.

The carbohydrates and fats have also been called "proteid sparers" because by keeping up the supply of heat and energy of the body they spare the proteids from that kind of work so that their main work may be that of tissue formation and growth.

It would take relatively a very large amount of proteid to furnish sufficient heat and energy. Therefore, if we should furnish the body with enough proteid for this we should over-furnish it with tissue-building material. It is thus economy to furnish carbohydrate foods for heat and energy and proteid for tissue-building.

Test For Starch.—Break up and crush the substance to be tested (a bit of potato or corn). Pour over it a few drops of iodine solution. If there is a large amount of starch present it will turn black, if but little starch is present it will turn blue.

Test For Grape or Cane Sugar.—Heat the substance to be tested, slightly, in a test tube with a little water. Add to this twice its bulk of Fehling's solution* (may be obtained at the drugstore). Heat

*To prepare Fehling's solution:

Solution 1.—Add to 35 grains of copper sulphate (blue vitriol) 500 cubic centimeters of water and put aside until dissolved.

Solution 2.—Add to 160 grains of caustic soda and 173 grains of Rochelle salts, 500 cubic centimeters of water. Mix equal parts of solutions 1 and 2.

the mixture or allow it to remain over night in a warm room. If grape sugar is present in any quantity, the contents of the tube will turn first greenish, then yellow and finally brick red.

Fats (butter, oils, oil of nuts, etc.).—Like carbohydrates, fats contain carbon, oxygen, and hydrogen but in different proportions. They are insoluble in and lighter than water. They are easily oxidized as we know from the rapidity with which they burn. Like carbohydrates, they are heat and energy producers and proteid savers.

Tests for Fats.—Rub the substance to be tested upon a sheet of white paper, or heat it in an oven upon paper. If oil is present, it will show as a grease spot.

Water.—Water undergoes no chemical change in the body. Its importance as a food is due to the fact that it forms a large percentage of the composition of the body, nearly 59% of the total weight. A large amount of water is thrown off daily as waste, through the skin and kidneys. This must be restored daily to keep the body well. Our food provides only about one-third of the water we need and we must drink three or four pints each day to supply the deficiency.

Water promotes digestion, by aiding in softening and dissolving the food and stimulating contractions of the muscle. A large amount of muscle and a much larger amount of blood is water.

Inorganic salts (chlorides, sulphates, carbonates, etc.).—Inorganic salts are found in the cells and fluids of the body, and particularly in the bones, of which they form an important part. They are non-oxidizable and hence have no importance as sources of energy. They are supposed to function in controlling the flow of water to and from the tissues. This is by virtue of the principle of osmotic pressure. These salts are supplied to the body largely through vegetable food.

Diffusion and Osmosis.—When one liquid is poured into another the resulting solution will be a blend of the two substances, if they are capable of mixing. That is, the molecules of one liquid become thoroughly intermingled with the molecules of the other, as when syrup is poured into water. This is diffusion.

If two such liquids are separated by an animal membrane, the molecules of each will pass through the membranes so that in time the solutions on each side will be equally diffused. This passage of the molecules of liquid through an animal membrane is known as osmosis. The "attraction" exerted mutually by the liquids is called *osmotic pressure.* Osmotic pressure varies with the density and temperature of the solutions. Osmosis and osmotic pressure are facts of great importance in animal physiology as we shall see when we study the nutrition of the cells.

Procure from the butcher a small bladder; moisten it and fill it with sugar solution. Insert a tube into the opening and tie the neck of the bladder tightly around the tube. Immerse this in a dish of water and note the result. The energy with which the water enters the solution of greater density is due to osmotic pressure.

Relative value of common foods.—Our meals consist usually of a "mixed diet," of fruit, nuts, cereal and eggs, or perhaps bread, meat, and vegetables. Experience has shown that a mixed diet is better suited to the appetite and to the needs of the body than a single food material. Eggs, milk and bread are nutritious because they contain almost no waste. Meat is valuable for its high percentage of proteid. Potatoes and other vegetables are valuable for their high percentage of carbohydrates. Some foods are valuable for their large percentage of water.

Daily diet.—Certain experiments have been made both in Europe and America to determine a "standard diet"—the amount of food that should be consumed in order to preserve the health. This amount varies of course with the occupation,- the sex and the age of the individual and with the climate.

Prof. Atwater of the U. S. Department of Agriculture gives the following table as approximating the average amounts of nutrients needed per day.

Conditions	Proteid lbs.	Carbo-hydrate	Fat lbs.	*Calories
Man with light muscular work.......	.22	.88	.22	2980.
Man with moderate work............	.28	2.99	.28	3570.
Man with active muscular work......	.33	1.10	.33	4060.

Principles involved in cooking food.—Cooking improves the taste of food, by bringing out its natural flavors. It renders food more wholesome by killing any noxious or poisonous organisms that may have collected on it in the markets. It makes the food more digestible by softening the fibers, and in vegetables by bursting the cell walls so that the digestive juices can get at it.

Economy in the purchase of foods.—The Department of Agriculture at Washington is giving much attention to this subject and bulletins of the results of investigations are published from time to time to furnish information about it.

"The cheapest food is that which supplies the most nutrient for the least money. The most economical food is that which is cheapest and at the same time best adapted to the wants of the eater."† If we adopt these as rules for the purchase of foods we must study tables of the relative values of foods and consult the markets for relative prices.

Food accessories.—We commonly add certain things to our foods to make them more palatable, to make them taste better, such as pepper, mustard, vanilla, cinnamon, nutmeg, vinegar, pickles, lemon juice, etc. These are condiments, or flavors, and contain none or but little of the food nutrients.

*A *calory* is the accepted unit for measuring heat. It is the amount of heat necessary to raise the temperature of one kilogram of water one degree.

†Farmers' Bulletin, 23, p. 20.

They are therefore known as food accessories. They are not absolutely necessary as part of the diet, but, used in limitation, they stimulate the appetite and favor the flow of digestive juices. They, therefore, have a place upon the table. If used in excess, however, they destroy the normal appetite for natural flavors and may over-stimulate the glands that furnish the digestive juices.

Stimulants.—There are certain other substances that primarily excite or stimulate the activity of certain parts of the body, chiefly the nervous system, without providing material for growth or repair, for heat or energy. These are stimulants. They are chiefly tea, coffee, cocoa, chocolate and alcoholic liquors. While in small amounts these may be harmless, it is not easy to tell how small this amount should be, and it differs with different dispositions.

Their chief injury to the body lies in the fact that, by stimulating the nervous system, they deprive the body of the sense of fatigue, or of the desire for sleep, and so also of the benefits derived from rest and sleep.

Alcohol.—A true food is a substance which nourishes the body, acts as a tissue builder or as a heat and energy producer.

It has been determined by experiment, that in very small amounts given at stated and widely separated periods, alcohol is oxidized in the body, and thus produces heat and energy as do the fat and carbohydrate foods. These are such doses as the physician sometimes gives when for some reason he must find an equivalent for fats and carbohydrates.

In large amounts, alcohol has been found to act as a drug, causing much harm to the tissues, poisoning them and disarranging them seriously.

Like other stimulants, and acting more quickly and injuriously, it excites the nervous system in a peculiar manner. Unlike other poisons, its use establishes a craving or appetite for it which eventually weakens the will and is apt to lead to intoxication.

In small amounts, then, alcohol may be considered as a kind of food but should be administered, like other medicines, under a physician's order. In large amounts it is recognized as a poison and dangerous. The direct action of alcohol upon certain organs will be considered later.

Narcotics.—Narcotics are substances which blunt the sensibilities and induce sleep. Tobacco, alcohol (in large quantities), opium, morphine and cocaine, are the most common. All narcotics are deadly poison when taken in large quantities. Some of them, like tobacco and alcohol may stimulate in small doses and narcotize in large doses.

Tobacco, like alcohol, affects the nervous system. It leads to weakness of the heart and irregular pulse by interfering with nerve regulation. The poisonous ingredient of tobacco is *nicotine*. It is this that makes boys sick and sleepy when they first begin to use tobacco. The constant use of tobacco impairs the digestion through its action on the salivary secretions. It produces hoarseness and catarrh through irritation of the mucous lining of the mouth.

CHAPTER XXII

DIGESTION AND ABSORPTION

Digestion.—We have learned that it is the function of food to nourish the cells of the body. The cells can, however, absorb liquid food only, so the food requires further treatment than mere cooking to render it of use to the cells.

It is the function of the *alimentary canal* and its assisting or digestive glands to dissolve thoroughly the food, to separate the nutritious from the non-nutritious, and to treat it with such reagents that it can be taken up by the cells. This is digestion.

The alimentary canal.—Digestion, as has been said, takes place in the alimentary canal. Our study of the alimentary canal of the frog, together with the use of the accompanying diagram (fig. 156), will aid us in understanding this structure in the human body. It is a continuous tube from the mouth to the anus. Part of the tube is twisted and doubled back upon itself, as shown in the figure. Its entire length, were it stretched out, is about thirty feet. Its diameter varies at different points, being widest at the stomach. There are outgrowths at different points called glands that furnish the digestive juices for dissolving and preparing the food. These glands pour their secretions into the various parts of the alimentary canal where they become thoroughly mixed with the food.

The alimentary canal is lined with a soft mucous membrane like that within the mouth. Its secreting cells furnish mucous for keeping the inner surface moist.

The mouth or buccal cavity.—If we close the lips and feel around with the tongue we find the mouth bounded on the front and sides by the *lips*, the *teeth*, the *gums* and *cheeks*. The tongue (fig. 157) lies on the floor of the mouth. The

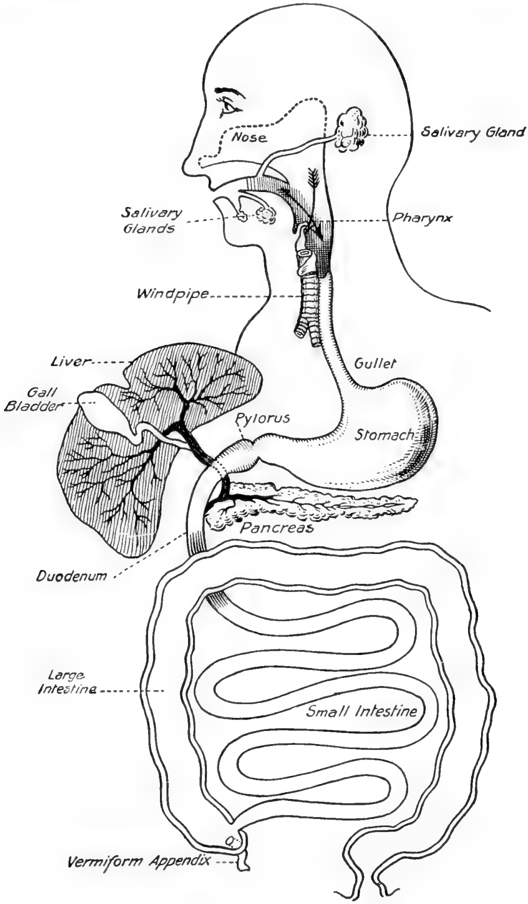


FIG. 156. Diagram of the alimentary canal. (Modified from Landois.)

hard palate and *soft palate* form the roof of the mouth. The pendant hanging from the soft palate is the *uvula*. During deglutition or swallowing the *uvula* closes the inner passage into the nasal cavity which lies above the palate (see fig. 157).

The teeth and tongue act mechanically upon the food, masticating it or breaking it up.

The teeth.—The teeth are important structures since they initiate the work of digestion. Those that grow in during the first two years of life are called *milk teeth*. They have smaller roots than the permanent teeth and appear while the jaws are small. As the jaws enlarge (during the sixth and seventh years) the second set or permanent teeth grow in and one by one replace the milk teeth. The permanent teeth need much care and attention as they must last throughout life.

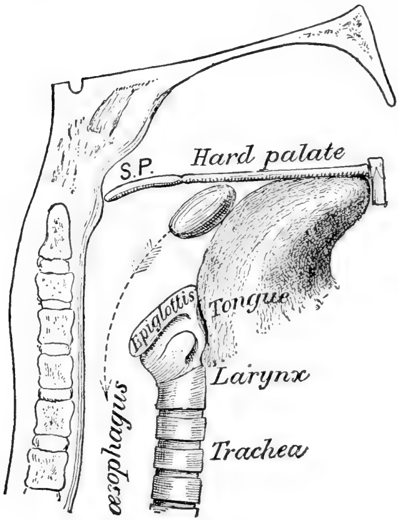


FIG. 157. Diagram of the buccal cavity showing the manner of closing the posterior nares during deglutition. (After Landois & Stirling.)

Kinds of teeth.—There are eight teeth in the front of the mouth (four on each jaw) called *incisors*, to bite and cut the food. The sharp pointed teeth on either side of the incisors are the *canines*. On either side of the canines there are two large teeth with two-pointed surfaces. These are the *bicuspids* or *premolars*. On either side of the premolars are three large *molars*. The premolars and molars are grinders. The third molars frequently do not appear until after the twentieth year, and are commonly called the wisdom teeth.

Structure of the teeth (fig. 158).—The teeth, though as hard as bone, are not bone but a hardened epithelium tissue. The part above the gum is the *crown* and is but a part of the whole tooth. Under the gum are the *neck* and *roots*. The roots are inserted into sockets in the jaws. The incisors and canines have but one root, the premolars have usually two roots and the molars have from two to five.

If a tooth is cut lengthwise as shown in the figure, there is exposed a central chamber, or *pulp chamber* filled with blood-vessels and nerves which have entered the cavity through the roots. The pulp chamber is surrounded by a layer of *dentine* (D), an ivory-like substance which makes up the bulk of the tooth. The dentine is protected on the crown by *enamel* (E), the hardest substance in the body, and on the roots by *cement* (C). The enamel protects the teeth from mechanical injury and from the effect of chemicals and bacteria.

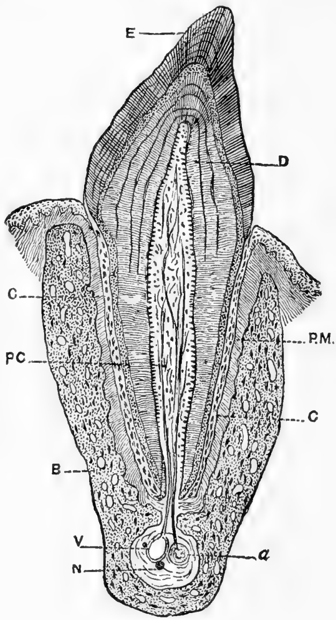


FIG. 158. Vertical section of a tooth in jaw. E, enamel; D, dentine; P. M., peridontal membrane; P. C., pulp cavity; C, cement; B, bone of lower jaw; V, vein; A, artery; N. nerve. (After Stirling.)

Care of the teeth.—As the teeth masticate or grind the food and prepare it for the action of the digestive juices, their condition has much to do with the health.

Decay of teeth is caused by injury to the enamel. This is due mainly (1) to the action of bacteria or particles of food that lodge between the teeth; (2) to tartar, a deposit of lime salts that collects on the teeth especially near the gums.

The teeth should be brushed with water after every meal to remove every particle of food from the mouth. Once or twice a week a good tooth powder like precipitate of chalk should be used. This is not hard enough to injure the enamel but removes the tarter. A dentist should examine the teeth about once a year.

Salivary glands.—The salivary glands open into the mouth. There are three pairs. These are named from their location: *parotid*, lying in front of and below the ears; *submaxillary*, lying beneath the lower jaw, and *sublingual*, lying beneath the mucous membrane in the floor of the mouth. The position and openings of these glands are shown in fig. 156.

Chemical action of saliva.—The salivary glands secrete a digestive juice called *saliva*. This is composed mainly of water and a certain enzyme called *ptyalin*.

An enzyme is an organic substance which acts chemically upon another substance so as to change its nature without itself becoming changed.

Ptyalin changes starch, an insoluble food, to sugar, a soluble food, that is, it digests starch.

The chewing process in the mouth thoroughly mixes the saliva with the food so that the enzyme can reach the starch. This is the first act of digestion. The mechanical action of moistening the food and thus preparing it for swallowing is quite as important as its chemical action. Food thus moistened stimulates the sensation of taste.

Experiment to Show Digestion of Starch.—Chew a piece of paraffin; this will start the flow of saliva in the mouth. Collect the saliva in a test tube. Test its chemical reaction with litmus paper. If it changes blue litmus to red it is alkaline. If it changes red litmus to blue it is acid. Add a little vinegar to the saliva and test again. Account for the different result. Partly fill a test tube with saliva, another with water, a third with saliva to which vinegar has been added. Test a bit of soda cracker for its starch reaction (see p. 297). Place the soda cracker (a little boiled starch will do as well) in each of the three test tubes and leave over night in a warm room. In the morning test the contents of each tube for starch and for sugar. In which has digestion taken place?

Deglutition.—Deglutition is the act of swallowing. Fig. 157 shows how it is begun. The tongue is raised to the roof of the mouth, and the uvula automatically closes the nasal passage. The food is pushed into the pharynx by means of the muscles at the base of the tongue.

The pharynx.—There are seven openings into the pharynx; one each to the mouth, the windpipe or larynx, and the oesophagus, a pair to the nasal passages, and a pair to the Eustachian tubes leading to the middle ear. The opening into the larynx (or glottis) is closed by the epiglottis during deglutition.

The pharyngeal cavity is lined with mucous membrane.

The oesophagus.—The pharynx narrows into the elongated oesophagus. This is also lined with mucous membrane and has muscular walls which by peristaltic contraction pass the food into the stomach. *Peristaltic contraction* is a contraction that starts at one end of a series of muscles and moves along the muscles in a wave. It may be imitated by pressing the fingers on a rubber tube and drawing them the length of the tube.

The abdominal cavity.—This is the large cavity shown in fig. 159 separated from the thorax or chest by the muscular diaphragm (D). At the back are the spinal column and lower ribs. Its base is formed by the large pelvic bones (P). The sides and front are covered with muscles. The cavity is lined with *peritoneum,* a membrane which is deflected over the organs lying in this region, and which supports them. This membrane secretes a fluid (*serous fluid*) which keeps it moist.

Form and structure of the stomach (figs. 156 and 159).—

The stomach is a pear-shaped organ lying just beneath the diaphragm. The oesophagus opens into its larger or *cardiac*

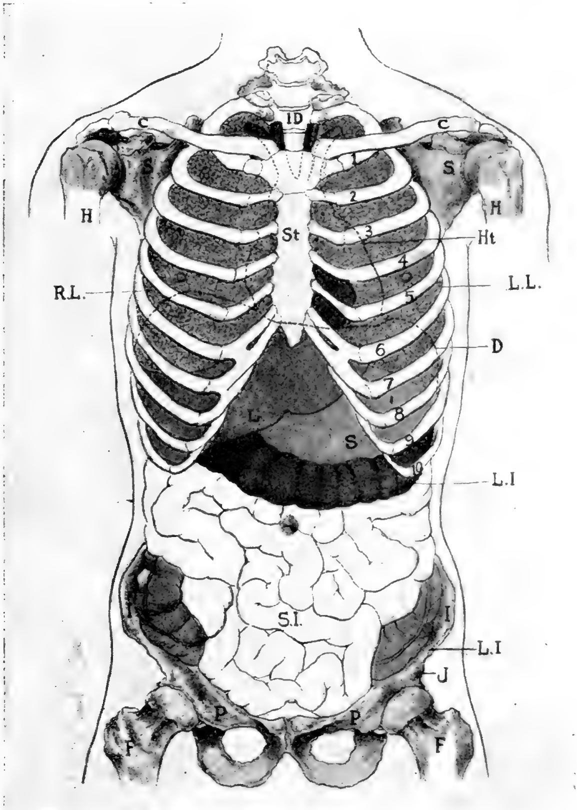


FIG. 159. Diagram of thorax and abdomen showing location of heart, viscera and lungs. C, clavicle; D, diaphragm; 10, first dorsal vertebra; F, femur; H, humerus; Ht, heart; I, ilium; L, liver; L. I., large intestine; L. L., left lung; P. pelvis; R. L., right lung; S. I., small intestine; S, scapula; St., sternum. (After Deaver.)

end which is at the left side. The walls are muscular, and distend as food enters. It is covered on the outside with the peritoneal membrane and lined by a mucous membrane. A submucous membrane lies between the muscular coats and the mucous coat or epithelium. The large blood vessels of the stomach lie in the peritoneum and send capillaries into the submucous coat. The mucous coat is smooth when the walls of the stomach are distended, but wrinkled when the stomach is empty and its walls collapsed.

The stomach narrows at its lower or *pyloric end* and opens into the small intestine (fig. 156).

Glands.—The mucous lining is covered with minute shallow pits, the openings of the *gastric glands.* The glands furnish certain enzymes, pepsin and rennin, all of which aid in digestion. The *pyloric glands* (fig. 160), which furnish pepsin only, lie in the pyloric end of the stomach. The *fundus glands* in the cardiac part of the stomach, are formed of several kinds of cells, and furnish pepsin, rennin and hydrochloric acid.

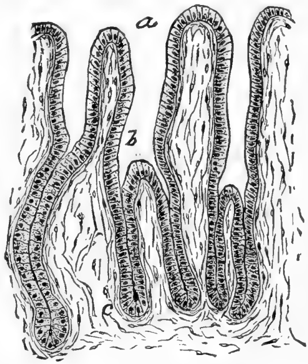


FIG. 160. Section of pyloric glands from human stomach. *a*, mouth of gland leading into a long wide duct (*b*), into which open the terminal divisions; *c*, connective tissue of mucosa. (After Piersoe.)

The gastric juice containing these enzymes acts in an acid medium upon proteid food, while the ptyalin of the salivary juice acts in an alkaline medium and upon carbohydrates.

The presence of food or food accessories in the stomach stimulates the flow of gastric juice.

Pepsin.—This enzyme changes proteid into a soluble form called *peptone.* It acts at a rather high temperature.

Rennin.—This enzyme acts upon milk, causing it to coagulate or separate into curds (the proteid part) and whey (mostly water). This separation prepares it for the action of pepsin.

Hydrochloric acid.—This secretion establishes the acid medium necessary for the action of pepsin and may dissolve some of the mineral salts.

The cardiac or fundic end of the stomach (fig. 156) acts as a reservoir for the food as it leaves the oesophagus. Here the food may remain for sometime while the starchy matter is further acted upon by the salivary juice.

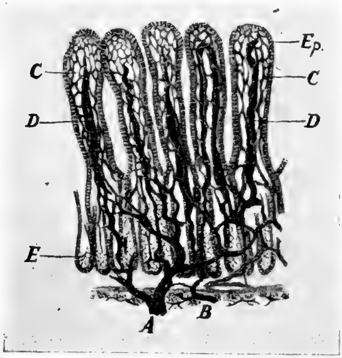


FIG. 161. Mucous membrane of the small intestine of the dog. A, artery; B, vein; C, capillaries; D, lacteals; E, glands of Lieberkühn; Ep., epithelial tissue. (After Cadiat.)

In the pre-pyloric and pyloric end digestion of proteid is begun by the gastric juice. This is the second stage in digestion. It results in a milky mass called chyme, which in part is ready for absorption and in part needs further treatment. This passes in small amounts into the small intestine.

The small intestine and the intestinal juices.—The intestine is a very long coiled tube held in place by a fold of the peritoneum called the *mesentery*. The mesentery is fastened at the back to the spinal column.

The coats of the small intestine are similar to those of the stomach. The inner surface of the small intestine is covered with minute papillæ or projections called *villi* (fig. 161). These are filled with blood vessels and lymphatic vessels. Between the villi are numerous minute pores. These are openings of tiny glands that secrete intestinal juices. Other digestive secretions found in the small intestine are the bile and the pancreatic juice.

The liver.—This is the largest gland in the body. It lies (fig. 159 Li) beneath the diaphragm, its lobes partly overlapping the stomach. Its cells, called *hepatic* cells, secrete bile. Its duct opens into the small intestine near the pyloric end. Unused bile is stored in a small sac or gall bladder connected by a duct with the bile duct near its distal end.

The pancreas (fig. 156).—This gland lies along the curvature of the stomach. Its cells secrete pancreatic juice. Its duct joins the bile duct near its opening into the intestine, so that bile and pancreatic juice intermingle while entering the intestines.

Digestion in the small intestine.—This is due to the combined action of the three digestive fluids mentioned, *intestinal juice*, *pancreatic juice* and *bile*.

The intestinal juice furnishes an enzyme that acts upon starches and sugars and upon fats. The pancreatic juice furnishes three enzymes, *trypsin*, *amylopsin*, *and steapsin*. Trypsin, like ptyalin, acts in an alkaline medium. Like pepsin it acts upon proteid converting it into peptone. Amylopsin (diastase), like ptyalin, acts upon starch, converting it into sugar. Steapsin (lipase) acts upon fat. Fat is chemically composed of fatty acid and glycerine. This combination must be broken up before fat can be made digestible. When once broken up, the fatty acids unite with the alkali present and form a soap which is soluble. This process is *saponification*. Fat must also be broken up into tiny droplets. This is *emulsification*. These two processes are accomplished by intestinal juice and steapsin.

Bile is alkaline and hence serves to neutralize the acid chyme and prepare it for the action of the intestinal and pancreatic juices. It also aids in emulsifying and saponifying fats.

Digestion may be artificially demonstrated as follows. Procure from a druggist some dry pancreatic extract. Dissolve 15 grs. of this in 2 oz. of warm water. (1) Half fill a test tube with this artificial digestive juice and place in it a small amount of cooked starch. (2) In a second tube, place a small amount of white of egg or other proteid with the artificial digestive juice. (3) In a third, place a few drops of olive oil and artificial digestive juice. Leave these preparations in a water bath or oven at 98° F. for 12 hours and note results.

When the food is thoroughly dissolved it has reached the last stage of digestion. It is now ready for absorption.

Absorption.—We have learned that the blood carries food to the deep seated cells of the body. The transfer of the digested food through the walls of the intestine to the blood is called absorption.

The sole object of absorption is to get the digested food into the blood. This takes it through the walls of the villi. Fig. 161 represents a series of villi cut through to show the loose network of blood capillaries and lymphatic capillaries (lacteals) within each one. Lymphatic vessels are like blood vessels in some ways but they carry a milky fluid and not red blood. The mucous membrane of the intestine is bathed by the digested food. To reach the blood and lacteals, this digested food must pass through the mucous membrane of the villi and the thin walls of the capillaries and lacteals.

This is accomplished by osmosis (see page 298). Only soluble substances can mix by osmosis, hence it is that starch, proteids and other foods must be dissolved or digested before they are ready for absorption.

Where absorption takes place.—A minute quantity of peptone (derived from proteids) may be absorbed in the stomach, and a small amount may pass into the large intestine and become absorbed there, but most of it passes through the walls of the villi of the small intestine into the blood.

The sugar (derived from carbohydrates) is absorbed into the blood through the villi also.

The fats (as emulsions or soaps) pass into the lacteals.

Water and salts pass into the blood mainly in the small and large intestine.

Alcohol is absorbed very quickly through the walls of the stomach. Its quick action upon the body is probably due to this fact.

Action of the liver upon nutrients.—Absorbed food is carried immediately by a large blood vessel (the portal vein) to the liver. Here it undergoes further changes before it is distributed to the cells of the body. Here glycogen or liver starch is formed of any normal excess of sugar in the blood and held as a reserve supply. Here, also, any poisonous compounds, that may have been absorbed with the food and that might injure the tissues, are removed.

The large intestine.—During its passage through the small intestine most of the digested food is absorbed, as we have learned. The undigested parts of the food, together with such poisons as have been collected by the liver, pass into the large intestine and out of the body through the *rectum*, by peristalsis. Constipation is the clogging of the rectum or large intestine. Constipation is dangerous because the poisons from the liver become reabsorbed. This results in biliousness, headache and often very serious troubles.

Hygiene of eating and digestion.—The body requires that some proteid, carbohydrate and fat and water shall be absorbed each day. The digestive system is regulated to care for a certain amount only. If too much is demanded of the alimentary canal, digestion is impaired and dyspepsia results. Digestion is a "chain of results;" first the cooking, then the masticating, and finally solution in the digestive juices. All this takes care and time. A poorly cooked meal or a hurried meal means a partially digested meal. Lack of the right kind of food and of exercise engender constipation. Indigestion and constipation are the signs by which we know that something is going wrong and must be remedied.

Effect of alcohol upon digestion.—While the use of alcohol may have a serious effect upon the activities of the body as a whole, through its influence on the nervous system, according to Chittenden and others it has little direct effect upon digestion. Their experiments have shown that it leaves the alimentary canal and enters the blood very soon after it reaches the stomach. In quantity it deprives the system of its normal healthy appetite.

CHAPTER XXIII

THE BLOOD AND CIRCULATION

BLOOD

We have seen that digestion prepares the food for the cells and that by means of absorption this food enters the blood. The blood is the common carrier between the absorptive surface of the small intestine and all the tissues of the body. It circulates within a closed system of tubes or blood-vessels, and substances that pass into or out of the blood must pass through the walls of the blood-vessels.

Composition of the blood.—If the finger is pricked with a clean needle and a drop of blood placed on a slide and looked at under the microscope, the blood will be seen as yellowish liquid, containing a great many tiny round disks and a few particles of irregular shape. The yellowish liquid is the *plasma*, the disks and other floating cells are *corpuscles* (red and white).

Structure and function of the red corpuscles.—The red corpuscles are biconcave disks without nuclei and contain a red pigment, *hæmoglobin.* It is the function of hæmoglobin to carry oxygen to the tissues and carbon dioxide from the tissues.

Structure and function of white blood corpuscles.—The white blood corpuscles are of many sizes and without definite form. They are colorless and nucleated. Many of them move about in the blood plasma like amœbæ. Some of the white blood corpuscles (*phagocytes*) take up from the blood foreign organisms such as disease producing bacteria. The formation of immunizing substances in the blood is attributed to *leucocytes.* Other corpuscles aid in the absorption of fats while others aid in forming a clot when a blood-vessel is wounded.

Blood plasma.—The plasma is the fluid part of the blood. It supports the red and white corpuscles. It is composed of much water, a substance called *fibrin,* certain salts, absorbed nutrients in the form of serum albumin, and certain wastes (urea and acids) from the tissue cells.

Blood clotting.—Blood exposed to the air forms a clot by the mixture of some of the white blood corpuscles and fibrin of the plasma. If a bowl of blood is stirred vigorously the fibrin may be separated from the serum and blood corpuscles. Blood clot or coagulation protects against the loss of blood when a blood-vessel is wounded.

The amount of blood in the body and its distribution.—A grown person is provided with about six quarts of blood which equals about one-thirteenth the weight of the body. This amount is constant under normal conditions, because the amount of food and oxygen given up to the tissues is balanced by the amount of waste received. The supply of blood to the heart and lungs, the liver and the skeletal muscles equals about seventy-five per centum of the whole amount in the body. It is distributed to the tissues according to their needs. An active gland or an active muscle requires more than a resting gland or muscle. During digestion and absorption a large supply goes to the stomach.

Effect of food, fresh air, exercise and rest upon the blood.—The healthy condition of the blood depends upon abundance of fresh air to supply it with oxygen; nutritious food and plenty of water to maintain the proper composition of the blood plasma and to supply iron for the red corpuscles; a sufficient amount of exercise so that all the arteries and capillaries may be thrown into activity; and sleep and rest that the demands of the tissues may not be too great a drain upon it. A short rest gives the blood time to carry away the wastes from the tissues.

CIRCULATION

In order that the blood may find its way from the absorptive cells of the intestine to every tissue of the body and from these to the lungs, it must circulate in a continuous flow. This it does by means of a closed system of vessels, the *blood-vessels*, and a pumping organ, the *heart*. The arteries carry blood away from the heart to the system and the lungs. The veins carry blood to the heart from the system and the lungs. Tiny anastomosing (many branched) vessels called *capillaries* connect the arteries and veins.

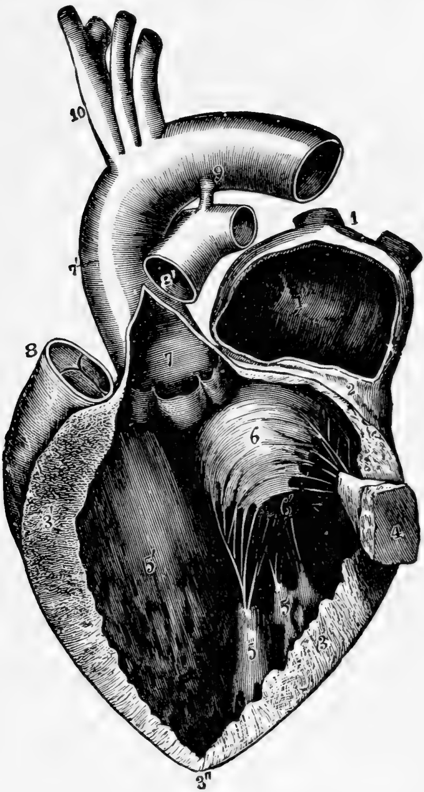
Structure and position of the heart.—In fig. 159 the heart may be seen lying in its natural position, a little to the left of the thoracic cavity, just above the diaphragm and between the two lobes of the lungs. The apex points downward and to the left.

The heart is enclosed within a sac called the *pericardium*. The walls of the heart are thick and muscular and are supplied with blood-vessels and nerves.

Internal structure of the heart.—The heart is divided by a muscular partition into right and left halves, having no intercommunication. Each half is separated into an upper and lower cavity, the *auricle* and *ventricle*. The right auricle opens into the right ventricle and the left auricle opens into the left ventricle. The blood flows from the auricles into the ventricles and out into the arteries. Fig. 162 shows the left side of the heart opened so that the inside may be seen. The opening between the left auricle and the left ventricle is guarded by a valve, the *mitral valve*, with two flaps (6,6′). These flaps are fastened by strong cords to tiny muscular pillars on the walls of the ventriculus (5,5). The cords prevent the flaps from being forced backward into the auricle when the heart beats.

The opening between right auricle and right ventricle is guarded by the *tricuspid valve.* This is similar in structure to the mitral except that there are three flaps instead of two.

The position of these valves in action is shown in figs. 163 and 164.



Blood-vessels directly connected with the heart.—The large veins open into the auricles. On the right side of the heart opening into the right auricle there are three veins, the *superior*

FIG. 162. Left auricle and ventricle opened and a part of anterior and left wall removed. **1**, two right pulmonary veins cut short; **1′**, within cavity of left auricle; 2, wall between auricle and ventricle; 3, 3′, 3″, cut walls of ventricle; 4, portion of wall of ventricle with muscular pillar to which tendons of mitral valve are attached; 5, 5, muscular pillars on inner wall of left ventricle; 5′, within cavity of left ventricle; 6, 6′ mitral valve; 7, commencement of aorta (with semilunar valve below); 7′, aorta; 8, root of pulmonary artery and its semilunar valve; 8′, continuation of the pulmonary artery; 9, artery connecting pulmonary artery and aorta; **10**, arteries arising from summit of aortic arch. (After Allen Thomson.)

vena cava (descending from the parts of the body above the heart) the *inferior vena cava* (ascending from the parts of the body below the heart), and the *coronary* vein arising in the walls of the heart.

On the left side of the heart opening into the left auricle there are four large veins, the *pulmonary veins*. Two of these arise in the left lung and two in the right lung. Two of these are shown at (1) in fig. 162. The large arteries arise in the ventricles. The aorta (7) arises in the left ventricle and carries the blood that is to be distributed to

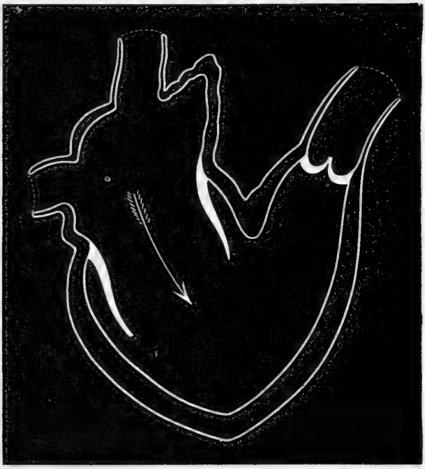


FIG. 163. Right cavities of the heart; auriculo-ventricular valves open, arterial valves closed. (After Dalton.)

the tissues of the body. Its branches go to the tissues carrying blood laden with food and oxygen.

The *pulmonary* artery (8) arises in the right ventricle and carries the blood that is to be distributed to the air chambers of the lungs. Its branches go to the walls of the lungs filled with blood laden with carbon dioxide which is there exchanged for oxygen. The openings from the ventricles into the arteries are guarded by semilunar valves shown in fig. 162. Their position in action is shown in figs. 163

and 164. Thus we see that the flow of blood from auricle to ventricle, and from ventricle to artery, can take place in one direction only. In case of diseased valves there may be a backward flow or regurgitation.

How the heart works.—The auricles are constantly filling with blood from the great veins. Both auricles contract at the same time, the auriculo-ventricular valves open and the blood is driven into the ventricles. The ventricles con-

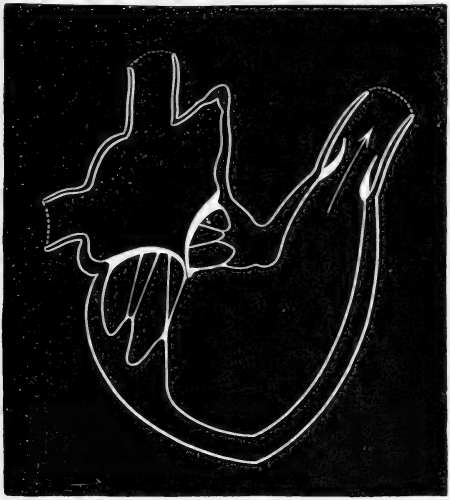


FIG. 164. Right cavities of the heart; auriculo-ventricular valves closed, arterial valves open. (After Dalton.)

tract at once and send the blood out into the great arteries.

The *heart beat* is the alternate contraction (*systole*) and relaxation or expansion (*diastole*) of the walls of the heart. In man this occurs about seventy-five times per minute under normal conditions. A child's pulse is more rapid.

Systemic circulation.—We have seen that the *aorta* carries food and oxygen to the tissues. It passes anteriorly from the left ventricle, then arches and passes posteriorly and dorsally, forming thus the arch of the aorta (fig. 162,7′). The dorsal aorta passes downward through the diaphragm near the spinal cord (fig. 167) to the lower part of the abdominal cavity. Here it divides into two great arteries, one to each of the lower limbs, the common iliac arteries.

Branches of the aorta.—Two small arteries, the *coronary* arteries, leave the aorta near its point of origin. These supply blood to the walls of the heart. From the arch of the aorta (fig. 162) three large arteries pass to the head, neck and shoulders. From the thoracic aorta, a number of small arteries pass to the muscles of the thorax, the pericardium and the oesophagus.

Abdominal aorta and its branches.—A series of arteries arise from the aorta in the abdomen.

1. Two *phrenic* arteries passing to the muscles of the diaphragm.
2. *Cœliac axis*—a short trunk that soon divides into three important branches supplying the stomach, liver, gall bladder, pancreas, and first part of the duodenum, and the spleen.
3. The *superior mesenteric* artery with its many branches supplying the small intestine (except the duodenum).
4. The *renal* arteries, passing to the kidneys.
5. The *inferior mesenteric* artery, supplying the large intestine and rectum.

All of these arteries break up into capillaries in the tissues they supply. Thus the aorta, through its branches, supplies blood to every part of the body.

The capillaries.—At the extremities of the arteries the blood-vessels branch into finer and finer branches until they end in vessels of minute size. These are the *capillaries*. They penetrate the tissues of the glands, muscles, skin, brain, etc. Capillaries with the blood corpuscles trickling through them may be seen in a frog's foot under the microscope.

The tissue cells are surrounded by a watery fluid called *lymph.* The capillaries are also bathed by lymph.

Composition and uses of lymph.—Lymph is composed partly of water and partly of food material derived from the capillaries through their walls. Lymph gives up food and water to the tissue cells and receives from them, through their walls, certain waste products. Oxygen also passes from the capillaries through the lymph to the cells, and carbon dioxide passes from the cells through the lymph to the blood.

We see, therefore, that the important changes in the blood take place in the capillaries and that the lymph surrounding the cells functions as a medium of interchange between the blood and the cells. This interchange is accomplished by the process of osmosis (see p. 298).

The veins.—As the arteries break up into capillaries, so the capillaries unite, after leaving the tissues, to form veins. The blood that flows to the tissues through the arteries is laden with food and oxygen. We have seen that much of this is exchanged in the capillaries for carbon dioxide and waste products. Hence it is that the blood in the veins is laden with these substances and needs to be purified before it again becomes fit for use by the tissue cells.

The blood is partly purified in the kidney, partly in the liver, and partly in the lungs. The blood from the intestines, stomach, spleen and pancreas, passes by way of the portal vein to the liver. In the intestines it has gathered the digested food, as already described on page 313. The portal vein breaks up into capillaries in the liver and some of the particularly deleterious waste products and poisonous substances that may have passed into the blood with the digested food, are here removed. From the liver the hepatic vein carries the blood into the vena cava ascending and thus back to the right auricle of the heart. Veins from other parts of the body, as the arms, legs, and muscles, return the blood from the capillaries of these parts, directly to the vena cava descending and so to the right auricle (fig. 165).

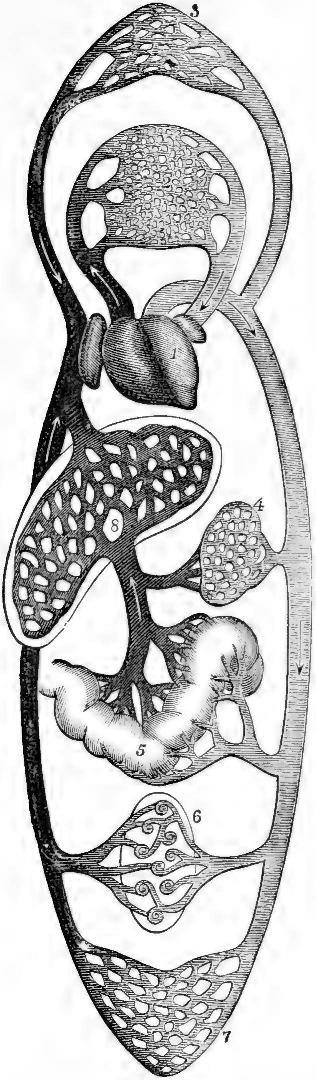
This completes the systemic circulation.

Pulmonary circulation.—We have learned that the systemic arteries carry blood away from the left ventricle, and that the veins return it to the right auricle. In this circulation the blood gathers food by absorption from the intestines, gives up food and oxygen to all the tissues and gets rid of certain waste products in the kidneys and liver, but it must also get rid of the large amount of carbon dioxide collected from the tissue cells. It does this through the pulmonary circulation.

The blood received into the right auricle from the system (through the vena cavas) is forced into the right ventricle through the tricuspid valve. It is then pumped out into the pulmonary artery which carries it to the lungs, as already stated. The pulmonary arteries break up into capillaries in the tissues of the air sacs of the lungs (fig. 176). Carbon dioxide in the blood is here exchanged for oxygen. The blood thus purified is collected by four large pulmonary veins (fig. 175, 13, 14, 15, 16) and sent back to the left auricle of the heart. Figure 165 shows the course of this blood-flow as just described.

We see, therefore, that all the blood leaves the heart by way of arteries and returns to the heart by way of capillaries and veins. We see that it all passes through one set of capillaries and that the blood from some of the organs (stomach, intestines, spleen and pancreas) passes through a second set of capillaries in the liver before returning to the heart.

How is the circulation of blood maintained?—The circulation of blood is effected as follows: The muscular ventricles pump the blood into the arteries. The valves between the ventricles and arteries prevent the reflux of blood. The fine capillaries, because of their immense number and small size, exert a certain resistance so that all the blood thus pumped out of the heart can not at once pass through them. The walls of the arteries are elastic and hence expand to ac-



commodate whatever blood fails to pass through the capillaries during the heart beat. The elasticity of the walls of the arteries exerts sufficient constant pressure to force the blood through the capillaries between heart beats. In this way the amount of blood passing through the capillaries between heart beats equals the whole amount that leaves the ventricle at each succeeding beat, and a constant flow is kept up.

The blood rushes very rapidly through the arteries, slowly but steadily through the capillaries, and moderately slowly through the veins.

During diastole the chambers of the heart enlarge and fill up with blood from the veins. During systole this blood is forced into the arteries.

The pulse.—During systole, a wave of muscular contraction begins in the auricles and ends in the ventricles. This sudden and forcible contraction of the heart causes a wave of contraction to run throughout the whole length of the arterial

FIG. 165. Diagram of circulation. 1, heart; 2, lungs; 3, head and upper extremities; 4, spleen; 5, intestine; 6, kidney; 7, lower extremities; 8, liver. (After Dalton.)

system. This is the *pulse wave.* It may be detected by the tip of the finger where the artery lies near the surface, as in the wrist, and the rate of the heart beat counted. This we call "feeling the pulse." It is used by physicians to determine the condition of the heart; for conditions affecting the heart will change the rate of the pulse beat.

Sounds of the heart.—The heart in action makes two sounds, one—a long sound (lub), caused by contraction, and another—a short sound (dub), caused by the closing of the valves. These strokes are repeated about seventy-two times a minute, day and night.

Nervous control of the circulatory apparatus.—When an organ is at work it needs a greater supply of blood than when at rest. After a meal the stomach and intestines need a large amount of blood. During exercise, the muscles need a large supply.

The caliber of the arteries of any organ is increased or decreased according to the needs of the organ. During activity of the organ, the caliber of its arteries is increased, and hence the organ receives an increased supply of blood. During rest, the caliber of the arteries is reduced and hence part of the blood supply is shut off.

This increase and decrease of the caliber of the blood-vessels is effected by the nervous system. There are *augmenting* (hastening) and *inhibiting* (checking) nerve fibers, passing from central nervous ganglia to each blood-vessel.

Effects of exercise upon circulation.—During muscular activity, or exercise, the muscles need a large supply of blood. The arteries of the muscles dilate and the heart increases the rapidity of its beat. This results in a rapid supply of blood to the lungs, a quick exchange of carbon dioxide and oxygen, and a large supply of oxygen to the muscle. In the muscle rapid metabolism is in progress which, if not overdone, invigorates the whole system. The heart may be weakened by over exercise or by vigorous exercise at long intervals only. The heart must be trained by well regulated exercise to respond to all demands upon it.

Regulation of heart action.—If a heart is cut off from the living body it goes right on beating for a while. This shows that cardiac or heart muscle differs from any other, since it does not require an impulse from the central nervous system to keep up its movements.

Inhibitory and acceleration fibers.—The heart is, however, supplied with two kinds of nerve fibers which regulate the force and rate of the heart beat. The acceleration fibers stimulate the heart to beat stronger and faster. The inhibitory fibers slow the beat and lessen its strength. The nerve centers where these fibers originate are believed to be stimulated by the products of muscular activity resulting from metabolism. Thus the activity of one organ regulates the activity of another and the work of one is adjusted to the demands of the other.

Treatment of cuts and bruises.—In cases of injury where the skin is broken, special precaution must be taken in dressing the wound to prevent bacteria or other microbes from infecting the wound and thus gaining entrance into the circulation. Lockjaw and blood poisoning are diseases that result from such infection. The first thing to do, therefore, is to wash the wound and the skin about the wound with a clean cloth or bit of absorbent cotton and soap, and apply a disinfectant such as weak corrosive sublimate (1 part to 100 parts water) or peroxide of hydrogen. If a large artery is cut, the high pressure in the arteries will cause the blood to flow out in spurts. In this case, the artery must be bandaged between the wound and the heart. To do this press the artery firmly with the finger until the blood ceases to flow. Then have someone tie a knot in a handkerchief or bandage and twist this loosely about the limb with the knot applied over the artery. Place a stick under the bandage, and twist it until the constriction is sufficient to check the flow of blood. If a vein is cut the blood will simply ooze out and may of itself form a clot that will stop the wound; if not, the blood flow may be stopped by applying a bandage over the wound, first disinfecting it and drawing the edges of the wound together.

In the case of a bruise, the skin is not broken, but the tissue or blood-vessels beneath the skin are crushed. This may cause a swelling and a dark appearance by the collection of blood and lymph at the spot. Gentle rubbing or a hot or ice-water application will ease the pain and keep down the swelling.

Effects of alcohol on circulation.—The use of alcohol may seriously affect the distribution of blood in the body. By weakening the inhibitory impulses, the blood-vessels of the skin become permanently dilated or enlarged so that a large amount of blood is found in the skin. This disarranges the normal adjustment of blood in the tissues. Such a disarrangement is more serious in cold than warm weather because it results in much loss of heat to the body.

CHAPTER XXIV

THE SKELETON AND MUSCLES

Two very important tissues of the body are the bones and muscles.

The skeleton (fig. 166A).—The bones, of which there are some two hundred or more in the body, are arranged and joined in such a way as to form the *skeleton*. The skeleton fulfills three purposes:

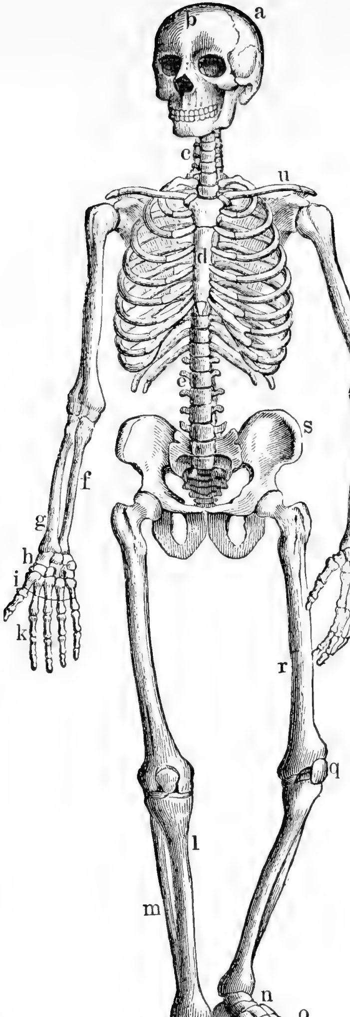
(1). It is made use of by the muscles to enable the body parts and the whole body to move about and handle things.

(2). It forms a framework to protect the delicate organs of other systems.

(3). It gives form and rigidity to the body.

In man, as in other vertebrate animals, the *axial skeleton* is formed of the bones of the skull, vertebral column or backbone, ribs, and sternum. The bones of the skull protect the brain. The vertebral column encloses the long dorsal nerve cord. The long, flat, curved ribs, articulating at the back with the vertebral column and in front with the sternum, protect the heart and lungs in the thoracic cavity (fig. 159). The large hip bones (pelvic bones, figs. 166, S and 159, P) form a sort of basket for the support of the organs of the abdominal cavity.

The bones of the legs and arms form the *appendicular skeleton*. The leg bones articulate with or join the pelvic bones, *pelvic girdle*, and the arm bones articulate with the shoulder bones, or *pectoral girdle*. A comparison of the skeleton of the toad (fig. 9) with that of man (fig. 166 A) shows that while the different bones vary in relative size and shape, the same regions are laid down in each.



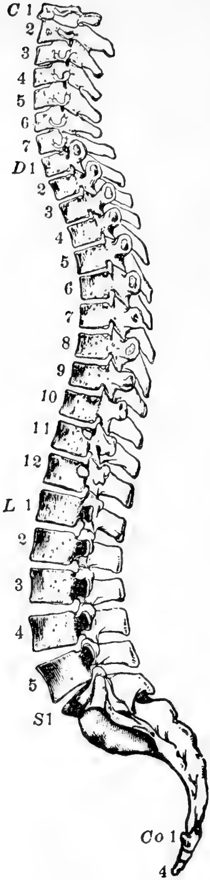


FIG. 166 B. Side view of spinal column. C-1 to 7, cervical vertebræ; D-1 to 12, dorsal vertebræ; L-1 to 5, lumbar vertebræ; S. 1. sacrum; Co. 1-4 coccyx. (After Martin.)

FIG. 166 A. Bony and cartilaginous skeleton. *a*, left parietal bone of cranium; *b*, frontal bone; *c*, cervical vertebræ; *d*, sternum; *e*, lumbar vertebræ; *f*, ulna; *g*, radius; *h*, carpals; *i*, meta-carpals; *k*, phalanges; *l*, tibia; *m*, fibula; *n*, tarsal bones; *o*, metatarsals; *p*, phalanges; *g*, patella (knee-pan); *r*, femur; *s*, pelvis; *t*, humerus; *u*, clavicle. (After Martin.)

The vertebral column (fig. 166).—The long backbone in man is composed of separate ringlike pieces, called *vertebræ*, placed one above the other. Each has several lateral projections for the attachment of muscles and for interlocking adjacent vertebræ. The vertebræ are held together by strong ligaments, passing from one vertebra to another. The first seven vertebræ are called *cervical* or neck vertebræ. The next twelve are the *dorsal* vertebræ. To each one of these is attached a pair of *ribs*, as shown in fig. 167. The last five are the *lumbar* vertebræ. The single large bone below the lumbar vertebræ is the *sacrum* and the curved tip at the end is the *coccyx*. The sacrum is really composed of five vertebræ fused together, and the coccyx of four bones fused into one. Each of the twenty-six vertebræ differs a little in shape from its neighbor, but all are nicely adjusted to one another.

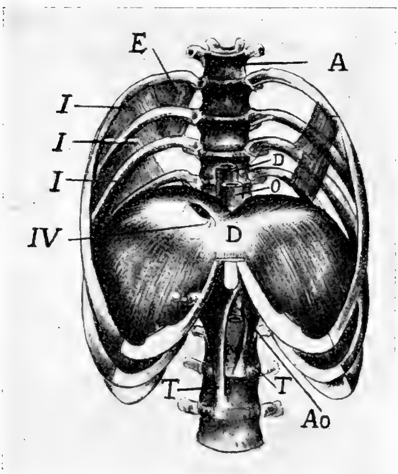


FIG. 167. Lower half of thorax with dorsal and lumbar vertebræ. A, sixth dorsal vertebræ; Ao, aorta; D, (lower) diaphragm; D, (upper) aorta passing through diaphragm; I, intercostal muscles; O, oesophagus; IV, opening in diaphragm for vena cava ascending; T T, tendons of right and left crura attaching diaphragm to 3rd, and 4th lumbar vertebræ. (After Allen Thomson.)

Between the vertebræ are pads of elastic *cartilage*. These act as cushions and prevent jarring of the vertebral column.

The ribs.—The ribs, articulating with the twelve dorsal vertebræ, are held in place by sheaths of connecting muscles (fig. 167). Each of the first seven ribs is attached to the *sternum* or breast bone by a rod of cartilage. The cartilaginous ends of the next three join with the cartilage of the seventh, while the remaining two are the so-called floating ribs, joined only to the vertebral column (figs. 166 A, and 159).

The skull (fig. 168).—The skull is formed by the union

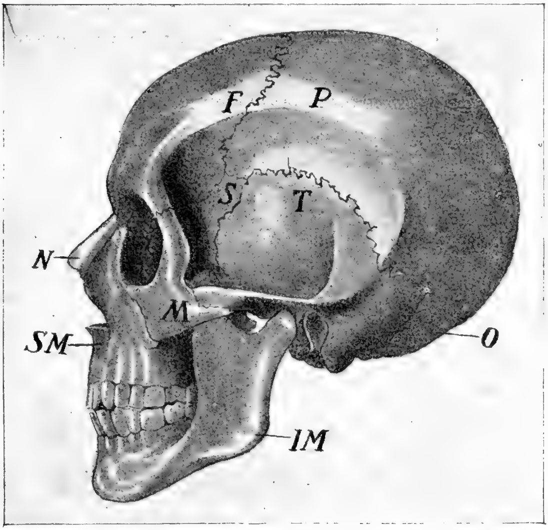


FIG. 168. A side view of the skull. F, frontal bone; P, parietal; S, sphenoid; T, temporal; N, nasal; M, malar; S M., superior maxilla; I M., inferior maxilla; O, occipital. (After Martin.)

of the *cranial* and *facial* bones. They are so fitted to one another that they completely enclose the brain. Some are perforated to admit the passage of nerves and blood-vessels. The *sphenoids* and *ethmoid* bones form the floor of the cranium. The *occipital* bone (*O*) lies at the back of the skull. The *temporal* bones (*T*) form the sides. Within the temporal bones are embedded the channels of the inner ear.

The *parietals* (*P*) lie above the temporals and meet on the top of the head. The *frontal* bone (*F*) covers the front part of the brain and forms part of the bony socket that protects the eye. The facial bones are those forming the jaws, the sides of the nose and the roof of the mouth.

Support of the skull.—The first spinal vertebra, the *atlas*, supports the skull. This bone articulates movably with the second vertebra called the *axis*, and permits of much movement, as nodding, turning the head, etc.

Pelvic and pectoral girdles.—The large *pelvic* bone (fig. 166 A-s) forms the pelvic girdle and contains the socket of the hip-joint (fig. 171), by means of which the legs are articulated with the axial skeleton.

The collar bones (*clavicles*) (fig. 159 C) and shoulder blades (*scapulas*) (fig. 159 S) form the pectoral girdle. The collar bones, one on either side, may be felt just beneath the neck. They articulate with the sternum in front and at their outer extremities with the upper bone of the arm. The two large shoulder blades at the back, the scapulas, are held in place merely by muscles attached to the ribs. At their outer ends they also articulate with the humerus. The pectoral girdle articulates with the axial skeleton through the clavicles only. This adjustment permits a wide range of motion to the arms.

Structure of a long bone.—A bone in a prepared skeleton, or one picked up in the field after it has been exposed to the weather for a long time, shows only the mineral matter of which it is composed. It has lost all of its organic or living material. A fresh bone, procured from the butcher, shows the features indicated in fig. 169. At each end is an enlargement or head, with certain protuberances for the attachment of muscles. The ends are capped with dense white elastic tissue or cartilage (fig. 170 *d*). These are the surfaces that articulate with other bones. The central shaft (fig. 169, x-z) is covered with a sheath of connective tissue,

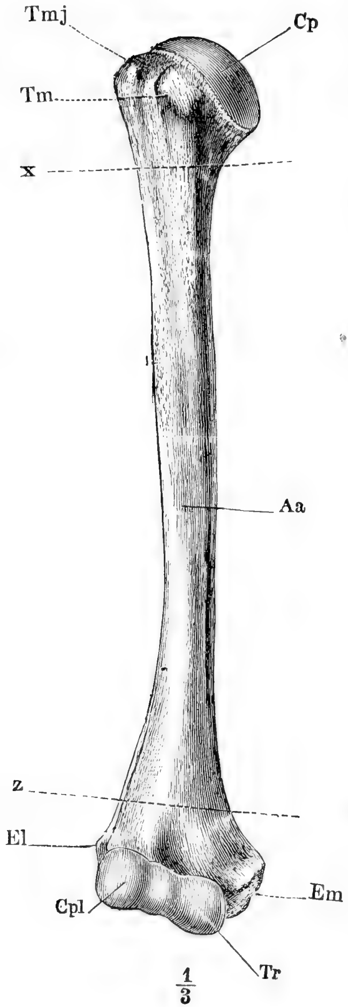


FIG. 169. Right humerus seen from in front. Cp, rounded surface of upper extremity; Tr, Cpl, rounded surfaces of lower extremity. Tmj, Tm, El, Em, prominences for attachment of muscles; Aa (x--z) central shaft. (After Martin.)

the *periosteum*, which is bone-forming material. Surfaces for articulation with other bones are smooth and covered with cartilage (Cpl, Tr and Cp).

A bone, sawed through the middle, as shown in fig. 170, exposes a dense layer of hard bone (b) enclosing, at the ends, a spongy mass of bone tissue (c), the spaces of which are filled with red *marrow*. Here red blood corpuscles are formed. The shaft encloses a space filled with yellow marrow (a). This is rich in fat and gelatin. This structure secures the maximum of strength for a given amount of bone material. In the ribs, or other flat bones, the entire outer wall is dense and hard, while the entire central part is made up of a spongy mass of bone filled with red marrow.

Chemical composition of bone.—Bone is formed from materials taken into the body with the food, chiefly lime, salts (mineral matter) and organic compounds. Place a small bone in dilute hydrochloric acid and leave it for several days. The acid will dissolve out the mineral matter, leaving the soft parts, the cartilage at the ends, the periosteum and the organic matter of the bone tissue. The bone so decalcified does not lose its shape but can be twisted and bent without breaking. Burn a bone in the fire. The organic matter disappears leaving the mineral matter only, which is now white and brittle. The animal matter, therefore, gives the bone flexibility, while the mineral matter gives it stiffness.

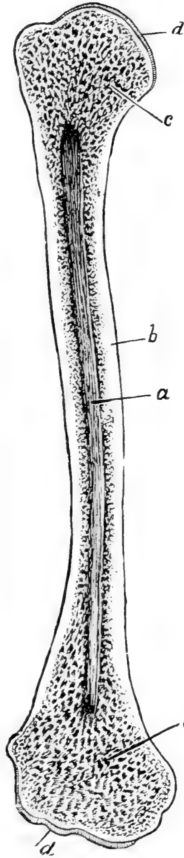


FIG. 170. Humerus, bisected lengthwise. *a*, marrow-cavity; *b*, hard bone; *c*, spongy bone; *d*, articular cartilage. (After Martin.)

Bone is nourished by blood that passes in blood-vessels through the periosteum into a series of microscopic canals that perforate the bone tissue.

Joints.—Movements between the limbs are accomplished by *joints* or *articulations*. There are four classes of joints, the *ball and socket*, like that of the femur or leg with the hip bone; the *hinge joint*, as at the elbow or ankle; the *gliding joint*, as the wrist and knee joints; and the *pivot joint* as exhibited by the articulation of axis and atlas in the neck. Figure 171 shows a perfect example of a ball and socket joint, the hip joint. On the left, the femur is shown held in place by bands of strong ligaments (H L) attaching it to the pelvic bone, and so arranged as to give perfect freedom of movement. On the right, these bands have been cut away to show the rounded head of the femur (*F*) fitting exactly into the socket and attached to its base by the *capsular ligaments.*

The surface of the ball and of the socket are each covered with a smooth elastic cartilage to prevent friction. Covering the inside of the ligaments there is a thin membrane, the *synovial membrane*, which secretes a thick viscid fluid

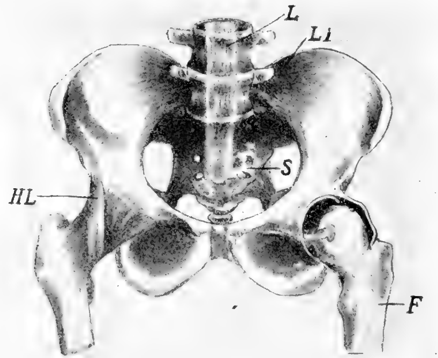


FIG. **171.** Articulation of pelvis and hip-joint seen from before. (The anterior half of the capsular ligament of the left hip-joint has been removed and the femur rotated outwards.) F, femur; H L, capsular ligament of hip-joint; S, sacrum; L, vertebral ligament inserted on sacrum; L I, ligaments inserted on vertebræ. (After Allen Thomson.)

called *synovial fluid.* This acts as a lubricating fluid for joints.

In a hinge joint, as at the elbow, the bones are so connected as to admit of motion in only two directions, like a door upon hinges.

Dislocation, fractures and sprains.—A dislocation occurs when the bones of a joint are forced out of place. The bones must be replaced at once by a physician. In the meantime the pain may be relieved by hot or ice cold applications.

Fractures.—A fracture is a break in a bone, and usually injures the periosteum and other tissues connected with the bone. In an accident of this kind the physician brings the two ends of the bones together and binds them between splints until new bone is formed and the fracture healed.

Sprains.—The tearing, or pulling out of place, of a ligament and muscles in the region of a joint results in a sprain. The physician must bandage a sprain tightly and the patient must rest the injured parts for many weeks. Relief from pain before the physician comes is afforded by hot applications and by arnica or other liniment.

Comparison and composition of skeleton of child and adult.—In very early life many of the bones are formed of cartilage. Later the real bone tissue is formed that supplants the cartilage except in the region of the joints. In youth, when bone tissue is first formed it is comparatively soft and flexible, the living or organic part far exceeding the mineral matter. It is for this reason that bones are less easily broken and more quickly repaired in youth than in age. It is for this reason also that young people must exercise much care in standing, walking and sitting correctly, for in youth the skeleton is sometimes permanently deformed by incorrect usage.

THE MUSCLES

Arrangement and structure.—The muscles in the human body, as in all animals, are the active organs of motion and locomotion. Each muscle constitutes a separate organ, composed of a mass of fibers collected in bundles and imbedded in connective tissue. The *biceps muscle* is a mass of muscle fibers on the front part of the upper arm. When the arm is hanging by the side at rest the muscle feels soft. It is then *relaxed* and at its greatest length. When the arm is bent at the elbow, the muscle is harder, shorter and bulges slightly. It is now *contracted.* Fig. 173 shows this muscle in both relaxed and contracted position. A muscle like the

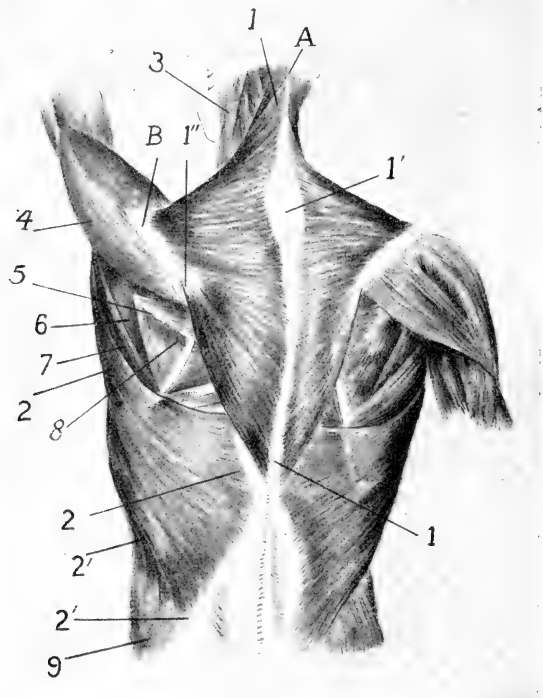


FIG. 172. Superficial muscles of trunk, shoulder and back viewed from behind. A, external occipital protuberance; **1-1**, trapezius muscles; **1′** oval tendon between right and left trapezius; **1″** insertion of trapezius; B, summit of shoulder (acronium); 2-2′, lateral muscle and insertion; 3, sterno-mastoid; 4, deltoid; 5, infraspinatus; 6, teres minor; **7**, teres major; 8, rhomboideus major; **9**, part of external oblique muscle of abdomen. (After Allen Thomson.)

biceps is attached to two bones by strong white elastic cords or *tendons.* One of the attachments serves as a fixed point or point of *origin* of the muscle; the other as the point of *insertion.* As the muscle shortens, the bone upon which the muscle is inserted moves. In the biceps, the shoulder blade is the point of origin, the radius of the forearm, the point of insertion. Fig. 174 shows other muscles of the forearm, inserted by tendons. In some parts of the body, as in the back, the muscles lie in sheets, one upon the other, and are attached at different places on the bones so as to render many movements possible (fig. 172).

Certain sets of muscles are used for holding the body erect; others are used in moving the whole body, as in walking, running or leaping; others for moving parts of the body as the arms, the jaws, the eyelids, eyes, etc.

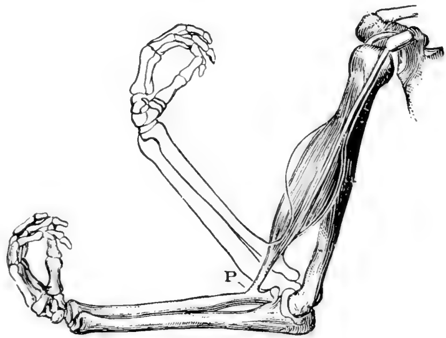


FIG. 173. Biceps muscle and bones of arm, illustrating flexion of elbow joint when muscle contracts. (After Martin.)

These muscles are entirely enclosed in a sheath of connective tissue called *perimysium.* This becomes extended at the ends as tendons. From the inner side of this sheath partitions pass inward, separating the groups of reddish muscle fibers into larger and smaller bundles, and binding all together into a distinct muscle. These partitions, or septa, also afford support to the numerous blood-vessels and nerves with which each muscle is supplied. Muscles of this type have been called *voluntary* muscles because they are for the most part under the control of the will. Such muscles are also called *striated* muscles from their cross-striated appearance shown under the microscope.

There are certain other muscles that form expanded membranes for enclosing cavities. These have no definite point of insertion. Such a sheet of muscle by its contractions and relaxations exerts a pressure that affects the movements of the contents of the cavity. Examples of this we have already found in the case of the muscles of the heart and arteries. Such also are the muscles of the oesophagus, stomach and intestines. Muscles of this type have been called *involuntary* muscles because they are regulated by the nervous system without any control of the will. Under the microscope these muscles present no appearance of striations and so have been called *non-striated* muscles.

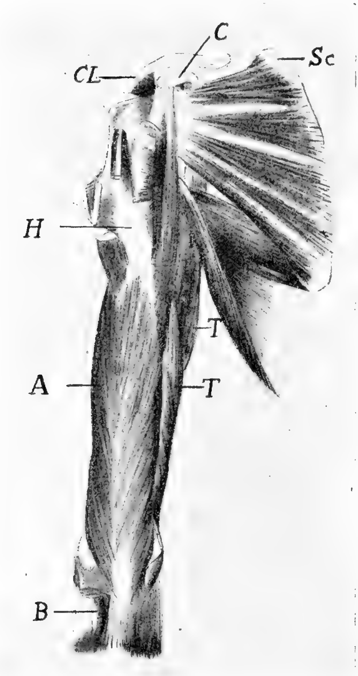


FIG. 174. Deep view of muscles and tendons of right shoulder. A, brachialis anticus; B, tendon of insertion of biceps (biceps removed); C, coracoid process of scapula; Cl, clavicle; H, humerus; Sc, scapula with attached subscapularis muscle. T-T, triceps. (After Allen Thomson.)

Blood and nerve supply.—Since every muscle of the body must be well supplied with nutriment and oxygen for its metabolism and for the work it performs, all muscles of the body are richly supplied with blood capillaries. These penetrate the connective tissues that separate the muscle fibers.

To each muscle also a nerve passes, distributing its nerve fibers through the connective tissues to the muscle cells. Without its nerve-supply, any muscle would be useless, for the nerve centers must initiate and control every motion.

Hygiene of muscles; necessity for exercise.—Muscular activity is absolutely essential to healthy living, and should therefore be as much a daily habit as eating or sleeping. Take a vigorous walk for a mile or two and note the result. The day may be cold, but the body is soon aglow with warmth, the heart beats more vigorously, the breathing is deep and invigorating. What is taking place in the body? The muscles are undergoing chemical change. Carbon dioxide and other wastes are being thrown into the blood, and large quantities of heat are being liberated so that the temperature of the body rises considerably. This calls for a rapid supply of blood to the muscle cells, that there may be a sufficient supply of food and oxygen. The heart responds by a quickened beat, driving the blood to the needy tissues. The heat regulating apparatus is brought into play. The small arteries of the skin dilate, and perspiration, laden with water and waste, is secreted by the glands of the skin. The blood-vessels of the internal organs constrict, reducing the blood flow to these organs. The respiratory movements become deeper and more frequent, and, probably most beneficial of all, the lymph circulation in the tissues is improved. The lymph having no propelling organ like the blood, is dependent upon the bodily movements, particularly the muscular movements, for its flow.

Muscular activity not only aids in the proper circulation of food and oxygen, but in keeping the muscles at a proper tension. An unused muscle becomes soft and flabby, and tires easily when demands are made upon it. Those forms of exercise are most valuable that call into play the greatest number of muscles. Walking is perhaps the best exercise because it exercises most of the body muscles and the muscles of the lungs and heart, and so "tones" up the whole system. Exercise, to be of most value, should be regular. It should not be taken immediately after a meal, because then blood would be withdrawn from the digestive system at a time when it is particularly needed there.

Fatigue and rest.—A feeling of weariness or muscular fatigue follows prolonged exercise at irregular intervals, or exercise of muscles occasionally used. If the heart has not been trained by constant exercise to keep up a vigorous movement of the blood, or if the heart is overworked, the waste matter (carbon dioxide and urea) produced by muscular activity accumulates in the tissues and the feeling of fatigue follows. Thus the waste products, as such, fulfill an important function as indicators that rest is needed. A rest of a few minutes, even, gives the blood time to carry off the waste; and the feeling of fatigue ceases.

CHAPTER XXV

RESPIRATION AND EXCRETION

RESPIRATION

Cell breathing.—Cell breathing, the exchange of carbon dioxide for oxygen, or the process of oxidizing the living cell, is the essential act of respiration.

The amœba takes its oxygen from the water which surrounds it, and discharges its carbon dioxide into the water. Cells of the body take their oxygen from and discharge carbon dioxide into the lymph which surrounds them. From the lymph carbon dioxide passes into the blood. The blood carries it to the lungs. The respiratory or breathing apparatus is a mechanism for supplying the blood with its needed oxygen and for removing from the blood its load of carbon dioxide. The apparatus may be considered to consist of the *lungs* and the *air passages* leading into them.

Position and structure of the lungs.—The lungs (figs. 175 and 159 R. L., L. L.) fill the greater part of the thoracic cavity. This cavity is lined by the *pleural membrane* which folds neatly back over all the organs in the cavity. The lungs are therefore suspended within this sac of pleural membrane. The portion of the membrane covering the lungs is separated from the portion lining the thoracic cavity by a liquid which reduces friction between the two walls. The lungs are shaped to fit around the heart which also lies in this cavity. The thoracic cavity is completely divided into two parts by a partition of connective tissue, within which lie the *trachea*, the oesophagus and large blood-vessels. One lung lies on either side of the partition. The trachea (fig. 175, 3) divides within the membranes into two branches or *bronchi* (fig. 175, 4) which pass through the membrane into the lungs. The bronchi divide, in the lungs, into smaller and smaller

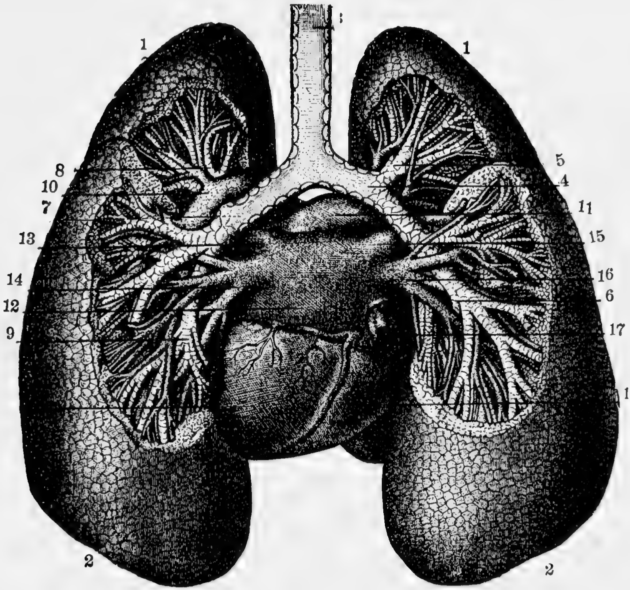


FIG. 175. Bronchi and lungs, posterior view, showing position of heart. 1, 1, summit of lungs; 2, 2, base of lungs; 3, trachea; 4, right bronchus; 5, branch to upper lobe of lung; 6, branch to lower lobe; 7, left bronchus; 8, branch to upper lobe; 9, branch to lower lobe; 10, left branch of pulmonary artery; 11, right branch; 12, left auricle of heart; 13, left superior pulmonary vein; 14, left inferior pulmonary vein; 15, right superior pulmonary vein; 16, right inferior pulmonary vein; 17, inferior vena cava; 18, left auricle of heart; 19, right ventricle. (After Sappey.)

branches, each culminating in a minute vessel or *bronchiole* (fig. 176) which ends in a small air sac or *alveolus*. The lungs are in reality masses of these tiny air sacs surrounded by connective tissue. It is through the thin walls of the alveoli that the interchange of carbon dioxide and oxygen, which results in freshening the blood, is made.

Air, during respiration, enters through the nostrils into the pharynx (figs. 156, 157). From the pharynx it passes through the glottis into the larynx and trachea. The larynx is the *voice-box*. The glottis is the opening of the voice-box, closed at times by a flap called the *epiglottis*.

The respiratory and the digestive paths cross in the pharynx. During respiration, the epiglottis is open giving free passage for air into the trachea. During feeding it closes over the glottis (fig. 157) so as to admit the passage of food into the oesophagus only.

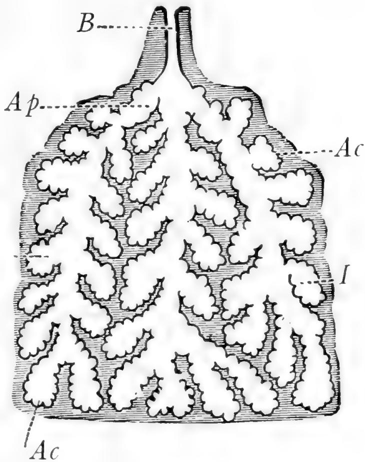


FIG. 176. A bronchiole. B, entrance; A p, alveolar passage: A c, air cells; I, infundibulum, or pouch into which the air cells open.

The heart lies in such a position (fig. 175) as to be able to send the blood through the pulmonary arteries directly into the lung tissues. The connective tissue lying between the alveoli contains a mass of pulmonary capillaries, and each one of the infinite number of red blood corpuscles is exposed separately to the air in the air cells. By this means the hæmoglobin of the blood corpuscles is kept saturated with oxygen.

The mechanics of breathing movements.—Breathing consists of inspiration, or taking the air through the air passages into the air sacs of the lungs, and expiration, or forcing air from the air sacs of the lungs out through the air passages and nostrils.

To accomplish an inspiration, the thoracic or pleural cavity must be enlarged. The pleural cavity is completely enclosed, being bounded on the front by the sternum, on the sides by the ribs with their intercostal muscles, and on the back by the backbone. The *diaphragm* forms the floor of the cavity. This is a dome-shaped sheet of muscle (figs. 159, D and 167, D) convex upward. In ordinary breathing, the muscles between the ribs, called intercostal muscles (fig. 167, I), the muscles between the backbone and ribs, called elevators of the ribs, and the muscles of the diaphragm are all brought into play. Contraction of these muscles elevates the ribs and lowers the diaphragm, thus enlarging the cavity. The air rushes in through the air passages and enters the lungs, expanding the elastic lung tissue until it fills the enlarged thoracic cavity. Immediately following inspiration the diaphragm assumes its normal position, the intercostal and elevator muscles relax, and thus the size of the pleural cavity is reduced. The pressure of the walls of the thorax upon the lungs forces the air out and expiration takes place.

The walls of the thorax move rhythmically normally sixteen or eighteen times a minute. This rate is increased during exercise.

Composition of inspired and expired air.—The essential components of air, from a physiological standpoint, are oxygen, nitrogen and carbon dioxide. There are a few other elements, but they have not been shown to have any physiological significance. There are also accidental constituents of the air varying with the locality.

The following table, given by Howell, represents the composition of ordinary inspired and expired air.

	Nitrogen	Oxygen	Carbon dioxide	Water
Inspired	79	20.96	0.04	
Expired	79	16.02	4.38	.60

The air loses 4.94 parts of oxygen in the lungs, and gains 4.34 parts carbon dioxide and .6 parts of water. Notice that the amount of gases inspired equals the whole amount of gases and water expired. This indicates the character and amount of exchange that has taken place in the blood during its pulmonary circulation. The blood is thus aerated in the lungs. The presence of carbon dioxide in expired air may be demonstrated by breathing through a straw into lime water. Carbonate of lime will be formed, giving the liquid a milky appearance. The presence of water, as vapor, is easily demonstrated by breathing upon glass.

Quantity of air breathed.—The lung capacity after the deepest inspiration is, in a grown person, about 330 cubic inches of air. About 30 cubic inches are inspired and expired during each ordinary act of breathing. This is known as *tidal air*. During the deepest possible inspiration about 230 cubic inches of air enter the lungs. This represents the vital capacity of the lungs. There is therefore at all times at least 100 cubic inches of air in the lungs. This is the *residual air* which is kept aerated by diffusion from the tidal air. Thus there is a constant supply of air in the lungs. This allows continuous exchange between the blood and lungs, while the exchange between the outer air and the lungs is intermittent.

Hygienic habits of breathing.—Breathing should be habitually deep in order to use all the parts of the lungs and to have as large an amount of tidal air as possible passing in and out of the lungs.

Occasionally the lungs should be tested to their fullest capacity by the deepest possible inspirations. This not only effects as perfect ventilation as possible, but exercises the respiratory muscles to their utmost extent, and exercise of these develops the capacity of the lungs.

Effects of exercise upon breathing.—During exercise there is an increased rapidity of tissue respiration. During exercise also, the heart responds with a quickened beat and the blood is carried more rapidly to the lungs. All this quickens the movements of the respiratory apparatus so that ventilation of the lungs may be more immediate and complete.

This shows that the circulatory apparatus and the respiratory apparatus must work together. Deep breathing would be of no avail were the heart not ready to respond by a vigorous beat. When we run too hard, we get "out of breath." This really means that the heart has become fatigued, that it has been pushed beyond its normal capacity.

Exercise must therefore not be excessive, but it must be vigorous and regular so as to keep the heart in training for the demands upon it.

Effects of tight clothing on respiration.—Anything that binds the walls of the thorax restricts the movements of the respiratory muscles, the muscles of the ribs and diaphragm. The result is that certain lobes of the lungs fail to enlarge and hence remain unventilated. It is said that more than sixty per cent of the beginnings of lung troubles are found in the unused portions of the lungs.

Suffocation and artificial respiration.—Suffocation results from depriving the lungs of oxygen. This may be brought about by poisonous gases in the air, by obstruction of the windpipe, or by drowning. Death may be prevented in cases of suffocation if artificial respiration is resorted to immediately. In artificial respiration the chest is expanded and contracted artificially so as to induce an inflow of air into the lungs. Three methods have been suggested. In the first method the subject is placed face downwards and pressure is exerted upon the back, then the body is rolled from this to a lateral position. The second method is to place the patient upon his back; then raise the arms above the head and body, and bring them down against the sides of the chest so as to compress the chest. A third method is to lay the subject face downward, placing a thick folded garment beneath the chest. "The operator then puts himself athwart or at the side of the subject, facing his head and places his hands on each side of the lower part of the back. He then slowly throws the weight of his body forward to bear upon his own arms, and thus presses upon the thorax of the subject and forces air out of the lungs. This being effected, he gradually relaxes the pressure by bringing his own body up again to a more erect position, but without moving the hands. These movements are repeated regularly, twelve to fifteen times per minute until normal respiration begins or its possibility is abandoned. It may require a half hour or more before independent breathing movements start."

Ventilation.—Ventilation is the circulation of the air of rooms or buildings by means of which fresh air is brought into the room and impure air removed. It may be accomplished by opening windows or by a mechanical "system" such as is often used in public buildings. An open fire place is a good ventilator. Ventilation must be rapid enough to remove vitiated air but not so rapid as to cause a draft.

Where many people occupy the same room some system of ventilation must be maintained or the supply of oxygen would soon be exhausted. If we always lived in the open air, as our ancestors did, there would be no need for artificial ventilation.

Foreign substances in the air.—In the air there is a large amount of floating dust, as we can see by observing the path of a ray of sunlight in the room. The cilia and hairs that line the air passages normally prevent this dust from entering the bronchial tubes. When rooms are carefully and frequently cleaned and dusted with a damp cloth the amount of dust in the air in an ordinary room is at a mininum and is not injurious. If the room is carelessly swept and dusted, the amount of dust in the air may be positively injurious. The dust may, in addition, contain germs of diseases. This is especially true in the sick room. Therefore the sick room should have special care and no one should enter except the nurse or caretaker.

EXCRETION

Besides the carbon dioxide that is thrown into the blood by the tissues, during their activity, certain nitrogenous compounds (the wastes) are also eliminated by the cells. As there is a special apparatus for removing the carbon dioxide from the blood so there are special organs for removing the nitrogenous wastes. These are the organs of excretion. They consist of the *skin* and *kidneys*. The manner of removal of nitrogenous waste from the blood is quite as interesting as the manner of removal of carbon dioxide.

THE KIDNEYS

Structure of the kidneys.—The human kidneys are located in the dorsal (lumbar) region next to the backbone and immediately beneath the diaphragm. There is one kidney on each side. A duct, or *ureter*, passes from each kidney to the *urinary bladder*. If a kidney is cut through crosswise (fig. 177) the ureter (u) is seen to widen into a cavity (p), the *pelvis* of the kidney. From the pelvis, branches, called *calices*, extend into the kidney substance. Of the solid part of the kidney there are two layers, the *cortex* (c) and the *medulla* (m). The medulla is divided into *pyramids* (pyramids of Malpighi) whose small ends (o) are directed into the pelvis.

The *renal artery* (R. A.) enters the kidney at the *hilus*, or depression on the inner side of the kidney below the ureter, and the branches of the *renal vein* (R. V.) leave it above the ureter.

The pyramids in the medulla are composed of hundreds of microscopic *tubules* (T). These open by minute pores at the points of the pyramids into the calices of the pelvis. They extend back through the medulla and convolute or wind about in the cortex. Here they form multitudes of tiny capsules which surround a network of capillaries. The branches of the renal artery pass into the connective tissue of the cortex, giving off a few branches to the pyramids.

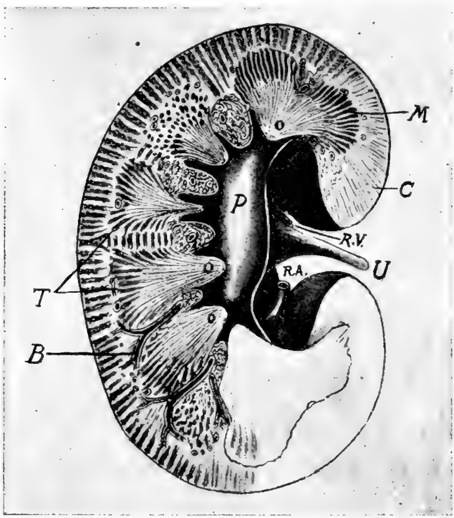


FIG. 177. Longitudinal section through the kidney, (pelvis and a number of renal calices). U, ureter; C, cortex; M, medulla; P, pelvis; T, tubules; B, blood vessel (arterial branch); R. V., branch of renal vein; R. A, branch of renal artery. O, O, pyramids. (Tyson after Henley.)

Then a branch enters each tiny capsule where it breaks up into a little ball of capillaries called a *glomerulus*. From the glomerulus a tiny vein passes to the tubules and there again breaks up into capillaries. This network of capillaries finally becomes the branches of the renal vein. These leave the kidney to carry the blood back again to the heart by way of the vena cava ascending.

The cells which line the capsules and part of the tubules are secreting cells (somewhat similar to those of the salivary glands and of the pancreas). These cells secrete water, inorganic salts and organic wastes (urea, etc.) from the blood. Thus the blood gets rid of its load of waste products. These accumulate in the tubules drop by drop, and finally exude into the calices and into the pelvis of the kidney and are then carried away to the bladder.

The amount of urine formed depends chiefly upon the quantity of blood sent to the liver and upon the healthful action of the kidneys. The wastes of the tissues, constantly accumulating in the blood, are as constantly being removed by the kidneys.

Cool temperature, the drinking of large quantities of water and the use of proteid food favor the healthy action of the kidneys.

THE SKIN

The skin is a complex organ of the body that performs several functions:

1. It protects the underlying structures as a covering.
2. It regulates the temperature of the body.
3. It receives the stimuli from without, by means of which the body is guided in its behavior.
4. It serves as an excretory organ.

Structure of the skin.—The skin consists of two layers (fig. 178), the *epidermis* (a), an outer or superficial layer, and the *dermis* (d), a deep layer or true skin.

The epidermis is composed of epithelial cells. The outer layer consists of flattened or dead cells that are constantly peeling off. This is sometimes called the *cuticle.* The inner cells of the epidermis are live growing cells, constantly dividing and forming new cells to take the place of those lost from the surface. The inner cells of the epidermis contain pigment granules which give the skin its color. On the palms of the hands and soles of the feet the cuticle becomes quite horny in structure.

The dermis or true skin is largely composed of connective tissue with a mass of blood-vessels, nerves, sweat glands and

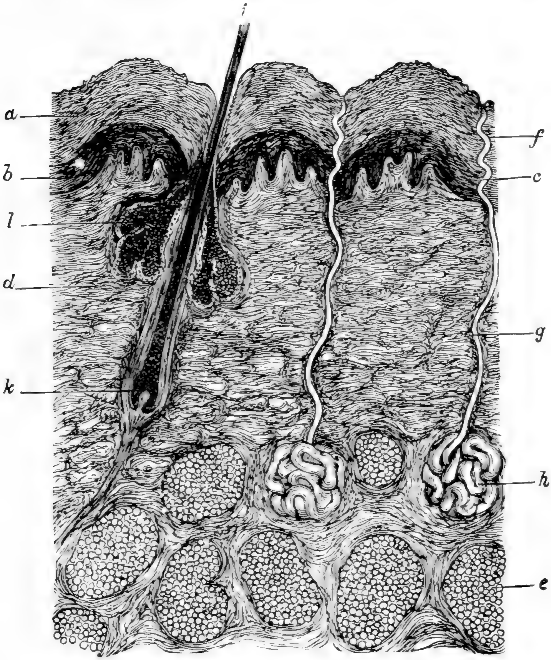


FIG. 178. Section perpendicularly through skin. *a*, epidermis; *b*, pigmentary layer of epidermis; *c*, papillary layer of dermis; *d*, dermis or true skin; *e*, fatty tissue; *f*, *g*, *h*, sweat glands and duct; *i*, *k*, hair with its follicle and papilla; *l*, sebaceous gland. (After Brubaker.)

hair follicles. This part of the skin is very sensitive owing to the numerous tactile corpuscles which are the end-organs of the nerves (fig. 183).

Nails.—The nails are modified epidermal cells. The growing part of the nail is embedded beneath the skin at the base of the nail. The nail protects the ends of the fingers and renders them more useful.

Hair.—Hair is similar to the nails in formation, that is it is epidermal in origin. A section of a hair shows it to be a long hollow shaft embedded at its base in a socket of dermis called a *hair follicle* (fig. 178, k). The socket is lined with an epithelial layer. The growing part of the hair is the *papilla* at its base. This is supplied with blood-vessels and sensitive nerves. These nerves are stimulated when a hair is pulled. Connected with each hair follicle is a tiny oil-secreting gland called a *sebaceous gland* (fig. 178, l). Its duct opens into the follicle and the secretion from the gland is poured out on the surface about the base of the hair, thus keeping the skin from becoming hard and dry, and, on the head, rendering the hair glossy.

The care of the hair means the care of the skin where the hair grows. The scalp must be kept clean and rubbed that a good circulation may be maintained, and the hair must be well brushed.

The scales of fishes and snakes, the hoofs and horns of cattle, and the feathers of birds are, like nails and hair, modifications of the epidermis and outgrowths from it.

Sweat glands.—The sweat glands of the skin are among the most important glands of the body, and with the kidneys, function as excretory organs.

These glands (fig. 178, f, g, h,) open in the tiny pits that may be seen covering the surface of the skin. The base of the gland lies coiled up in a little compact knot, deep in the dermis or true skin (g, h,). Here it is surrounded by lymph and numerous blood capillaries and is supplied with nerve fibers. These glands are microscopic but very numerous, probably 2500 or more to the square inch, so that their combined secretion amounts to a great deal.

The skin as an excretory organ.—The principal waste given off by the skin is water in the form of perspiration. The amount varies under different conditions. Usually it evaporates immediately so as to become invisible. During warm weather when there is a large amount of blood in the skin, water is collected in large drops upon the skin-surface. As a result of muscular activity, and sometimes during illness, other wastes are eliminated by the sweat glands, particularly when the kidneys fail to function properly. Hence it is that the skin is an important organ of excretion and an important help to the kidneys.

Regulation of the temperature of the body.—The skin has a still more important function to perform for the body, and this is the regulation of its temperature.

The body must be maintained at a somewhat constant temperature (varying from 97.5° to 99.5° F.) to fulfill its functions normally and healthfully. During cell activity much heat is generated. In a warm climate the body receives heat also from the surrounding atmosphere. But the temperature of the body can remain constant only when the amount of heat produced within the body and received from without is equal to the amount it gives out. Should the amount produced and the amount received increase above that given off, the temperature would rise abnormally.

The body gives off heat through the aid of the skin in two ways. First, by radiation. The blood as it flows through the organs where metabolism is going on, as the muscles or kidneys, becomes heated. As it flows to other organs less active it transfers part of its heat to surrounding tissues by conduction. Or the heat may be radiated from the surface of the skin, as heat is radiated from a stove. This takes place when the atmosphere is cooler than the body. The greater the difference in the temperature of the atmosphere and that of the body the greater the amount of heat lost and the more rapidly the body cools.

When, however, the surrounding atmosphere is warmer than the body how is the body to be cooled? The changing of a substance from a liquid to a gaseous state always requires heat. Place a drop of ether on the finger and notice the effect as it evaporates. The feeling of cold is due to the heat used up by its rapid evaporation. Or, moisten the back of the hand and then blow upon the moistened surface. Then blow upon the dry surface of the other hand. In the latter case, the hand feels the warm breath. In the former case the hand feels cool because the heat is used up in evaporating the water. Thus, when perspiration forms, it evaporates through the use of a large amount of heat. This heat is furnished by the blood and thus the blood is cooled. This is the natural means of cooling the body in a warm atmosphere.

Importance of cleanliness.—Since the skin is an excreting organ of some importance and a heat regulator of much importance the tiny pores of the sweat glands must be kept open and the skin must be kept clean. When perspiration collects upon the surface of the skin, the liquid part quickly evaporates or is absorbed by the underwear.

The solid substances remain upon the surface of the skin. The cast-off epidermal cells collect there, as well as the many foreign substances with which the skin may come in contact. Even the dust in the air adheres to the oily secretion of the sebaceous glands. Any of these substances would soon clog the tiny pores of the sweat glands and of the sebaceous glands were they not removed by frequent bathing. Vigorous exercise before bathing adds to the benefits of the bath by opening up the pores and covering the skin with its natural secretions.

Treatment of burn.—In the case of burns or scalds the outer epidermal skin, the natural protector of the dermis, is separated from it and broken, so that the dermis becomes exposed to the air. This is exceeding painful. A burn should therefore be covered at once with a paste of baking soda or thick oil. This will keep out the air and reduce the inflammation. A mixture of lime water and linseed oil is also a good remedy for scalds.

CHAPTER XXVI

NERVOUS SYSTEM

General function of the nervous system.—The digestive system takes care of the food we eat; it crushes it, mixes it with digestive juices and gets it ready for the use of the body tissues. The respiratory system furnishes the blood with oxygen for the tissues. The circulatory system carries the food and oxygen to the tissues. The excretory system eliminates waste from the body. The muscles by reason of their property of contractility, enable the body to accomplish all of its movements, whether voluntary or involuntary.

The life of the cells of all the tissues, depends upon the harmonious working together of all the systems. The activities of the body must therefore be co-ordinated. This is brought about by the nervous system. Fibers from the central nervous system pass to every organ and tissue of the body. The distribution of nerves is so extensive that, as Dr. Hardesty says, if all other tissues of the body could be "dissolved away there would still be left, in gossamer, its form and proportions—a phantom of the body composed entirely of nerves."

The nervous system, therefore, controls and harmonizes the functions of all the other organs of the body.

Structure of the nervous system.—In the human body, the brain and spinal cord lie essentially as they do in the frog and other vertebrate animals studied. The brain (fig. 179, F T O) is enclosed by the bony plates of the skull. It is continued downward, as the spinal cord, through the spinal

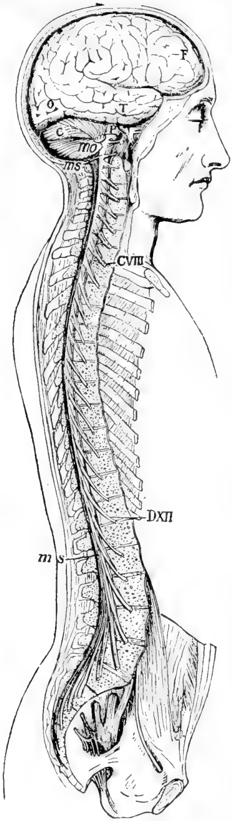


FIG. 179 A. Central organs of the nervous system. F. T. O., frontal, temporal and occipital lobes of the cerebrum; C, cerebellum; P, pons varolii; mo, medulla oblongata; ms-ms, upper and lower limits of the spinal cord; CVIII, 8th cervical nerve; DXII, 12th dorsal nerve. (Quain after Bourgery.)

cavities of the vertebræ. Both brain and spinal cord are further protected by three membranes of connective tissue. Of these the *dura mater* is the tough outer coat. The *pia mater* is the delicate inner membrane. This is closely applied to the surface of the brain and spinal cord following all the fissures. It is vascular, that is, it contains the blood-vessels which supply the cells of nervous tissue with blood and oxygen and remove waste. Between the dura mater and the pia mater is an inner coat, the *arachnoid membrane*. This membrane contains large spaces filled with a fluid (the *cerebro-spinal fluid*). This, like the serous fluids surrounding the heart and lungs, is a protective fluid.

Structure of the brain (fig. 179 A and fig. 179 B).—Like the brain of the cat (see page 67) the human brain consists primarily of three parts, the *fore brain*, *mid brain*, and *hind brain*. The fore brain or *cerebrum* is large and conspicuous. It comprises nine-tenths of the brain's bulk and almost completely covers the other parts. This disproportion in size gives some indication of its very great importance as compared with that of the other parts. The cerebrum is characterized by many convolutions. Seen from above its right and left halves (hemispheres) are separated from each other by a deep fissure. They are connected below by a broad nerve mass, the *corpus callosum.*

From the under surface of the brain, the other parts can be made out. The fissure continues back to the mid brain.

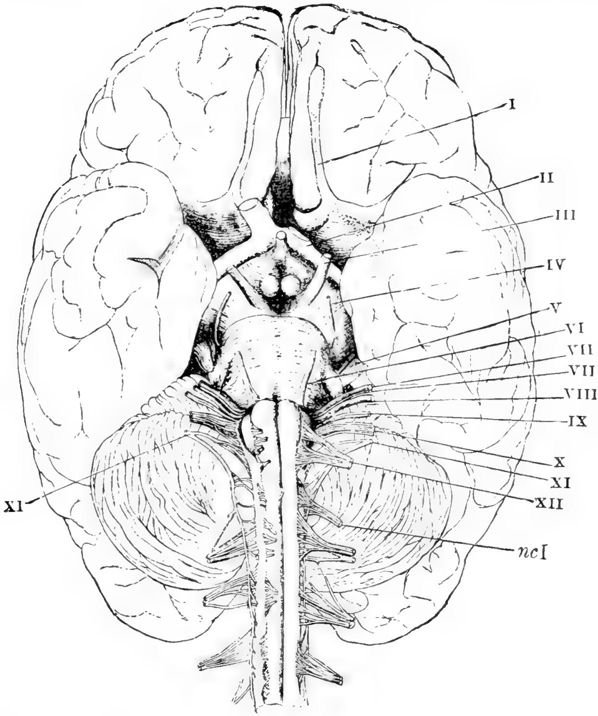


FIG. 179 B. Ventral view of brain, showing origin of cranial nerves. I, olfactory; II, optic; III, ocular motor; IV, patheticus; V, trigeminal; VI, abducent; VII, facial; VIII, auditory; IX, glossopharyngeal; X, pneumogastric; XI, spinal accessory; XII, hypoglossal; ncI, 1st spinal nerve. (After Martin.)

The two long *olfactory lobes* project forward from in front of the mid brain. The *optic nerves* arise from it. Posterior to the mid brain lies the hind brain, consisting of the large wrinkled lobes of the *cerebellum* (fig. 179 A, c), lying apparently one on either side of the *medulla oblongata*. The two lobes of the cerebellum are connected by a mass of nerve fibers called the *pons varolii* (fig. 179 A). The medulla oblongata (fig. 179 A, mo) is continued ventrally into the spinal cord.

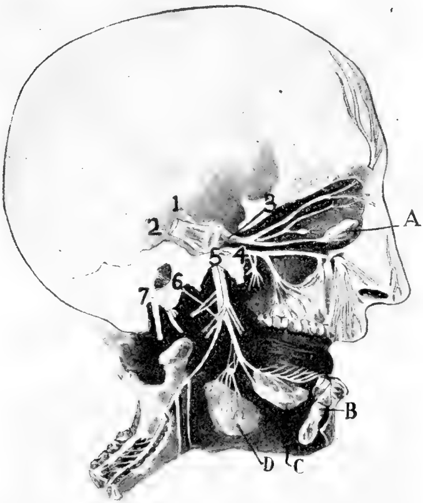


FIG. 180. General plan of branches of trigeminal or fifth nerve. 1, small root of 5th nerve; 2, large root; 3, placed on bone above opthalmic nerve, (with frontal, lachrymal and nasal branches); 4, superior maxillary division; 5, inferior maxillary division; 6, chordi tympani; 7, facial; A, lachrymal gland; B, lower jaw; C, sub-lingual gland; D, submaxillary gland. (After a sketch by Charles Bell.)

The cranial nerves.—The twelve cranial nerves arise from the under side of the brain (fig. 179 B, I to XII).

(1) The *olfactory* nerves arise from the anterior end of the olfactory lobes. These pass to the nasal passages and are the nerves of smell.

(2) The *optic* nerves pass to the eyes. They are the nerves of sight.

(3) The *oculo-motor* nerves pass to certain muscles of the eyes. They are the nerves that partly control the movements of the eye-balls.

(4) The *patheticus* nerves go also to muscles of the eye.

(5) The *trigeminal* nerve goes to different regions of the face and the salivary glands. Figure 180 shows the general plan of branching of the trigeminal nerve.

(6) The *abducent* nerves, like the third and fourth, pass also to certain muscles of the eye.

(7) The *facial* nerves go to the muscles of the head and face.

(8) The *auditory* nerves go to the ear. It is the nerve of hearing. Its distribution is shown in figure 187.

(9) The *glosso-pharyngeal* nerves pass to the tongue and other parts of the mouth and throat.

(10) The *vagus* or *pneumogastric* nerves go to the oesophagus, larynx, lungs, stomach, heart and intestines.

(11) The *spinal accessory* nerves go to the neck and shoulders.

(12) The *hypoglossal* nerves go to the muscles of the tongue.

Each nerve consists of a mass of fibers surrounded by a sheath of connective tissue. Each fiber is a fine thread-like process continuous somewhere with a nerve cell. That is, it is a branch of a nerve cell. Each of the hundreds and thousands of nerve fibers within a single nerve functions independently of all the others.

Internal structure of the brain.—If the brain is sliced through or sectioned, the solid part will be seen to be composed of two kinds of matter, white and gray. The gray matter follows the outer surface of the brain and the folds, and is known as the *cortex* of the brain. The white matter forms the *core* of the brain. The *cell bodies* of the brain lie in the cortex. The fibers, passing from a cell body in one part to a cell body in another part, or from a cell body in the cortex of the brain down to the cranial nerves or into the spinal cord, lie in or form most of the white matter of the brain.

The spinal cord.—The spinal cord is an extension of the medulla oblongata. It extends from the medulla (at the *foramen magnum* or opening through the skull) through the vertebral cavities to the lumbar vertebræ (fig. 66 B). It is slightly enlarged in the neck region and again in the lumbar region. It is protected by three coats, like the brain. The cord is partly divided into halves by two deep fissures (fig. 181). In the cervical and lumbar regions the cord

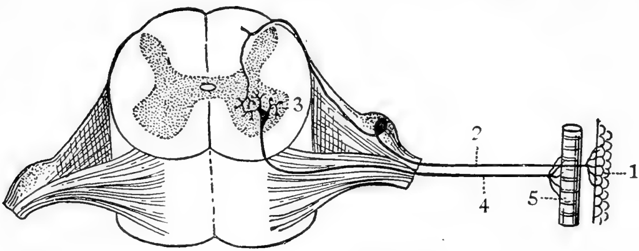


FIG. 181. Diagram of a simple reflex arc. 1, sensory surface; 2, afferent nerve; 3, motor cell in gray matter of cord; 4, efferent nerve; 5, muscle. (After Morat and Dayton.)

gives off a series of spinal nerves. These occur in pairs. Each one arises from the cord by two roots, an anterior and posterior (fig. 181). These roots unite to form the single nerve on either side.

The posterior root of a spinal nerve is the sensory root, the anterior one is the motor root. The posterior root bears a *ganglion*, an enlargement of nerve tissue within which is found a collection of sensory nerve cells. Fig. 181 shows the relation of the gray and white matter within the spinal cord. It shows also the path of impulses from the sensory nerve ending in the skin (1) to the cell bodies in the ganglion and spinal cord, and from them to the muscle (5).

Structure of a neurone or nerve cell.—A *neurone*, commonly called a nerve cell, consists of a cell body and its processes. There are usually several short processes called *dendrites* and one long process or *axon* with a central fiber or *axis cylinder*. Dendrites are usually branched like the limbs of a tree. The axon becomes the nerve fiber of the nerves. Impulses pass to and from the cell body along the axis cylinder of the axon. The dendrites of each cell body surround or come into close contact with the dendrites of other cell bodies so that communication is believed to be established between them; that is, an impulse may travel from one cell to another through its dendrites.

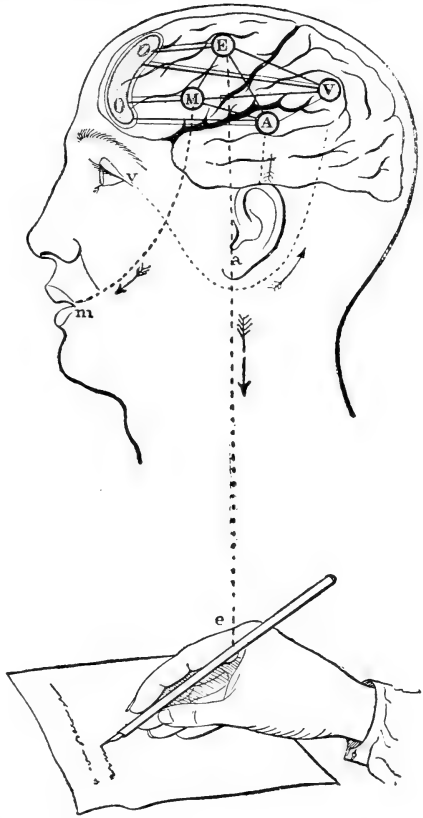


Fig. 182. Diagram showing relation of centers of language and their principal associations. A, auditory center; V, visual center; M, motor speech center; E, motor writing center; O. O., intellectual center. (After Grasset.)

External stimuli have their origin in a nerve ending in some part of the body, as in the retina of the eye. Visual stimuli are carried along the axis cylinders of the nerves to the cortex of the brain where the center of sight, or visual center, is located. The cells in the visual center transmit the impulse to its dendrites. These dendrites are in contact with dendrites from the auditory centers, the intellectual center, the speech centers, etc. Any of these dendrites or all of them may be stimulated. The stimulation might thus result in speech, or in motion with the hands or feet, or it might produce a thought (fig. 182).

The manner in which nervous impulses originate is unknown, but it is believed to be due to the character of the metabolism of the nerve cells.

Classification of nerve fibers.—A nerve fiber is either *sensory* (afferent) or *motor* (efferent) or *commisural.* Sensory fibers carry impulses from the cell endings in the tissues to the cell bodies within the central nervous system. Motor fibers carry impulses away from the cell body within the central nervous system to the cell endings in the tissues. Thus in fig. 181 the motor root contains a mass of efferent fibers, while the sensory root contains a mass of afferent fibers. A stimulus at 1 produces a motion at 5. Commisural fibers connect cells within the central nervous system.

A reflex action.—Such an action as that pictured in fig. 181 is known as a *reflex action*, because it takes place without the exercise of the will. In this case no impulse passes up through the spinal cord to the brain calling into play the intellectual centers, or consciousness. The spinal cord is the center of most, though not of all, reflex action. Most reflexes are more complex than the one illustrated, for a sensory impulse may stimulate several motor nerves of the cord and a complicated set of actions may result.

Excitation and inhibition of reflexes.—Certain nerve fibres carry impulses that excite action, while others carry impulses that inhibit or keep from action the muscles or glands to which they are distributed. We do not know whether there are separate sets of fibers for each of these functions, but we know that in some way there are excitory and inhibitory influences. The function of the nervous system to excite or to inhibit is very important with reference not only to the control of the organs of the body but with reference to its own interaction. Co-ordination could not take place without it.

Hygiene of the nervous system.—Since the nervous system is connected with every part of the body, and controls and co-ordinates the work of every organ of the body, the demands upon it are very great. The skeletal muscles may rest during the activity of the digestive system. Or the organs of the digestive system may rest while we play our games or prepare our lessons. But the nervous system must remain in activity or we will lose the game or fail in our lesson. The nervous system therefore needs special care so that in the hurry and rush of life it will not be so overcrowded by work and worry that it will fail to respond in a healthful way.

Things that cause nerve strain.—Unwholesome conditions of living, such as overeating, eating at all hours, living in poorly ventilated rooms, neglect of exercise and lack of sufficient sleep, smoking and the use of alcohol; these are the things that materially affect the health of the nervous system.

It is often said of the business man, "he has nervous prostration from overwork;" or of a student, "he is broken down through overstudy." Could we know the real facts we should probably see in each case that the man or the boy had neglected exercise, or taken the minimum amount of sleep, or was suffering from the result of both these mistakes.

While muscular exercise is refreshing and change of occupation sometimes prevents undue demands on certain sets of nerve elements, nevertheless every exertion costs the nervous system something, and nothing can take the place of the complete relaxation that comes through sleep. Every child should sleep at least ten hours, and ordinarily every adult at least eight hours each night. Thus only can the brain cells rest and recuperate for the next day's activities.

Necessity of food and fresh air.—From what we have learned of the function of nerve cells and of metabolism of cells in general, we know that an active nerve cell is constantly using up energy, and is constantly wasting away and being rebuilt. This necessitates a constant supply of nutriment and oxygen. The blood furnishes these to the nerve tissues just as to all other tissues, hence when we are eating proper food and breathing in the fresh air we are satisfying the needs of the nerve tissues as well as those of other parts of the body.

Effect of alcohol on the nervous system.—In its normal healthy condition, the nervous system is an efficient regulator of the bodily activities. It inhibits or excites the various organs of the body according to their needs. We can readily understand that any substance, which, when taken into the body, interferes with the nervous system as a regulator of the body, is a deleterious substance. This is what alcohol does. Chiefly, it paralyses the inhibitory centers so as to weaken or dissipate the control of the nervous system. It causes an abnormal distribution of blood by its action upon certain nerve centers. Dr. D. S. Jordan in the "Popular Science Monthly," Feb. 1898, sums up the effect of alcohol and other stimulants upon the nervous system in these words:

"The healthy mind stands in clear and normal relations to Nature. It feels pain as pain. It feels action as pleasure. The drug which conceals pain or gives false pleasure when pleasure does not exist forces a lie upon the nervous system. The drug which disposes to reverie rather than to work, which makes us feel well when we are not well, destroys the sanity of life. All stimulants, narcotics, and tonics which affect the nervous system in whatever way, reduce the truthfulness of sensation, thought and action. The man who would see clearly, think truthfully and act effectively must avoid them."

CHAPTER XXVII

SPECIAL SENSES

Classification of special sense organs.—We have discussed in the previous chapter the mechanism which controls sensory and motor impulses. The peripheral end of each sensory (afferent) nerve fiber is always a specialized structure of some kind and is called a *sense organ* or *end organ*. Each kind of sense organ is adapted to respond to a certain kind of stimulus only. The impulse thus originated travels back to the brain or spinal cord through the afferent fiber and the brain then becomes conscious of a sensation, or a reflex action results.

In former times it was customary to refer to the five senses of man as *sight*, *hearing*, *touch*, *taste*, and *smell*. The sense of touch has been shown by physiologists to consist of four distinct qualities, *pressure*, *heat*, *cold* and *pain*. For each quality there is a specialized end organ with its particular fiber passing back to the brain. These four sense organs are grouped together as *cutaneous sense organs* because their end organs are found in the skin. Certain spots in the skin respond only to pressure, others to heat, others to cold. The pain spots are most numerous and the warmth spots least numerous. These spots may be demonstrated by touching the back of the hand here and there with a metallic point. You will notice, if the point be colder than the hand, that certain spots feel pressure only, others pain, and others cold. These different sensations are due to the microscopic nerve endings, or end organs, that lie in the epidermal tissue of the skin (fig. 183). It is believed that those end organs that give the sense of pain lie nearer the surface, while those for the sense of warmth lie more deeply in the skin.

The pressure spots are very close together at the tips of the fingers and on the tongue, a condition which makes these places very sensitive to touch. Most parts of the body are covered with fine hairs. Physiologists have shown that pressure points lie over the hair follicles, and that the pressure nerve fibrils end in a ring surrounding the hair follicle. Any movement of the hair, therefore, stimulates the nerve fibril.

FIG. 183. Papillæ of skin in palm of hand (epidermis removed). E, end organ of nerve; N, nerve; B, blood-vessels; V, capillaries. (After Sappey.)

Sense of taste.—The sense of taste is carried to the brain through nerve fibers that have their end organs in the mouth-cavity, particularly on the tip, the borders and the back of the tongue.

The *circumvallate papillæ* shown in fig. 184 are the largest taste papillæ, but are few in number. In all of the taste papillæ there are found certain minute organs formed of a mass of delicate cells each ending in a microscopic hair which projects at the surface of the organ. These organs are called *taste buds* and are the true sense cells, the hair-like process being the part that is stimulated by substances in solution. There are four primary taste sensations, namely sweet, bitter, salty and acid, and these are distributed to different parts of the tongue. All other tastes are combinations of these. A taste sensation is aroused by substances in solution only.

Sense of odor.—The end organs of the sense of odor, or the olfactory sensation, lie in the upper part of the nose, just above the hard palate. They are formed of groups of epithelial cells each bearing on its free end a little tuft of hairs. At the other end the cell is continued into a nerve fiber which passes back to the olfactory bulb of the brain. During inspiration air currents bring vapors or gases into the nasal passages. These are dissolved in the moisture of the mucous membrane lining the nasal passage and can then stimulate the hair-like processes of the sensory cells. Substances that are swallowed may send their vapors into the nasal passage through the opening of this passage into the pharynx, and thus one sometimes confuses the sense of taste and the sense of odor. The stimulation caused by the flavors of fruits, for instance, while really affecting the olfactory organs seems to affect the taste organs.

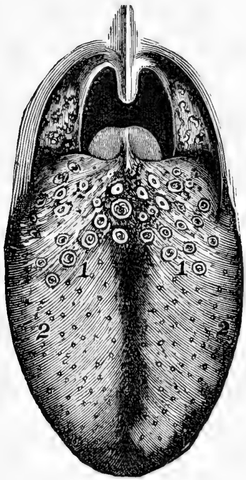


FIG. 184. Upper surface of the tongue. **1**, circumvallate papillæ; 2, fungi-form papillæ. (After Brubaker.)

Sense of sight. Structure of the eyes.—The eyes are complex structures nearly spherical in form and set deeply into the sockets of the cranium. Procure the eye of a sheep or calf of the butcher, and study its parts.

The eyeball is protected in front by movable folds of skin called eyelids. The hairs along their edges serve to keep out dust and slightly to shade the eye. The lids are lined with a mucous membrane which furnishes moisture. This acts as a lubricant so that the eyelids close over the eyes without friction. This membrane is also deflected over the surface of the eye. On the upper outer side of the eye is situated a gland, the *lachrymal gland.* This secretes a salty fluid which also serves to keep the eye moist and clean of dust. At the inner angle of the eye, next the nose, a tiny duct ordinarily carries into the nasal passage any excess of this secretion. If the membrane covering the eye is irritated or strong emotion is aroused there is such a copious flow of this secretion that the tear duct fails to carry it off and it overflows the edges of the eyelids as tears.

The orbit of the eye is lined with a fatty layer which forms a sort of cushion for the eyeball. The *optic nerve* (fig. 185,o) enters the eyeball from behind, through an opening in the socket. This nerve is composed of fibers which pass to the visual centers of the brain.

The eyeball is held firmly in place and moved from side to side or up and down by six strong muscles. These muscles are controlled by motor nerves from the third, fourth and sixth cranial nerves. The muscles of the eyeballs contract and relax in pairs so that the eyes move together.

The eyeball consists of three concentric coats surrounding and enclosing certain transparent substances through which the light passes to the inner coat of the eye. On this inner coat the sensory surface is found.

The outer coat is the *sclerotic* coat (fig. 185,S), commonly known as the white of the eye. It is formed of very tough dense connective tissue, and serves as the main protecting coat. In the front part of the eye, the sclerotic is transparent and bulges slightly outward. This part is known as the *cornea* (fig. 185, C). Within the sclerotic coat and closely applied to it is the *choroid coat* (Ch). This is a connective tissue layer through which ramify the blood-vessels of the eye. It also contains large quantities of black pigment, so that no light can enter the eyeball except through the cornea. In the front of the eye, where it meets the cornea, the choroid coat leaves the sclerotic and projects toward the long axis of the eye, as a circular muscular curtain with an opening in the middle. This is the *iris* (I), and is the part of the eye that we see as hazel, gray, or blue. The *pupil* is the opening in the iris.

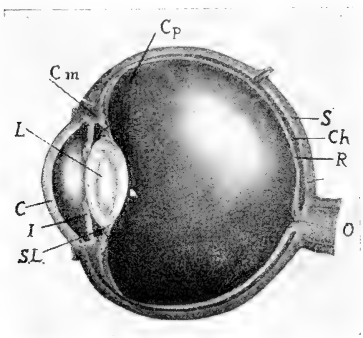


FIG. 185. Horizontal section of the eyeball. S, sclerotie coat; ch, choroid coat; R, retina; O, optic nerve; Cp, ciliary processes; Cm, ciliary muscles; L, lens; C, cornea; I, iris; S. L, suspensory ligament. (After Brubaker.)

Where the choroid coat leaves the sclerotic coat it is firmly joined to it by small but strong and important muscle processes called *ciliary processes* (Cp), which, with the suspensory ligament (SL) hold the lens in place.

Within the choroid coat is the third and innermost coat, called the *retina* (R). The retina is composed of sensory nerve endings that are sensitive to light. The fibers from these nerve cells pass backward to the brain through the optic nerve (O).

Behind the iris lies the *crystalline lens* (fig. 185, L). Its front surface is slightly flattened. The space between the lens and the cornea is filled with a clear transparent liquid, the *aqueous humor*. The cavity of the eyeball back of the lens is also filled with a transparent semi-solid or jelly-like substance called the *vitreous humor*.

Functions of the eye.—In general structure, the human eye is like a camera. The cornea and lens of the eye correspond to the lens of the camera, and the retina corresponds to the sensitive plate.

The pupil of the iris determines the amount of light that shall enter the eye.

How a lens forms an image.—A ray of light passing from a rarer to a denser medium is bent or refracted from a straight line. Therefore rays of light when they enter a convex lens as shown in fig. 186, are bent so that they all converge at point A behind the lens, that is, they come to a focus at this point. Thus rays of light from the arrow A—B passing through the lens form a picture on the retina at *b—a*.

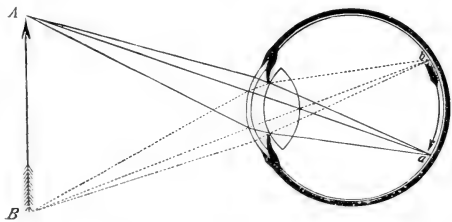


FIG. 186. Refraction of rays of light and formation of an image on the retina. A-B, object; b-a, image on retina. (After Brubaker.)

Accommodation of the eye to different distances.—A photographer changes the relative position of the camera lens and the sensitive plate by focusing for near or far objects. He increases the distance between the lens and the sensitive plate, which is at the back of the camera, for near objects, and decreases it for distant objects. When a camera is focused for a near object it will give only a very indistinct picture of a far object. And so with the eye. Hold up a pencil in front of the eye between the eye and the door. Upon looking at the pencil you see it clearly but see the door beyond indistinctly. Looking beyond the pencil to the door, the door is seen clearly and the pencil indistinctly. The eye in looking first at a near and then at a far object changes its focus. The walls of the eye, unlike the walls of the camera, are immovable, but there is a very neat arrangement for changing the focus by changing the thickness of the lens. That is, the eye accommodates itself, by a self-regulating mechanism, to near and far objects.

The choroid coat exerts a constant pull upon the lens through the suspensory ligaments (fig. 185, SL). This pull slightly flattens the lens, that is, makes it less convex, so that it will focus *far* objects upon the retina. But when the ciliary muscles (fig. 185, Cm) contract they pull the choroid coat forward so that it fails to exert a pull upon the lens. The lens then, of its own elasticity, becomes more convex and will then focus *near* objects upon the retina. The involuntary movements of these muscles therefore enable the eye automatically to accommodate itself to near and far objects.

Sensation of sight.—The sensation of sight is, however, not located in the retina, but in a certain part of the cortex of the cerebral hemispheres. The cells affected by the light are in the retina. Nerve fibers from these cells pass back, as shown in figure 182, through the optic nerve to the nerve-centers of sight in the brain.

The essential parts therefore, of the sight-apparatus are the retina, the optic nerve and nerve centers in the brain. All the other parts are accessory parts to render the function of these more perfect.

Hygiene or care of the eyes.—Because the eyes are such extremely delicate structures they must be treated with as much care as the most delicate piece of machinery.

Anything that affects the general health affects the eyes very quickly. Therefore what has been said about good food, fresh air and exercise being necessary for other parts of the body applies to the care of the eyes as well.

Reading in a bright light, as with sunshine upon the book, or in a dim light, as at dusk, weakens the muscles that operate the lenses and the eyeballs. A flickering light is exceedingly bad as it over-exerts the muscles of accommodation.

If the eye has a defect of structure, as when the eyeball is too short or too long, the picture is blurred because the image is not formed exactly upon the retina. We say we cannot see clearly. When the image is formed in front of the retina, the defect is called near-sightedness or *myopia*. When the image comes to a focus back of the retina, the defect is called *hypermetropia*. In case of either of these

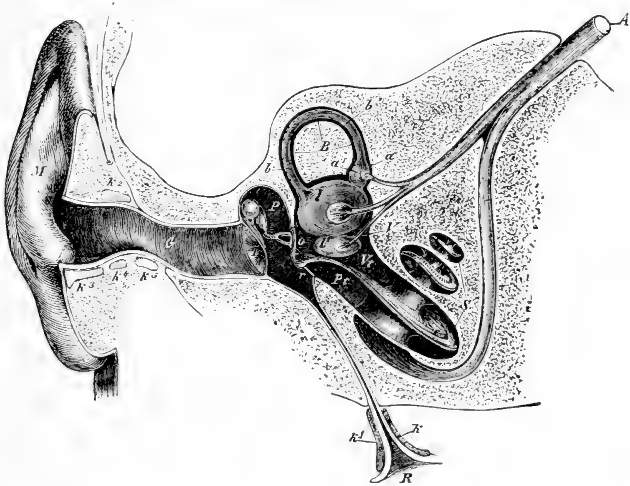


FIG. 187. Semidiagrammatic section through the right ear. M, pinna; G, meatus; T, tympanic membrane; P, tympanic cavity or middle ear; R, Eustachian tube; r, fenestra rotunda; o, fenestra ovalis; V, vestibule; B, a semicircular canal; S, cochlea; A, auditory nerve; K, 1, 2, 3, 4, 5, cartilages; Vt, passage of cochlea opening into vestibule; Pt, passage of cochlea opening into tympanic cavity; a^1, l, l^1, ampullæ of the semi-circular canals; c, organ of Corti. (After Martin.)

troubles glasses should be worn to overcome the defects, otherwise the strain upon the eye, in its effort to focus sharply, will be so great as to affect the nervous system seriously and cause headaches.

Astigmatism is another common defect of the eye due to irregular curvature of either the surface of the cornea or that of the lens. This must also be corrected by glasses. Only a good oculist, by careful examination of the eyes, can tell the kinds of glasses that are needed for the various defects.

Auditory sensations (sound and hearing).—The ear is an organ specially adapted to receive vibrations of air and to transmit them to the auditory nerve. It is made up of three principal parts called the outer, middle and inner ears.

The outer ear.—The part that we commonly call the ear is known as the *pinna* (fig. 187, M). It forms a sort of funnel or trumpet for catching the sound-waves, and leads into a funnel-shaped canal, the *meatus* (G). The sebaceous glands of this canal produce the wax of the ear. This serves to keep the ear drum or *tympanic membrane* (T) moist and to render it flexible.

The middle ear or tympanic cavity (P) is lined with mucous membrane and filled with air. The air is admitted to it through the *Eustachian tube* (R) which opens into the pharynx. The tympanic membrane forms the outer covering of this cavity. This membrane is thrown into vibrations by the sound waves that have passed through the meatus.

On the inner surface of the cavity of the middle ear are two openings which, like the one on the outer surface are covered with membranes, the *fenestra rotunda* (r) and the *fenestra ovalis* (o). There is a chain of three small bones strung across the cavity from the tympanic membrane to the fenestra ovalis. These bones are named from their peculiar shapes, the *hammer* (*malleus*), the *anvil* (*incus*), and the *stirrup* (*stapes*). One end of the malleus rests on the inner side of the tympanic membrane, the other end rests upon the incus. The incus lies between the malleus and the stapes and the stapes connects the inner end of the incus with the fenestra ovalis. Vibrations of the tympanic membrane, due to air pressure on its outer surface, are transmitted to the inner ear at the fenestra ovalis through these small bones. The air received into the middle ear through the Eustachian tube serves to equalize the pressure upon the tympanic membranes. When this tube is clogged up with mucous, as when one has a cold, deafness results.

The inner ear consists of an irregular cavity hollowed out of the temporal bone, known as the *bony labyrinth.* It consists of three parts, the *vestibule* (V), the *semicircular canals* (B) and the *cochlea* (S). The vestibule communicates with the tympanic cavity by the fenestra ovalis (closed by the stapes). It opens into the semicircular canal and into the cochlea. These parts are all lined by a membrane, called the *membranous labyrinth.* This membrane secretes a fluid, the *endolymph,* which fills semicircular canals, vestibule and cochlea.

One of the canals lies in a horizontal plane (when the body is upright) while the other two lie in a vertical plane but at right angles to one another. The membrane lining the three canals contains a series of nerve endings. Nerve fibers from the auditory nerve (fig. 187, A) are distributed to these endings. Our sensations of position in space, or equilibrium, are gained through the nerve endings of the semicircular canals.

The cochlea is a complicated organ with a very delicate set of sensory cells, known collectively as the *organ of Corti* (fig. 187, c). These cells are the very delicate nerve endings of fibers from another part of the auditory nerve, as shown in the figure. The nerve endings in the organ of Corti are stimulated by the vibrations in the endolymph which bathes them. The endolymph receives vibrations through the small chain of bones.

Care of the ears.—The inner ear is well protected and can scarcely be injured by external causes. Colds or sore throat frequently cause stoppages of the Eustachian tube that may result in inflammation of the ear or deafness. Such cases should be treated by a physician. The ear should be guarded against sudden loud sounds lest they break the tympanic membrane.

If it becomes necessary to remove an extra secretion of wax from the meatus, it should be done by washing the ear with warm water. In no case should a sharp instrument be used, lest the tympanic membrane be injured.

CHAPTER XXVIII

MICROÖRGANISMS AND SANITATION

Microörganisms are the lowest forms of life. They are invisible to the naked eye. They are often called germs or microbes, and some of them are of the utmost importance because of their relation to human welfare.

The plant microörganisms which especially concern us are known as *bacteria*. Animal microörganisms are known as *Protozoa*.

Bacilli (rod-like), cocci (ball-like), and spirilla (spiral) are all forms of bacteria. They multiply in number very rapidly. In a few hours certain kinds increase from a few individuals to 200,000,000,000. This enormous rate of increase makes them very powerful organisms in effect though very small and weak individually. They may be found almost anywhere. They abound in stale milk, in impure water, and in decaying substances, in which they are indeed the actual cause of decay.

Certain kinds of bacteria may be easily observed. Set aside a glass of milk for a few days until it sours. Then put a drop of the milk upon a glass slide under a cover glass and look at it under the microscope. The little swarming bodies, each consisting of a single cell, or speck of protoplasm, are bacteria. The souring of the milk is caused by the action of the bacteria upon the sugar of the milk. Another species may be observed by putting some dry grass in a dish of water and leaving it for a few days. A scum forms on the surface. Examine a bit of this scum under the microscope. The myriads of tiny rod-like structures swarming about, among which larger animalculæ are darting, are bacteria.

Of the many kinds of bacteria some are useless to man, some are of benefit, while many are positively dangerous. Those found in the scum are probably harmless and may even be beneficial as scavengers.

Bacteria feeding upon substances such as meat, fish, milk, etc., decompose or rot them.

The importance of bacteria in the economy of our lives is so great that it has given rise to a study called "bacteriology."

Beneficial bacteria.—When the farmer plows his field, he turns under the soil the dry grasses from the top surface. These are then attacked by certain bacteria which decompose them and set free the chemical compounds of which they are composed. These substances, mostly originally derived from the soil, are thus again returned to the soil to enrich it for the use of growing plants. The manufacture of cheese and butter would be impossible without the aid of certain bacteria.

Harmful bacteria.—For many years now, owing chiefly to the work of Pasteur and Koch, it has been known that several diseases that inflict mankind are caused by the parasitic growth of certain microörganisms in the human body. These harmful microörganisms break down or poison the blood or other body tissues and thus greatly derange the normal functions. The derangement results in disease and even death. It is of importance, therefore, for everyone to know how to prevent the spread of such diseases that result from the attacks of bacteria. These are the infectious and contagious diseases such as tuberculosis, typhoid fever and diphtheria. Malaria and certain other diseases are known to be caused by Protozoan microbes. The cure of patients having these or other diseases lies for the most part in the hand of the physician, but the prevention of the diseases lies chiefly in the hands of the individual and the community. The best rule for the individual to observe is so to regulate his diet, his exercise, his rest, and his bathing that he may build up a healthy body that will of itself be resistant to disease. He should also take great care to avoid exposure to infection.

Bacteria or other microbes often gain entrance into the system through impure milk, impure meat, impure water or other impure food. One of the objects in cooking food is to sterilize it thoroughly. Sterilization is the killing of all bacterial life by the application of heat. Bacteria also gain entrance into the system, sometimes, through wounds. For this reason a wound, large or small, should be carefully disinfected as described on page 327, and should be bound with disinfected or sterilized bandages. Strong acids, alkalies or other substances that will kill microbes are called disinfectants.

Quarantine.—When a person is ill of an infectious or contagious disease, it is necessary as a matter of safety to other people to place him by himself, allowing no one to enter the room but the nurse and doctor. Thus he is quarantined. When ships come into harbor from a foreign port, they are placed in quarantine until the health officers have examined the passengers so as to be sure there are no persons on board with contagious diseases.

Disinfection.—After a patient has been ill of an infectious or contagious disease, and before the quarantine has been removed, the room he has occupied, with everything in it, must be made germ-free. This is known as disinfection. The burning of sulphur is an ordinary method of disinfection. The fumes of the burning sulphur kill any harmful bacteria that may be in the air, in the clothing, or on the walls. There are other disinfectants that are furnished or suggested by Boards of Health.

Immunity.—During an epidemic, that is, when a contagious disease as smallpox or diphtheria seems to be spreading through a community, it becomes necessary to take extreme precautions against it. Gradually physicians and bacteriologists are discovering means of making people *immune* or thoroughly resistant to diseases. The first step in these discoveries is the thorough investigation of the disease and the nature of its cause. The next step is to find out what substance will, if inoculated or injected into the blood, serve as an effective preventive of the disease.

Immunity from smallpox was discovered over a hundred years ago in the use of the comparatively harmless vaccine or virus of cowpox. This was a great discovery and its use has prevented the spread of many epidemics of smallpox. The discovery of the use of antitoxin for the cure and prevention of diphtheria has also been of great benefit to mankind. As science advances, other such means of producing artificial immunity from disease will be discovered until infectious disease will come to be largely under the control of man.

Public hygiene and sanitation.—In a large community, there are always a great many careless and ignorant people. It therefore becomes necessary to appoint boards and officers to look after the public health. It is the duty of a board of health, through its officers, to examine all the conditions affecting the health of the people at large. It must examine public supplies such as milk, water, ice, meats, etc. It must examine the dairies that furnish milk to the community, see that the cows are healthy, the buildings clean, and that the milk pails and pans are thoroughly sterilized, etc. It must look after the water supply, to be sure that there is no opportunity for its contamination with impurities. It must inspect the markets to see that no tainted meats or other dangerous foods are offered for sale. It must see that the city is well drained and that the sewers of houses are properly connected with the city drainage system. In short, a health board must take charge of everything that affects the health of the people, and hence its duties are many and of the utmost importance.

In most cities there is a special "street cleaning" department which attempts to have all rubbish and garbage removed from the streets before it begins to decay so that there may be nothing lying about of obnoxious or disease-breeding character.

In many ways the city authorities can regulate conditions so that fresh air, pure water and pure food are assured to the community, but it is the duty of each citizen to have an intelligent knowledge of the laws of hygiene and sanitation, not only that he himself may run no risks but that he may not be the cause of any risks to his neighbor or to the community.

CHAPTER XXIX

ANCIENT AND MODERN MAN

The written history of man goes back about five thousand years. The recorded history of the Greeks and Romans dates from about ten centuries or less before Christ although it is certain that the actual history of the Grecian people is far older. The earliest writings of the Chinese and Egyptians and Arabians carry us back to a period three or perhaps four thousand years earlier than the Christian era. But it is also certainly true that the civilization of these peoples extends far into prehistoric times. Traces of the ancient Ethiopian civilization of 10,000 years ago are claimed to have been found.

Where history leaves off archæology takes up the work of deciphering man's earlier civilization and manners, and where there are no more sculptured stones and pictured walls discoverable, the student of geology and paleontology and the student of anatomy unite to interpret the story told by exhumed bones and relics of man and his earliest animal companions.

Bones of undoubted human origin have been found in long-buried caves with those of the mammoth, the cave-bear and other extinct animals of Glacial times. There is no doubt that man lived on this earth at least as far back as the beginning of this present geologic epoch, the Quaternary (or Pleistocene) and it is probable, though not proved to anything like the unanimous satisfaction of anthropologists, that he existed in late Tertiary times.

At any rate the human species, upright, large-brained, with wit enough to chip flints into rough weapons, and to make fire, and probably capable of speech, lived on this earth one hundred thousand years ago. Some geologists make this distance backward in time a shorter one by half; most make it twice as long. At least it was back to the days of great wild animals now extinct, and when other animals and plants that now live only in the Arctic regions lived in middle Europe.

During the Quaternary epoch four successive large animal species have lived in and disappeared from France, namely, the cave-bear, the mammoth, the reindeer and the aurochs.

FIG. 188. Specimen of Indian picture-writing. (After Lubbock.)

Man has lived contemporaneously with them all. He used their flesh for food and has left representations of them in rude carvings and drawings. All through these times he used stone implements chipped and shaped by his hands. These relics exist by thousands in all the great museums of the world. And, besides, as we shall see in a moment, the early Quaternary man has left his own bones to prove even more positively his existence.

From a geologic epoch earlier than Quaternary there are in existence certain suggestively shaped pieces of flint, called eoliths, concerning which a great strife rages among the scientific men. Some say they show the indubitable crude work of earliest man; others say that their shape and chipped character are due to the fortuitous action of the elements. If these eoliths are of human shaping, the dawn of man's history goes very much farther back than we now know it to go.

The English anthropologist, Abbott, has lately drawn a word picture, on the basis of his discoveries near Hastings, of a scene from the life of prehistoric man:

FIG. 189. Vertebra of young reindeer with flint arrowhead imbedded in the bone. From the Cave of Perigord, France. (After Lartel and Christy.)

"In a corner formed by the cliff face and a projecting fissure wall squatted one of the old fellows chipping away at a flint, a heap of which lay by his side. In his hand was a hard-worn quartzite hammer-stone, one of the most cherished objects of his life. Near him crouched his wife, and possibly offspring, collecting the flakes he struck off, and sorting them into little heaps according to the purposes for which they were suitable. Near him was another old fellow, working away at one of those beautiful bi-concavo-convex ridged-back, finely-worked, round-based, spear tips; he had finished the prize all but one blow, which would have removed the implement from the flint block in a finished condition, when he, too, stops of a sudden. Near to him are several others splitting bones either for their marrow or for material for implements, etc. One old fellow has broken a leg bone of one of the trophies just secured in the chase; beside him are two pointed flint wedges. He has already inserted one into the narrow cavity, and the bone* is splitting in several places but the skeletal element is firm and healthy, and grips the wedge tightly, and splitting requires force applied several times.

FIG. 190. Drawing of mammoth on piece of mammoth tusk. From the Cave of the Madeleine in southwest France. The drawing was made by prehistoric man of the early Post-Glacial times. (One-third natural size of the drawing.)

"A little farther away there is a fire on the hearth which has baked the underlying loam into a red brick for several feet in extent. Over this is roasting a boar's head, till the jawbones are becoming so exposed that before the great episode of the evening is finished they will all be reduced to charcoal. Near at hand there are also several of the community engaged in taking off the damaged flint points broken in the chase, and replacing these truncated butt ends with new flint tops; consigning these broken portions to the accumulating midden or refuse heap. The number of these flint butt ends that have accumulated tell us that these flint

*Now in the British Museum.

tools, whether on sticks or sinews as fish hooks, or bound to hafts or reeds, suffered greatly in use, and required periodical replacing. At this moment an esteemed implement has come into the hands of one of the old fellows. It is broken asunder across its center, and out of some respect for it he is putting a new point to it, working off those delicate minute flakes in the manner characteristic of the race. He has run his bone flaker up one side, and left an edge such as no other system of flint working can produce. He has just begun the other, and apparently in a minute or two

FIG. 191. Drawing of a feeding reindeer, on a piece of reindeer horn. From the Cave of Thayngen, Switzerland. (After Mark.)

bi-symmetry will again be obtained with a sharp piercing point as a result, but he stops just as suddenly! Near him, upon the hot ashes of a fire, stands the coarse earthen pot, the prototype of our modern tar kettle—the earliest saucepan we know; its bottom and sides are incrusted with a thick layer of soot, telling of the withstanding of the ordeal of fire accompanying many an evening meal, while close by is a pile of calcined flints beneath burning wood, cooking a clay-invested rabbit. Near by are several flat-bottomed vessels, the prototypes of our first saucers or basins, although the soot upon their bottoms tells the tale of their having been put upon the blazing fire. Everyone is busy; everyone appears intent upon what he is doing, when an alarm is raised, and everyone in the settlement has stopped what he is doing. It is the enemy! Down goes the core upon which the first man is engaged; even his cherished quartzite hammer is dropped in the alarm. Down goes the marrow-bone, with the flint wedge firmly gripped, and down is thrown the implement finished all but for one blow. The pot is left upon the hearth, the heap of hot stones, and everyone flees for dear life, which, in all probability is barely saved! From the discovery of human bones it is probable that all did not escape, and those who did were afraid to come back again for a long period; and between this time and renewed operations the Zephyrs and good old Aeolus had spread a curtain of blown sand over it all, and thus preserved the picture of the times for thousands of years, to delight the soul of the prehistoric archæologist at the close of the nineteenth century, A. D."

FIG. 192. Drawing of a naked man, with short spear, hunting wild horses. From the Cave of the Madeleine, France; carved on the handle of a primitive bone ornament. (After Lartet and Christy.)

The oldest actual human bones are those found in various places in Belgium, France, Germany, Croatia and elsewhere in Europe in geological formations far more recent than those of the eoliths. They all come from Pleistocene (Quaternary) formations. Our prehistoric ancestors, represented by these grim relics, have been called the Neanderthal man, the Spy man, the Krapina man, the man of Correze, etc., depending on the location of their final resting-place. And all of them agree in revealing certain characteristics which show that they were men of a lower order of development than men of historic times. In all, the brain cavity was much smaller than ours, the forehead was low and retreating, the jaw prominent but with little chin, and in some the leg bones seem to be a little bent as if the erect posture were not so perfectly acquired as now. In fact anthropologists are pretty well agreed to call this early prehistoric man the primitive or fossil man, *Homo primigenius*, to distinguish him from historic man, *Homo sapiens*.

The general course of human development from the dawn of man up to the present is indicated by the names that have

FIG. 193. Remains of the Neanderthal man, in the Provincial Museum of Bonn. (From *Weltall w. Menschheit*).

been given to successive periods in this long history.

The first period is called Paleolithic or Old Stone Age, when man was contemporary with the cave-bear and mammoth, rhinoceros, reindeer and hyena in Europe and with other ancient animals in Asia and Africa and perhaps Brazil. No indubitable remains of paleolithic man have yet been discovered in North America. The Calaveras skull of California nor the Lansing man of Kansas nor any other of the few American remains which when first found were attributed to the man of prediluvial times have been able to prove their claim to such remote antiquity. The mound builders and Aztecs were human beings of times far younger than those of the first men.

The Old Stone age seems to have been a very long one and is sometimes divided into the Mammoth Age, and the Reindeer Age.

The next general period was the Neolithic or Newer Stone Age when man's weapons and implements were of polished stone and he set up large stones as monuments and used caves and grottoes for burial as well as for dwelling-places.

FIG. 194. Skull cap of *Pithecanthropus erectus*, the fossil man-like ape of Java. (Shown from above and in profile; from *Weltall u. Menschheit.*)

This was not a long period but different races of man seem to have arisen in it and there were great wars and migrations.

Next came the Metal Age, usually subdivided into the Ages of Copper, of Bronze, and of Iron, according to the kind of metal chiefly used for implements. Thousands of relics of these ages exist in the museums, and evidences of much differentiation and dispersal of races, with varying manners of life, are plain.

From these ages, still prehistoric, man slowly emerges into the light of decipherable history. The great variety and abundance of his tools and specially constructed dwelling and burial places; the carved sculptures and pictures and inscriptions on his monuments and walls; the remains of his food and clothing exhumed from graves, all taken together constitute material enough for the archæologist to begin writing the story of human civilization. It includes the history of the shell-fish eaters of Denmark whose kitchen middens or shell heaps were a thousand feet long, two hundred feet wide and three feet thick; of the ancient lake dwellers of Switzerland and Italy and Austria and France; of the Sardinian builders of great monuments called Nuraghi; of the *broch* builders of Scotland and the dolmen makers of Brittany and other parts of the world; and of still other ancient races known to us by special relics or constructions. It is all a fascinating story and no youth should fail to read some good telling of it, such as Joly's "Man Before Metals."

FIG. 195. Skull of ancient man from the Cave of Spy, Belgium. (After Fraipont's photograph of the original in the Museum of Liege; from *Weltall u. Menschheit.*)

As man lives on the earth today he looks upon himself, and rightly, as a kind of organism very far removed from all other kinds and as one of great unity of character. But he recognizes within this large and distinctive unity a considerable diversity in stature, color, hair-shape, degree of mental development, language and manner of life generally represented by men of various tribes and races. It is said by philologists that more than 1000 different languages are spoken on the earth today. The distinct man races are not so many as that of course, but these many different languages suggest in some measure how various living man is.

The differences in men are mostly correlated pretty closely with geographical distribution and are readily discovered to be also and more importantly correlated with genealogy. On these differences are based the separation of the man species into many races of closer or wider relationship and hence similarity of appearance and behavior.

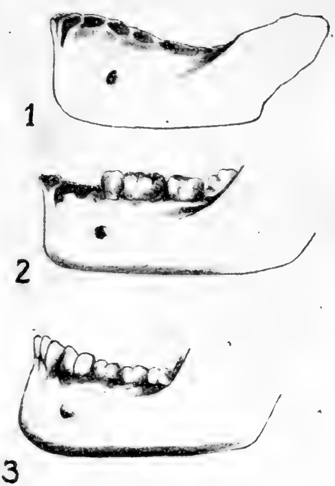


FIG. 196. Lower jaw bones of 1, prehistoric man, found in the Cave of the Naulette, Belguim; 2, a Melanesian savage of the New Hebrides Islands; 3, a modern Parisian. Note the marked difference in development of chin. (After Broca.)

The races of man arose far back in prehistoric night. Some of these races have disappeared but new ones and more have taken their places. There are races existing today that have a life but little above that of the men of the Stone Age. The Fuegians of Patagonia and the savages of Australia use stone and bone implements of crudest character. The New Caledonians use polished stone and rough iron implements. The Weddas of Ceylon, the Akkas and Bushmen of Central Africa and the Papuas of Melanesia live in a stage of barbarism, and even have a physical makeup, much like that of prehistoric man. They are indeed a sort of living link connecting *Homo sapiens* with *Homo primigenius.*

Different anthropologists and ethnologists classify and catalogue the existing human races differently but they are in pretty fair agreement about the principal categories. Four basic great groups are generally recognized, namely, the Ethiopic, the Mongolic, the Caucasic and the American. The Pacific island-inhabiting peoples of Melanesia, Malaysia,

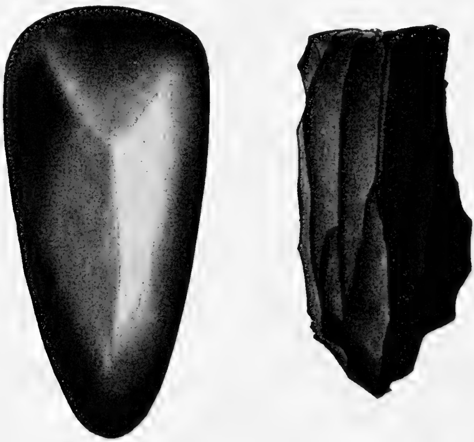


FIG. **197**. At right, a carved flint from Denmark, of the Old Stone Age; at left, a polished stone axe head from Ireland, of the New Stone Age.

Polynesia and Australia may also be grouped together as a fifth or Insular and Littoral race. Each of these races is probably independently traceable back to Pleistocene man. Within each one of these great groups are several sub-groups or branches, as the Northern, Central and Southern branches of the American race; and in each branch are one or more stocks as the Arctic, Atlantic, and Pacific stocks of the Northern American; and finally each stock may include several groups or peoples, as the Tinneh, Algonquin, Iroquois and other peoples of the Atlantic stock.

The differences among these races, branches, stocks, etc., are originally largely the outcome of different environments. By the early migrations of prehistoric man the different parts of the great continents and the principal islands were successively reached and inhabited. But all these regions differ more or less from each other in their temperature, humidity, amount of sunshine or cloudiness, freedom from or prevalence of storms and rigorous conditions of life, abundance and kind of vegetation, presence or absence of rivers, lakes and ocean, etc., etc. These physical differences of environment have certainly chiefly determined the stature, color, brain development, hair character, size of teeth, prominence of jaws, muscular conditions and other structural characters on which race distinctions are made.

FIG. 198. Head of the "Hottentot Venus" from a mould taken after death, now in the Paris Museum of Natural History. (After Quatrefages.)

These structural conditions are, of course, intimately allied to physiological and mental and moral conditions and habits. Indeed, this alliance or relation is partly that of cause and effect. Ethnologists recognize physiological and mental and moral differences among peoples just as they do structural differences and use these differences to help trace out racial and stock relationships. Likeness and unlikeness of language have been of great service in the study of relationships. But for the actual distinguishing and classification of different peoples physical characteristics are used first of all and given most weight.

The characters chiefly relied on to distinguish races and stocks are shape of skull, shape of nose, eyes, jaws and whole face, width of pelvis, color of skin, and character of hair.

For example, all the various peoples and stocks and branches of the American race agree in having coffee-colored skin, straight or wavy hair and medium nose. This race has great unity of type although it ranges over two continents from the Arctic to the Antarctic regions. The most developed early peoples of the race lived in Mexico and Peru; the lowest lived and still live in Patagonia.

All the white peoples belong to the Caucasic or Caucasian race. The name is not a good one because it suggests an origin in the Caucasus, which it did not have. The American ethnologist Brinton maintains that it undoubtedly arose in Southern Europe and Northern Africa. Indeed these two regions were probably one in early Quaternary times. And he believes that the present types of the race have come from this region rather than, as more popularly thought, from Asia. However, the principal historic nations of Europe are descended from Aryan stock, which most ethnologists believed to have migrated into Europe from Asia. But Brinton denies even this, holding that the Aryan ancestors of the European races originated in Europe itself. The white race of America is, of course, the off-shoot by direct immigration and descent of the historic European races.

Fig. 199. Head of Orion, Negrito-Papuan of Tidore. Cast now in the Paris Museum of Natural History. (After Quatrefages.)

The Mongolic or Asian race includes a great many peoples represented by an enormous number of individuals all characterized by their yellowish skin color, straight coarse black hair, flat-bridged nose, small and more or less oblique-lidded eyes. It includes two large branches, one called the Sinitic, comprising the Chinese, Tibetans, and

FIG. 200. An Akka pygmy from Equatorial Africa.

Indo-Chinese (Birmese, Siamese, Annamese, Tonkinese, etc.); the other called the Siberic branch, including the Japanese, Koreans, Manchus, Kamschatkans, Tartars, Finns, Magyars, etc. This race possesses one of the oldest civilizations of the world and all of the great world religions except Christianity.

Lowest of the great races is the Ethiopic or Negro, whose members are black-skinned, black-eyed, wooly-haired, full-jawed and generally long-skulled. The race is mostly confined to regions of great heat and humidity, its center being the hot, low, broad valley of the great river Niger. There are three principal branches of the race, the Negrillo, the true Negro and the Negroid. To the Negrillo branch belong what are probably the lowest of living human peoples, the Akkas and other pygmies of Equatorial Africa and the Bushmen of Southern Africa. These peoples have no settled abodes, build no towns, cultivate nothing. They live by hunting and fishing and exchange of the trophies of the chase with neighboring agricultural people. They use the bow and arrow and many are cannibals.

The Negrillos are only approached in their primitive condition by the Papuans of New Guinea, some of whose tribes do not even know the bow and arrow. The Fuegians of Patagonia have also an extremely low culture, although physically they are well developed. But the African Negrillos have a physical make-up but little in advance of the prehistoric men of the Stone Age. Their brain cavity is about 1250 c.c. compared with the 1600 c.c. of the European; their facial angle is less, their maxillary angle less; and, in fact, in all those measurements and characters which go to separate man from the other mammals the Akkas and Bushmen of Africa, with perhaps the native Australians, are distinctly lowest and most animal like. Also these peoples, are, on the whole, in the lowest stage of culture of any of the human kind. But low as this culture may be it is yet something wholly unapproached or resembled in the life of the lower animals. Man's relationship to the animals is revealed only in his anatomy and physiology; not in his habits of life, his social and religious relations.

PART V

ANIMALS IN RELATION TO EACH OTHER, TO PLANTS, AND TO THE OUTSIDE WORLD

CHAPTER XXX

THE STRUGGLE TO LIVE, ADAPTATION AND DISTRIBUTION

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 sparrow 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 hosts 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? Presumably 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.

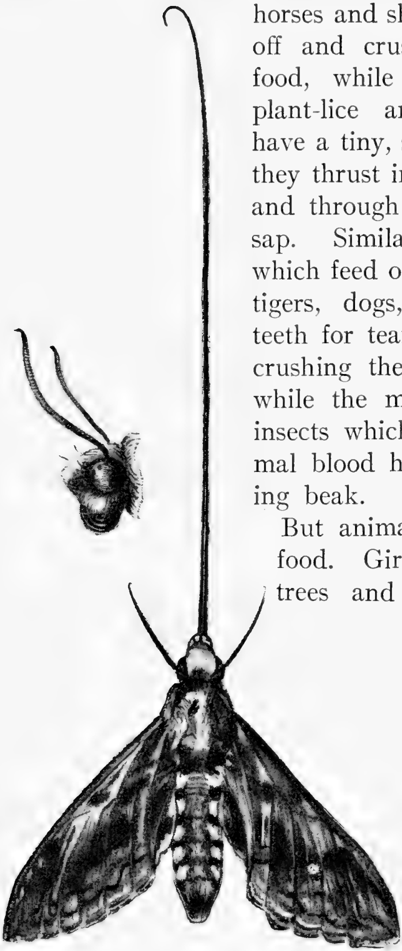


FIG. 201. Sucking proboscis of a sphinx moth; in small figure (the head of the moth seen in profile) the proboscis is shown coiled up on the under side of the head, the normal position when not in use. (One half natural size).

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. 201), 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. 202) 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. 202. A preying mantis. (Natural size.)

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 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-

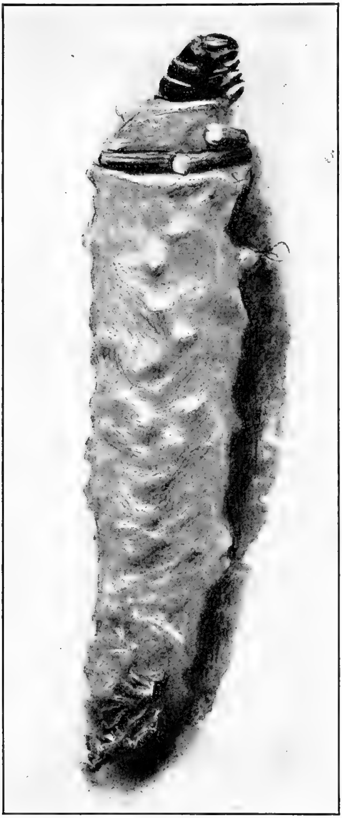


FIG. 203. Bag-worm; the larva of a moth that builds a protecting case out of silk and bits of stick, in which the whole body except horny head thorax and legs, is concealed. (Natural size.)

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 a later 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.

The distribution of animals.—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, 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 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

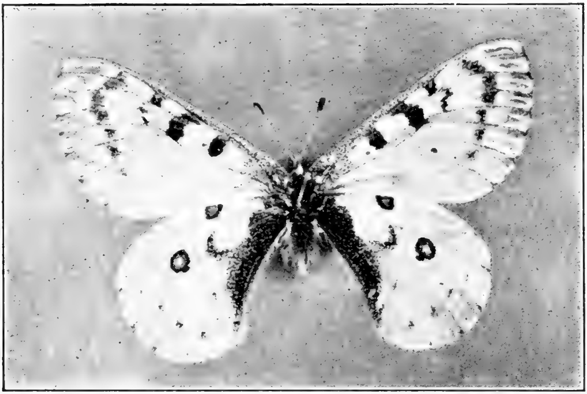


FIG. 204. The Parnassian butterfly, *Parnassius smintheus,* which lives in the Rocky Mountains and Sierra Nevada at an altitude of 5000 feet and above. (Natural size).

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, say one or two miles square, about the schoolhouse, 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 animal distribution see Heilprin's "Distribution of Animals," or Beddard's "Zoo-geography."

CHAPTER XXXI

ANIMAL PARASITES AND DEGENERATION

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. 205), which belongs to the crab and crayfish class. 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 tumorlike sac fastened to the crab by means of the feeding rootlets. Loss by degeneration of the body-parts is carried very far in this case.

Numerous other parasites live, like Sacculina, attached firmly to their host, and do not move about. They are

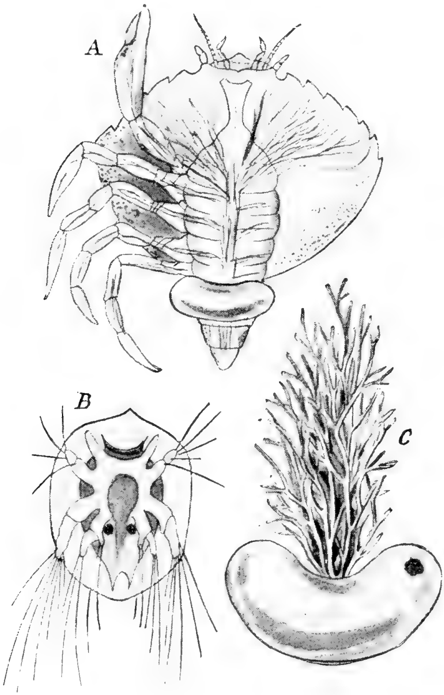


FIG. 205. Sacculina, a parasitic crustacean; A, attached to a crab, the root-like processes of the parasite penetrating the body of the host; B, the active larval condition; C, the adult removed from its host. (Enlarged; after Haeckel.)

carried by the host. Such parasites are usually without wings, legs, or other locomotory organs. Because they have given up locomotion they have no need of organs of orientation, those special sense organs like eyes and ears and feelers which serve to guide and direct the moving animal; and most non-locomotory parasites will be found to have no eyes, nor any of the organs of special sense which are accessory to locomotion, and which serve for the detection of food or enemies. Because these important organs, which depend for their successful activity on a highly organized nervous system, are lacking, the nervous system of parasites is usually very simple and undeveloped. Again, because the parasite usually has for its sustenance the already digested highly nutritious food elaborated by its host, most parasites have a very simple alimentary canal, or even no alimentary canal at all. Finally, as the fixed parasite leads a wholly sedentary and inactive life, the breaking down and rebuilding of tissue in its body go on very slowly and in minimum degree, and there is no need of highly developed respiratory and circulatory organs, so that most fixed parasites have these systems of organs in simple condition. Altogether the body of a fixed, permanent parasite is so simplified and so wanting in all those special structures which characterize the higher, active, complex animals, that it often presents a very different appearance from those animals with which we know it to be nearly related.

Internal parasites.—Inside the body of most animals live various parasites belonging to the great branch of worms. The tapeworm and the deadly trichina (fig. 206; for account see p. 147) are conspicuous examples of these. The tapeworm (fig. 207) 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 food already partly digested in the intestine of its host. It has no eyes or other special sense-organs, nor any organ of locomotion. 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

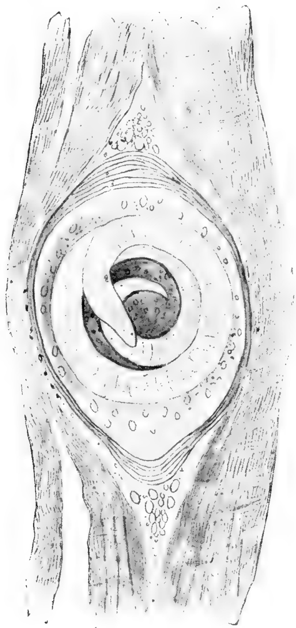


FIG. 206. *Trichina spiralis*, encysted in muscle of a pig. (Greatly enlarged.)

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 thus it finds its way into the alimentary canal and thence into the intestine of man. It now continues to develop until it becomes full grown.

Many animals are infested by minute parasites belonging to the Protozoa or one-celled animals. The class Sporozoa of the Protozoa is composed almost exclusively of parasitic species living in the blood, liver, alimentary canal, and

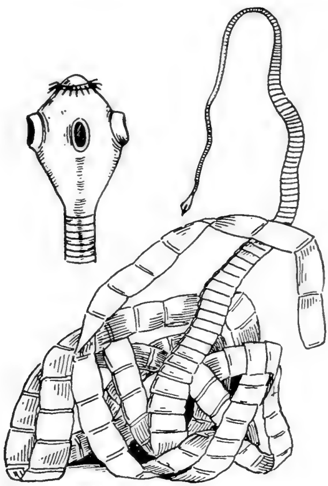


FIG. 207. Tape worm; the head, magnified, at left; the whole worm may be several yards long. (After Lenckart.)

other organs and tissue of animals. Over seven hundred and fifty kinds of these Sporozoan parasites have been described. Some of them, as has already been told in Chapter XII are parasites of the human body causing terrible infectious diseases among us.

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 butterfly 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

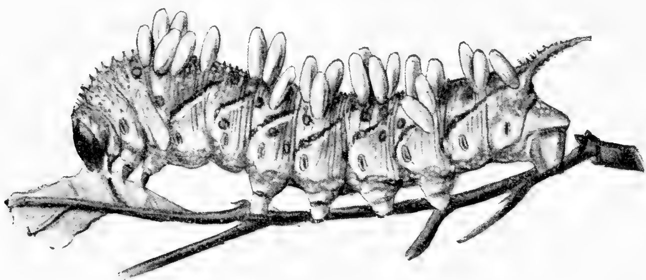


FIG. 208. Larva of a sphinx moth, with cocoons of a parasitic ichneumon fly. (Natural size.)

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.

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. 209), 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. 210). 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.

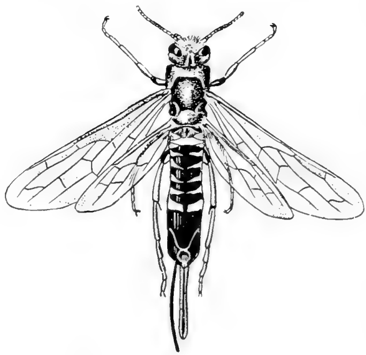


FIG. 209. The pigeon horn-tail, Tremex. (Natural size.)

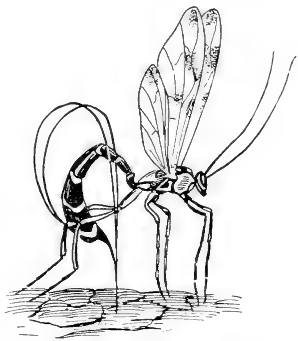


FIG. 210. Thalessa drilling into the burrow of Tremex. (Natural size; after Comstock.)

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. 211). Specimens of these parasites should be obtained and examined under a microscope to 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.

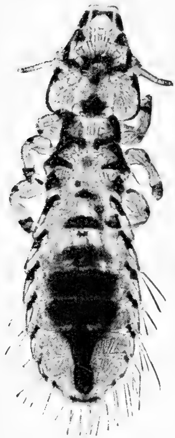


FIG. 211. A biting bird louse, *Nirmus praestans*, from the tern, *Sterna maxima*. (About 1-12 of an inch long; photo-micrograph by Geo. E. Mitchell.)

Parasites of the human body.—Our own body is infested, or may be, by many different parasites. More than fifty species of worms have been recorded as human parasites. The tapeworms and trichinæ, already referred to, may enter our body when we eat under-cooked meat, especially pork, which has not been properly inspected. Flukeworms of various species may live in the liver, lungs, intestine and even in the brain. A small round worm of the genus *Uncinaria*, called hookworm, which seriously affects the blood, has been found to be a very common parasite, being especially abundant in the South. Various Filariæ or blood worms cause frightful diseases among the natives of tropic lands. Elephantiasis, in which the patient's leg or arm may become so enlarged as to weigh as much as all the rest of his body, is one of these filaria-caused diseases from which a third of all the Samoans suffer.

Even more serious in their results than the diseases and troubles caused us by parasitic worms are those produced by Protozoan parasites. Associated with these diseases caused by animal parasites are those caused by the parasitic growth in our bodies of bacteria and bacilli, which are one-celled plants.

There are many other examples of parasitic life to be

FIG. 212. 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.)

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 XXXII

MUTUAL AID AND COMMUNAL LIFE

It is an altogether too common idea that in Nature all is one fierce and unrelenting warfare for place and food and life itself. While the "struggle to live" usually means to the layman student of Nature an unrelieved competition and often personal combat on the part of any one animal species or individual, to the experienced naturalist it is a large and general term which includes a great many kinds of shifts for a living, some of which may depend on a total cessation of individual competition and the adoption of the principle of mutual aid. Many individuals of one kind of animal may live together in a single elaborately organized community, as with the honeybee and the ants, where each individual works for all in a measure never yet realized among men. Or individuals of different species of animals may live together in more or less developed conditions of mutual tolerance and even helpfulness. Gregarious, commensal, social and communal forms of life are all abundantly represented among the lower animals. So that the phrase "struggle to live" must be understood to include altruistic as well as competitive and warring means. It must be understood to signify simply "means to live."

Commensalism.—The living together in peace and often to mutual advantage of individuals of different kinds of animals is called *commensalism*, or messmatism.

Among the coral reefs in the South Seas there lives an enormous kind of sea anemone or polyp. Individuals of this great polyp measure two feet across the disk when fully expanded. In the interior, the stomach cavity, which communicates freely with the outside by means of the large mouth opening at the free end of the polyp, there may often be found a small fish (*Amphiprion percula*). That this fish is purposely in the gastral cavity of the polyp is proved by the fact that when it is dislodged it invariably returns to its singular lodging place. The fish is brightly colored, being of a brilliant vermilion hue with three broad white cross bands. The discoverer of this peculiar habit suggests that there are mutual benefits to fish and polyp from this habit. "The fish being conspicuous, is liable to attacks which it escapes by a rapid retreat into the sea anemone. Its enemies in hot pursuit blunder against the outspread tentacles of the anemone and are at once narcotized by the 'thread cells' shot out in innumerable showers from the tentacles, and afterwards drawn into the stomach of the anemone and digested."

Small fish of the genus Nomeus may often be found accompanying the beautiful Portuguese man-of-war (Physalia) as it sails slowly about on the ocean's surface. These little fish lurk underneath the float and among the various hanging thread-like parts of the Physalia, which are provided with stinging cells. The fish are protected from their enemies by their proximity to these stinging threads. Similarly, several kinds of medusæ are known to harbor or to be accompanied by the young, or small adult fishes of the genera *Caranx* and *Psenes*.

Hermit crabs live in the shells of molluscs, most of the body of the crab being concealed within the shell, only the head and grasping and walking legs protruding. In some species of hermit crabs there is always to be found on the shell near the opening a hydroid polyp. "This hydroid is carried from place to place by the crab, and in this way is much aided in obtaining food. On the other hand, the crab is protected from its enemies by the well-armed and dangerous tentacles of its companion. On the tentacles there are many thousand long slender stinging threads, and the fish that would eat the hermit-crab must first deal with the stinging anemone." If the hydroid be torn away from the shell the crab will wander about seeking another polyp. When he finds one, he struggles to loosen it from the rock

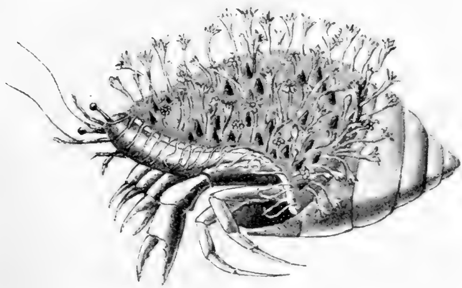


FIG. 213. Hermit crab within a shell on which is growing a hydroid polyp colony. (After Weismann.)

to which it is attached, and does not rest until he has torn it loose and placed it on his shell.

In the nests of the various species of ants and termites many different kinds of other insects have been found. Some of these are harmful to their hosts, in that they feed on the food stores gathered by the industrious and provident ant, but others appear to feed only on refuse or useless substances in the nest. Some appear to be of help to their hosts by cleaning the nests and by secreting certain fluids much liked by the ants. Over one thousand species of these myrmecophilous (ant-loving) and termitophilous (termite-loving) insects have been recorded by collectors as living habitually in the nests of ants and termites. Many of them (they are mostly small beetles and flies) have lost their wings and have had their bodies otherwise considerably modified, often in such wise that they come greatly to resemble in external appearance the ants with which they live.

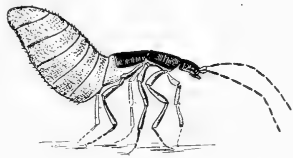


FIG. 214. *Termitogaster texana*, a rove-beetle (Staphylinidae) which lives in the nests of the termite, *Eutermes Cinereus*, in Texas. (Natural size 1 1-2 mm; after Bowes.)

The relations between ants and aphids (plant lice) are often referred to in popular natural histories and books about insects as examples of symbiosis of unusual interest. Unfortunately, however, not enough careful study has been given to many of these apparently true examples of symbiosis to enable us to be certain of the truth of the alleged care and guarding of the ant-cows, as Linnæus called these aphids, by their milkers, the ants. That ants do swarm about the aphids to lap up the "honey dew" excreted by them is wholly true, and the very presence of the sharp-jawed and pugnacious ants must keep away many enemies of the defenseless plant lice, toothsome morsels for the lady-bird beetles, flower-fly larvæ and other predatory insects.

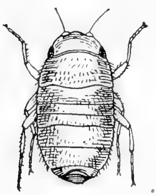


FIG. 215. *Aenigmatis blattoides*, a Phorid fly, which lives in the nest of the ant, *Formica fusca*, in Denmark. (Thirteen times natural size; after Meinert.)

In the case of the interesting relations between the corn root aphid, *Aphis maidis-radici*, of the Mississippi Valley States, and the little brown ant, *Lasius brunneus*, however, we have the careful observations of Professor Forbes to rely on. In the Mississippi Valley, this aphid deposits in autumn its eggs in the ground in corn fields, often in the galleries of the little brown ant. The following spring before the corn is planted, these eggs hatch. Now, the little brown ant is especially fond of the honey dew secreted by the corn root lice. So when the latter hatch in the spring, before there are corn roots for them to feed on, the ants carefully place them on the roots of certain kinds of grass and knot-weed (*Setaria*, *Polygonum*) and there protect them until the corn germinates. They are then removed to the roots of the corn. It is probable that the ants even collect the eggs of the aphids in the autumn and carry them into their nests for protection and care.

The studies of Wheeler and others have revealed some interesting cases of the living together of different species of ants. In some cases one of the ant species may be living almost wholly at the expense of the other species, as does the little yellow thief-ant, *Solenopsis molesta*. Although this ant sometimes lives in independent nests, more often it is to be found living in association with some large ant species—it consorts with many different hosts—feeding almost exclusively on the live larvæ and pupæ of the host. The thief-ant is so small and obscurely colored that it seems to live in the nests of its host practically unperceived. The *Solenopsis* nest may be found by the side of the host nest, around it, or partly in it, the tiny Solenopsis galleries ramifying through the nest mass of the host, and often opening boldly into these large galleries. Through their narrower passages, too narrow to be traversed by the hosts, the tiny thief-ants thread their way through the host nest in their burglarious excursions.

But there are numerous cases of a less one-sided advantage in the association of different species. As an example, the conditions exhibited by the red-brown ant, *Myrmica brevinodes* and the smaller *Leptothorax emersoni* (conditions made known by Wheeler's careful observations) may be briefly described. The little *Leptothorax* ants live in the *Myrmica* nests, building one or more chambers with entrances from the *Myrmica* galleries, so narrow that the large *Myrmicas* cannot get through them. When needing food the *Leptothorax* workers come into the Myrmica galleries and chambers and, climbing on the backs of the Myrmica workers, proceed to lick the face and the back of the head of each host. A *Myrmica* thus treated, says Wheeler, "paused, as if spell-bound by this shampooing and occasionally folded its antennæ as if in sensuous enjoyment. The *Leptothorax* after licking the *Myrmica's* pate, moved its head round to the side and began to lick the cheeks, mandibles, and labium of the *Myrmica*. Such ardent osculation was not bestowed in vain, for a minute drop of liquid—evidently some of the recently imbibed sugar-water—appeared on the Myrmica's lower lip and was promptly lapped up by the *Leptothorax*. The latter then dismounted, ran to another *Myrmica*, climbed on its back, and repeated the very same performance. Again it took toll and passed on to still another *Myrmica*. On looking about in the nest I observed that nearly all the *Leptothorax* workers were similarly employed."

Wheeler believes that the *Leptothorax* get food only in this way. They feed their queen and larvæ by regurgitations. The *Myrmicas* seem not to resent at all the presence of their *Leptothorax* guests, and indeed may derive some benefit from the constant cleansing licking of their bodies by the shampooers. But the *Leptothorax* workers are careful to keep their queen and young in a separate chamber, not accessible to their hosts. This is probably the part of wisdom, as the thoughtless habit of eating any conveniently accessible pupæ of another species is wide-spread among ants.

Social and communal life.—The simplest form of true social life exists among those animals in which many individuals of one species keep together, forming a great band or herd. Such animals are said to be gregarious in habit, and this gregariousness is undoubtedly advantageous to the individuals of the band. The great herds of reindeer in the North, and of the bison or buffalo which once ranged over the Western American plains are examples of a gregariousness in which mutual protection from enemies, as wolves, seems to be the principal advantage gained. The bands of wolves which hunted the buffalo show the advantage of mutual help in aggression as well as in protection. Prairie-dogs live in great villages or communities which spread over many acres. By shrill cries they tell each other of the approach of enemies, and they seem to visit each other and to enjoy each other's society a great deal, although that they are thus afforded much actual active help is not apparent. The beavers furnish a well-known and very interesting example of mutual help; they exhibit a communal life, although a simple one. They live in villages or communities, all helping to build the dam across the stream which is necessary to form the marsh or pool in which the nests or houses are built.

An interesting series of gradations from a strictly solitary through a gregarious to an elaborately specialized communal life is shown by the bees. Although the bumblebee and the honeybee are so much more familiar to us than other bee kinds that the communal life exemplified by them may have come to seem the usual kind of bee life, yet as a matter of fact, there are many more kinds of solitary bees than of social ones. The general character of the domestic economy of the solitary bees is well shown by the interesting little green carpenter bee, *Ceratina dupla*. Each female of this species bores out the pith from five or six inches of an elder branch or raspberry cane, and divides this space into a few cells by means of transverse partitions. In each cell she lays an egg, and puts with it enough food—flower pollen—to last the grub or larva through its life. She then waits in an upper cell of the nest until the young bees issue from their cells, when she leads them off, and each begins active life on its own account. The mining bees *Andrena*, which make little burrows in a clay bank, live in large colonies—that is, they make their nest burrows close together in the same clay bank, but each female makes her own burrow, lays her own eggs in it, furnishes it with food—a kind of paste of nectar and pollen—and takes no further care of her young. Nor has she at any time any special interest in her neighbors. But with the smaller mining bees, belonging to the genus *Halictus*, several females unite in making a common burrow, after which each female makes side passages of her own, extending from the main or public entrance burrow. As a well-known entomologist has said, *Andrena* builds villages composed of individual homes, while *Halictus* makes cities composed of apartment houses (fig. 217). The bumblebee, however, establishes a real community with a truly communal life, although a very simple one. The few bumblebees which we see in winter time are queens; all other bumblebees die in the autumn. In the spring a queen selects some deserted nest of a field mouse, or a hole in the ground, gathers pollen which she molds into a rather large irregular mass and puts into the hole, and lays a few eggs on the pollen mass. The young grubs or larvæ which soon hatch feed on the pollen, grow, pupate, and issue as workers—winged bees a little smaller than the queen.

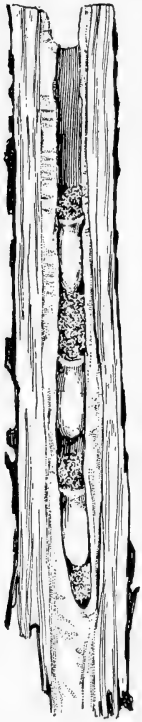


FIG. 216. Nest-tunnel of a carpenter bee. (Natural size.)

These bring more pollen, enlarge the nest (fig. 218), and make irregular cells in the pollen mass, in each of which the queen lays an egg. She gathers no more pollen, does no more work except that of egg-laying. From these new eggs are produced more workers, and so on until the community may come to be pretty large. Later in the summer males and females are produced and mate. With the approach of winter all the workers and males die, leaving only the fertilized females, the queens, to live through the winter and found new communities in the spring.

Honeybees live together, as we know, in large communities. We are accustomed to think of honeybees as the inhabitants of beehives, but there were bees before there were hives. The "bee tree" is familiar to many of us. The bees, in Nature, make their home in the hollow of some dead tree trunk and carry on there all the industries which characterize the busy communities in the hives.

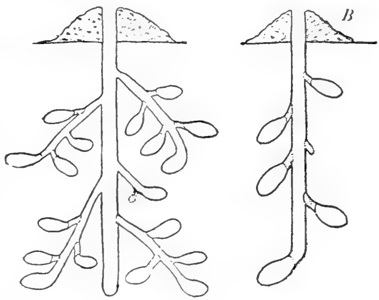


FIG. 217. Diagrams of nest-burrows of short-tongued mining-bees. B, nest of Andrena; A, compound nest of Halictus.

These industries and indeed the whole life of a honeybee community are so interesting and informing and withal so readily studied in any schoolroom that I give in the following pages some detailed directions and suggestions for a careful school study of the life of this fascinating insect.

The life of a honeybee.—In studying the life of the honeybees one must observe them in the hive as well as in the field. It is therefore highly desirable to have an "observation" hive (fig. 219), 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 encloses 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 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 enclosed broad shallow tunnel, covered above with glass, connecting the two openings. Over the glass top of the tunnel lay a sheet of dark card-

FIG. 218. Nest of bumble-bee, *Bombus* sp., showing opening at surface of the ground and brood-cells in cavity underneath. (Adapted from McCook.)

board, 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. Note the gathering of flower pollen (fig. 220). Where does the bee put the pollen as it collects it? Why doesn't the pollen fall off? Kill a bee in a killing-bottle and examine care-

FIG. 219. An "observation" beehive with glass top and sides. (Drawn from hive in the author's laboratory.)

fully 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. 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. 221). 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 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

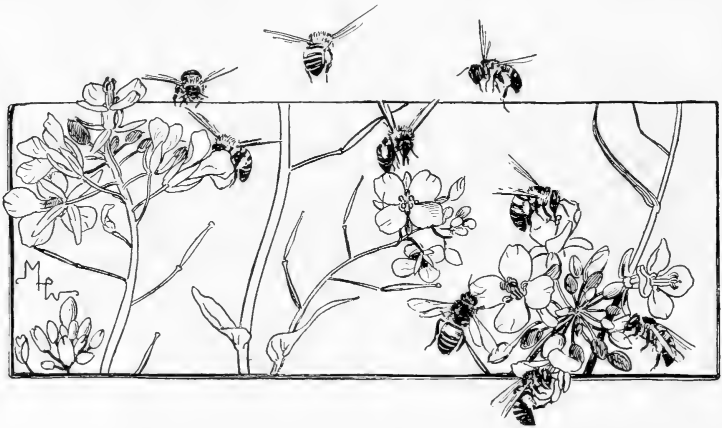


FIG. 220. Honeybees gathering pollen and nectar.

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 hindmost 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 nec-

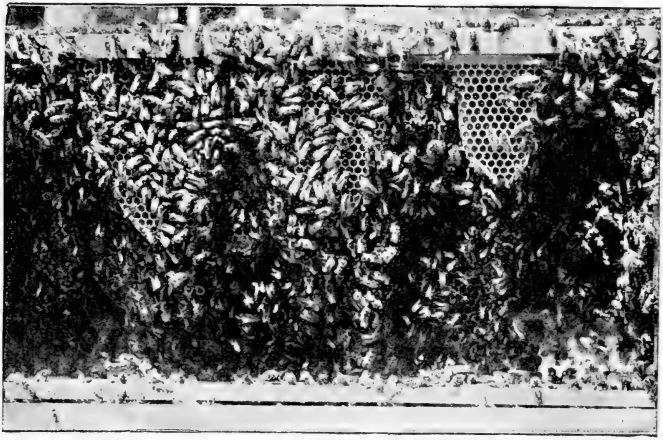


FIG. 221. Honeybees building comb. (After Benton.)

tar 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.

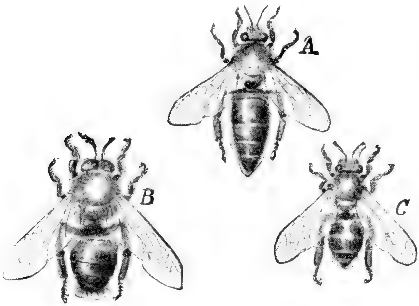


FIG 222. The honeybee *Apis mellifica;* A, queen; B, drone; C, worker. (From specimens.)

A honeybee community is made up of three kinds of individuals (fig. 222), 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. 223), 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

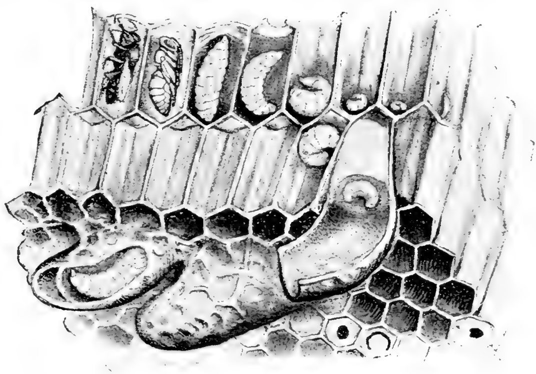


FIG. 223. Worker brood and queen-cells of honeybee; beginning at the upper right end of cells and going to the left is a series of egg, young larvae, old larvae, pupa, and adult ready to issue; the large curving cells below are queen-cells. (After Benton.)

cell change into pupæ and lie quiescent for thirteen days when they become fully developed bees. They now 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. 223). 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 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 honeybee 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 honeybees offer a splendid example of mutual aid instead of bitter war among individuals of a species. To be sure there is competition among different honeybee 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.

CHAPTER XXXIII

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

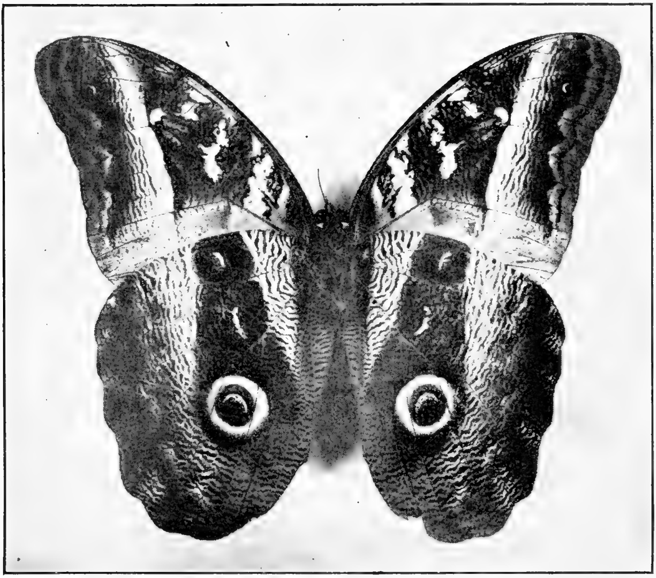


FIG. 224. Owl butterfly, *Caligo*, under side. (Two thirds natural size.)

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.

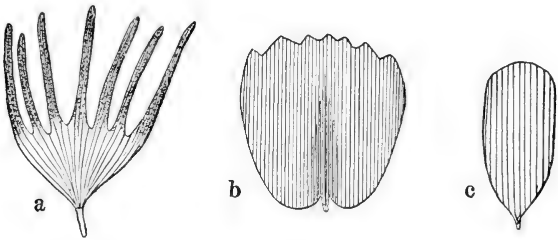


FIG. 225. Single scales from moths and butterflies; *a*, from *Tolype velleda*; *b*, from *Castnia* sp., *c*, from *Micropteryx aruncella*. (Greatly magnified.)

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. 225). 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, iridescent and changeable, on their wings. The common 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.

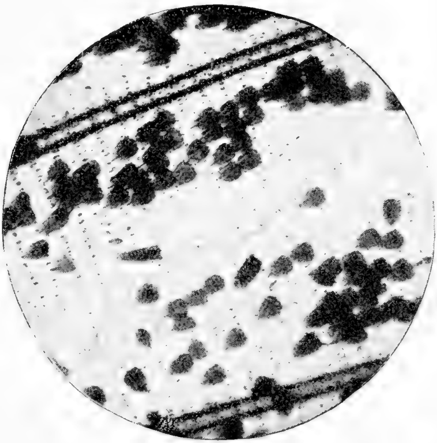


FIG. 226. A small, partly denuded part, much magnified, of a wing of the small blue butterfly, *Lycaena* sp., showing the scales and the pits in the wing-membrane, in which the tiny stems of the scales are inserted. (Photo-micrograph by G. O. Mitchell.)

Examine under the microscope a bit of wing from which most of the scales have been rubbed (figs. 226 and 227). 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 others' 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. 228) 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 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.

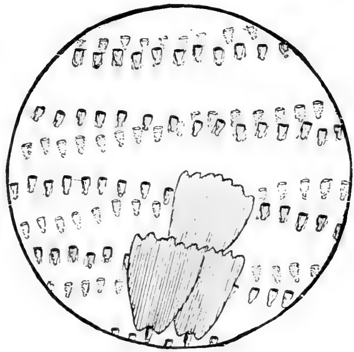


FIG. 227. Bit of rubbed wing of a butterfly, *Grapta* sp., greatly magnified, to show the rows of scale insertion pits on both upper and lower sides of the wing.

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.

FIG. 228. Diagram to show the shingling arrangement of the scales over the surface of a butterfly's wing; the short black bars indicate scales in cross-section, and the broad central bar, the wing in cross-section.

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 live successfully. 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. 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.

FIG. 229. The so called deaths'-head sphinx moth; this moth is looked on with superstitious dread by many people. (Natural size.)

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's 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 evergreen foliage of trees in warm regions live green tree-frogs and tree-snakes and insects.

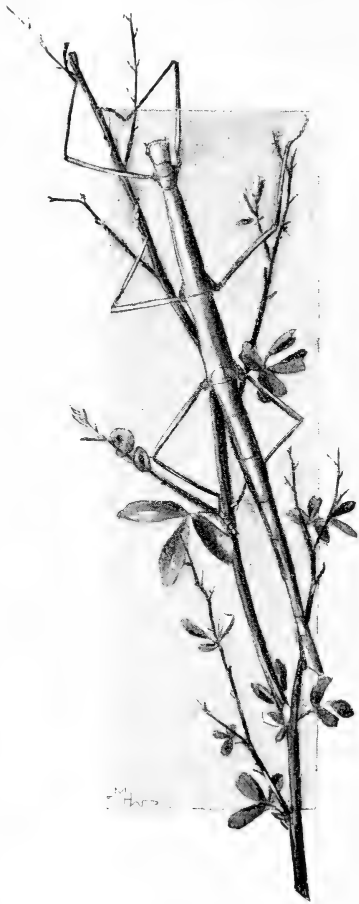


FIG. 230. The twig insect or walking-stick, *Diapheromera femorata.* (Natural size.)

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 recoggnized, is the walking-stick insect (fig. 230). 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

FIG. 231. The dead-leaf butterfly, *Kallima* sp., a remarkable case of special protective resemblance.

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. 231), 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.

FIG. 232. Larva of the monarch butterfly, conspicuously marked with black and whitish-yellow wings, and distasteful to birds. (Natural size.)

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 are colored like their surroundings. Often indeed color and pattern are such as to make an animal very noticeable.

The common large red-brown monarch, or milkweed butterfly (fig. 233), is a conspicuous object whether in flight or alighted on some flower or branch. But the birds do not attack it; and for the 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

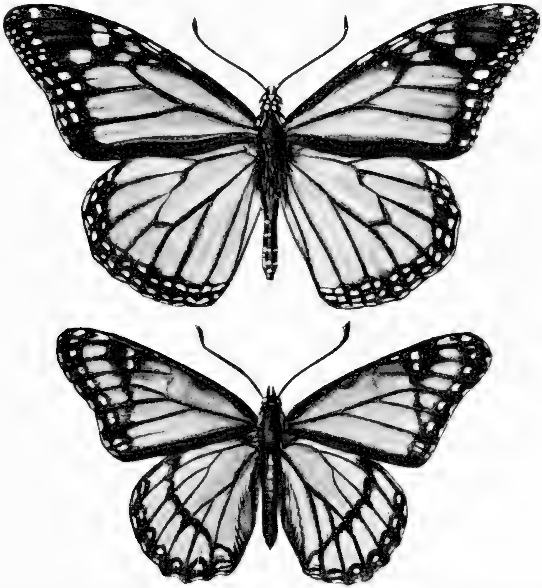


Fig. 233. The monarch butterfly, *Anosia plexippus* (above), distasteful to birds, and the viceroy, *Basilarchia archippus* (below), which mimics it. (Natural size.)

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.

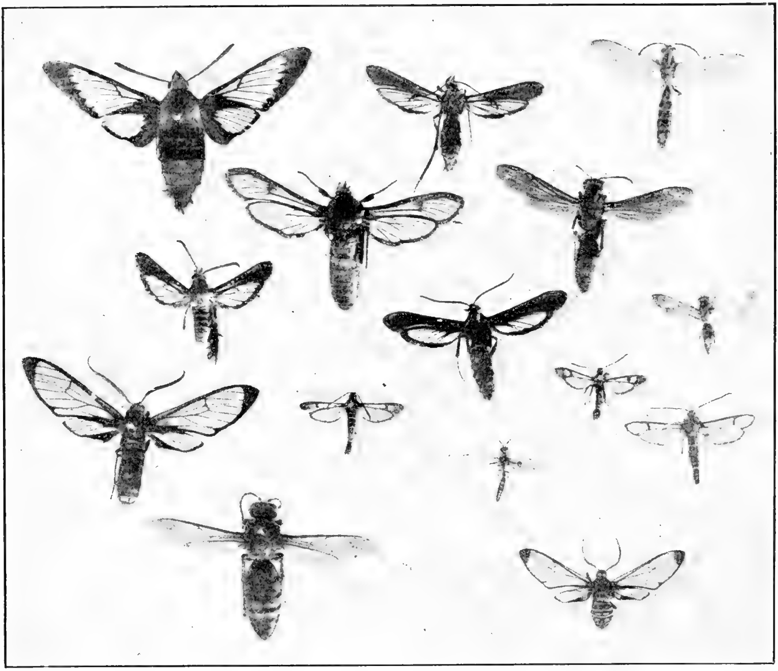


FIG. 234. Various moths and wasps, the moths having the appearance of wasps, probably through mimicry, for the sake of the protection afforded by their being mistaken for the stinging insects. (Natural size; photograph by the author.)

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. 233), 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 markings 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 wide-spread 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 the male birds are for the purpose of pleasing and attracting the females 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 XXXIV

INSECTS AND FLOWERS

The nectar of flowers is a favorite food with many insects; all the moths and butterflies, all the bees, and many kinds of flies are nectar-drinkers. Flower-pollen, too, is food for other hosts of insects, as well as for many of those which take nectar. The hundreds of bee kinds are the most familiar and conspicuous of the pollen-eaters, but many little beetles and some other obscure small insects feed largely on the rich pollen-grains. But the flowers do not provide nectar and pollen to these hosts of insect guests without demanding and receiving a payment which fully requites their apparent hospitality. And several particular things about this payment are of especial interest to us. These are, first, the unusual character of the payment received; second, the great value of it to the plants; and finally, the strange shifts and devices which the plants exhibit for making the payment certain. This payment is the cross-pollinating of the flowers by their insect visitors. (Cross-pollination is simply the bringing of pollen from the stamens of one flower to the pistils of another flower of the same plant species.)

In 1793 a German naturalist named Christian Conrad Sprengel published a book called "The Discovered Secret of Nature in the Structure and Fertilization of Flowers." This discovered secret was that insects were instrumental in pollinating flowers and that the colors and shapes of flowers helped to attract insects and compel them to do this pollinating. But it was reserved for the great Darwin to describe in wonderful detail this mutually advantageous interrelation between flowers and insects and to explain its chief causal factors. These are, first, the real advantage to the plant of cross-pollination, and, second, the action of natural selection in modifying both flowers and insects for the sake, or by the reason, of this advantage.

Fertilization among plants is like fertilization among

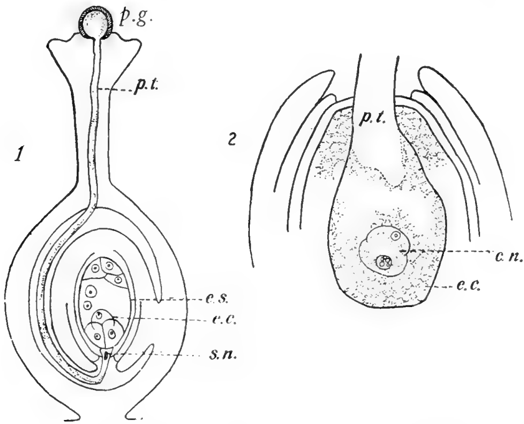


FIG. 235. Diagram of section of pistil and ovary of a flower, showing the descent of the pollen tube and its entrance into the ovule. *p. g.*, pollen-grain; *p. t.*, pollen-tube; *e. s.*, embryo sac; *e. c.*, egg-cell; *s. n.*, sperm nucleus. Left-hand figure (1) shows the pollen-tube grown down, around and up into the ovary with the sperm-nucleus just entering the ovule; right-hand figure (2) shows the fusion of the sperm-nucleus. (After Stevens.)

animals; a germ- (sperm-) cell from one individual (male or hermaphrodite) fuses with a germ- (egg-) cell from another (female or hermaphrodite) individual or from the same (hermaphrodite) individual. The sperm-cells are contained in pollen produced in the anthers of stamens; the egg-cells lie in the ovaries at the base of the pistils, these pistils having an exposed pollen-catching surface (stigma) at their free tip. Before actual fertilization can occur pollination must take place; pollination being the bringing and applying of ripe pollen-grains to the ripe surface of the stigma. How fertilization then takes place is succinctly explained by fig. 235 and its caption, which are copied from Stevens ("Introduction to Botany," Boston, 1902).

The advantage of cross-pollination, as first experimentally proved by Darwin and since then confirmed by other experimenters and by hosts of plant breeders, lies in the fact that the seeds from cross-pollinated plants usually produce stronger plants than are produced by the seeds of self-pollinated plants. To effect cross-pollination plants have developed two kinds of means; first, means to attract insects and humming-birds, and to insure cross-pollination as the result of their visits; second, means to prevent self-pollination. Also insects that visit flowers have developed certain peculiarities of structure and habit which correspond to the special character of the flowers chiefly visited by them. These reciprocal modifications of flowers and insects have gone so far in some cases that certain plants and certain kinds of insects cannot exist apart from each other. Many flowers are not fertile when fertilized by their own pollen and these may have no other possible means of getting pollen from other plants except by insect visits.

The principal means which have been developed to avoid self-fertilization are the following: first, having flowers either only staminate or pistillate; these different flowers may occur on the same plant individual or only on separate individuals; second, having both pistils and stamens on each flower but with the pollen not ripe at the same time as the stigma; third, having the stamens and pistils in the same flower of different length or having them so situated that the pollen will be unlikely to fall on the stigmas.

The principal means for insuring cross-pollination are: first, the secretion of nectar to feed insects; second, the development of odor, color, pattern and shape to guide them to the flower and when there to the nectar and pollen in such a way as to insure their brushing against either the stamens or stigmas; third, modifications of shape so as to prevent the stealing of nectar and pollen by non-helpful insects; and fourth, blossoming at those times in the year when the particularly helpful insects are most numerous, and the opening of flowers at such times, in daylight, twilight or at night, as exactly to accord with the food seeking times of the insects. The great variety in the shape, color and patterns of flowers suggests the great variety that actually exists in the ways in which flowers attract and at the same time profit by the insects.

The nectar, which is what most insects come to the flowers to get, is a sweetish liquid secreted by special tissues called nectaries. These may occur on any part of the flower, but they are most frequently found at the bases of the stamens, petals, and ovaries, and rarely on the calyx. In the plum and peach they form a thick inner lining of the cup-shaped receptacle. In nasturtiums the nectar is secreted in a long spur from the calyx.

Some flowers of simple construction expose their nectar freely to all sorts of insects, but others conceal it in various ways so that it is accessible only to insects of certain kinds. A frequent device is to have some parts of the corolla close the way to the nectar so that small insects which would not assist in cross-pollination are excluded, and only those which are strong enough to push aside the barrier or have proboscides of proper construction to thrust past it can obtain nectar and accomplish the transference of the pollen.

The pollen, which is sought for only by bees and a few little beetles, is a normal product of the flower and it is only necessary that there be enough of it to supply the insects and yet supply the plant's own use for fertilization. The oldest and most primitive means developed among plants to effect cross-pollination, a means still used by all the conifers, the grasses and many other plants mostly without sepals and petals, is the production of vast quantities of light loose pollen grains to be distributed by the winds. "Sulphur rains" that come sometimes at the pollen ripening time of pinetrees are simply showers of wind-blown yellow pollen from the forests. With nectar and pollen ready for use the plant has yet to advertise its sweets to the insects, and for this brilliant colors and attractive odors are relied on. An odor attractive to insects is not always pleasing to us, for the Araceæ, some Trilliums and others have a carrion-like odor "combined with dull colors often marked with livid blotches or veins like dead animal bodies, and these flowers attract flesh-flies and carrion-beetles which are the pollinating agents." The simpler insect-visited flowers, such as those of the apple, cherry, wild rose, ranunculus, etc., are mostly wide open and accessible to a large variety of insect visitors. They are all abundant pollen providers and some secrete nectar which is easily got at. But to get either nectar or pollen the insects have to scramble over and among the many crowded stamens of the center, dusting themselves well during the process with pollen, which is carried on to the next flower visited and there probably rubbed off on to the stigma. To such simple flowers, and to others like them, as the Umbelliferæ and the numerous Compositæ, many kinds of insects may come. For example, Robertson found 275 different insect species visiting an Umbellifer in three months in Illinois, and 146 kinds visiting a golden rod in 11 days.

With the flowers of tubular corolla the nectar can be got at only by insects especially provided with long tongues, such as bees and some flies, moths and butterflies. The deeper kinds of flowers are mostly visited by insects with especially long proboscides. The common jimson-weed, *Datura stramonium*, is, as Stevens says, an excellent example of this. "The corolla is about five centimeters long, and the cavity of the tube is closed at about the middle of its length by the insertion of filaments there. When the flower opens in the evening it emits a strong musky odor, and a large drop of nectar is already present in the bottom of the tube; so that large sphinx moths, leaving the places of seclusion occupied by them during the day, are attracted by the strong odor and white color of the flowers.

"Flying swiftly from flower to flower, the moth thrusts its long proboscis to the bottom of the tube and secures the nectar; and while it is tarrying briefly at each flower, keeping itself poised by the swift vibration of its wings, it is pretty certain to touch with its proboscis both anthers and stigmas, which stand close together at about the same height near the mouth of the corolla. Both cross- and self-pollination might be brought about in this way, but as Darwin has shown, the foreign pollen would probably possess the greater potency, and cross-fertilization would be apt to result. The harmonious relation between length of the insect proboscis and depth of the flower corolla is strikingly shown by all the sphinx moths and the flowers they visit.

Another kind of arrangement of flower structure which tends to preserve the nectar for certain special kinds of insects is well illustrated by the salvias, snap-dragon, and other similar flowers. In these the corolla is irregular and the stamens and pistils are so arranged that insect visitors are compelled to visit the nectary in one particular manner, a manner such as to insure their touching the anthers or stigma or both. In the snap-dragon the opening of the flower-cup is normally closed, but when a bee alights on the broad keel or platform (composed of two petals grown together) its weight so depresses this platform as to open the way into the flower-cup, which closes at once when the bee goes in and drinks the nectar. Scrambling and twisting about in the narrow chamber it thus thoroughly dusts itself with pollen, or thoroughly dusts the stigma with pollen acquired from a previous visit to another flower. Miscellaneous small insects alighting on the keel are not heavy enough to depress it, and thus are prevented from entering and stealing the nectar. In the salvias (sages) the corolla is similarly tubular below and two-lipped above, the lower lip serving as an alighting-platform for the insect visitors (usually bees), while the arched upper lip covers and protects the stamens and pistil.

Fig. 236. Honeybee at Asclepias flowers, with legs still fast in a stigmatic chamber of the flower last visited. (Natural size; after Stevens.)

In the scarlet sage (Salvia sp.) cross-pollination is accomplished by humming birds, which, hovering in front of the narrow mouth of the flower-cup, thrust deeply into it their long bills in the search for small insects which may have entered for nectar. Other flowers regularly visited and cross-pollinated by humming birds are the scarlet currant, various painted cups (Castilleias), the scarlet mimulus, the wild columbine, the trumpet-creeper, the spotted touch-me-not, the cardinal-flowers, cannas, and fuchsias. Red seems to be the attractive color for humming birds.

A wonderful arrangement to insure cross-pollination by insects is that shown by the milkweeds of the genus Asclepias. Stevens has described this so well ("Introduction to Botany," p. 191 et seq.) that I simply quote here most of his account.

"As shown in fig. 236, the sepals and petals are reflexed; the stamens are joined throughout their length, and are united to a thick and flat structure at their apices, known as the stigmatic disk, which is also united with the top of the two pistils. The pistils are entirely enclosed by the stamens and the stigmatic disk. Five spreading, hollow receptacles for the nectar grow out and upward from the bases of the stamen.

"Each pollen-sac contains a compact mass of pollen-grains which never become separated from one another, and so constitute what is termed a pollinium. The two contiguous pollinia of adjacent anthers are united by horny rods which converge upward and join with a horny dark body known as the corpusculum, which is hollow and has a slit along its outer face. This slit is relatively broad at the bottom, and tapers toward the top, thus forming a clip in which the feet of the insects get caught. Between each pair of anthers there is a deep recess closed by two vertical lips which stand wider open at the bottom than at the top, and the recess also narrows at the top. The opening between the lips at the top stands exactly beneath the slit in the corpusculum.

"The surface of the flower is slippery, so that when a bee, for instance, visits it, a good foothold is not obtained until the bee slips its foot into the recess between the anthers, termed the stigmatic chamber. Having obtained a foothold, the bee thrusts its sucking-apparatus into the hollow nectar-receptacle and obtains the nectar which has invited it to the flower. When the bee, however, seeks to go to another flower, its foot slips upward and becomes caught in the slit in the corpusculum. A struggle now ensues which usually results in the bee pulling the two pollen-masses, united to the corpusculum, through the narrow slits at the tops of the pollen-sac; and thus laden, it seeks another flower, and there slips its foot, together with the pollen-masses, into the stigmatic chamber.

"Now when the bee attempts to leave the flower, the pollen-masses become tightly wedged at the narrow apex of the chamber, and a hard pull is required to break them loose from the foot. Finally, as the foot is being drawn from the stigmatic chamber it catches into the corpusculum directly above and pulls out a second pair of pollen-masses. Thus the bee goes from flower to flower and from plant to plant, repeatedly pulling pollen-masses from their sacs and depositing them in the stigmatic chamber. Fig. 236 is from a photograph of a honey-bee gathering nectar from Asclepias-flowers. One of the hind legs is still in the stigmatic chamber of the flower, which the bee has just deserted."

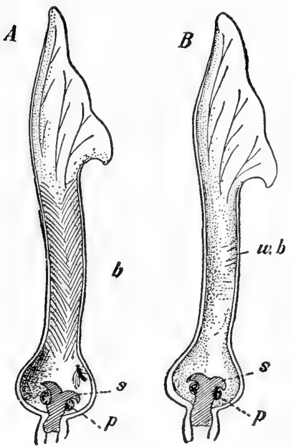


FIG. 237. Flower of *Aristolochia clematitis* in longitudinal section: A, before fertilization by little fly; B, after fertilization; *p*, pollen-masses; *s*, stigma; *b*, bristly hairs; *wb*, without bristly hairs. (After H. Muller.)

Hive-bees, although common visitors to Asclepias, are really hardly strong enough to insure pulling loose from the flowers, and many of them besides numerous flies and small butterflies, get caught and die in the flower-heads. Robertson has noted nine species of insects thus killed by *Asclepios cornuti.* Bumble-bees and large wasps and large butterflies are the most certain milkweed pollinators.

Still another markedly different kind of specialization to effect cross-pollination by insects is that shown by many Araceæ and Aristolochiaceæ. The flower (fig. 237) in these plants consists of a long tubular perianth (spathe) with a constriction near the base, the narrow opening into the cavity below being nearly closed by stiff downward-pointing hairs, so as to make a sort of floral eel-trap. It really is an insect-trap; small flies crawl down the long tube and through the narrow opening in search of nectar; but when ready to return find themselves imprisoned by the downward-pointing hairs. After a while the stigmas, which mature before the anthers and have likely been pollinated (with pollen brought from other flowers) by the entering insects, wither, a drop of nectar is secreted for the benefit of the captured insects, and the anthers mature, exposing their ripe pollen-grains. The hairs in the throat of the flower gradually shrivel up and release the insects which are now well showered with pollen falling on them from the anthers above. Visiting another Arum-flower, they hardly fail to rub off some of this pollen on the mature stigmas. Sometimes more than a hundred small flies will be found imprisoned in a single Arum.

Classic examples of apparently the wildest vagaries in flower structure are those presented by the orchids. But Darwin's fine work revealed the method in all this floral madness. Orchids are pollinated almost exclusively by insects, and the extravagant shapes and color-patterns are all means for accomplishing cross-pollination. Any one interested at all in the interrelation between flowers and insects should read Darwin's account of the orchids and their insect visitors, in his book "On the Fertilization of Orchids by Insects."

The above few examples of the interrelations between flowers and insects are not exceptional cases. Indeed, this state of affairs is the rule throughout the families of flowering plants. The absence of it is the exception. Cross-pollination by insects is far more abundant than self-pollination.

It is of distinct interest to note that no plants of colored flower-parts existed (in geologic time) before the time of winged insects. The insects which we know today as the pollen- and nectar-feeders, hence flower visitors, began to be abundant in the world coincidentally with or a little in advance of the flowering plants. Mutually helpful and mutually adapting themselves to each other, the flies, bees, moths, and butterflies, on the animal side and all those plants with flowers of varied shapes, color, and patterns, on the vegetable side, have developed so successfully during the course of the history of the earth that in present times flower-visiting insects and insect-attracting flowers have come to be the most specialized and notable members of each of their great groups of organisms.

APPENDIX I

PUPIL AND SCHOOLROOM EQUIPMENT

Note-books and drawings.—Each pupil should have a note-book of about 8 x 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.

Equipment of schoolroom.—The equipment of the classroom or laboratory will, of necessity, depend upon the opportunities afforded the teacher by the school officers to provide such facilities as instruments, books, and charts. If dissections are to be seriously and properly made, however, some equipment is indispensable. Flat-topped tables, not over 30 inches high, a few compound microscopes (one is much better than none), as many simple lenses, or, far better, simple dissecting-microscopes, as there are students, dissecting-dishes, a pair of bone-clippers, one injecting-syringe, a bunch of bristles, water, a few simple reagents and some inexpensive glassware, as slides, cover-glasses, watch-crystals, and fruit- or battery-jars for live cages and aquaria, make up a sufficient equipment for good work. Much can be done with less, and perhaps a little more with some additional facilities.

The dissecting-pans should be of galvanized iron or tin, oblong, about 6 x 8 inches by 2 inches deep, with slightly flaring sides. If an iron wire be run around the margin, and the margin bent back over it, it will strengthen the dish, and make a broader and smoother edge for the hands to rest on. Diagonally across the dish, about one-fourth inch from the bottom, should run a thick wire. A layer of paraffin one-half inch thick should cover the bottom. It should be poured in melted, when the diagonal wire will be imbedded in it and will hold it in place. Acids must not be put into the pan.

The reagents necessary are alcohol of 95 per cent and 85 per cent, and formalin of 4 per cent (the formaldehyde sold by druggists is 40 per cent and should be diluted ten times with water), these for preserving material for dissection; chloroform for killing specimens; glycerin for making temporary microscopic mounts, and 20 per cent nitric acid for preparing specimens for study of the nervous system. In addition there will be needed the few other materials mentioned in the following paragraphs as necessary in the preparation of injecting-fluids, the staining of fresh tissue and preserving by special methods.

A list of reference books desirable in the laboratory is appended as a separate paragraph (see p. 466).

Collecting and preparing material for use in the laboratory.—As directions have been given here and there through the book for the collecting and preparing of the various kinds of animals chosen as subjects of the laboratory exercises, it will only be necessary to give here directions for making certain special mixtures and for the special preparation of specimens by injection, etc. Specimens to be used for dissection should be kept in alcohol 85 per cent or in formalin of 4 per cent. Alcohol is better for the earthworm, but for the other examples formalin is either better or as good, and as it is much cheaper it may well be chosen for the general preservative.

Methyl green, a stain used for coloring fresh tissues. Dissolve the methyl green powder in water, using about as much powder as the water will take up. Add a few drops of acetic acid.

Injecting-masses.—Injections are best made with preparations of French gelatine, but white glue will answer most purposes. For fine injection use a combination of the following: 1 part of a solution of gelatine, 1 part to 4 parts of water; 1 part of a saturated solution of lead acetate in water, and 1 part of a saturated solution of potassium bichromate in water. A mixture of these when hot gives a beautiful yellow injection-mass which, filtered, will pass through the finest capillaries. For different colorings use dry paints, which come in ultramarine blue, vermilion, and green. The gelatine should be thoroughly soaked before the coloring-matter is added. A mistake is generally made in using the injection-mass too thick. One part by weight of gelatine to six or even more parts of water is a good proportion. The gelatine as well as glue-masses should be made in a water-bath, which consists of one dish placed within another outer one containing warm water. The mass should be injected warm, *not hot*, after which the injected specimen is to be placed in cold water until the injecting-mass has set. Glue (the ordinary white kind) can be used for most injections just as the gelatine was used, but should not be so much diluted. All injection-masses should be filtered through a cloth before using.

Preparing skeletons.—In general, skeletons are best cleaned by boiling. After most of the flesh has been cut away the skeleton should be boiled in a soap solution until the remaining parts of the muscles are thoroughly softened. The soap solution is made of 2,000 c.c. of water, preferably distilled, 12 grams of saltpetre, and 75 grams of hard soap (white). Heat these until dissolved, then add 150 c.c. of strong ammonia. This stock solution is mixed with four or five parts of water, when the mixture is ready for use. The bones after boiling are rinsed in cold water, brushed and picked clean, then left to dry on a clean surface.

Preserving anatomical preparations.—Many specimens worth keeping will be found, and for them a solution known as Fischer's formula is suggested as good, especially for brains. Fischer's formula is made up as follows: 2,000 c.c. of water, 50 c.c of formalin, 100 grams of sodium chloride, and 15 grams of zinc chloride. These are mixed together until thoroughly dissolved. Open preparations well before placing them in the liquid and use about twenty times the volume of the object to be preserved.

To keep fresh dissections.—For materials which are dissected fresh and must be kept over for several days in a fresh condition add a few drops of carbolic acid to the water which covers them. Carbolized water (2 per cent in water) will preserve a great many tissues for a long time. Hearts will remain for years in a supple condition in this solution.

Obtaining marine animals, microscopic preparations, etc.—For schools not on the seashore the marine animals such as starfishes, etc., which are to be dissected or examined as examples of the branches to which they belong must be obtained as preserved specimens from dealers in such supplies. Among such dealers on the Atlantic coast are the Marine Biological Laboratory, Woods Holl, Mass.; F. W. Walmsley, Academy of Natural Sciences, Philadelphia, Pa.; and and C. S. Brimley, Raleigh, N. C.; on the Pacific coast, the Supply Department, Hopkins Seaside Laboratory, Stanford University, California. Ward's Natural Science Establishment, Rochester, N. Y., and the Kny-Scheerer Co., New York City, supply almost any biological specimens asked for. These establishments furnish ready made dissections and sets illustrating life-history and metamorphosis. The few permanent microscopic preparations which are mentioned in the book as desirable to have can be made by the teacher if he has had any training in microscopical technic. If not, they may be bought cheaply of such dealers in natural history supplies as the Bausch & Lomb Optical Co., Rochester, N. Y.; the Kny-Scheerer Co., 17 Park Place, New York City; Queen & Co., 1010 Chestnut Street, Philadelphia, Pa., and numerous others. From these dealers also can be bought all of the laboratory supplies, such as lenses, slides, cover-glasses, dissecting-scalpels, scissors and needles, etc., mentioned in this book.

Reference books.—Throughout the preceding chapters exact references have been made to various books, as many of which as possible should be 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. Most of the books referred to, together with some others, 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 the books desired may be handed to any book-dealer, who will order them and who should in all cases be able to get them for at least no more than publisher's list prices.

Agassiz, E. C. Editor. Louis Agassiz, Life and Correspondence. 1890, Houghton, Mifflin & Co. $2.50.

Bailey, F. M. Handbook of Birds of Western U. S. 1902, Houghton, Mifflin & Co. $3.50.

Baskett, J. N. Story of the Fishes. 1899, D. Appleton & Co. $0.75.

—— The Story of the Birds. 1899, D. Appleton & Co. $0.65.

Beddard, Frank. Animal Coloration. 1892, Macmillan Co. $3.50.

—— Zoogeography. 1895, Macmillan Co. $1.60.

Beebe, C. W. The Bird: Its Form and Function. 1909, Henry Holt & Co. $3.50.

Bendire, Chas. Directions for Collecting, Preparing, and Preserving Birds' Eggs and Nests. Distributed by U. S. National Museum.

Bird Lore, an Illustrated Journal about Birds Appleton Co. $1.00 a year.

Calkins, G. N. The Protozoa. 1901, Macmillan & Co. $3.00.

Chapman, Frank. Handbook of the Birds of Eastern North America. 1899. D. Appleton & Co. $3.00.

—— Bird Life. 1900, D. Appleton & Co. $2.00.

Comstock, A. B. How to Keep Bees. 1905, Doubleday, Page & Co. $1.00.

Comstock, J. H. Manual for the Study of Insects. 1897, Comstock Publishing Co. $3.75.

—— Insect Life. 1901, D. Appleton & Co. $1.50.

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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 IX. Harmless snakes are easily kept in glass-covered 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 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 for the schoolroom menagerie. In Chapters VIII and XIV 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. 238). The glass should fit closely when shut, to prevent the escape of the insects.

"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.

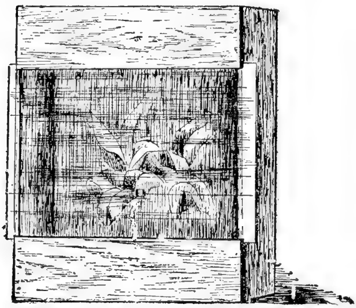

FIG. 238. Soap-box breeding-cage for insects.

"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.

"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 mid-winter.

"An excellent breeding-cage is represented by fig. 239. 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.

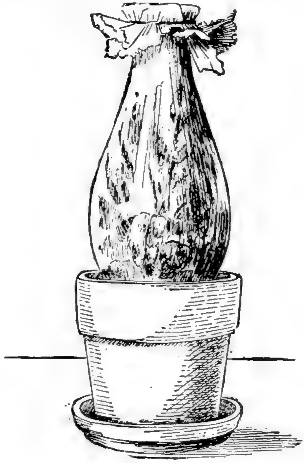

FIG. 239. Lamp-chimney and flower-pot breeding-cage for insects.

"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.

FIG. 240. Battery-jar aquarium.

"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. 240). 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.

"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 high-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 high-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. 241. Insect killing-bottle; cyanide of potassium at bottom, covered with plaster of Paris.

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. 241) 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 (see p. 464). 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. 242) (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 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.

FIG. 242. Insect properly pinned up.

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. 243 and 244) 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.

"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.

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.

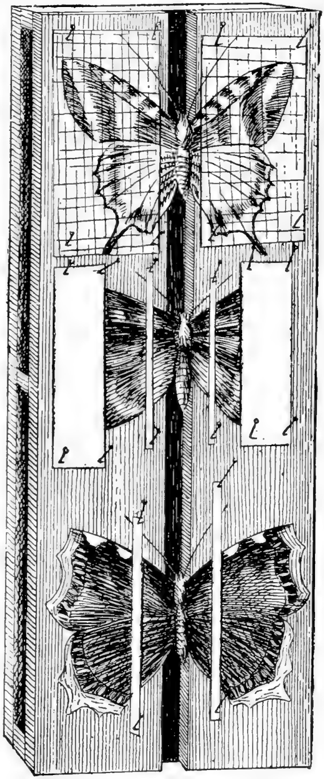

FIG. 243. Setting-board with butterflies properly "spread". (After Comstock.)

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, 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 of 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.

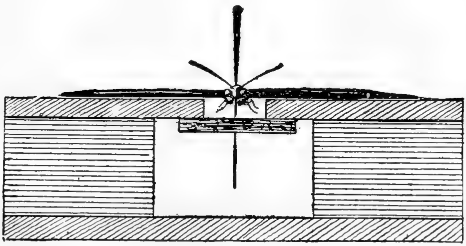

FIG. 244. Setting-board in cross-section to show construction. (After Comstock.)

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 dealers in naturalists' supplies, see p. 464). 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

*The following directions for making skins of mammals were written for this book by Professor W. K. Fisher of Stanford University, an experienced collector.

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 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.

END

INDEX

References to illustrations are indicated by an asterisk (*).

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