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TWENTIETH CENTURY TEXT-BOOKS

EDITED BY

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FORMERLY SUPERINTENDENT OF HIGH SCHOOLS, CHICAGO

Murres and nests (*Uria lomvia arra*), Walrus Island, Pribilof group.
Photograph by Harry Chichester.

TWENTIETH CENTURY TEXT-BOOKS

ANIMAL FORMS

A SECOND BOOK OF ZOOLOGY

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PREFACE

The present volume is designed to meet the needs of the beginning student of zoology. Accordingly, technical and scientific names have been avoided as far as possible, and those used are fully explained in the text or elsewhere. The opening chapters deal with the characteristics of living things, and, in contrasting animals and plants, attempt to bring into relief the distinguishing marks of all animals. Then follows a discussion of the cell and protoplasm, preparing the way for the examination of a series of animals representative of each of the great groups, from the simplest to the most complex. These are considered from the view-point of structure; but considerable attention is also paid to the functions of their parts, to their habits and life-history, so that while the representatives examined are, for the sake of simplicity, relatively few in number, they are, it is believed, thoroughly typical. Hence, with a knowledge of the facts presented, the student should have a broad view of the animal kingdom, and a foundation on which to base future study and observation. It is perhaps unnecessary to add that from the study of books alone no one can really make such knowledge his own. A personal acquaintance with even a few animals in their native haunts, and an understanding of the structure and the function of their parts gained from dissection and experiment, is essential to a full comprehension of what the student learns from text-book and teacher.

The greater number of illustrations are new, and have been drawn or photographed from living or preserved material. When not otherwise accredited, the drawings have been made by Miss Mary H. Wellman and J. Carter Beard, to whom the authors extend their sincere thanks. Our obligations are also due to Mr. Walter K. Fisher, who has made the drawings of the vertebrate dissections; to Messrs. A. L. Melander and C. T. Brues, of Chicago, Ill.; Mr. Wm. H. Fisher, of Baltimore, Md.; Rev. H. K. Job, of Kent, Conn.; Mr. Wm. Graham, of Pasadena, Cal.; and Dr. R. W. Shufeldt, of New York city, for numerous photographs.

David Starr Jordan,
Harold Heath.

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ANIMAL FORMS

CHAPTER I

INTRODUCTION

1. **Divisions of the subject.**—Biology is the science which treats of living things in all their relations. It is subdivided into Zoology, the science which deals with animals, and Botany, which is concerned with plants. The field covered by each of these branches is very extensive. Within the scope of zoology are included all subjects bearing on the form and structure of animals, on their development, and on their activities, including the consideration of their habits and the wider problems of their distribution and their relations to one another.

These various subjects are often conveniently grouped under three heads: Morphology, which treats of the form and structure or the anatomy of organisms; Physiology, which considers their activities; and Ecology, which includes their relations one to another and to their surroundings. All the phases of plant or animal existence may be considered under one or another of these three divisions.

2. **The difference between animals and plants.**—Generally speaking, we have little difficulty in seeing that the objects about us are either living or lifeless; but the boundary line between the two great divisions of living things, the animals and plants, can not always be so clearly drawn. This is especially true of the simpler forms of life which frequently combine both animal and plant characteristics; but in the

greater number of more highly developed species the line of separation is clearly marked. It is very easy, for example, to distinguish the oak-tree or the rose from a horse or a butterfly, and, as we shall see, the differences are not based merely on outward appearance.

In the oak-tree, for example, the roots reaching down into the earth, with the branches and leaves spreading out into the air and sunlight, are admirably fitted for taking up the food, which consists of very simple materials, less complex than those forming the diet of an animal. This permits a continuous existence in one place, and accordingly we note the entire absence of locomotion and the organs controlling it, which form so conspicuous a part of the body of an animal. Also in the production of flowers and seeds, and in the growth of the seed into the tree, we detect many characteristics peculiar to plants.

3. **Characteristics of an animal.**—On the other hand, the squirrel, for example, or any other animal, is unable to subsist on water, air, and elements from the soil. These creatures demand the highly diversified materials found in the bodies of plants and of animals. Such being the case, they do not remain anchored to one spot (except in a relatively few cases), but are compelled to lead an active existence. The power of voluntary movement, or movement in response to internal impulse, is thus the first and one of the most striking peculiarities of animals.

In the second place, the food of plants enters the body in a soluble condition and is readily transferred to the organs requiring it. While in the animals, the nutritive materials pass into the body in an insoluble state and demand a varied preliminary treatment, usually within a special digestive tube, before they are fit to be absorbed. In the squirrel, by way of illustration, the food is first ground to a pulp by the action of the teeth, and, moistened with saliva, is swallowed and passed into the stomach, where it is subjected to the solvent action of the gastric

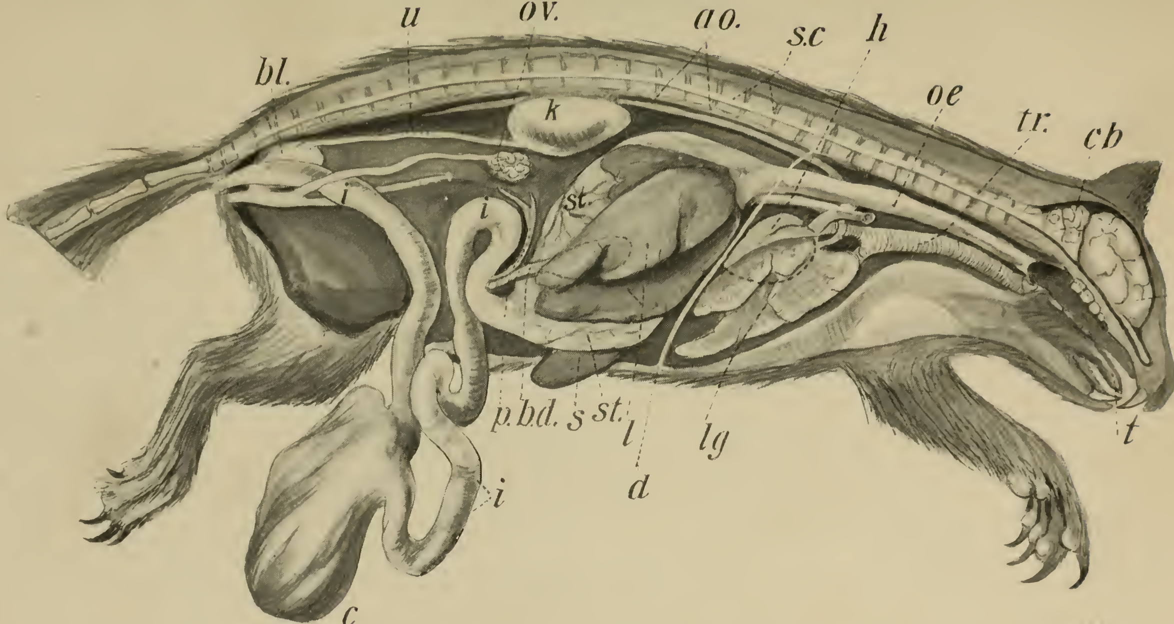

Fig. 1.—Dissection of ground squirrel (*Spermophilus*) with viscera slightly displaced. *ao.*, aorta ; *b.d.*, bile duct ; *bl.*, bladder ; *c*, blind pouch of intestine or cæcum ; *cb*, brain ; *d*, diaphragm ; *h*, heart ; *i*, intestine ; *k*, kidney ; *l*, liver ; *lg*, lung ; *oe*, esophagus ; *ov.*, ovary ; *p*, pancreas ; *s*, spleen ; *s.c*, spinal cord ; *st.*, stomach ; *t*, tongue ; *tr.*, trachea ; *u*, ureter.

juice. From the stomach it is made to enter the intestine, and is further acted upon by fluids from the liver, the pancreas, and the glands of the intestines themselves. Thus treated it becomes changed from an insoluble state into a fluid which readily penetrates the coats of the digestive tract.

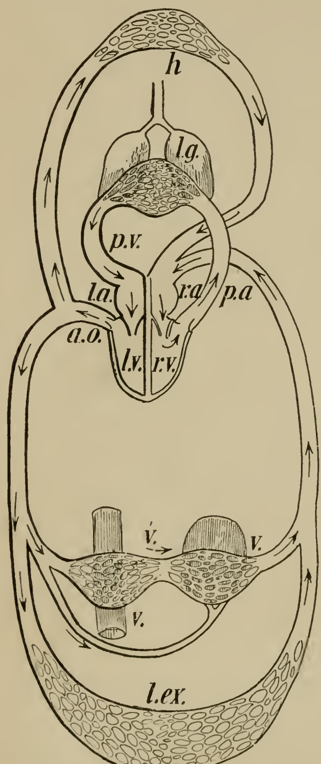

Fig. 2.—Diagram of heart and blood-vessels of the squirrel or other mammal. *a.o.*, aorta; *h*, vessels of head; *l.a.*, left auricle; *l.ex.*, vessels of lower extremities; *lg.*, lung; *l.v.*, left ventricle; *p.a.*, pulmonary artery; *p.v.*, pulmonary vein; *r.a.*, right auricle; *r.v.*, right ventricle; *v.*, vessels of viscera. Arteries are represented by heavy walls.

Many of the organs of the body are placed at a considerable distance from the food as it comes through the coats of the stomach and intestine. In order to supply them with the necessary nourishment a distributing apparatus is required. This is the office performed by the circulatory system, for as rapidly as the food penetrates the walls of the digestive tract it enters the blood, and by the beating of the heart is driven to all parts of the body, which are thus continually kept in a state of repair. The blood serves also to remove waste substances from the various structures or organs of the animal body and to transfer them to the kidneys, skin, or lungs, which effect their removal from the body.

4. **Muscular and nervous systems.**—Owing to the fact that animals, as a rule, are compelled to move about in search of food, we find two highly developed systems, the muscular and nervous, which are absent

in the plants. The first of these, constituting what is usually known as the lean meat, is a relatively complex system of organs, differing widely according to the work performed. In the higher animals—the squirrel, for example—there are not less than five hundred muscles, which are under the control of the nervous system.

The nervous system consists of the brain and spinal cord, which in the squirrel are concealed and protected

Fig. 3.—Skeleton of squirrel, showing its relation to the body.

within the skull and back-bone. From them many nerves pass outward to the muscles, and as many pass inward from the eye, ear, nose, tongue, or skin. By the action of these sense-organs the animal determines the nature of its surroundings, detects its food, recognizes the presence of its enemies, and is thus able to direct its movements to the greatest advantage.

5. **Multiplication of animals.**—The organs thus far considered serve to perpetuate the animal as an individual; but some provision must also be made for the continuance of the race. In the economy of nature each animal before

its death should leave offspring to take the place of the parent when it falls from the ranks. This is effected in various ways. In some of the simpler animals the body may divide into two equal parts, each of which becomes a complete individual. In other cases the animal detaches a relatively small portion of its body, much as a gardener cuts a slip from a plant, and this likewise develops into a new organism. In the greater number of animals, very clearly illustrated by the birds, eggs are produced which under favorable conditions develop into an organism resembling the parents.

6. **Summary.**—Animals are thus seen to lead active, busy lives, collecting food, avoiding enemies, and producing and and caring for their young. While the activities of all animals are directed to their own preservation and to the multiplication of their kind, these processes are carried on in the most diverse ways. The manner in which an organ or an organism is made, and the method by which it does its work, are mutually dependent one on the other. As there is an enormous number of species of animals, each differently constructed, there is, accordingly, a very great variety of habits. As we shall see, the lower forms are remarkably simple in their construction, and their mode of existence is correspondingly simple. In the higher types a much greater complexity exists, and their activities are more varied and are characterized by a high degree of elaboration. In every case, the animal, whether high or low, is fitted for some particular haunt, where it may perform its work in its own special way and may lead a successful life of its own characteristic type.

CHAPTER II

THE CELL AND PROTOPLASM

7. **Cells.**—If we examine very carefully the different parts of a squirrel under the high powers of the microscope we find that they are composed of a multitude of small structures which bear the same relations to the various organs that bricks or stones do to a wall; and if the investigation were continued it would be found that every organism is composed of one or more of these lesser elements which bear the name of *cells*. In size they vary exceedingly, and their shapes are most diverse, but, despite these differences, it will be seen that all exhibit a certain general resemblance one to the other.

8. **Shape of cells.**—In many of the simpler organisms the component cells are jelly-like masses of a more or less spherical form, but as we ascend the scale of life the condition of affairs becomes much more complex. In the squirrel, for example, we have already noted the presence of various organs for carrying on different functions, such as those of digestion, circulation, and respiration; and, further, the cells composing these various parts have been modified in accordance with the duties they have to perform. In the muscles the cells are long and slender (Fig. 4, D); those forming the nerves and conveying sensations to and from all parts of the body, like an extensive telegraph system, are excessively delicate and thread-like; in the skin, and lining many cavities of the body, where the cells are united into extensive sheets, they range in shape from high and columnar to flat and scale-like forms (Fig. 4, E, F, G).

The cells of the blood present another type (Fig. 4, B); and so we might pass in review other parts of the body, and continue our studies with other groups of animals, always finding new forms dependent upon the part they play in the organism.

9. **Size of cells.**—Also in the matter of size the greatest variations exist. Some of the smallest cells measure less than one micromillimeter ($\frac{1}{25000}$ of an inch) in diameter. Over five hundred million such bodies could be readily stowed away into a hollow sphere the size of the letter beginning this sentence. In a drop of human blood of the same size, between four and five million blood-cells or corpuscles float. And from this extreme all sizes exist up to those with a diameter of 2.5 or 5 c.m. (one or two inches), as in the case of the hen's or ostrich's egg. On the average a cell will measure between .025 to .031 m.m. ($\frac{1}{1000}$ and $\frac{1}{800}$ of an inch) in diameter, a speck probably invisible to the unaided eye. While the size and external appearance of a cell are seen to be most variable, the internal structures are found to show a striking resemblance throughout. All are constructed upon essentially the same plan. Differences in form and size are superficial, and in passing to a more careful study of one cell we gain a knowledge of the important features of ali.

10. **A typical cell.**—Some cell, for example that of the liver (Fig. 4, A), may be chosen as a good representative of a typical cell. To the naked eye it is barely visible as a minute speck; but under the microscope the appearance is that of so much white of egg, an almost transparent jelly-like mass bearing upon its outer surface a thin structureless membrane that serves to preserve its general shape and also to protect the delicate cell material within. The comparison of the latter substance to egg albumen can be carried no further than the simple physical appearance, for albumen belongs to that great class of substances which are said to be non-living or dead, while the cell material

or *protoplasm*, as it is termed, is a living substance. We know of no case where life exists apart from protoplasm, and for this reason the latter is frequently termed the physical basis of life.

In addition to the features already described, the protoplasm of every perfect cell is modified upon the interior to

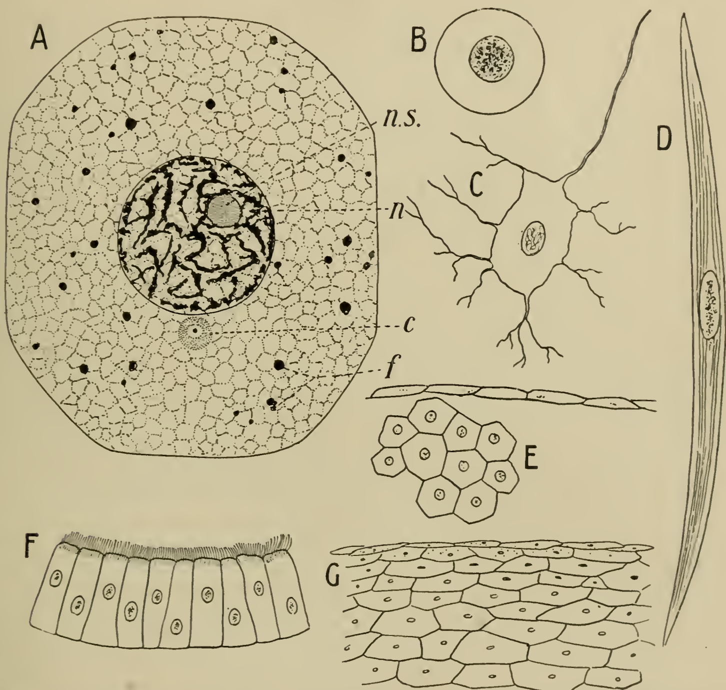

Fig. 4.—Different types of cells composing the body of the squirrel or other highly developed animal. A, liver-cell; *f*, food materials; *n*, nucleus. B, blood-cell. C, nerve-cell with small part of its fiber. D, muscle fiber. E, cells lining the body cavity. F, lining of the windpipe. G, section through the skin. Highly magnified.

form a well-defined spherical mass known as the *nucleus*. Other structures are known to occur in the typical cell. Experiment shows that the nucleus and cell protoplasm are absolutely indispensable, whatever their size and shape, and therefore we are at present justified in defining the cell as a small mass of protoplasm enclosing a nucleus.

11. **Structure of protoplasm.**—When seen under a glass of moderate power protoplasm gives no indication of any definite structure, and even with the highest magnification it presents appearances which are not clearly understood. According to the commonly accepted view, it consists of two portions, one, the firmer, forming an excessively delicate meshwork (Fig. 4, A) enclosing in its cavities the second more fluid part. Therefore, when highly magnified, the appearance would be essentially like a sponge fully saturated with water; but it should be remembered that in the protoplasm the sponge work, and possibly the fluid part, is living, and that both are transparent.

There are reasons for thinking that the structure and the composition of protoplasm may change somewhat under certain circumstances. It certainly is not everywhere alike, for that of one animal must differ from that of another, and different parts, such as the liver and brain, of the same form must be unlike. These differences, however, are minor when compared to the resemblances, for, as we shall see, this living substance, wherever it exists, carries on the processes of waste, repair, growth, sensation, contraction, and the reproduction of its kind.

CHAPTER III

THE PROTOZOA

12. **Single-celled and many-celled animals.**—In almost every portion of the globe there are multitudes of animals whose body consists of but a single cell; while those forms more familiar to us, and usually of comparatively large size and higher development, such as sponges, insects, fishes, birds, and man himself, are composed of a multitude of cells. For this reason the animal kingdom has been divided into two great subdivisions, the Protozoa including all unicellular forms and the Metazoa embracing those of many cells.

13. **Single-celled animals.**—The division of the Protozoa comprises a host of animals, usually of microscopic size, inhabiting fresh or salt water or damp localities on land in nearly every portion of the globe. The greater number wage their little, though fierce, wars on one another without attracting much attention; others, in the sharp struggle, have been compelled to live upon or within the bodies of other animals, and many have become notorious because of the diseases they produce under such circumstances. A few are in large measure responsible for the phosphorescence of the sea; and still others have long been favorite objects of study because of their marvelous beauty. Adapted for living under diverse conditions, the bodily form differs greatly, and yet all conform to three or four principal types, of which we may gain a good idea from the study of a few representative forms.

14. **The Amœba.**—Among the simplest one-celled animals living in the ooze at the bottom of nearly every fresh-water stream or pond is the *Amœba* (Fig. 5, A), whose body is barely visible to the unaided eye. Under the microscope

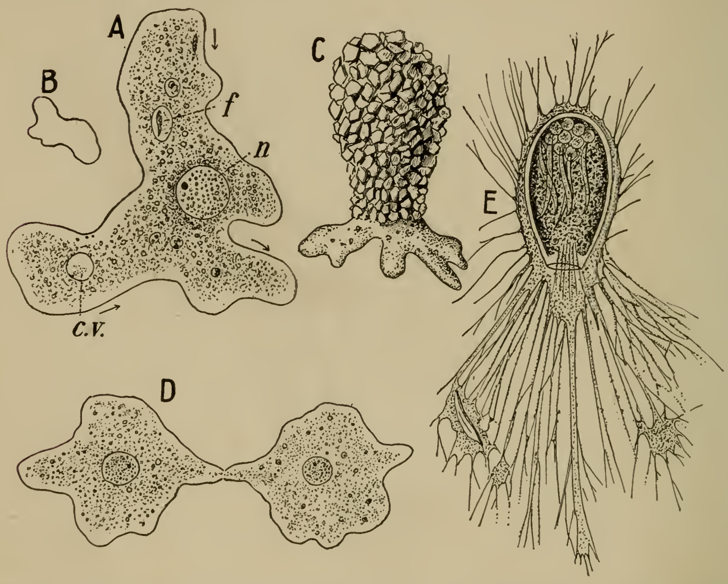

Fig. 5.—A, the *Amœba*, highly magnified, showing *c. v.*, pulsating vacuole ; *f*, food particle ; *n*, nucleus. The arrows show the direction of movement. B, shape of same individual 30 seconds later. C, an amœba-like animal (*Difflugia*) partially enclosed in a shell. D, an *Amœba* in the process of division. E, Gromia, another shelled protozoan (after Schulze).

it is seen to consist of an irregular, jelly-like mass of protoplasm totally destitute of a cell wall. Unlike those animals with which we are familiar, the body constantly changes its shape. A rounded bud-like projection will be seen to appear on one side of the body and the protoplasm of adjacent regions flows into it, thereby increasing its extent. Similar projections at the opposite end of the cell are withdrawn, and their substance may flow into the newly formed lobe, which gradually swells in size and pushes forward. Thus, by constantly advancing the front part of the body and retracting the hinder portion, the cell glides or flows along from place to place.

Upon meeting with any of the smaller organisms upon which it lives, projections from the body are put out which gradually flow around the prey and it becomes pressed into the interior of the cell. The process is not unlike pushing a grain of sand into a bit of jelly. There is no mouth. Any point on the surface serves for the reception of food. Oxygen gas also is taken into the body all over the surface, and wastes and indigestible material are cast out at any point. Nothing exists in these simple forms comparable to the complex systems of organs that carry on these processes in the squirrel.

The bodily size of animals is limited, and to this general rule the *Amœba* is no exception, for upon gaining a certain size, the nucleus divides into two exactly similar portions, and very soon afterward the rest of the body separates into two independent masses of equal size (Fig. 5, D), each of which, when entirely free, contains a nucleus. In this way two daughter amœbæ are formed possessing exactly the characters of the parent save that they are of smaller size; but it is usually not long before they reach their limit of growth, when division occurs again, and so on, generation after generation.

It not infrequently happens, however, that the pond or stream, in which the *Amœba* and other Protozoa live, dries up for a portion of the year. In such an event the body assumes a spherical shape, develops a firm, horn-like membrane about itself, and thus *encysted* it withstands the summer's heat and dryness and may be transported by the wind, or otherwise, over great distances. When the conditions again become favorable the wall ruptures and the *Amœba* emerges to repeat its life processes.

15. **Some relatives of the Amœba.**—All amœba-like forms, to the number of perhaps a thousand species, possess this same method of locomotion, but many present some inter-

esting additional characters. For example, the form represented in Fig. 5, C, constructs a sac-like skeleton of tiny pebbles cemented together, into which it may withdraw for protection. Others construct similar envelopes of lime or flint, and still others, as they continue to grow, build on additional chambers, giving rise to a great variety of forms often of wonderful beauty. In the tropics, particularly, some of the shelled Protozoa are so abundant that they may impart a whitish tinge to the water, and in some places their empty shells on falling to the bottom form immense deposits. The chalk cliffs of England are in large measure made up of such shells.

16. **The Infusoria.**—A little over two hundred years ago it was discovered that wherever water remained stagnant it became favorable for the rapid multiplication of a large number of species of Protozoa which live in such situations. These are known as Infusoria, and, like the preceding species, are usually of microscopic size and of the most varied shapes. The first striking feature of their organization is the presence of a delicate though relatively firm external cell membrane known as the *cuticle*, which preserves a definite shape to the body. Such a method of locomotion as exists in the preceding group is consequently an impossibility, but other and more highly developed structures perform the office. These latter organs are of two types, and their general characteristics may be readily understood from an examination of a few species living in the same localities as the *Amœba*.

17. **The Euglena.**—The first type exists in the common fresh-water organism known as *Euglena*, represented in Fig. 6, A. Here the spindle-shaped body is surrounded by a delicate cuticle perforated at one point, where a funnel-shaped depression, the gullet, leads into the soft protoplasmic interior. From the base of this depression the protoplasm is drawn out in the form of a delicate whip-like process known as the *flagellum*. This structure, always

permanent in form, constantly beats backward and forward with great rapidity in a general direction represented in the diagram (Fig. 6, *c*). The movement from *a* to *b* is much more rapid than the reverse, from *b* to *a*, which results, like the action of the human arm in swimming, in driving the organism forward. Not only does the flagellum serve the purpose of locomotion, but it also produces currents in the water which may serve to bear minute organisms down into the gullet, whence they readily pass into the soft pro-

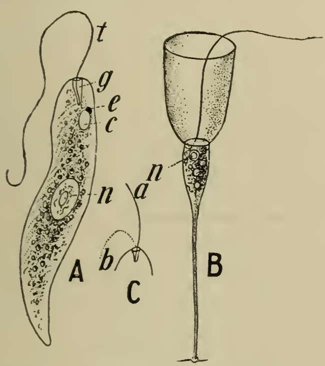

Fig. 6. — Flagellate Infusoria. A, *Euglena viridis*; *c*, pulsating vacuole; *e*, eye-spot; *g*, gullet; *n*, nucleus; *t*, flagellum. B, *Codosiga*, with collar surrounding the flagellum. C, diagram illustrating the action of the flagellum. All figures greatly enlarged.

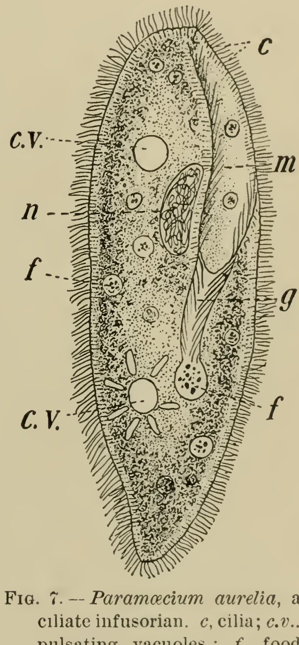

Fig. 7. — *Paramœcium aurelia*, a ciliate infusorian. *c*, cilia; *c.v.*, pulsating vacuoles; *f*, food particles; *g*, gullet; *m*, buccal groove; *n*, nucleus.

toplasm of the body, there to undergo the processes of digestion and assimilation. In some forms the protoplasm in the region of the flagellum is drawn out in the form of a collar (Fig. 6, B), whose vibratory motion also aids in conveying and guiding food into the body.

18. **The Slipper Animalcule.**—The second type of locomotor organ may be understood from a study of the

Slipper Animalcule (*Paramœcium*, Fig. 7), abundant in stagnant water. In this form the cuticle surrounding the somewhat cylindrical body is perforated by a great number of minute openings through which the internal protoplasm projects in the form of delicate threads. Each process, termed a *cilium*, works on the same principle as the flagellum, but it beats with an almost perfect rhythm and in unison with its fellows, drives the animal hither and thither with considerable rapidity.

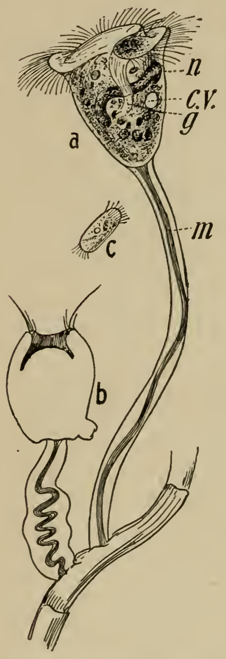

Fig. 8.—*Vorticella*, an attached ciliate infusorian, highly magnified. a, fully extended individual; *c.v.*, pulsating vacuole; *g*, gullet; *n*, nucleus. b, contracted specimen. c, small free-swimming individual, which unites with a stationary individual (one partly united is shown in specimen b).

On one side of the body is a furrow which deepens as it runs backward and finally passes into the gullet (*g*), which leads into the interior of the body. Throughout the entire extent it is lined with cilia which create strong currents in the surrounding water and in this way conduct food down the gullet into the body. Embedded in the outer surface of the body, in among the cilia, are also a number of very minute sacks, each containing a coiled thread which may be discharged against the body of any intruder, so that this form is supplied with actual organs of defense. Two *pulsating vacuoles* (*c.v.*) or simple kidneys are also present, consisting of a central reservoir into which a number of radiating canals extend.

19. **The Bell Animalcule and other species.**—The Bell Animalcule (*Vorticella*, Fig. 8) is often found in the same situations as the Slipper Animalcule, which in certain respects it resembles. It is generally attached by a slender stalk, and where many

are growing together they appear like a delicate growth of mold upon the water weed. The stalk is peculiar in being traversed by a muscle fiber arranged in a loose spiral, which upon any unusual disturbance contracts together with the body into the form shown in Fig. 8, *b*.

These few examples serve to show the general plan of organization and the method of locomotion of the Infusoria; but, as upward of a thousand species exist, with widely differing habits, many interesting modifications are present. Some have been driven in past time to adopt a parasitic mode of life within the bodies of other animals. At present they are devoid of locomotor organs, and as they absorb nutritive fluids through the surface of the body all traces of a mouth are also absent. The reproductive processes also are peculiar, but they do not concern us now.

20. **Characteristics common to the Protozoa.**—We have now studied the principal structures which serve in locomotion among these simple one-celled forms, also the means by which they catch their food, and we shall now glance at the internal processes, which are much the same in all.

After the food has been taken into the cell, it is probably acted upon by some digestive fluid, for it soon assumes a granular appearance and finally undergoes complete solution. In every case the oxygen is absorbed through the general surface of the body, and uniting with the living substance, as in the squirrel, liberates the energy necessary for the performance of the animal's life work. The wastes thus produced in a large number of forms simply filter out from the body without the agency of anything comparable to a kidney, but in several species they are borne to a definite spot, the pulsating vacuole (Figs. 5, 7, 8, *c.v.*), where they gradually accumulate into a drop about the size of the nucleus. The wall between it and the exterior now gives way and the excretions are passed out. In active individuals this process may be repeated two or three times a minute, but it is usually of less frequent occurrence.

The loss in bodily waste is continually made good by the manufacture of the food into protoplasm, and if the income be greater than the outgo growth ensues. But, as in all other forms, growth is limited, and ultimately the cell is destined to divide, resulting in two new individuals. This process may be repeated many times, but not indefinitely, for sooner or later various members of the same species unite in pairs temporarily or permanently, exchange nuclear material, and separate again with apparently renewed energy and the ability to divide for many generations.

21. **Simple and complex animals.**—It is important to note that these same processes of waste, repair, growth, feeling, motion, and multiplication are the same as those of the squirrel, and, furthermore, are common to all living creatures, so that the difference between animals is not in their activities, but in their bodily mechanisms ; and according to the perfection of this, the animal is high or low in the scale. Comparing, for example, the *Amœba* and Slipper Animalcule, which are relatively low and high Protozoa, we find in the former that any part of the body serves in locomotion and in the capture of food, while in the latter these same functions are performed by definite structures, the cilia and gullet. Now it is well known that a workman is able to make better watch-springs, when this is his sole duty, than another who must make all parts of the watch ; and likewise where a definite task is performed by a definite structure, it is more efficiently done than where any and every part of the body must carry it on. So the *Amœba*, in which definite tasks are performed by any part of the body indifferently, is less perfect and thus lower than the *Paramœcium*, where these functions are performed by special organs. As we ascend the scale of life we find this division of labor among special parts of the body more complete, the organs and therefore the animal more complex, and better fitted to carry on the work of its life.

CHAPTER IV

THE SPONGES

22. **Their relation to the Protozoa.**—While the greater number of one-celled forms are not united with their fellows, there are several species where the reverse is true. In Fig. 9, for example, a fresh-water form known as *Pandorina* is represented, consisting of sixteen cells embedded in a spherical, jelly-like substance, each one of which is precisely like its companions in form and activity. The aggregation may be looked upon as a colony of sixteen Protozoa united together to derive the benefit of increased locomotion and a larger amount of food in consequence. As a result of such a union they have not lost their independence, for if one be separated from the main company it continues to exist.

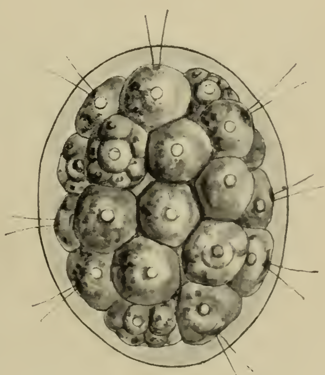

FIG. 9.—*Pandorina* (from Nature). Highly magnified.

From such a simple colonial type we may pass through a series of several more complex forms which reach their highest development in the beautiful organism, *Volvox* (Fig. 10). In this form the individual members, to the number of many thousand, are arranged in the shape of a hollow sphere. The united efforts of the greater number, which bear on their outer surfaces two flagella, drive the colony with the rolling movement from place to place. As just indicated, some individuals lack the flagella, and their subsequent careers show them to be of a peculiar type. Sooner or later each undergoes a series of divisions forming a little globe of cells, which migrates into the interior of the parent sphere and develops into a new colony. Within a short time the walls of the parent break, liberating the imprisoned young, which continue the existence of the species while the parent organism soon decays.

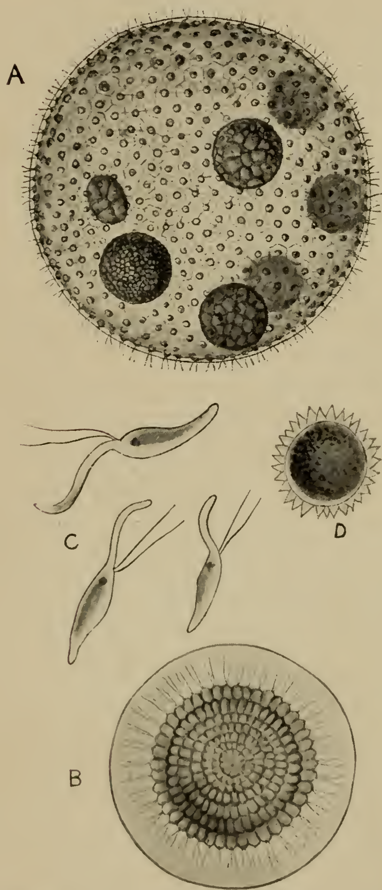

Fig. 10.—A, *Volvox minor*, entire colony (from Nature). B, C, and D, reproductive cells of *Volvox globator*. All highly magnified.

Under certain circumstances, instead of developing colonies by such a method, some of the cells may store up food matters and become eggs, while others, known as sperm-cells, develop a flagellum, and separating from the colony swim actively in the surrounding water, where each finally unites with an egg. This union, like that of the two individuals in *Vorticella* (Fig. 8, *b*, *c*), results in the power of division, and the egg enters upon its development, dividing again and again. The cells so produced remain together, form a sphere, and finally develop a *Volvox* colony.

In such associations as *Volvox* an important step has been taken beyond that of *Pandorina*, for there is a division of the labors of the colony among its various members, some acting as locomotor cells while others are germ-cells. These are now so dependent one upon the other that they are unable to exist after separation from the main company, just as a part of the squirrel is incapable of leading an independent existence. A higher type of organism has thus arisen intermediate between the simple one-celled animals and those of many cells, especially the sponges—a relation which is more readily recognized after an examination of the latter.

23. **Development of the sponge.**—As with all many-celled animals, the sponge begins its existence as an egg, in this case barely visible to the sharp unaided eye. Fertilized by its union with a sperm cell, development commences, and the first apparent indication of the process will be the division of the cell into two halves (Fig. 11, A, B). Each half redivides into four, these again into eight cells, and this process is repeated, giving the young sponge the general form of *Pandorina*. The divisions of the cells still continue and result in the formation of a hollow globe of cells (called the *blastula*, Fig. 11, E, F) similar to *Volvox*, and at this point the young larva leaves the parent.

The next transformation consists in a pushing in of one side of the sphere, just as one might press in the side of a hollow rubber ball. The depression gradually deepens, and finally results in the formation of a two-layered sac known as the *gastrula* (Fig. 11, G). At this stage of its existence the sponge settles down for life in some suitable spot, by applying the opening of its sac-like body to some foreign object. In assuming the final form a new mouth breaks through what was once the bottom of the sac, canals perforate the body wall, a skeleton is developed, and the characteristic features of the adult are thus attained.

24. **Distribution.**—The sponges are aquatic animals, and, with the exception of one family consisting of relatively few species, all are inhabitants of the sea in every part of

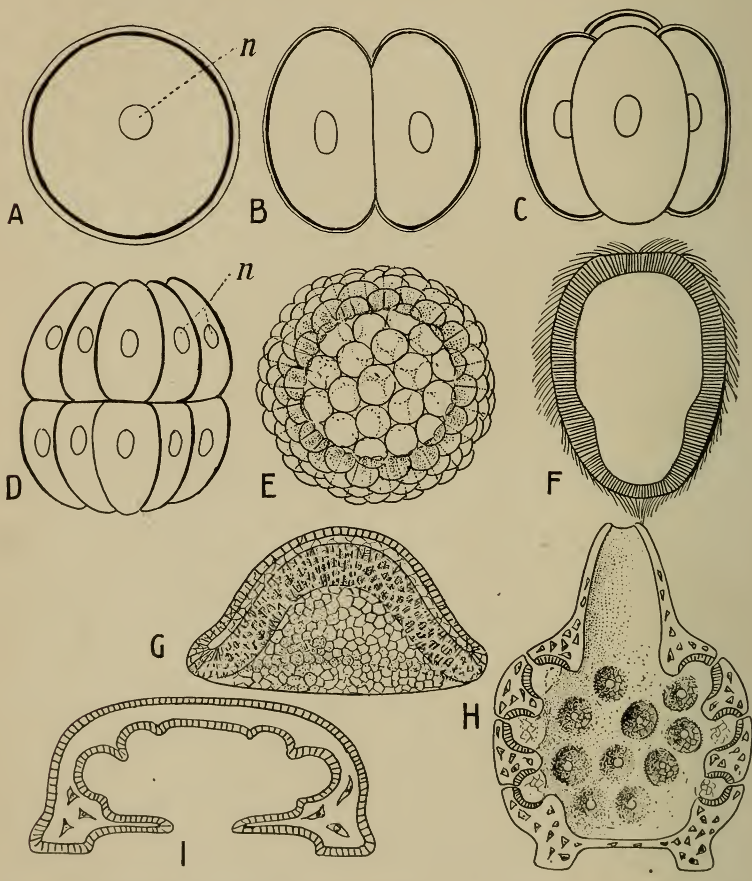

Fig. 11.—Diagrams illustrating the development of a sponge. A, egg-cell; *n*, nucleus. B, C, D, 2-, 4-, and 16-cell stages. E, *blastula*. F, section through somewhat older larvæ. G, *gastrula*. H, young sponge. I, section through somewhat younger larvæ than H.

the globe. The larger number occupy positions along the shore, becoming especially abundant in the tropics; but other species occur at greater depths, several species living between three and four miles from the surface. Unlike the majority of animals, all members of this group are securely fastened to some foreign object, such as rocks, the supports of wharves, or with one extremity embedded in the sand. As we have seen, the young enjoy a free-swimming existence and are swept far and wide by means of tidal currents, but sooner or later these migrations are terminated in some suitable locality, where the sponge passes the remainder of its existence. During this time some species may never exceed the size of a mustard-seed, while others attain a diameter of three feet, or even more. Sponges also vary exceedingly in shape, some having the form of thin encrusting sheets, others being globular, tubular, cuplike, or highly branched (Fig. 12).

25. **The influence of their surroundings.**—In by far the larger number of cases an animal possesses the bodily form of the parent. External agencies may modify this to some extent, but usually only to a limited degree. A squirrel, for example, resembling its parent, may grow to a relatively large or stunted size according to the food supply, and it may become strong or weak according to the amount of exercise, and various other changes may result owing to outside causes; but as a result of these influences the animal is rarely so modified that one is unable to distinguish the species. Many of the sponges, however, are exceptions to this general rule. If, for example, some of the young of a certain parent develop in quiet water or in an unfavorable locality, they will usually be low, flat, and unbranched; while the others, growing in swiftly running waterways, develop into tall, comparatively delicate and highly branched individuals. Under such circumstances not only does the external form become modified, but the internal organization may undergo profound change. The entire organism is plastic and readily molded by the influence of its surroundings, and the consequent lack of definite characters often renders it impossible

to assign such forms to a definite position among the sponges.

26. **Structure of a simple sponge.**—In the simpler sponges the body is usually vase-shaped (Fig. 13), with the base fastened to some foreign object, while at an opposite end an opening leads into a comparatively large internal cavity. This latter space is also put in communication with the exterior by a multitude of minute pores which penetrate the body wall. In

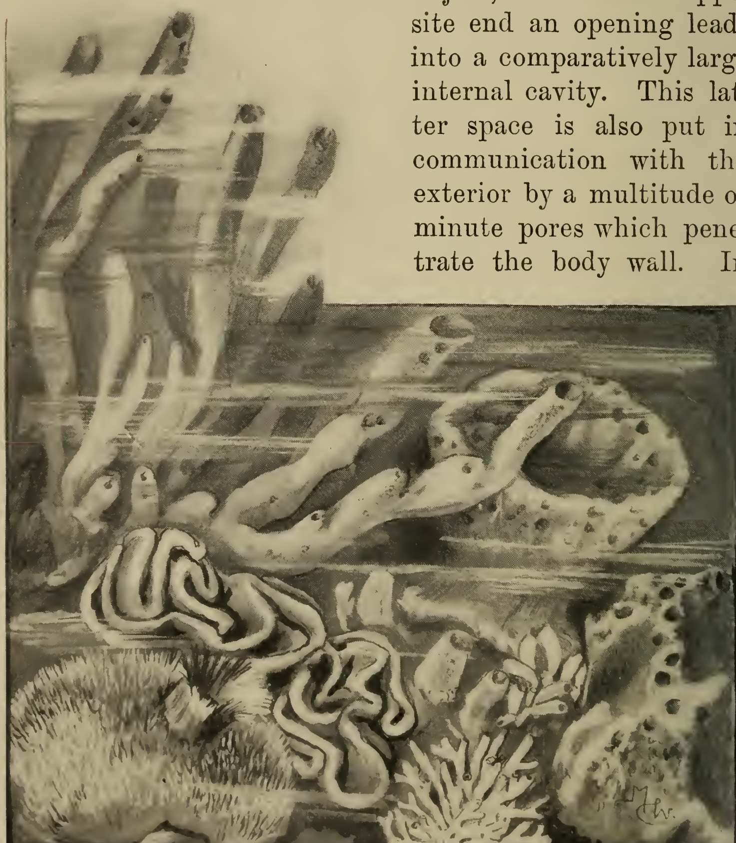

FIG. 12.—Various forms of sponges, natural size. (From Nature.)

the living condition currents of water continually pass through these smaller canals, and out of the large terminal opening, thus bringing within reach of the body minute floating organisms or organic remains which serve as food. The mechanism by which this process is effected, and the various other structures of the body, are in large part invisible from the exterior, requiring the study of thin sections of the sponge to make them clearly understood.

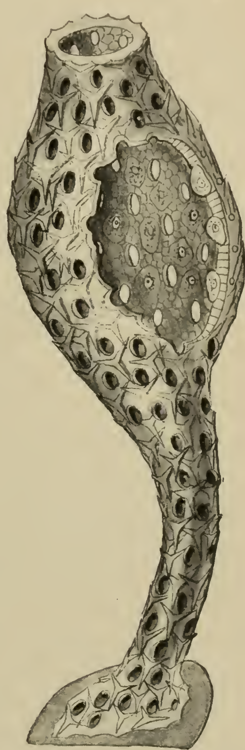

Fig. 13.—One of the simplest sponges (*Calcolynthus primigenius* (after Haeckel). A portion of the wall has been removed to show the inside.

Under the microscope such a section shows the body of a sponge to consist of an immense number of variously formed cells constituting three distinct layers (Fig. 14). Not only do these layers consist of different kinds of cells, but the duties performed by each are different. For example, a glance at Fig. 14 will show that in the inner layer certain columnar cells exist, provided with a flagellum and encircling collar, the appearance being strikingly like certain of the Protozoa (Fig. 6, B). During life their whip-like processes, lashing backward and forward in perfect unison, produce currents of water which continually pass through the body. The food thus entering the animal is taken up by the cells of the inner layer as it passes by. The supply, however, is usually more than sufficient to meet the demands of this layer, and the excess is passed on to the middle and outer layers. The exact method by which this occurs is still a matter of doubt, but there seems to be little question but that each cell of the body receives its food in a practically unmodified condition, requiring that it digest as well as assimilate. The oxygen necessary to this latter process is absorbed by all parts of the body in contact with the water.

27. **Skeleton of sponges.**—When it is remembered that the protoplasm composing the cells of the sponge has about the same consistence as the white of egg, it will be readily understood why the greater number of sponges possess a skeleton. Without such a support the larger globular or branched forms could not exist, and even in the smaller members there would be danger of a collapse of the body walls and consequent stoppage of the food supply, owing to the closure of the pores. So in all but a very few thin or flat forms a skeleton appears in the young sponge almost before growth has fairly begun, and this increases with the body in size and complexity. It is formed by the activity of the cells of the middle layer, and may be composed either of a lime compound resembling marble, or of flint, or of a horn-like substance resembling silk, or these may exist in combination in certain species. When consisting of either of the first-named substances it is never formed in one continuous piece, but of a vast multitude of variously shaped crystal-like bodies termed spicules (Fig. 15). These occur everywhere throughout the body, firmly bound together

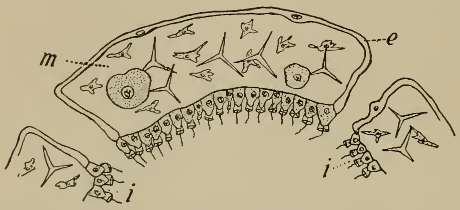

FIG. 14.—Portion of wall of sponge, showing three layers. *e*, outer layer; *i*, inner layer, consisting of collared cells; *m*, middle layer, consisting of irregular cells, among which are the radiate spicules and egg-cells.


FIG. 15.—Different types of sponge spicules.

by means of cells, or so interlocked that they form a rigid support to which the fleshy substance is bound and through which the numerous canals penetrate.

In a relatively few species only does the skeleton consist of horn, though there are many in which horn and flint exist together. In the former event, if the skeleton be elastic and of sufficient size, it becomes valuable to others than the naturalist, for the familiar sponges of commerce are the horny skeletons of forms usually taken in the West Indies or in the Mediterranean Sea. In these localities the animals are pulled off by divers, or with hooks, and are then spread out in shallow water where the protoplasmic substance rapidly decays. The remaining skeleton, thoroughly washed and dried, is ready for the markets of the civilized world.

Examining a bit of such a "sponge" under a magnifying glass, it will be seen that the skeleton is not composed of various pieces, but of one continuous mass of branching fibers, which interlace and unite in apparently the greatest confusion; yet in the living animal these were perfectly adapted to the position of the canals and the general needs of the animal.

Besides being a scaffold-work to which the fleshy portions of the body are fastened, the skeleton serves also for protection. In some species, needle-like spicules as fast as they are formed are partly pushed out over the entire surface of the body, giving the appearance of a spiny cactus; or in other cases they are arranged in tufts about the canals, effectually preventing the entrance of any marauder. Thus perfectly protected, the sponges have but few natural enemies, and hence it is that in favorable localities they grow in great profusion.

28. **Race histories and life histories.**—We have now traced living things from their simplest beginnings, where they exist as single cells, and have seen that in bygone times similar forms have united into simple colonies, and these

through a division of labor among the constituent cells have resulted in *Volvox*-like colonies. There are the strongest reasons for the belief that as these simple forms scattered into various surroundings and underwent changes to meet the shifting conditions, they assumed different degrees of complexity that have resulted in the animal forms of the present day.

It may have been noticed also that the sponge in its development passes through these stages: a single-celled egg; later, a young form similar to *Pandorina*, then growing to look like *Volvox*, and finally assuming its permanent form. The history of the race of sponges and their development through a long line of ancestry of increasing complexity is thus told by the sponge as it develops from the egg into the adult; and, so far as we know, all the many-celled animals in their growth from the egg repeat more or less clearly the stages passed through by their forefathers.

CHAPTER V

THE CŒLENTERATES

29. **General remarks.**—This division of the many-celled animals includes the jelly-fishes, sea-anemones, and corals. A few species live in fresh water, but the majority are confined to the sea, being found everywhere from the shoreline and ocean surface to the most profound depths. Adapted to different surroundings and modes of life, they constitute a vast assemblage of the most bewildering diversity. In some cases their resemblance to plants is remarkable, and the term zoophyte or "plant animal," occasionally applied to them, is the relic of former times when naturalists confounded them with plants. Even to-day certain species are sometimes collected and preserved as seaweeds by the uninformed.

The general plan on which all cœlenterates are constructed is a simple sac, in some respects resembling that of the lower sponges, yet, since the modes of life of the members of the two groups are usually quite unlike, we shall find many profound differences between them.

30. **The fresh-water Hydra.**—The bodily plan comes out most clearly in the *Hydra* (Fig. 16, A, D), which occurs upon the stems and leaves of submerged fresh-water plants in this and other countries. Its body, of a green or grayish color, according to the species, scarcely ever attains a diameter greater than that of an ordinary pin nor a length exceeding half an inch. One end of the cylindrical organism is attached to some foreign object by means of a sticky secretion, but as occasion requires it may free itself, and by

means of a "measuring-worm" movement travel to another place.

Examined under a hand lens, the free end of the body will be found to support six to eight prolongations known as *tentacles*, which serve to convey food to the mouth, centrally located in their midst. This opening, unlike that of the sponges, is the only one leading directly into the large central gastric cavity which occupies nearly the entire animal (Fig. 16, D). As in the sponge, the cells of the body are arranged in the form of definite layers, but the middle one is represented only by a thin gelatinous sheet.

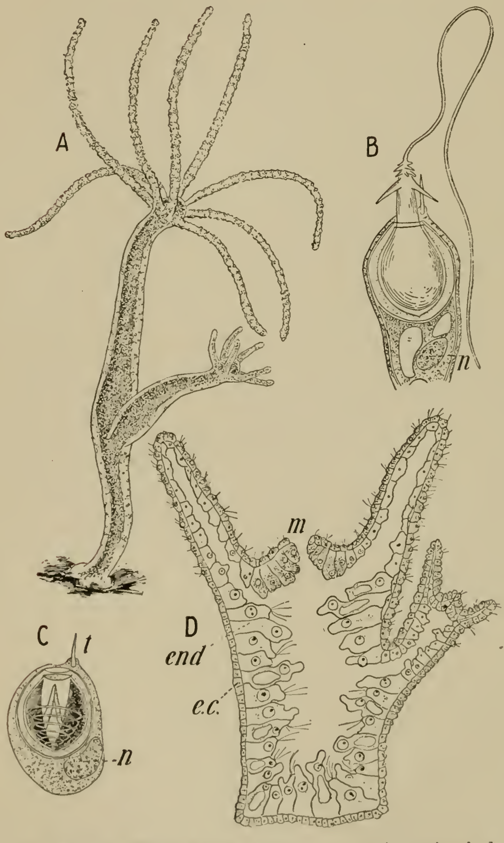

Fig. 16.—The fresh-water *Hydra*. A, entire animal, developing a new individual (enlarged 25 times). B, C, nettle-cells (after Schneider); D, section through the body.

31. **Organs of defense.** — These are the so-called *lasso* or *nettle-cells* (Fig. 16, C). Some of the cells of the outer layer possess, in addition to the elements of the typical cell, a relatively large spherical sac filled with a fluid, and also a spirally wound hollow thread

provided with barbs near its base. On the outer extremity of the nettle-cell projects a delicate bristle-like process, the *trigger hair*. These cells are especially abundant on the tentacles (Fig. 16, A, D), forming close, knob-like elevations or "batteries," thus rendering it practically impossible for any free-swimming organism to avoid touching them in brushing against the body. In such an event the disturbances conveyed through the trigger hair set up in some unknown way very rapid changes in the cell. This causes the sac to discharge the coiled thread and barbs into the body of the intruder, which is rendered helpless by the paralyzing action of the fluid conveyed through the thread. Thus benumbed it is rapidly borne to the mouth and swallowed. In time new nettle-cells develop to take the place of those discharged and consequently worthless.

32. **Digestion of food.**—Upon the interior of the body of *Hydra* and all of the cœlenterates the food, by reason of its large size, is incapable of being taken into the various cells. It is necessary, therefore, to break it up into smaller masses, and this is accomplished through the solvent action of the digestive fluid poured over it from some of the cells of the adjacent inner layer. When subdivided, the granules swept about the gastric cavity by the beating of the flagella (Fig. 16, D) are seized by the processes on the free surfaces of the remaining inner layer cells, where they undergo the final stages of digestion; then in a dissolved state they become absorbed and assimilated by all the cells of the body.

33. **Methods of multiplication.**—Very frequently, especially if the *Hydra* has been well fed, two or three processes arising as outpushings of the body wall may be noted upon the sides of the animal (Fig. 16, A, D). If these be watched from time to time they are found to increase in size, and finally, upon their free extremities, to develop a mouth and surrounding tentacles. Up to this point growth has taken place as a result of the assimilation of nutritive substances supplied from the parent; but a con-

striction soon occurs which separates the young from the parent, and from that time on the two lead independent existences. At other times this *asexual* method of multiplication is replaced by *sexual* reproduction, where new individuals arise from fertilized eggs. Both eggs and sperm arise in *Hydra* and in some other animals in the same individual, but in all such cases the eggs are fertilized by sperm which escape from some other individual. The fertilized egg, surrounded by a firm coat, separates from the parent, drops to the bottom, and after a period of rest develops into a little *Hydra* which hatches and enters upon a free existence.

Fig. 17.—Different types of Hydrozoan colonies. From Nature, the lower species magnified about 50 diameters.

34. **Hydrozoa, or Hydra-like animals.**—Attention has already been directed to the fact that the structure of *Hydra* is the simplest of the cœlenterates; nevertheless, the thousand or more species belonging to this class which present a much more complicated appearance (Fig. 17) possess many fundamental *Hydra*-like characters. It is owing to this fact that this assemblage of forms has been placed in the class of the Hydrozoa, or *Hydra*-like animals.

With but very few exceptions the members of this class are marine, usually living near the shore-line, where at times their plant-like bodies occur in the greatest profusion attached to rocks, seaweeds, or the bodies of other animals, particularly snails and crabs. Fig. 17 (upper colony) gives a good idea of one of the more complex forms, whose tree-like body attains in some cases the relatively giant height of from 15 to 25 c.m. (six to ten inches). In early life it bears a close resemblance to a *Hydra*. Buds form in much the same way, but they retain permanently their connection with the parent, and in turn bear other buds, until finally the form shown in the figure is attained. In the meantime root-like processes have been forming which afford firm attachment to the object upon which the body rests. Also during this process the cells of the outer layer form a horny external skeleton ensheathing the entire organism except the terminal portions (the hydranths, Fig. 18, B) bearing the tentacles. The gastric cavities of all communicate, and the food captured by one ministers in part to its own needs and, swept through the tubular stalks and roots, is also shared by all other members.

35. **Jelly-fishes and the part they play.**—During the process of growth a number of stubby branches arise which differ from the ordinary type in shape, and also in many cases as regards color. These club-like, fleshy portions develop close-set buds (Fig. 18, *c*) which early assume a bell-like shape, the point of attachment corresponding to the handle, while the clapper is represented by a short, slender

process bearing on its end an opening which becomes the mouth (Fig. 18, A). Around the margin of the bell numerous tentacles develop, and at the same time the gelatinous substance situated between the outer and inner layers of the bell expands to a relatively enormous degree, giving it an increasing globular form and glassy appearance.

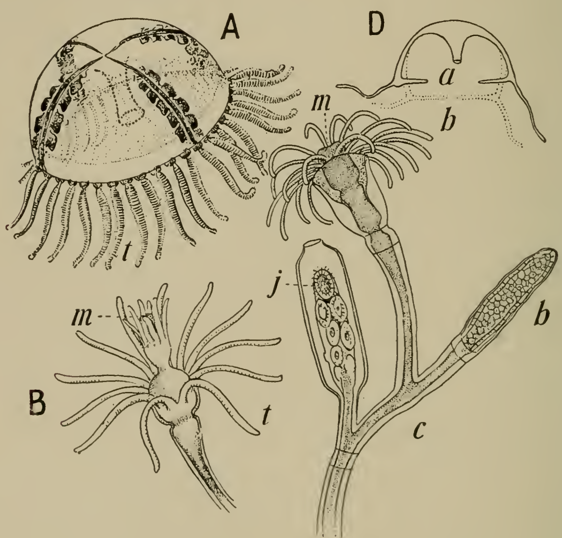

FIG. 18.—A jelly-fish (*Gonionemus*), slightly enlarged. The stalked mouth is shown in dotted outline. B, C, enlarged portions of a hydroid colony bearing the mouth and tentacles ; *j*, a capsule within which the jelly-fish develop ; D, diagram of jelly-fish, illustrating its method of locomotion.

Finally, vigorous movements rupture the connection with the parent, and this newly developed outgrowth, usually small, becomes an independent organism popularly termed a jelly-fish. While the external form of the jelly-fish appears to be widely different from the hydranths, a more careful study shows the difference to be superficial. Some zoologists believe that jelly-fishes are simply buds which have become fitted to separate and swim away from the colony in order to distribute the young, as described hereafter.

When the stalked colonies are very abundant the jelly-fishes may be liberated in such multitudes that the upper surface of the ocean for many miles may be closely packed with them in numbers reaching far into the millions. In these positions they are carried both by oceanic currents and through the alternate expansion and contraction of the bell, a movement resembling the partial closing and opening of an umbrella. In the jelly-fish the contraction is the more vigorous and rapid, and as it takes place the opening in the velum or veil (Fig. 18, *b*) is so narrowed that the water in the subumbrella space (*a*) is driven through it with considerable force, which results in driving the body in the opposite direction.

The life of a jelly-fish is perhaps of short duration, lasting not more than a few hours in some species, up to two or three weeks in others, but during that period they produce multitudes of eggs which develop into minute free-swimming young. These settle down on some rock or seaweed, and soon develop a *Hydra*-like body which, after the fashion described above, grows into another tree-like colony.

36. **Alternation of generations.**—It will be noticed that the offspring of the jelly-fishes are not jelly-fishes, but stalked colonies, and these latter forms give rise to jelly-fishes. This is known as the *alternation of generations*, the jelly-fish generation alternating with the colonial form. This characteristic is of the greatest service in preventing the extermination of the race. Were the stalked forms to give rise directly to other stationary colonies, it is obvious that before long all the available space in the immediate locality would be filled. The food supply, always limited, would not suffice, and starvation of some or imperfect development of all would result; but by means of the free-swimming jelly-fish new colonies are established over very extensive areas, and favorable situations are held by all.

37. **More complex types.**—As mentioned above, there are perhaps upward of a thousand species of Hydrozoa, all with

essentially the same structure but with various modes of branching (for some of the commoner modes, see Fig. 17). In some of the higher forms a division of labor has arisen among various members of the association which has led to most interesting results. For example, Fig. 19 represents a species of hydroid found investing the shells of sea-snails occupied by hermit crabs (Fig. 60). To the unaided eye its appearance is that of a delicate vegetable growth, but when placed under the microscope it is found to consist of a multitude of *Hydra*-like animals united by a hollow branching root system connecting the gastric cavities of all of them (Fig. 19). Certain individuals (*a*) with tentacles and a mouth resemble a *Hydra*; others, without a mouth and tentacles, are reduced to a club-like form (*b*) liberally supplied with nettle-cells upon their free extremities; while the third type (*c*), likewise devoid of a mouth, possesses rudiments of tentacles below which are borne numerous clumps of reproductive cells. The first type, the only one possessing a mouth, captures the food, and after digesting it distributes the greater portion to the remaining members by means of the connecting root system; those of the second form, defending the others by means of their nettle-cells against the inroads of a foreign enemy, are the soldiers of the colony; while the third type produces the eggs from which new individuals develop.

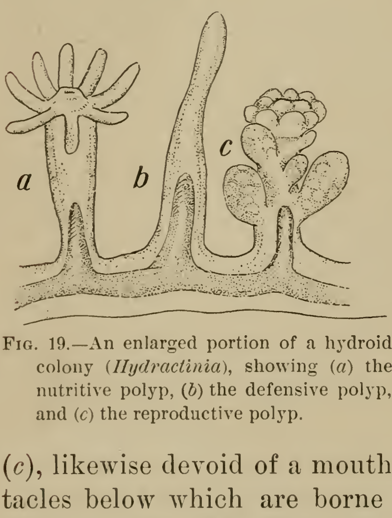

Fig. 19.—An enlarged portion of a hydroid colony (*Hydractinia*), showing (*a*) the nutritive polyp, (*b*) the defensive polyp, and (*c*) the reproductive polyp.

In some of the higher Hydrozoa, the Portuguese man-of-war (Fig. 20), this division of labor has reached a more advanced stage of development, and in addition the entire colony is fitted for a free-swimming existence. What corresponds ordinarily to the attached stalk in other forms terminates in a bladder-like expansion, distended with gas, that serves as a float. From it are suspended individuals resembling great streamers sometimes many feet in length, without mouths, but loaded with nettle-cells that enable them to capture the food, which is conveyed to the second type, the nutritive polyps. Each of these is a simple tube bearing a mouth, and within them the food is digested and distributed by means of a branching gastric cavity extending throughout the entire colony. Then there are individuals like mouthless jelly-fishes which bear the eggs and care for the perpetuation of the colony; and besides these there may be some whose duty it is to defend the rest, and others whose active swimming movements, together with the wind, drive the colony about. Thus united, sharing the food supply and working for the general welfare of all, the members of this colony live in greater security and with less effort than if, as separate individuals, each was fighting the battles of life alone.

FIG. 20.—A colonial jelly-fish (*Physalia*). From Nature.

38. **Scyphozoa.**—The greater number of the larger and more conspicuous jelly-fishes are included under this term. In general shape and locomotion they resemble those of the

preceding group (Fig. 21), but, while the latter are generally very small, these forms are commonly from four to twelve inches in diameter, and some measure one to two meters (three to six feet) across the bell. They are also distinguished by means of tentacles which extend from the corners of the mouth sometimes to a distance of several feet, and together with the marginal tentacles are formidable weapons for capturing small crabs, fishes, and other animals which serve as food. In turn these forms serve as the food of many whales, porpoises, and numerous fishes which hunt them down, though the amount of nourishment they contain is probably relatively small owing to the fact that in their composition there is a large percentage of water (99 per cent in some species). The lobed margin of the bell, the absence of a definite swimming organ or velum, and the character of several of the internal organs, distinguish the larger from the smaller jelly-fish; but the greatest difference, however, is in the method of development.

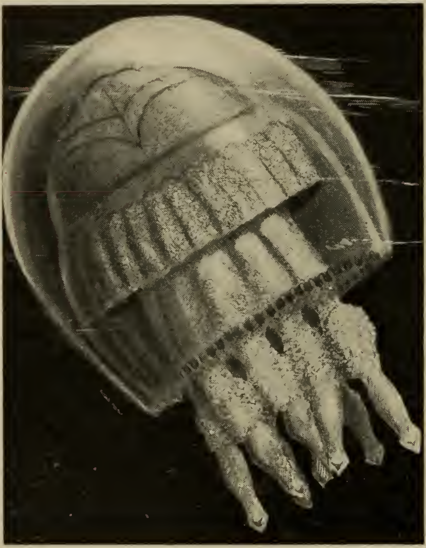

Fig. 21.—A jelly-fish (*Rhizostoma*), about one-fourth natural size.

39. **Development.**—The eggs arise from the inner layer of the jelly-fish and drop into the gastric cavity, where each develops into a ciliated two-layered sac in some respects like that of a young sponge. Swimming away from the parent, they finally settle down, and attaching themselves (Fig. 22, *a*) assume the external form and habits of the sea-

anemones, described in the next section. In the course of time remarkable changes ensue, which first manifest them-

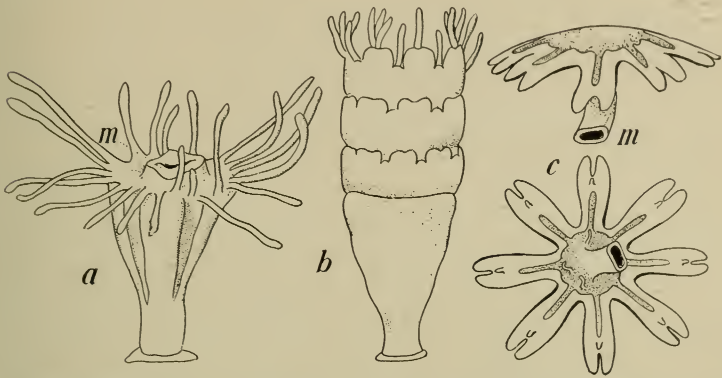

Fig. 22.—Stages in the development of a scyphozoan jelly-fish. *a*, the attached young, which in *b* has separated into a number of disks, each of which becomes a jelly-fish, *c*.—After Korschelt and Heider.

selves in a series of grooves encircling the body. These grow deeper, and the body of the animal finally comes to resemble a pile of saucers with the edge of each developed into a number of lobes (Fig. 22, *b*). One after another each saucer, to preserve the simile, raises itself from the top of the pile and swims away, and is clearly seen to be a jelly-fish, though considerably unlike the adult. As growth proceeds, however, it undergoes a series of transformations which result in the adult form.

Fig. 23.—An attached scyphozoan jelly-fish (*Haliclystus*). Natural size, from Nature.

40. **Sea-anemones.**—In its external appearance the sea-anemone (Fig. 24) bears some resemblance to the *Hydra*, but is of a much larger size (1 to 45 c.m., or $\frac{1}{2}$ inch to $1\frac{1}{2}$ feet in diameter), and is frequently brilliantly colored. The number of tentacles is also more numerous, and the mouth leads into the body by means of a slender esophagus (Fig. 25). Numerous partitions from the body wall extend inward, and many unite to the esophagus, keeping the latter

Fig. 24.—Sea anemones (the two upper figures) and solitary coral polyps.

in position. Below the esophagus each partition projects into the great cavity of the body and bears upon its inner free edge several important structures. The first of these, known as the mesenteric filaments (Fig. 25), appearing like delicate frills, plays an active part in the digestion of the food. Associated with these are long, slender threads, closely packed with innumerable lasso-cells, which may be thrown out through openings in the body wall when the animal is attacked. Lasso-cells are also very numerous on the tentacles, which are thus to some extent defensive, but are chiefly active in capturing the crabs and small fish which serve as food.

The partitions also carry eggs which may undergo the first stages of their growth within the body, and when finally able to swim are sent out through the mouth opening by hundreds to seek out favorable situations, there to settle down and remain. In some species the young may sometimes arise as buds, as in *Hydra* (Fig. 24), and in others the animals have been described as splitting longitudinally into two equal-sized young.

FIG. 25.—Longitudinal section through the body of a sea-anemone. *oe*, esophagus; *m. f.*, mesenterial filaments; *r.*, reproductive organs.

41. Corals.—The coral polyps also belong to this group, showing a very close resemblance to the sea-anemones. In most cases they develop a firm skeleton of lime, commonly known as "coral," which serves to protect and support the body. In a few species the polyps throughout life are solitary, and with skeleton comparatively simple (Fig. 24); but the larger number of species become more complex by developing buds, which retain their connection with the parent, and in turn produce other outgrowths with the ultimate result that highly branched colonies are produced (Fig. 26). At the same time the outer layer of the body is continually forming a skeleton which encloses the colony as a sheath, except at the termination of each branch, where the mouth and tentacles are located. In certain species—for example, the sea pens (*Pennatula*) and sea fans (*Gorgonia*)—a skeleton may be

FIG. 26.—Small portions of coral colonies, with some of the polyps expanded.

formed of myriads of lime spicules, somewhat like those of the sponge, which are bound together by the fleshy substance of the body; but the skeleton of most of the common forms in the ocean, and the coral found in general collections, is stony. According to their method of branching, such specimens have received various popular names, such as brain, stag-horn, organ-pipe, and fungous corals.

Nearly all species, like the sea-anemones, are brilliantly colored during life, and several are highly phosphorescent. All are marine, and while they are found everywhere, from the shore-line to great depths, the more abundant and larger species inhabit the clear, warm waters of the tropics down to a depth of one hundred and sixty feet. In such regions the stag-horn corals especially grow in the wildest profusion, and become tall and greatly branched. Except in quiet water they are continually being broken by the waves, beaten into fragments, and the resulting sand is deposited about their bases. As a result of this continuous growth and erosion, there have been formed from coral sand mixed with the shells of mollusks and the skeletons of various Protozoa several of the islands along the Florida coast and many of those of the Pacific, some of them hundreds of miles in extent.

CHAPTER VI

THE WORMS

42. **General Characteristics.**—The bodies of the animals comprising the two preceding groups are exposed on all sides equally to the water in which they live and are radially symmetrical; but in the worms, one side of the body is fitted for creeping, and for the first time we note a well-marked dorsal (back) and ventral (under) surface. In the former, the body, like a cylinder, may be divided into similar halves by any number of planes passing lengthwise through the middle; but in the worms, the right and left halves only are exposed equally to their surroundings, and there is, accordingly, only one plane which divides the body into corresponding halves, so that these animals, like all higher forms, are bilaterally symmetrical. In creeping, also, one end of the body is directed forward and it thus becomes correspondingly modified. It usually bears the mouth, and may be provided with eyes, feelers, or organs of touch, and various other structures which enable the worm to recognize the nature of its surroundings. The nervous and muscular systems are better developed than in the foregoing groups, and we note a greater vigor and definiteness in the animal's movements, and in various ways the worms appear better able to avoid or ward off their enemies, recognize and select their food, and in general adapt themselves to the conditions of life.

The division of the worms is a very large one, and in some respects difficult to define, owing to the close resemblance which many of them show to animals in other groups. All the invertebrates, therefore, except the crabs and insects, were placed in one group until subsequent study made it possible to classify them more exactly. According to the general shape of the body, and the arrangement of internal organs, worms are divided into a number of groups, chief among which are the flatworms, the thread or roundworms, and the ringed worms or annelids.

The Flatworms

43. **Form and habitat.**—The flatworms, as their name indicates, are much flattened, leaf-like forms, some species living in damp places on land, in fresh-water streams or ponds, or along the seacoast, while a variety of other species are parasitic. The free forms (Fig. 27) are usually small, barely reaching a length greater than five or seven centimeters (2 to 3 inches), but some of the parasitic species (Fig. 31) attain the great length of six to thirteen meters (20 to 40 feet).

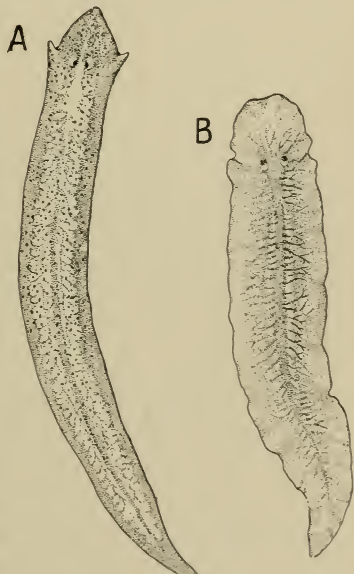

Fig. 27.—A, fresh-water flatworm (*Planaria*); B, marine flatworm (*Leptoplana*). Enlarged, from Nature.

The free-living forms usually occur on the under side of stones, and frequently are so delicate that a touch is sufficient to destroy them. A few species are almost transparent, while many are colored to harmonize completely with their surroundings, so that, even though fragile and defenseless, they escape the attacks of enemies by being overlooked. The night-time or dark days are their hunting season, and at such periods they may be found moving about with a steady gliding motion (due to cilia covering the entire body), varied occasionally by a looping, caterpillar movement, or by swimming with a flapping of the sides of the body. When watched at such times they may sometimes be seen to snatch up small worms, snails, small crabs and insects, which serve as food.

More closely examining one of these forms, for example, the species usually found on the under side of sticks and stones in our shallow fresh-water streams (Fig. 27, A), we note that the forward end is not developed into a well-defined head as in the higher worms, but is readily determined by the presence of very simple eyes and tentacles, while the lower creeping surface is distinguished by a lighter color and the presence of the mouth. Through this small opening a slender proboscis (in reality the pharynx) may be extended some distance, and may be seen to hold the small organisms upon which it lives until they are sufficiently digested to be taken into the body.

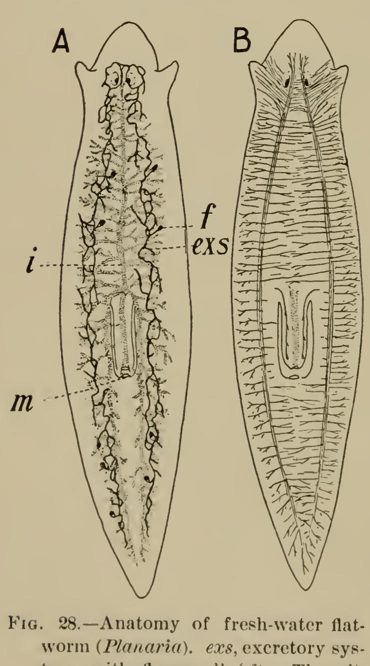

Fig. 28.—Anatomy of fresh-water flatworm (*Planaria*). *exs*, excretory system, with flame-cell (*f*). The alimentary canal is stippled. B, nervous system.

44. **Digestive system.**—In the smaller flatworms, some of which are scarcely larger than many of the Protozoa, the alimentary canal is a simple unbranched tube; but in the larger forms such an apparatus is replaced by a greatly branched digestive tract which furnishes an extensive surface for the rapid absorp-

tion of food, and extending deep into the tissues of the body, carries nutriment to otherwise isolated regions. In the fresh-water forms and their allies there are three main branches of the intestine (Fig. 28), while in many of those from the sea there are several, and their arrangement affords a basis for their general classification.

45. **Excretory system.**—In the sponges and cœlenterates the wastes are cast out by the various cells into the gastric cavity or at once to the exterior without the aid of any pronounced system of vessels; but in the flatworms several of the organs are deeply buried within the tissues of the body and a drainage system becomes a necessity. This consists of a paired system of vessels extending the length of the animal (Fig. 28) and provided with numerous branches, some of which open at various points on the surface of the body, while the others terminate in spaces (Fig. 29, *s*) among the organs in what are known as flame-cells. The substances which accumulate in these spaces are gathered up by the flame-cell, poured into the space it contains, and by means of the vibratory motion of its flagellum (*f*), a movement bearing a fancied resemblance to the flickering of a flame in the wind, are borne through the tubes to the exterior.

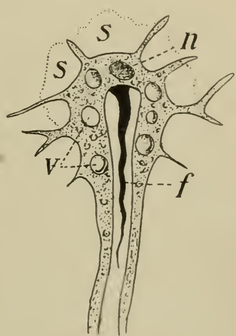

Fig. 29.—Flame-cell of flatworm (after Lang). *f*, flagellum; *n*, nucleus; *s*, spaces among the organs of the body; *v*, waste materials.

46. **Nervous system and sense-organs.**—In the sponges no definite nervous system is known to exist, the slight movements which the cells are able to undergo being regulated somewhat as they are in the Protozoa. Among the cœlenterates certain of the cells scattered over the surface of the body are set aside as nerve-cells, and, more or less united by means of fibers extending from them, convey impulses over the body. In the flatworms the larger number of nerve-cells

are collected into two definite masses (Fig. 28, B), which constitute a simple brain on which the eyes are situated and from which bundles of nerve fibers pass to all parts of the body, the two extending backward being especially noticeable. As in the squirrel, these are distributed to the muscles and other organs to regulate their activity, while those distributed to the skin, especially in the forward part of the body, convey stimuli produced by touch. The branches connecting with the eyes enable the animal to distinguish light from darkness, but are probably too simple to allow it to clearly distinguish objects of the outside world. The sense of smell and possibly that of taste are also present, but are relatively feeble.

Some other characters of this class will be noted in the consideration of the two following classes.

47. **Parasitic flatworms (trematodes)—parasitism.**—Mention has already been made of the associations of two animals as "messmates" for mutual benefit, such as the Hydractinia growing on the surface of the shell inhabited by the hermit crab, to which it gives protection by means of its nettle-cells, while in turn being borne continually into regions abounding with food. More frequently, however, one animal derives benefit from another without making any compensation. For example, many species of flatworms live within the shells of certain snails and upon the bodies of sea-urchins and starfishes, where they gather in their food supply safe from the attacks of enemies. Such associations are probably without much if any inconvenience to the animal thus inhabited, and it also appears probable that the tenants are transients, using the mollusk or starfish only as a temporary home. But from this condition of affairs it is only a short step to the parasitic habit, where the association becomes permanent and the occupant is provided with various structures which prevent its separation from its host. This latter kind of union occurs throughout the group of trematodes; all are parasitic, and

their internal organization, so closely resembling that of the free-living forms as to need no further description, indicates that they are descendants of the latter. In the greater number the body is flat, and a few species still retain their outer coat of cilia; but since these are no longer of service as locomotor organs they have generally disappeared, and in their place numerous adhesive organs, such as spines, hooks, and suckers (Fig. 30), have arisen, which enable the animals to hold on with great tenacity. Thus attached to its host, and using it as a convenient and comparatively safe means of locomotion, the parasite may still continue to capture small animals for food or may derive its nourishment from the tissues of the host. In addition there are numbers of internal parasites, living almost exclusively in the bodies of vertebrate animals, scarcely a single one escaping their ravages.

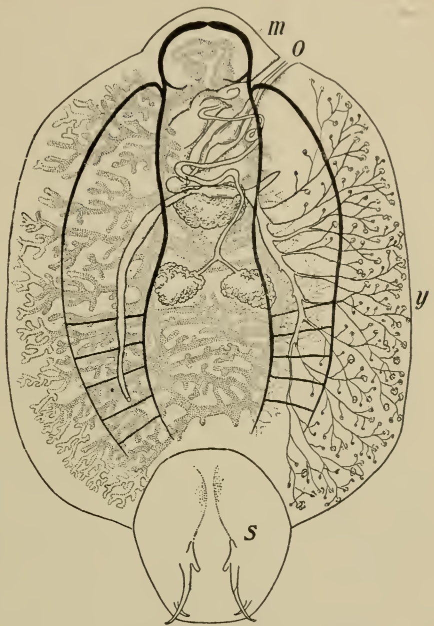

FIG. 30. — A parasitic flatworm (*Epidella*). *m* mouth; *o*, opening of reproductive system; *s*, sucker and spines for attachment. The digestive system is stippled; nervous system black. Enlarged 8 times, from Nature.

48. **Life history.**—In the external parasites the young hatch out and with comparative ease make their way to another host; but the young of an internal parasite, inhabiting the alimentary canal, have a very slight chance indeed of ever reaching a similar location in another host.

For this reason an almost incredible number of eggs is laid, and some extraordinary measures are employed in effecting the desired result. Probably the best-known example is that of the liver fluke inhabiting the bile-ducts in the sheep. Each worm lays several hundred thousand eggs, which make their way from the host, and if they chance to fall in pools of water or damp situations may proceed to develop, otherwise not. If the surroundings be favorable, the young, like little ciliated Infusoria, escape from their shells and restlessly swim or move about for a short time, and if during this time they come in contact with certain species of snails living in these situations they at once bore into their bodies. Here they produce other young somewhat resembling a tadpole, that now make their escape from the snail. In a short time each one crawls upon a blade of grass, and surrounds itself with a tough shell, where it may remain for several weeks. If the grass on which they rest be eaten by a sheep, they finally make their way to the bile-ducts and there become adult. The life cycle is now complete; the young form has found a new host; and the process shows how wonderfully animals are adapted to the conditions which surround them, and how closely they must conform to these conditions in order to exist.

49. **The tapeworms (cestodes).**—The cestodes, or tapeworms, are also parasitic flatworms in which the effects of such a mode of life are strongly marked. They occur almost exclusively in the bodies of vertebrate hosts and exhibit a great variety of bodily forms, in some cases resembling rather closely the trematodes, but in others strikingly different. In the latter type the body is usually of great length (from a few centimeters to upwards of sixteen meters (50 feet)), and terminates in a "head" (Fig. 31) provided, in the different species, with a great variety of hooks and spines and numbers of suckers for its attachment to the body of the host. From the head the body extends backward in the gradually enlarging ribbon-like body, slender at

first and scarcely showing the segments which finally become so prominent a feature.

When carefully examined, a two-lobed brain is found in the "head," and from it nerves extend the entire length of the body, followed throughout their course by the tubes of the excretory system; also each segment contains a perfect reproductive system, so that even if it be separated from the others it may continue to exist for a considerable length of time. Furthermore, the tapeworms are surrounded by the predigested fluids of their host; a special alimentary canal is therefore superfluous, and all traces of it have disappeared.

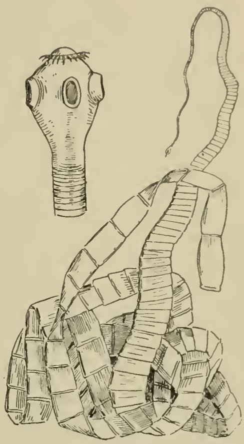

Fig. 31.—Tapeworm (*Tænia solium*). In upper left-hand corner of figure is the much enlarged head. —After Leuckart.

50. **Development.**—As the animal clings in this passive way to the body of its host the segments, loaded with eggs ready for development, separate one after another from the free end of the body, pass to the exterior, and slowly crawling about like independent organisms, lay great numbers of eggs, which may find an intermediate host as in the life cycle of the liver fluke, and so in time find their permanent resting-place. Fortunately in all these parasitic forms, though an inconceivably great number of eggs are laid, only a comparatively few reach maturity. Even these, however, may cause at times great destruction among the higher, and especially our domestic, animals, often doing damage amounting to many millions of dollars per year.

51. **The tapeworm in relation to regeneration.**—It has been known for more than one hundred and fifty years that some of the lower animals possess to a surprising degree the ability to regenerate parts of the body lost through injury. The *Hydra*, hydroids, and some of the jelly-fishes

may be cut into a number of pieces, each of which will develop into a complete individual; and this power of recovery from the injuries produced by enemies is of the greatest service in the perpetuation of the species. This ability is also present in certain flatworms, and some species are known which voluntarily separate the body into two portions, each of which becomes an adult. In other species a similar process results in the formation of a chain of six individuals, placed end to end, the chain finally breaking up into as many complete worms. It is possible that the tapeworm may also be looked upon as a great chain of united individuals produced by the division of a single original parent, which becomes adapted for attaching the others until they separate. These latter are capable only of a very sluggish movement, and, devoid of mouth and alimentary canal, are not able to digest their food, but their life work is to so lay their eggs that they may develop into other individuals, and for this they are well adapted.

Nematodes (Threadworms)

52. **General characters.**—This class of worms is composed of an enormous number of different species, some parasitic, others free all or a portion of their lives, and in view of the fact that they inhabit the most diverse situations it is remarkable that they are so uniform in their structure. In all the body is slender, and the general features of its organization may be readily understood from an examination of the "vinegar eel" (Fig. 32, A). This small worm (not an eel), a millimeter or two in length, lives on the various forms of mold that grow in fermenting fruit juices, especially after a little sugar or paste has been added. A tough cuticle surrounds the body, preserving its shape and at the same time protecting the delicate organs against the action of the acids in which it lives. Through this may be seen great bands of muscles extending the entire length of the body and producing the wriggling movements of swimming

or crawling. They also give support to a brain, which is in the form of a collar encircling the pharynx near the head, and to the great nerves which extend from it. Still further within the transparent body the alimentary canal may be distinguished as a straight tube passing directly through the animal. This latter system lies freely in a great space, the body cavity, traces of which may exist in the flatworms in the form of small hollows among the organs into which the kidneys open. It is possible that in this form also the kidneys open into this space, and it is roomy enough besides to afford lodgment for the reproductive organs in addition to a large amount of fluid which is probably somewhat of the nature of blood. A space in some respects similar to this occurs in all the animals above this group, and as we shall see, it is often curiously modified and serves for a number of different and highly important purposes. In the roundworms the fluid it contains probably acts in the nature of a blood system, distributing the food and oxygen to various parts of the body and carrying the wastes to the kidneys for removal.

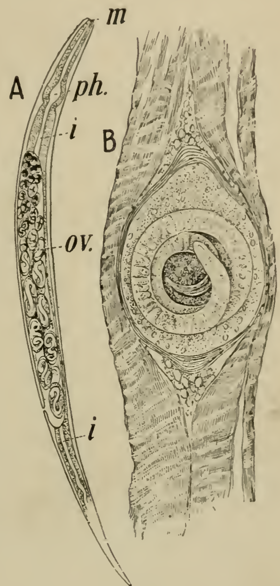

Fig. 32. — Thread- or round-worms. A, vinegar eel (*Anguillula*); *m*, mouth; *ph.*, pharynx; *i*, intestine; *ov.*, developing young. B, *Trichina*. From Nature, greatly enlarged.

53. **Multiplication.**—In the matter of the production of new individuals the greatest differences exist. In some threadworms, for example the "vinegar eel," eggs develop within the body and the young are born with the form of the parent. In other cases the eggs are laid in the water, where they, too, may directly grow to the adult condition; but in

the greater number of species the development is roundabout, and one or more hosts are inhabited before the young assume the adult condition. Such is the case with the dreaded *Trichina* (Fig. 32, B), which infests the bodies of several animals, particularly the rat. When these forms are introduced into the alimentary canal of the rat, for example, they soon lay a vast quantity of eggs, sometimes many millions, which develop into young that bore their way into the muscles of the body, where they may remain coiled up for years. If the body of the rat be eaten by some carnivorous animal, these excessively small young are liberated during the process of digestion and rapidly assume the adult condition in the alimentary canal, likewise giving rise to young which pursue again this same course of development.

Another example of a complicated life history is in the *Gordius* or "horsehair snake" (a true worm and not a snake) frequently seen in the spring in pools where it lays its eggs. These eggs develop into young which bore their way into different insect larvæ, which are in turn eaten by some spider or beetle, and the worm thus transferred to a new host. In this they grow to a considerable size, and then make their exit from the body of the host and finally become adult.

54. **Spontaneous generation.**—It is only within comparatively recent years that such life histories have been understood. Formerly the sudden appearance of these and other forms in various situations were accounted for on the ground that they arose spontaneously without the intervention of any living creature. Even yet we hear of the transformation of horsehairs into hairworms, and of frogs, earthworms, and several other animals from inorganic matter, but such assertions are based on superficial observations, and at the present time no exception is known to the law that living creatures arise from preexisting living parents. "All life from life" (*omnium vivum ex vivo*) is a universal law.

ANNELIDS OR SEGMENTED WORMS

55. **The earthworms and their relatives.**—Leaving the groups of the parasitic animals, which have been driven from the field of active existence and in many ways are degraded by such a mode of life, we pass on to the higher free-living worms, where brilliant colors, peculiar habits, or remarkable adaptations render them peculiarly interesting. In considering first their general organization, we may use the earth-

FIG. 33.—Earthworm (*Lumbricus terrestris*). *m*, mouth ; *c*, girdle or clitellum.

worm (Fig. 33) (sometimes called angle-worm or fish-worm) as a type because of its almost universal distribution.

The body is cylindrical, shows well-marked dorsal and ventral surfaces, and, as in all of the annelids, is jointed, each joint being known as a *segment*. Anteriorly it tapers to a point, and the head region bearing the mouth is ill-defined, unlike many sea forms, yet serves admirably for tunneling the soil in which all earthworms live. In this process the animal is also aided by bristles or *setæ* which project from the body wall of almost every segment and may be stuck into the earth to afford a foothold.

56. **Food and digestive system.**—The earthworms are nocturnal animals, seldom coming to the surface during the day except when forced to do so by the filling of their tunnels with water or when pursued by enemies. At night they usually emerge partially, keeping the posterior end of the body within the burrow, and thus they scour the surrounding areas for food, which they appear, in some cases at least, to locate by a feeble sense of smell. They also frequently extend their habitations, and in so doing swallow enormous quantities of earth from which they digest out any nutritive substances, leaving the indigestible matter in

coiled "castings" at the entrance of the burrows. In thus mixing the soil and rendering it porous they are of great service to the agriculturist.

Although earthworms are omnivorous they also manifest a preference for certain kinds of food, notably cabbage, celery, and meat, which leads us to think that they have a sense of taste. All these substances are carried within their retreats and devoured, or are used to block the entrance during the day. The food thus carried within the body is digested by a system (Fig. 34) composed of several portions,

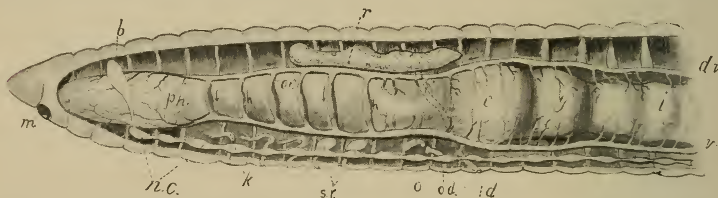

FIG. 34.—Earthworm (*Lumbricus*) dissected from left side. *b*, brain; *c*, crop; *d*, outer opening of male reproductive system; *dv*, dorsal blood-vessel; *g*, gizzard; *h*, pulsating vessels or "hearts"; *i*, intestine; *k*, kidney; *m*, mouth; *n. c.*, nerve-cord; *oe*, esophagus; *o*, ovary; *od*, oviduct; *ph*, pharynx; *r*, testes; *s.r.*, seminal receptacles; *v.v.*, ventral vessel.

each of which is modified for a particular part in the process. The mouth (*m*) leads into a muscular pharynx (*ph*) whose action enables the worm to retain its hold on various objects until swallowed, and this in turn is continuous with the esophagus. From here the food is passed into the thin-walled crop (*c*), and from this storehouse is gradually borne into the gizzard (*g*), whose muscular walls reduce it to a fine pulp now readily acted upon by the digestive fluids. These, resembling in their action the pancreatic juice of higher animals, are poured out from the walls of the intestine into which the food now makes its way; and as it courses down this relatively simple tube the nutritive substances are absorbed while the indigestible matters are cast away.

57. **Circulatory system.**—In all the groups of animals up to this point the digested food is carried over the body by a simple process of absorption, or in the threadworms by

means of the fluid in the body cavity; but in the earthworm the division of labor between different parts of the body is more perfect, and a definite blood system now acts as a distributing apparatus. This consists primarily of a dorsal vessel lying along the dorsal surface of the alimentary canal (Fig. 34), from which numerous branches are given off to the body wall, and to the digestive system through which they ramify in every direction before again being collected into a ventral vessel lying below the digestive tract. In some of the anterior segments a few of the connecting vessels are muscular and unbranched, and during life pulsate like so many hearts to force the blood over the body, forward in the dorsal vessel, through the "hearts" into the ventral vessel, thence into the dorsal by means of the small connecting branches.

Some of the duties of this vascular system are also shared by the fluid of the body cavity, which is made to circulate through openings in the partitions by the contractions of the body wall of the animal in the act of crawling. In this rough fashion a considerable amount of nutritive material and oxygen are distributed to various organs, and wastes are carried to the kidneys to be removed.

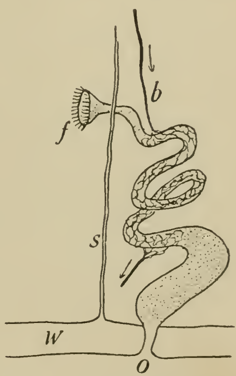

FIG. 35.—Diagram of earthworm kidney. *b*, blood-vessel; *f*, funnel opening into body cavity; *o*, outer opening; *s*, septum; *w*, body wall.

58. **Excretion.**—In nearly all of the segmented worms there is a pair of kidneys to every segment (Figs. 34, 35). Each consists of a coiled tube wrapped in a mass of small blood-vessels, and at its inner end communicating with the body cavity by means of a funnel-shaped opening. In some unknown way the walls of the kidney extract the waste materials from the blood-vessels coursing over it and pass them into its tubular cavity. At the same time the cilia about the mouth of the funnel-shaped extremity are

driving a current from the body-cavity fluids, which wash the wastes to the exterior.

59. **Nervous system.**—The nervous system of the earthworm consists first of a brain composed of two pear-shaped masses united together above the pharynx (one shown in Fig. 34), from which nerves pass out to the upper lip and the head, which are thus rendered highly sensitive. Two other nerves also pass out from the brain, and, coursing down on each side of the pharynx like a collar, unite below it and extend side by side along the under surface of the digestive system throughout its entire extent. In each segment the two halves of this ventral nerve-cord are united by a nerve, and others are distributed to various organs, which are thus made to act and in proper amount for the good of the body as a whole.

In its relation to the outside world the chief source of information comes to the earthworm through the sense of touch, for definite organs of sight, taste, and smell are but feebly developed, while ears appear to be entirely absent. Nevertheless these are sufficient to enable it to lead a successful life, as is evidenced by the great number of such forms found on every hand.

60. **Egg-laying.**—In digging up the soil where earthworms abound one frequently finds small yellowish or brownish bodies looking something like a grain of wheat. These are the cocoons in which the earthworms lay their eggs, and the method by which this is performed is unique. We have already noted the presence of a swollen girdle (the *clitellum*) about the body of the worm. At the breeding season this throws out a fluid which soon hardens into an encircling band. By vigorous contractions of the body this horn-like collar is now slipped forward, and as it passes the openings of the reproductive organs the eggs and sperms are pushed within it. They thus occupy the space between the worm and the collar, and when the latter is shoved off over the head its ends close as though drawn to-

gether by elastic bands. A sac, the cocoon, is thus produced, containing the eggs and a milky, nutritive substance. In a few weeks the worm develops and, bursting the wall of its prison, makes its escape.

61. **Distribution.** — The earthworms and their allies are found widely distributed throughout the world, and all exhibit many of the characters just described. The greatest differences arise in their mode of life: some are truly earthworms, but others are fitted for a purely aquatic existence in fresh water or along the seacoast; a few have taken up abodes in various animals and plants, and in some of these situations they extend far up the sides of the higher mountains. In all, the head is relatively indistinct, the number of bristles on each segment few, and for this and other reasons all are included in the subclass Oligochæte, or "few-bristle" worms.

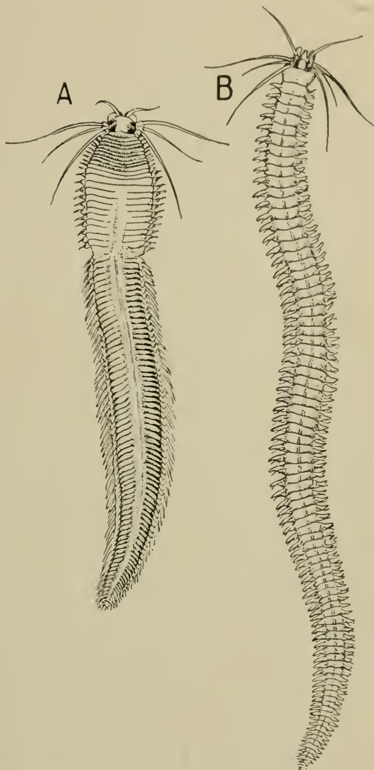

FIG. 36.—A marine worm (*Nereis*). A, appearance at breeding season, and B, at other times.

62. **Nereis and its allies.**—In many of the above-mentioned situations members of a more extensive group of worms are found, with highly developed heads and many bristles arranged along the sides of the body. These are the Polychætes or "many-bristle" worms, and as a representative we may take *Nereis* (Fig. 36), a very common

form along almost any seashore. The body presents the same segmented appearance as the earthworm, but the head (Fig. 37, A) is provided with numerous sense organs, chief among which are four eyes and several tentacles or "feelers."

The segments behind the head

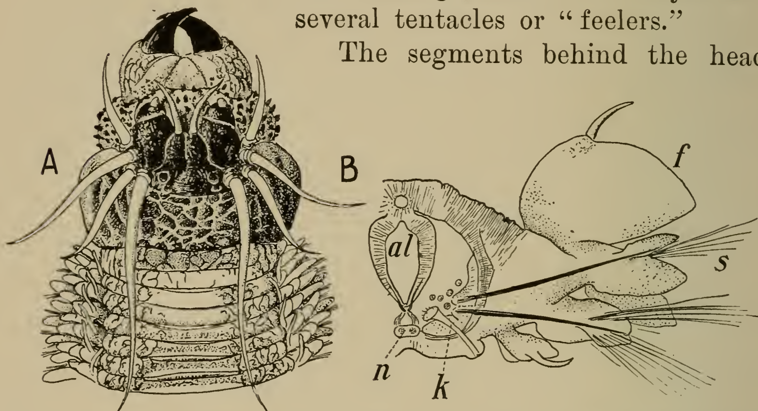

Fig. 37.—A, head and one of the lateral appendages (B) of a marine worm (*Nereis brandtii*); *al*, intestine; *f*, "gill"; *k*, kidney; *n*, nerve cord; *s*, bristles for locomotion.

differ very little from one another, and, unlike those of the earthworm, each bears a pair of lateral plates (Figs. 36, 37, B) or paddles with many lobes, some of which bear numerous bristles. By a to-and-fro movement these organs aid in pushing the animal about, or may enable certain species to swim with considerable rapidity.

As in all other worms, respiration takes place through the surface of the body, the area of which is increased by the development, on certain portions of the paddles (parapodia), of plates penetrated with numerous blood-vessels, which thus become special respiratory organs or gills (Fig. 37, B).

In their internal organization the Polychætes are constructed practically on the same plan as the earthworms, the principal difference being in the reproductive system. In the earthworm this is restricted to some of the forward segments, while in the present group the eggs and sperms are developed in almost every segment, whence they are finally swept to the exterior through the tubes of the kidneys (Fig. 37, B).

The Nereis and its immediate relatives are all active forms, and by means of powerful jaws, which may be quickly extended from the lower part of the mouth cavity, they capture large numbers of small crustaceans, mollusks, and worms which happen in their path. Others more distantly related make their diet of seaweed, and many living on the sea bottom swallow great quantities of sand, from which they absorb the nutritious substances.

63. **Sedentary forms.**—Preyed upon by many enemies, a large number of species have been forced to abandon an active existence save in their early youth, and to construct many interesting devices for their protection. Numerous species, shortly after they commence to shift for themselves, build about their bodies tubes of lime (Fig. 39), from which they may emerge to gather food and into which they may dash in times of danger. As the worm grows the tube is correspondingly enlarged, and these tubes, in all stages of construction and variously coiled, may be found on almost every available spot at the seashore, and may often be seen on the shells of oysters in the markets.

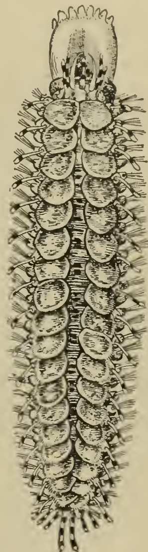

Fig. 38.—A common marine worm (*Polynœ brevisetosa*), with extended proboscis and overlapping plates covering the back.

In other species the tube is like thin horn, and may be further strengthened or concealed by numerous pebbles, bits of carefully selected seaweeds, or highly tinted shells, which give them a very attractive appearance. Such species usually develop out of immediate contact with other forms, but a few live so closely associated together that their twisted tubes form great stony masses, sometimes several feet in diameter.

64. **Effects of an inactive life.**—In many species such a sedentary life has resulted in the almost complete disappearance of the lateral appendages, which therefore no longer serve as organs of respiration, and this function has been shifted accordingly on to other structures. These new organs are situated principally on the exposed head,

Fig. 39.—Sedentary tube-dwelling marine worms, upper left hand *Sabella* (one-half natural size), the remainder *Serpula* (enlarged twice). From life.

and Fig. 39 shows the general appearance of some common species. The corners of the mouth have expanded into great plumes, sometimes wondrously colored like a full-blown flower, and these, bounteously supplied with blood-vessels, act as gills. When disturbed, the plumes are hastily withdrawn into the tube, and some of the so-called serpulids (Fig. 39, bottom of figure) close the entrance with a funnel-shaped stopper. While the plumes are primarily respiratory organs, they also act as delicate feelers, and may even bear a score or more of eyes; and in addition, being covered with cilia, create the currents of water which bring minute organisms serving as food within reach of the mouth.

65. **Development.**—Unlike the earthworms, the Polychætes lay their eggs in the sea water, where they are left alone to develop as best they may. Both the male and female *Nereis*, as the egg-laying time approaches, undergo remarkable changes in their external appearance, resulting in the form shown in Fig. 36, A. They are now active swimmers, and thus are able to scatter the fertilized eggs over wide and more or less favorable areas. The young also for a time are free-swimming, but finally end their migrations by settling to the sea bottom, where they gradually attain the adult condition.

As in some of the flatworms, reproduction may also arise asexually by the division of the animal into two or more parts, each of which subsequently becomes a complete individual. In other species growth of various parts may result in two complete worms at the time of separation; and from such forms we may trace a fairly complete series up to those in which the original parent breaks up into twenty to thirty young.

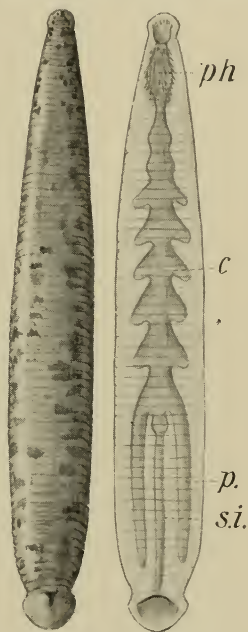

FIG. 40.—A leech (*Macrobdella*). Right-hand figure illustrates alimentary canal. *ph*, pharynx; *c*, crop; *p*, lateral pouches; *s.i.*, intestine.

66. **The leeches.** — At first sight the leeches (Fig. 40), or at least the smaller, more leaf-like forms, might be mistaken for flatworms, especially for some of the parasitic species. As in the latter, the mouth is surrounded by a sucker, and another is located at the hinder end of the body, but beyond this point the resemblance ceases. The

outer surface is delicately marked off into eighty or a hundred rings, of which from three to five are included in one of the deeper true segments corresponding to those of other annelids. From two to ten pairs of simple eyes are borne on the head, and owing to the fact that they are active swimmers, or move by caterpillar-like looping, locomotor spines are unnecessary and absent. In their internal organization, however, there are many features which indicate a close relationship with the Oligochætes or few-bristle worms. The nervous, circulatory, and certain characteristics of the excretory systems are decidedly similar, but, on the other hand, some facts are difficult to explain on such a theory, and have led some zoologists to the belief that the relationship of these animals can not at present be determined.

67. **Haunts and habits.**—The leeches usually dwell in among the plants in slowly running streams, but some occur in moist haunts on land, and a considerable number live in the sea. All are "bloodsuckers"—fierce carnivorous worms, whose bite is so insidiously made that the victim frequently is ignorant of their presence. Fishes, frogs, and turtles are the most frequently attacked, but cattle and other animals which come down to drink also become their prey. In some of the tropical countries the land-leeches are present in large numbers secreted among the leaves, and so severe are their attacks that various animals, even man, succumb to their united efforts. Adhering by their suckers, they puncture the skin, some using triple jaws, and fill themselves until they become greatly distended, when they usually drop off and digest the meal at leisure. In certain species the intestine is provided with lateral pouches (Fig. 40), which serve to store up the food until the time for digestion arrives. A full meal is sufficient with some species to last for two or three months, and the medicinal or horse-leech when gorged with food may consume a year in digesting it.

68. **Egg-laying.**—The eggs of some leeches are stored up in a cocoon like that of the earthworm, which is attached to submerged plants or placed under stones. When the young are able to lead independent lives they emerge with the form of the parent. A leaf-like form, *Clepsine*, sometimes found adhering to turtles, fastens the eggs to the under side of its body, and the young when hatched remain there for several days, adhering by their posterior suckers.

CHAPTER VII

ANIMALS OF UNCERTAIN RELATIONSHIPS

In this chapter we shall consider in a brief way a number of different groups of animals whose relationships are uncertain. Up to the present time the study of their habits, structure, and development has been of too fragmentary or unrelated a character to enable the majority of zoologists to agree upon their classification. Nevertheless, many of them are highly interesting and attractive, often very common, and in some respects they hold important positions in the animal kingdom.

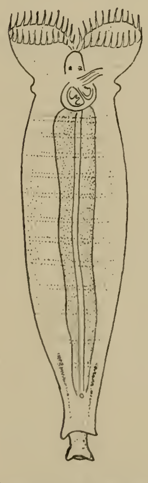

Fig. 41.—A wheel-animalcule (*Rotifer*).

69. **The rotifers or wheel-animalcules.**—The rotifers or wheel-animalcules are relatively small and beautiful organisms, rarely ever longer than a third of an inch, but at times so abundant that they may impart a reddish tinge to the water of the streams and ponds in which they live. At first sight they might be mistaken for one-celled animals, but the presence of a digestive tract and of reproductive elements soon dispels such a belief. Examined under the microscope, the more common forms are seen to possess an elongated body terminating at the forward end in two disk-like expansions beset along the edges with powerful cilia. These serve to drive the animal about, or, when it remains temporarily attached

by the sticky secretion of the foot, to sweep the food-particles down into the mouth. Through the walls of the transparent body such substances are seen to pass into the stomach, where they are rapidly hammered or rasped into a pulp by the action of several teeth located there. In the absence of a circulatory system the absorbed food is conveyed by the fluid of the body-cavity, which also conveys the wastes to the delicate kidneys. Several other features of their organization are of much interest, especially to the zoologist, who believes that he gains from their simple structure some ideas of the ancestors of the modern worms, mollusks, and their allies. During the summer the rotifers lay two sizes of "summer eggs," which are remarkable for developing without fertilization. The large size give rise to females, the smaller to males, the latter appearing when the conditions commence to be unfavorable. The "winter eggs," fertilized by the males and covered with a firm shell, are able for prolonged periods to withstand freezing, drought, or transportation by the wind. The adults also are able under the same adverse conditions to surround themselves with a firm protective membrane and to exist for at least a year. Once again in the presence of moisture the shell dissolves, and in a surprisingly short space of time they emerge, apparently none the worse for the prolonged period of quiescence.

70. **Gephyrea.**—There is a comparatively large group of worm-like organisms, over one hundred species in all, which at present hold a rather unsettled position in the animal kingdom. Some of the more common forms (Fig. 42) living in the cracks of rocks or buried in the sand, usually in shallow tide pools along the seashore, have a spindle-shaped body terminated at one end by a circlet of tentacles which surround the mouth. On account of their external resemblance to many of the sea-cucumbers (Fig. 92), they were earlier associated in the same group; but an examination of their internal organization inclines many zoologists

to the belief that the ancestors of some of these animals were segmented worms whose present condition has arisen possibly in accordance with their sluggish habits. This view is strengthened by the fact that in a very few species the larvæ are distinctly segmented, but lose this character in becoming adult. As before mentioned, the greater number of species live in burrows in the sand or crevices in the rocks, from which they reach out and gather in large quantities of sand. As these substances pass down the intestine the nutritive matters are digested and absorbed, while the indigestible matters are voided to the exterior. When large numbers are associated together they are doubtless important agents in modifying the character of the sea bottom, thus acting like the earthworms and their relatives.

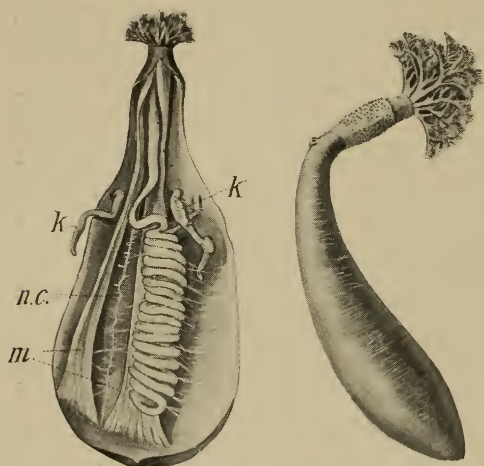

Fig. 42.—A gephyrean worm (*Dendrostoma*). Specimen on left opened to show *k*, kidney, *m*, muscle bands, and *n.c.*, nerve-cord.

71. **The sea-mats (Polyzoa).**—The sea-mats or Polyzoa constitute a very extensive group of animals common on the rocks and plants along the seashore, and frequently seen in similar situations in fresh-water streams. A few lead lives as solitary individuals, but in the greater number of species the original single animal branches many times, giving rise to extensive colonies. In some species these extend as low encrusting sheets over the objects on which they rest; while in others the branches extend into the

surrounding medium and assume feathery shapes (Fig. 43), which often bear so close a resemblance to certain plants

FIG. 43.—Lamp-shells or Brachiopods (on left of figure), fossil and living, and (on right) plant-like colonies of sea-mats.

that they are frequently preserved as such. What their exact position is in the animal scale it is somewhat difficult to say; but judging especially from their development, it appears probable that they are distant relatives of the segmented worms.

72. **Lamp-shells or Brachiopods.**—Occasionally one may find cast on the beach or entangled in the fishermen's lines or nets a curious bivalve animal similar to the form shown in Fig. 43. These are the Brachiopods, or lamp-shells. The remains of closely related forms are often abundant as fossils in the rocks (Fig. 43). Over a thousand species have been preserved in this way, and we know that in ages past they flourished in almost incredible numbers and were scattered widely over the earth. Unable to adapt themselves to changing conditions or unable to cope with their enemies, they have gradually become extinct, until to-day scarcely more than one hundred species are known. These are often of local distribution, and many are comparatively rare.

For a long period the Brachiopods, owing to their peculiar shells, were classed together with the clams and other bivalve mollusks. The presence of a mantle also strengthened the belief; but closer examination during more recent years has shown that the shells are dorsal and ventral, and not arranged against the sides of the animal as in the clams. Another peculiar structure consists of two great spirally coiled "arms," which are comparable in a general way to greatly expanded lips. The cilia on these create, in the water currents which sweep into the mouth, the small animals and plants that serve as food. The internal organization resembles in a broad way that of the animals considered in the previous section, and it now appears that both trace their ancestry back to the early segmented worms.

73. **Band or nemertean worms.**—In a few cases band or nemertean worms have been discovered in damp soil or in fresh-water streams. These are commonly small and inconspicuous, and are pigmies when compared with their marine relatives, which sometimes reach a length of from fifty to eighty feet. Many of the marine species (Fig. 44) are often found on the seashore under rocks that have been exposed

by the retreating tide. They are usually highly colored with yellow, green, violet, or various shades of red, and are so twisted into tangled masses that the different parts of the body are indistinguishable. As the animal crawls about, a long thread-like appendage, the proboscis, is frequently shot out from its sheath at the forward end of the body and appears to be used as a blind man uses his stick. At other times, when small worms and other animals are encountered, the proboscis is shot out farther and with greater force, impaling the victim on a sharp terminal spine (Fig. 44). The food is now borne to the mouth, located near the base of the proboscis, is passed into the digestive tract, traversing the entire length of the body, and is farther operated on by systems of organs too complex to be considered here.

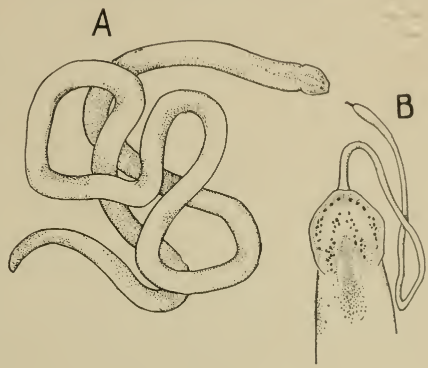

Fig. 44.—A band or nemertean worm. A, entire worm; B, head, bearing numerous eyes and spine-tipped proboscis.

CHAPTER VIII

MOLLUSKS

74. **General characters.**—For very many years the mollusks—that is, the clams, snails, cuttlefishes, and their allies—have been favorite objects of study largely because of the durability, grace, and coloration of the shell. The latter may be univalve, consisting of one piece, as in the snails, or bivalve, as in the clams and mussels, and may possess almost every conceivable shape, and vary in size from a grain of rice to those of the giant clam (Tridacna) of the East Indian seas, which sometimes weighs five hundred pounds. These external differences are but the expression of many internal modifications, which, while adapting these animals for different modes of life, are yet not sufficient to disguise a more fundamental resemblance which exists throughout the group. In some respects the mollusks show a close resemblance to the annelid worms, but, on the other hand, the body is usually more thick-set and totally devoid of any signs of segmentation. In every case the skin is soft and slimy, demanding moist haunts and usually the protection of a shell, and the body is modified along one surface to form a foot or creeping disk which serves in locomotion. The internal organization is somewhat uniform, and will admit of a general description later on. Mollusks are divided into three classes, viz.: The Lamellibranchs, embracing the clams; the Gasteropods, or snails; and the Cephalopods, or cuttlefishes, squids, and related forms.

75. **Lamellibranchs (clams and mussels).**—Numerous representatives of this class, such as the clams and mussels,

occur along our seacoasts or are plentifully distributed in the fresh-water streams and lakes. They are distinguished from other mollusks by a greatly compressed body, which is enclosed in a shell consisting of two pieces or *valves* locked together by a hinge along the dorsal surface. Raising one of these valves, the main part of the body may be seen to occupy almost completely the upper (dorsal) part of the shell (Fig. 45), and to be continued below into the muscular hatchet-shaped foot (*ft.*), which aids the clam in plowing its way through the sand or mud in which it lives. Arising on each side of the back of the animal and extending its entire length is a great fold of skin, which completely lines the inner surface of the corresponding valve of the shell. These are the two mantle lobes (*m*) instrumental in the formation of the shell, and enclosing between them a space containing the foot and a number of other important structures, the most conspicuous of which are the gills (*g*), consisting of two broad, thin plates attached along the sides of the animal and hanging freely into the space (mantle cavity) between the mantle and the foot. Owing to this lamella-like character of the branchia or gills the class derives its name, lamellibranch. To illustrate the relations of these various organs to one another the clam has been compared to a book, in which the shells are represented by the cover, the fly-leaves by the mantle lobes, the first two and last two pages by the gills, and the remaining leaves by the foot. In the clams, however, the halves of the mantle, like the halves of the shell, are curved, and thus enclose a space, the mantle cavity, which is partly filled by the gills and foot.

Unlike the other mollusks which usually lead active and more aggressive lives, the clams show scarcely a sign of a head and tentacles, and other sense organs are likewise absent from this region. The mouth also lacks definite organs of mastication, and as devices for catching and holding food are not developed, the food is brought to the mouth by means of the cilia on the great triangular lips or *palps* which bound it on each side (Fig. 45, A, *p*).

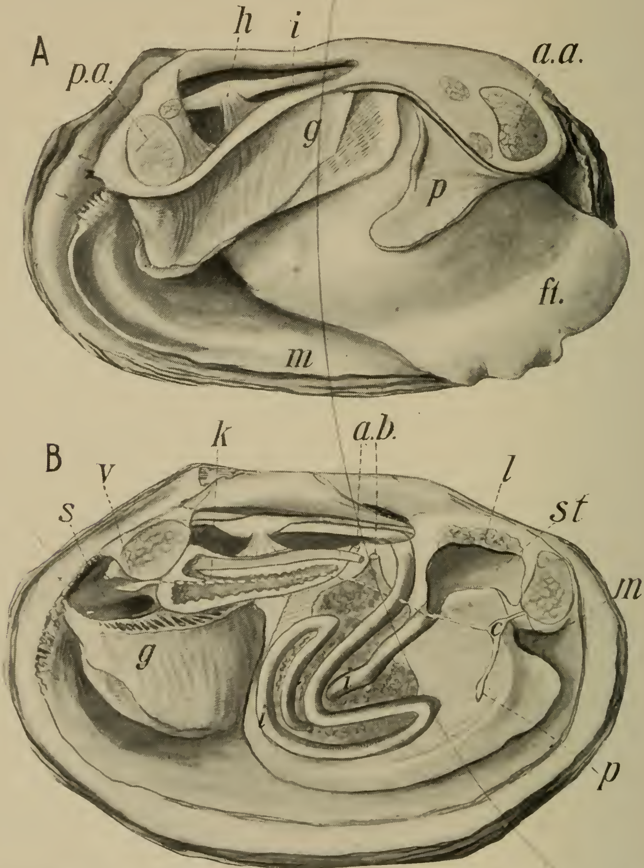

FIG. 45.—Anatomy of fresh-water clam. A, right valve of shell removed; B, dissection to show internal organs. *a*, external opening of kidney; *a.a.*, the anterior muscle for closing the shell; *b*, opening of reproductive kidney; *c*, brain; *ft.*, foot; *g*, gill; *h*, heart; *i*, intestine; *k*, kidney; *l*, liver; *m*, mantle (upper fig.), mouth (lower fig.); *p*, palp (upper fig.), foot nerves (lower fig.); *p.a.*, hinder muscle for closing the shell; *s*, space through which the water passes on leaving the body; *st*, stomach; *v*, nerves supplying viscera.

Between the halves of the shell in the hinge region is a horny pad that acts like a spring, and without any muscular effort on the part of the clam keeps the shells open.

These are also united by two great adductor muscles, located at opposite ends of the animal (Fig. 45, A, *a.a.*, *p.a.*), which in times of disturbance contract and firmly close the shell. Upon their relaxation the shell opens, the clam extends its foot, and plows its way leisurely through the mud, or remains buried, leaving only the hinder portion of its gaping shell exposed. Through this opening a current of water is continually passing in and out, owing to the action of the cilia covering the gills, and by placing a little carmine or coloring matter in the ingoing stream we may trace its course through the body. Passing in between the mantle and the foot it travels on toward the head, giving off small side streams which are continually made to enter minute openings in the gills, whence they are conducted through tubes in each gill up to a large canal at its base, where it is carried backward to the exterior. In this process oxygen gas is supplied to the number of blood-vessels traversing the gills, and at the same time considerable quantities of minute organisms and organic *débris* are hurried forward toward the head, where they encounter the whirlpools made by the cilia on the lips and are rapidly whisked down into the mouth and swallowed.

75. **Rock- and wood-boring clams.**—Other similar forms are rendered even more secure through their ability to bore in solid rock. In the common Piddock, for example (Fig. 46), the shell is beset with teeth like a rasp, which gradually enlarge the cavity as the animal grows, until it becomes a prisoner with no means of communication with the exterior save the small opening through which the siphons project. This is also the case with the *Teredo*, improperly called the shipworm, which swims about for some time during early life and then, about the size of a small pinhead, settles down upon the timbers of wharves or unsheathed ships, into which it rapidly tunnels. Throughout life its excavation is extended sometimes to a distance of two to three feet, and imprisoned yet safe at

the bottom of its burrow, it extends its slender siphons up the tube and out of the entrance for its food supply. Often hundreds of individuals enter the same piece of wood, which becomes thoroughly riddled within a short

FIG. 46.—The piddock (*Zirphæa crispata*), a rock-boring mollusk. Natural size, from life.

time, and though giving no outward sign of weakness may collapse with its own weight. Incalculable damage is thus rendered to the shipping interests, and in consequence much has been done to check their ravages, but they are far from being completely overcome.

76. **Other stationary species.**—A large number of other species, while small and inconspicuous, are also free to

move about, but as they become larger they lose this ability either wholly or periodically. In the edible mussels (*Mytilus*, Fig. 47), for example, which are associated in great numbers on the rocks along our coasts, the foot early becomes long and slender and capable of reaching out a considerable distance from the shell to attach threads (byssus), which it spins, to foreign objects. These are remarkably strong, and when several have been spun it becomes a matter of much difficulty to dislodge them. After remaining anchored in one situation for a while the mussel may vol-

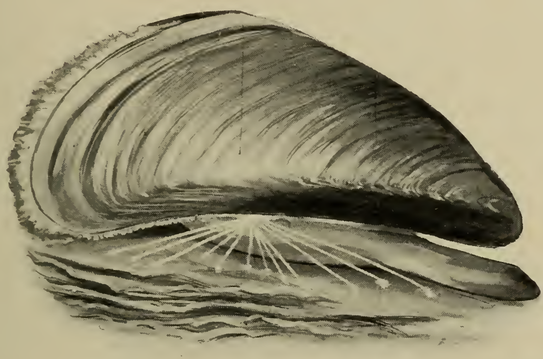

FIG. 47.—The edible mussel (*Mytilus edulis*), showing the threads by which it is attached. Natural size, from life.

untarily free itself, and in a labored fashion move to some other more favorable spot where it again becomes attached, but there are numerous species, such as "fan shells" (*Pinna*), scallops, *Anomia*, and a few fresh-water forms, where the union is permanent.

Finally, in the oysters, some of the scallops, and a number of less familiar forms, the young in very early life drop down upon some foreign object to which the shell soon becomes firmly attached, and in this same spot they pass the remainder of their lives. The oyster usually falls upon the left half of its shell, which becomes deep and capacious enough to contain the body, while the smaller right valve acts as a lid. As locomotion is out of the question, the foot never develops, and the shell is held by only one adductor muscle, whose point of attachment in the oyster is indicated by a brown scar in the interior of the shell.

77. **Internal organization.**—It is thus seen that the external features of the clam are variously modified, according to the life of the animal, but the internal organization is much more uniform. In nearly every species the food consists of floating organisms, which are driven by the palps into the mouth and on to the simple stomach, where it is subjected to the solvent action of the fluids from the liver (Fig. 45, B, *l*) before entering the intestine. This latter structure is usually of considerable length, and in the active species extends down into the foot, and it is also peculiar in penetrating the ventricle of the heart. Traversing the intestine the nutritive portion of the food is absorbed, and is conveyed over the body by a circulatory system more highly developed than in the higher worms. On the dorsal side of the clam, in a spacious pericardial chamber, the large heart is situated (Fig. 45, *h*), consisting of a median highly muscular ventricle surrounding the intestine and of two thin auricles, one on either side. From the former, two arteries with their numerous branches convey the blood to all parts of the body, where it accumulates, not in capillaries and veins, but in spaces or *sinuses* among the muscles and various organs, constituting a somewhat indefinite system of channels which lead to the gills and kidneys. In these latter organs the blood delivers up the waste which it has accumulated on its journey, and absorbing a supply of oxygen, it flows into the great auricles, which in turn pass it into the ventricle to circulate once more throughout the body.

The excretory apparatus, consisting usually of two kidneys, of which one may degenerate in many snails, bears a close resemblance to that of the annelids. In the clam, for instance, each consists of a bent tube symmetrically arranged on each side of the body (Fig. 45, B, *k*), and the inner ends (*a*), corresponding to the ciliated funnel of the annelid kidney, open into the pericardial cavity. Their walls are continually active in extracting wastes from the blood supplied to them, and these, together with the substances swept out from the pericardial cavity, traverse the tube and are carried to the exterior. In other mollusks the kidney may be more compact, or greatly elongated, or otherwise peculiar, but in reality they bear a close resemblance to those of the clam.

78. **Nervous system.**—The nervous system, like the excretory, differs considerably in different mollusks, yet the resemblances are fairly close throughout. In the clam the cerebral ganglia corresponding to the "brain" in annelids is located at either side, or above the mouth, and from it several nerves arise, the larger passing downward to two pedal ganglia (*p*) embedded in the foot and to the visceral ganglia (*v*) far back in the body (Fig. 45, B). These nerve centers continually send out impulses which regulate the various activities of the body and also receive impressions from without. These come chiefly through the sense of touch, for in the clams the other senses are usually either feebly developed or altogether absent.

79. **Development.**—In the mollusca new individuals always arise from eggs, which are commonly deposited in the water and there undergo development. In the fresh-water clams the reproductive organ is usually situated in the foot (Fig. 45), while in the oyster and similar inactive species it is attached to the large adductor muscle. In these latter, and in many other marine forms, the eggs are shed directly into the sea, where they are left to undergo their development buffeted by winds and waves and subject to the attack of numerous enemies. Under such circumstances the chances of survival are slight, and for this reason eggs are laid in vast numbers, which have been variously estimated for the oyster, for example, from two to forty million. Develop-

ment proceeds at first much as in the sponge, but soon the shell, foot, gills, and various other molluscan structures put in an appearance, and the few surviving young which have been free-swimming now settle down in some favorable spot, and attach themselves or burrow according to their habit.

80. **Life history of fresh-water clams.**—The life history of our common fresh-water clams is perhaps one of the most remarkable known among mollusks. The parent stores the eggs, as soon as they are laid, in the outer gill plate, and there, well protected, they undergo the first stages of their development, which results in the formation of minute young enclosed in a bivalve shell beset with teeth. These are often readily obtained, sometimes as they are escaping from the parent, and when examined under the microscope are seen to rapidly open and close their shells in a snapping fashion when in the least disturbed. In a state of nature this latter movement may result in attaching the young to the fins or gills of some passing fish, which is necessary to its further development. Within a short time it becomes completely embedded in the flesh of its host, from which, as a parasite, it draws its nourishment, and during the next few weeks undergoes a wonderful series of transformations resulting in a small mussel, which breaks its way through the thin skin of the fish and drops to the bottom.

81. **The gasteropods.**—The gasteropods, including snails, slugs, limpets, and a host of related forms, fully twenty thousand different species in all, are found in most of our fresh-water streams and lakes and in moist situations on land, while great numbers live along the seashore and at various depths in the ocean, even down as far as three miles. Examining any of them carefully we find many of the same organs as in the clams, but curiously changed and adapted for a very different and usually active life. In our common land snails (Fig. 48), which we may well examine before passing on to a general survey of the group, the first

striking peculiarity is in the univalve shell, with numerous whorls, into which the animal may at any time withdraw completely. Ordinarily this is carried on the back of the spindle-shaped body, which is fashioned beneath into a great

FIG. 48.—The slug (*Ariolimax*) and common snail (*Helix*). From life.

flat sole or creeping surface that bears on its forward border a wide opening through which mucus is continually issuing to enable the snail to slip along more readily. Slime also exudes on other points on the surface of the body and affords a valuable protection against excessive heat and drought.

Unlike the clams, the forward end of the body is developed into a well-marked head bearing the mouth and a complicated mechanism for gathering and masticating food, together with two pairs of tentacles, one of which carries the eyes. On the right side of the animal, some distance behind the head, is the opening of the little sac-like mantle cavity (Fig. 48) which contains the respiratory organs, and into which the alimentary canal and the kidneys pour their wastes. The relation of these organs to the mantle cavity is the same as in the clams, though the cavities differ much in size and position.

82. **Other snails. The shell.**—Extending our acquaintance to other species of snails, we find the same general plan of body, although somewhat obscured at times by

many modifications. A foot is generally present, also a more or less well-developed head, and the body is usually surrounded by a shell which varies widely in shape and size in different species. In the common limpets the early coiled shell is transformed into an uncoiled cap-like one, and in the keyhole limpets is perforated at its summit. The chitons or armadillo-snails (Fig. 49), often found associated with the limpets, carry a most peculiar shell consisting of eight plates, which enables the animal to roll up like an armadillo when disturbed. A shell is by no means a necessity, however, for in many species, such as the beautiful naked snails or Nudibranchs (Fig. 50) common along our coasts, it may be entirely absent, or, as in the ordinary slugs, reduced to a small scale embedded in the skin.

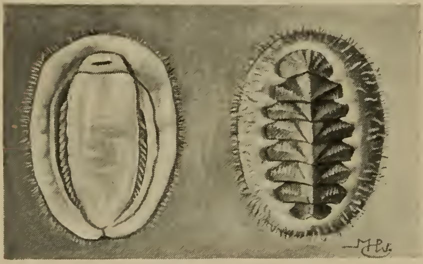

Fig. 49.—The chiton, armadillo-snail or sea-cradle. The left-hand figure shows mouth in center of proboscis, the broad foot on each side of which are numerous small gills. The right-hand figure shows the mantle and shell, composed of eight plates. From life, one-half natural size.

83. **Respiration.**—A considerable quantity of oxygen is absorbed through the skin, as in all mollusks, but the chief part of the process is usually taken by the plume-like gills, one or two in number, which are located in the mantle cavity. In the chitons (Fig. 49) the number of gills is greater, amounting in some species to over a hundred, while in the Nudibranchs (Fig. 50) gills are absent, their places being taken by more or less feathery expansions of the skin on the dorsal surface.

Many of the gasteropods left exposed on the rocks by a retreating tide retain water in the mantle cavity, from which they extract the oxygen until submerged again.

Others breathe by means of gills while under water, and by the surface of the body and the moist walls of the mantle

FIG. 50.—Three different species of naked marine snails or Nudibranchs. Natural size, from life.

cavity when exposed. In some of the small Littorinas attached so far from the sea as to be only occasionally washed by the surf this latter method may prevail for days together—in fact they live better out of water than in it. It is not difficult to imagine that such forms, keeping in moist places, might wander far from the sea, and, losing their gills, become adapted to a terrestrial life. It is believed that in past times this has actually occurred, and that our land forms trace their descent from aquatic ancestors. To-day they breathe by a lung—that is, they take oxygen through the walls of the mantle cavity, as the slug may be seen to do, though in some species traces of the old gill yet remain.

84. **Food and digestive system.**—Many mollusks live upon seaweeds, and the greater number of terrestrial forms are fond of garden vegetables or certain kinds of lichens, but, on the other hand, the latter, together with a large number of marine snails, are carnivorous. In all cases the food requires to be masticated, and, unlike the clams, the mouth is usually provided with horny jaws, and an additional

masticatory apparatus which consists of a kind of tongue with eight to forty thousand minute teeth in our land forms (Fig. 51), while in certain marine snails they are beyond computation. With the licking motion of the tongue this rasp tears the food into shreds before it is swallowed, and in the whelks or borers it serves to wear a circular hole through the shells of other mollusks, which are thus killed and devoured. This latter process is facilitated by the secretion of the salivary glands, which has a softening effect upon the shell. Ordinarily the saliva of snails exercises some digestive action.

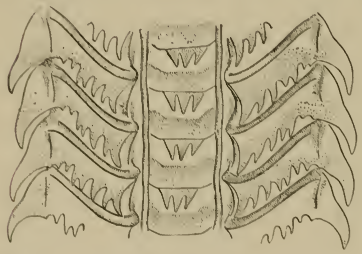

Fig. 51.—A small portion of the radula or tongue-rasp of a snail (*Sycotypus*).

In the stomach of some snails are teeth or horny ridges which also are instrumental in crushing the food, and in numerous minor respects peculiarities exist in different species according to the nature of the food; but in its general features the digestive tract is similar to that of the clams.

The processes of circulation and excretion are also carried on by means of systems which show a certain resemblance to those of the clams. As might be expected, certain differences exist, sometimes very great, but they are of too technical a nature to concern us further.

85. **Sense-organs of lamellibranchs and gasteropods.**—The eyes of mollusks differ widely in their structure and the position they occupy in the body. In our common land snails two pairs of tentacles are borne on the head, the lower acting as feelers, while each of the upper ones bears on its extremity the eye, appearing as a minute black dot (Fig. 48). In this same position the eyes of many marine snails occur, but there are numerous species in which there are other accessory eyes. In many of the

limpets, for instance, there are numbers of additional eyes carried on the mantle edge just under the eaves of the shell, and forming a row completely encircling the body. (In the scallops there are two rows of brilliantly colored eyes, set like jewels on the edges of the mantle just within the halves of the shell.) In the chitons the eyes of the head disappear by the time the animal attains maturity, and in some species at least their place appears to be taken by great numbers of eyes, sometimes thousands, which are embedded in the shells. On the other hand, eyes are completely absent in certain species of burrowing snails and in several living in the gloomy depths of the sea far from the surface; they appear to be absent also from fresh-water clams; but the fact that certain species close their shell when a shadow falls upon them, leads to the belief that while actual eyes are not present the skin is extremely sensitive to light. This is also the case with many snails.

86. **Smell.**—Since the sense of sight is generally undeveloped in the mollusks, they rely chiefly upon touch and smell for recognizing the presence of enemies and food. Tentacles upon the head and other parts of the body, and a skin abundantly supplied with nerves, show them to possess a high degree of sensibility; but in the greater number of species the sense of smell is of chief importance. Many experiments show that tainted meat and strongly scented vegetables concealed from sight and several feet distant from many of our land and sea mollusks will attract them at once. In these forms the sense of smell appears to be located on the tentacles, but additional organs, possibly of smell, are located on various portions of the body, usually in the neighborhood of the gills.

87. **Taste and hearing.**—Several mollusks appear to be almost omnivorous, but others are decidedly particular in their choice of food, which leads us to suspect that they possess to some extent the sense of taste. Nerves supplying the base of the mouth have also been detected, which

may be those of taste; but experiments along the line are difficult to perform, and our knowledge of this subject is far from complete. The same is true of hearing. Certain organs, interpreted as ears and located in the foot, have the form of two hollow sacs, containing one or more solid particles of sand or lime, whose jarrings, when effected by sonorous bodies, may result in hearing. On the other hand, it is held by some that they, like the semicircular canals of higher animals, may regulate the muscular movements which enable the animal to keep its balance.

88. **Egg-laying habits and development.**—The egg-laying habits of the gasteropods differ almost as widely as their haunts. The terrestrial forms lay comparatively few eggs, ranging in size from small shot to a pigeon's egg in some of the tropical species. These are buried in hollows in the ground or under sticks and stones, and after a few weeks hatch out young snails having the form of the adult. The same is also true of most of the fresh-water snails, which lay relatively smaller eggs embedded in a gelatinous mass frequently found attached to sticks and leaves, or on the walls of aquaria in which they are confined. Many marine species construct capsules of the most varied patterns which they attach to different objects, and in these the young are protected until they hatch. In the limpets and many of the chitons the eggs are laid by thousands directly in the water, and after a short time develop into free-swimming young, differing considerably from the parent in appearance. Those escaping the ravages of numerous enemies finally settle down in a favorable situation and gradually assume the form of the adult.

89. **Age, enemies, and means of defense of lamellibranchs and gasteropods.**—How much time is consumed by the young in growing up, and the length of time they live, are questions generally unsettled. It is said that the oyster requires five years to attain maturity, and lives ten years; the fresh-water clam develops in five years, and some species live from

twelve to thirty years; and the average length of life of the snail appears to be from two to five years. Certain it is that mollusks have numerous enemies besides man which prevent multitudes from living lives of normal length. Birds, fishes, frogs, and starfishes beset them continually, and many fall a prey to the ravages of internal parasites or to other mollusks. Under ordinary circumstances the shell is sufficient protection, and the spines disposed on the surface in many species render the occupant still less liable to attack. Many snails carry on the foot a horny or calcareous plate known as the operculum, which closes the entrance of the shell like a door against intruders. Certain noxious secretions poured out from the skin also serve as a means of defense, and many Nudibranchs (Fig. 50) bear nettle-cells on the processes of the body, which probably render them distasteful to many animals. Finally, there are numerous clams, mussels, snails, and slugs whose colors harmonize so closely with their surroundings that they almost completely baffle detection, and enable them to lead as successful a life as those provided with special organs of defense.

90. **Cephalopods.**—The animals belonging to this class, such as the squids and cuttlefishes (Fig. 52), are by far the most highly developed mollusks. They are of great strength, capable of very rapid movements, and several species are many times the largest invertebrates. In almost every case there is a well-defined head bearing remarkably perfect eyes, and also a circle of powerful arms provided with numerous suckers which aid in the capture of food (Fig. 52). Posteriorly the body is developed into a pointed or rounded visceral mass which to a certain extent is free from the head, giving rise to a well-marked neck. Some forms, such as the squids (Fig. 52, upper figure), are provided with fins which drive the animal forward, but in common with other cephalopods they are capable of a very rapid backward motion. By muscular movements water is taken

into the large mantle cavity within the body, a set of valves prevents its exit through the same channels, and upon a vigorous contraction of the body walls the water is forced out rapidly through the small opening of the funnel, which

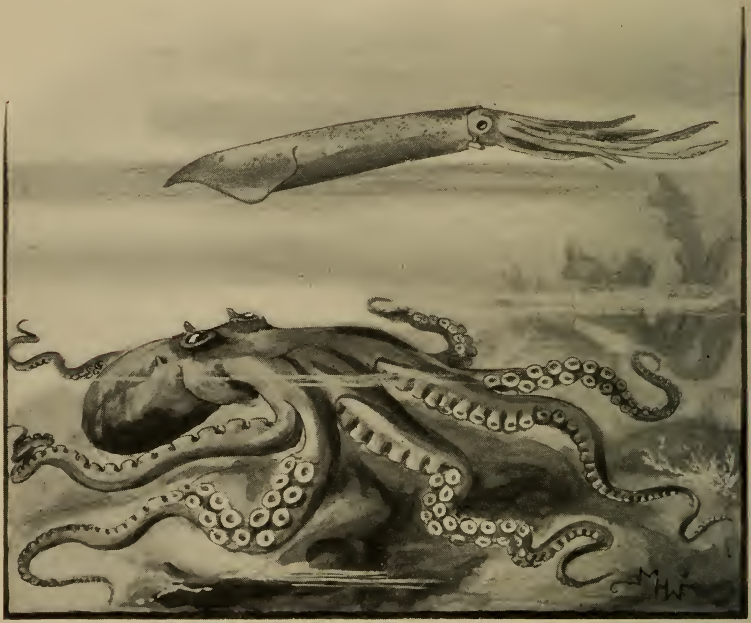

FIG. 52.—Cephalopods. Lower figure, the devil-fish or octopus (*Octopus punctatus*). The upper figure represents the squid (*Loligo pealii*) swimming backward by driving a stream of water through the small tube slightly beneath the eyes. From life, one-third natural size.

drives the animal backward after the fashion of an exploding sky-rocket. In this way they usually escape the fishes and whales that prey upon them, but an additional device has been provided in the form of a sac within the body, whose inky contents may be liberated in such quantity as to cloud the water for a considerable distance, and thus enable them to slip away unseen into some place of safety.

Most of the cephalopods are further protected by their ability to assume, like the chameleon, the color of the object upon which they rest. In the skin are embedded multitudes of small spherical sacs filled with pigments of various colors, chiefly shades of red, brown, and blue, each sac being connected with a nerve and a series of delicate muscles. If the animal settles upon a red surface, for example, a nerve impulse is sent to each of the hundreds of color sacs of corresponding shade, causing the muscles to contract and flatten the bag like a coin, and thus exposing a far greater surface than before, they give the animal a reddish hue. In the twinkling of an eye they may completely change to another tint, or present a mottled look, and some may even throw the surface of the skin into numerous small projections that make the animal appear part of the rock upon which it rests. These devices not only serve for protection, but they also aid in enabling these mollusks to steal upon their prey, chiefly fishes, which they destroy in great numbers with lionlike ferocity.

The devil-fishes and a number of other species are usually found creeping along the sea bottom, generally near shore, and are solitary in their habits, while the squids remain near the surface and frequently travel in great companies, sometimes numbering hundreds of thousands. In size they usually range from a few inches to a foot or two in length, but a few devil-fishes and squids attain a greater size, some of the latter reaching the enormous length of from forty to sixty feet. There are many stories of their great strength and of their voluntarily attacking people and even overturning boats, but the latter are in almost every case sailors' yarns.

In their external organization the cephalopods have little to remind one of any of the preceding mollusks, and their internal structure shows only a distant resemblance. In the Octopi (Fig. 52) the shell is lacking; in the squid it is called the pen, and consists of a horn-like substance without any lime deposit; in the cuttlefishes it is spongy and plate-like, and is a familiar object in the shops; and, finally, in the nautilus it is coiled and of considerable size, and, unlike that of any other cephalopod, it is carried on the outside of the animal. Interiorly it is divided by a number of partitions into chambers, the last one of which is occupied by the animal.

The alimentary canal shows some resemblance to that of other mollusks, but, as in the case of the other systems of the body, it possesses a far higher state of development. The mouth is situated in the center of a circle of arms, which in reality are modified portions of the foot, and is furnished with two parrot-like jaws. From this point the esophagus leads back into the body mass to the stomach, which with the liver and intestine are sufficiently like those of the clam and snail to require no further comment.

Respiration is effected by the skin to a certain extent, but chiefly by two gills (four in the nautilus), and the circulatory system, which conveys the blood to and from these organs and over the body with its complex heart, arteries, capillaries, and veins, is more highly developed than in any other invertebrate.

As might be expected in animals with so great sagacity and cunning, the nervous system of the sense-organs reach a degree of development but little short of what we find in some of the vertebrates. The chief part of the nervous system is located in the head, protected by a cartilaginous skull, a very rare structure among invertebrates; and while the different ganglia may be recognized in a general way and be found to correspond to a certain extent to those of foregoing mollusks, they are so largely developed and massed together that it is impossible at present to understand them fully. From this point nerves pass to all regions of the body, to the powerful muscles, the viscera, and the organs of special sense, controlling the complex mechanism in all its workings.

There is no doubt that the cephalopods see distinctly for considerable distances, and a careful examination of the eye of the squids and cuttlefishes has shown them to be remarkably complex and in many respects to be constructed upon much the same plan as those of the vertebrates. As to the other senses not so much is known, but undoubtedly many species of cephalopods are possessed of a shrewdness and cunning not shared by any other invertebrates, save some of the insects and spiders, and are vastly more highly organized than their molluscan relatives.

91. **How species originate.**—We have now examined a considerable portion of the animal kingdom, tracing its members from their simplest beginnings as single cells, through the formation of colonial types, and up through the sponges, cœlenterates, worms, and mollusks. It is important once more to note that they all perform the functions concerned in nutrition and reproduction, and only these. The differences which exist are those of structure. The *Hydra* and the clam, for example, perform the same duties, but their bodily apparatus differs widely, and the completeness and perfection of the work varies accordingly. The more the work to be performed by an organism is divided up among especially adapted organs, so that each of the latter has, as far as possible, only one thing to do, the higher is the organism.

As stated earlier in the account, it is believed that the more complex animals arose from the simpler; that if we could trace the history of any of the great groups back toward their first beginnings, we would find them all to have originated from one ancestral form, that in turn owes its descent from yet simpler forms.

Let us see something of how this has come about. We all know that vast numbers of young are born into this world which never come to maturity. It is said that if all the young of the codfish were to live their allotted time, it would be less than fifteen years before the sea would become literally packed with them. Numerous enemies, the lack of food, and other agencies annihilate the larger part. We also know that no two offspring are exactly alike. They exhibit individual differences. One bird may have a larger bill than another of the same brood which excels in length of wing. As noted above, all the offspring will not attain maturity. Those best adapted to their surroundings will have the best chances of survival. The increased length of bill or wing may be slight, but it may be just this amount which enables the bird to probe deeper or fly farther and thus secure the requisite amount of food. A premium is placed on length of wing or bill generation after generation, with the result that a long-billed species arises distinct from the long-winged which trace their ancestry back to the same parents. It is the same principle which enables the breeder to increase the swiftness of the race-horse and the strength of the draft-horse, or the gardener to develop from the wild rose the great number of widely different varieties. In the same way other slight peculiarities over very many generations may enable other forms to gradually adapt themselves to still different modes of life. Thus vast numbers of organisms gradually become modified in form and complexity, and are adapted to lives which insure them a comparative degree of safety and less competition with other species.

CHAPTER IX

ARTHROPODS. CLASS CRUSTACEA

92. **General characters.**—In the Arthropods, that is, the crabs, lobsters, shrimps, insects, spiders, and a vast host of related forms, the body is bilaterally symmetrical, and is composed of a number of segments arranged in a series, as in the earthworm and other annelids. A hornlike cuticle, sometimes called the shell, bounds the external surface—in early life thin and delicate, but later relatively thick, and often further strengthened by lime salts. Along the line between the segments this coat of mail remains thin and forms a flexible joint. Appendages also are borne on each segment, not comparatively short and fleshy outgrowths like the lateral appendages of many of the worms, but usually long and jointed (hence the name Arthropod, meaning jointed foot), and variously modified for many different uses.

93. **Classification.**—The species belonging to this group outnumber the remainder of the animal kingdom. Their haunts also are most diverse. Some are adapted for lives in the sea and fresh water, others for widely different situations on land, and a great number are constructed for a life on the wing. A certain resemblance exists among them all, but the modifications which fit them for their different habitats are also profound, and have resulted in the division of the Arthropods into five classes. The first class (*Crustacea*) contains the crayfish, crabs, etc.; the second (*Onychophora*) includes the curious worm-like peripatus (Fig.

66); the third (*Myriapoda*, meaning myriad-footed) embraces the centipeds and "thousand-legs"; the fourth (*Insecta*) contains the insects; and the fifth (*Arachnida*) includes the scorpions, spiders, and mites.

94. **The Crustacea.**—The number of species of crustaceans is estimated to be about ten thousand, and while the greater number of these are marine, many are found in fresh water and a few occur on land. In size they range from almost microscopic forms to the giant crabs and lobsters. They differ also in shape to a remarkable degree, but at the same time there is a decided resemblance throughout the group, except in those species which have become modified by a parasitic habit. The characteristic external skeleton is invariably present, and gives evidence of the deep internal segmentation of the body. In the simple Crustacea this is very apparent, but in the higher forms it is usually more or less obscured, owing to the fusion of some of the different segments, especially those of the head, as in the crayfish (Fig. 59).

The class of the Crustacea is subdivided into two subclasses (*Entomostraca* and *Malacostraca*), the first containing the fairy-shrimps (*Branchipus*, Fig. 53) and their allies, the copepods (such as Fig. 54), the barnacles (Fig. 55), and a number of other species. In their organization all are comparatively simple, usually small, and the appendages show relatively little specialization. The other subclass contains the more highly developed and usually large-sized Crustacea, among which are the shrimps, crayfishes, lobsters, crabs, and a number of other forms.

95. **Some simple Crustacea.**—While the members of the first subclass are minute and inconspicuous, several species are often remarkably abundant in our small fresh-water pools. Among these is the beautifully colored fairy-shrimp (*Branchipus*, Fig. 53), with greatly elongated body and leaf-like appendages, whose relatively simple character leads the zoologist to think that they are among the simplest

Crustacea, and in several points resemble the ancestral form from which all the modern species have descended. Some nearly related forms are provided with a great fold of the body-wall, which may almost completely conceal the animal from above, or it may be formed like a bivalve clam-shell, within which the entire body may be withdrawn. This

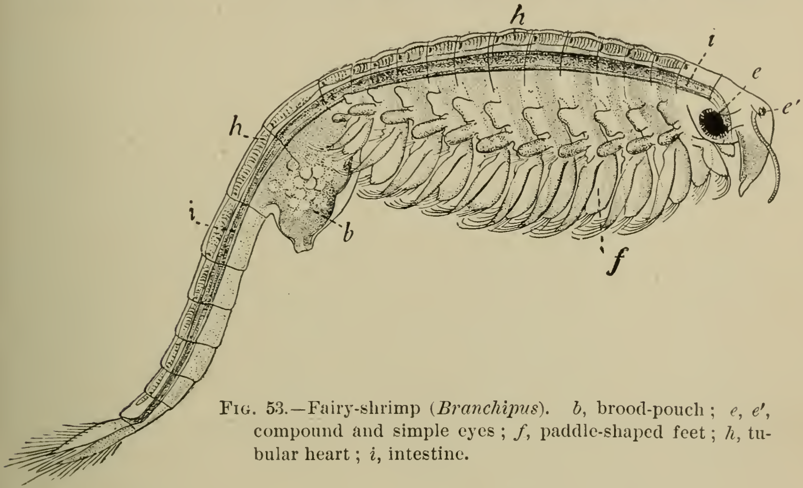

Fig. 53.—Fairy-shrimp (*Branchipus*). *b*, brood-pouch; *e*, *e'*, compound and simple eyes; *f*, paddle-shaped feet; *h*, tubular heart; *i*, intestine.

latter character is also found in the water-fleas (*Daphnia*), very much smaller forms, and sometimes occurring in millions on the bottoms of our ponds and marshes. They are readily distinguished from the fairy-shrimp by the shortness of the body, the small number of appendages, and by their habit of using their antennæ as swimming organs, which gives to their locomotion a jerky, awkward character.

96. **Cyclops and relatives.**—*Cyclops* (Fig. 54), the representative of a number of lowly forms belonging to the order of Copepods, is one of the commonest fresh-water Crustacea. The forward segments of the spindle-shaped body are covered by a large shield or carapace, the feet are few in number, and, like its fabled namesake, it bears an eye in the center of the forehead. Nearly related species are also remarkably abundant at the surface of the sea, at times occur-

ring in such vast numbers that they impart a reddish tinge to the water over wide areas, and at night are largely responsible for its phosphorescence. Many others are parasitic in their habits, and scarcely a salt-water fish exists but that at one time or another suffers from their attacks. On the other hand, many fresh- and salt-water fishes depend upon the free-swimming forms for food, and hence, from an economic point of view, they are highly important organisms.

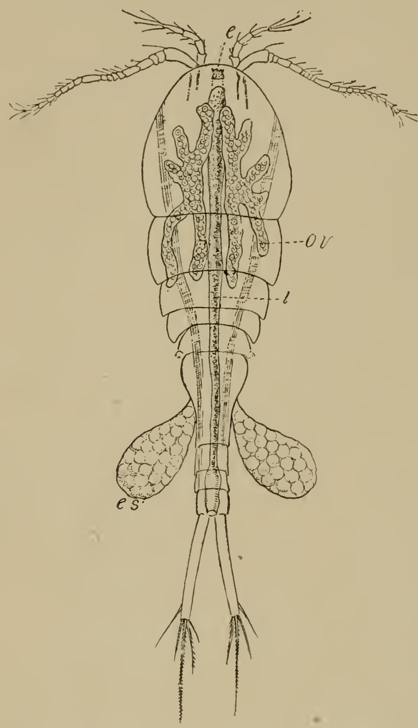

FIG. 54.—Cyclops. *e. s.*, eggs; *i*, intestine; *ov*, reproductive organ.

97. **Barnacles.** — The parasitic habit and the lack of locomotion has also produced marvelous changes among the barnacles, so great that originally they were placed among the mollusks; and as with the parasitic copepods, their true position was only known after their life-history had been determined. In the goose-barnacles * the body, attached by a fleshy stalk to foreign objects, is enclosed by a tough membrane, corresponding to the carapace of other Crustacea, in which are embedded five calcareous plates. This

* So called because of the belief, which existed for three hundred years prior to the present century, that when mature these animals give birth to geese.

is open along one side, and allows the feather-like feet to project and produce currents in the surrounding water which brings food within reach. In the acorn-barnacles (Fig. 55) the stalk is absent, and the body, though possess-

FIG. 55.—Barnacles. Acorn-barnacles chiefly in lower part of figure; goose-barnacles above. Natural size.

ing the same general character as the goose-barnacles, is shorter, and enclosed in a strong palisade consisting of six calcareous plates.

The larger number of barnacles attach themselves to the supports of wharves, the hulls of ships, floating timbers, the rocks from the shore-line down to considerable depth, and a few species occur on the skin of sharks and whales. On the other hand, there are several species which are parasitic, and in accordance with this mode of life exhibit various degrees of degeneration. In the most extreme cases (*Sacculina*) the sac-like body, attached to the abdomen of crabs, is entirely devoid of appendages and any signs of segmentation. A root-like system of delicate filaments extends from the exposed part of the animal into the host and absorbs the necessary nutriment. The mouth and alimentary canal are accordingly absent—in fact, the body contains little but the reproductive organs and a very simple nervous system.

98. **Structure.**—In the internal organization of these smaller crustaceans many differences may be noted, though they are usually less profound than the external. Ordinarily the alimentary canal is a straight tube passing through the body, and is provided with a pouch-like stomach, and a more or less clearly defined liver. In all, except the parasitic species, the external mouth-appendages masticate the food, and in a very few of the above-described groups it may be further ground between the horny ridges on the stomach-walls. After this preliminary treatment it is subjected to the action of the digestive juices, and when liquefied is absorbed into the body. Here it is circulated by a blood-system of widely different character. In many cases definite arteries and veins are absent. The blood courses through the body in the spaces between the different organs propelled by the beating of the heart, which it is made to traverse. In Cyclops (Fig. 54) even the heart is absent, and the blood is made to circulate by contractions of the intestine. In most of these smaller Crustacea considerable oxygen is absorbed through the body-wall; but in several species, for example, the fairy-shrimp (Fig. 53), special gills are developed on the appendages of the body.

99. **Multiplication.**—Among the Crustacea thus far considered the males are usually readily recognized owing to their small size. The females also are usually provided with brood-pouches in which the developing eggs are protected. In almost every case the young are born in the

form of minute larvæ, provided with three pairs of appendages, a median eye (Fig. 56), and a firm external skeleton or cuticle. This latter prevents the continuous growth of the larvæ or *nauplius*, and every few days it is thrown off, and while the new one is forming the body enlarges. During this time new appendages are developed, so that after each moult the young crustacean emerges less like its former self and more and more like its parents. In the barnacles, after several moults have taken place, the young become permanently attached by means of their first antennæ, their thoracic feet change into feathery appendages, and several other changes occur. In some of the parasitic barnacles (*Sacculina*) the larva attaches itself to a crab, throws off its various appendages, and, after other great degenerative changes, enters its host. For a time, therefore, their development is toward greater complexity, but the later stages constitute a *retrograde metamorphosis*.

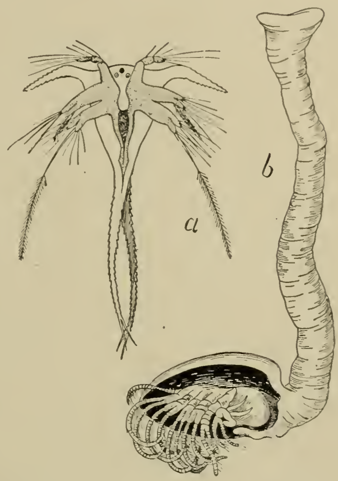

FIG. 56.—Development of a barnacle (*Lepas*). *a*, larva ; *b*, adult.

100. **More complex types.**—The larger, more useful, and usually more familiar Crustacea belong to the second division (subclass Malacostraca). It comprises such animals as the shrimps, crayfish, lobsters, crabs, and a number of other forms which are at once distinguished from the preceding by the constant number of segments composing the body. Of these, five constitute the head, eight the thorax, and seven the abdomen. The head segments are always fused together, and with them one or more thoracic segments unite to form a more or less complete cephalothorax. Also,

some of the head segments give rise to a great fold of the body-wall, the carapace, which extends backward and covers all or a part of the thorax, with which it may firmly unite, as in the crayfish. The appendages are usually highly specialized, and are made to perform a variety of functions.

101. **The shrimps.**—Among the simplest of these are the opossum-shrimps (Fig. 57) and their relatives, small trans-

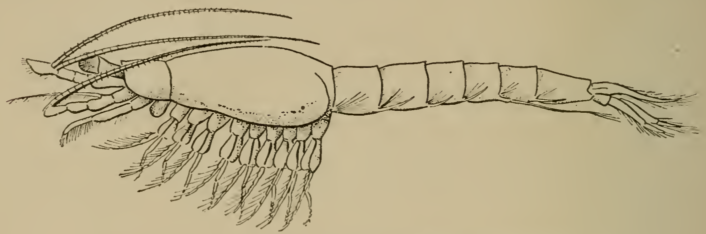

Fig. 57.—The opossum-shrimp (*Mysis americana*).

parent creatures often seen swimming in great numbers at the surface of the sea or hiding among the seaweeds along the shore. In general appearance they resemble crayfishes or prawns, but are readily distinguished by the two-branched thoracic feet. This "split-foot" character also occurs among many of the preceding Crustacea, and is generally a badge of low organization, tending to disappear in the more highly organized forms. In this and other respects the shrimps are especially interesting in their relation to the preceding Crustacea, and in the fact that they may closely resemble the ancestors of the modern prawns (Fig. 58), lobsters, crayfishes, and crabs.

102. **Crayfishes and lobsters.**—The last-mentioned species and their allies, usually large and familiar forms, constitute a group known as the decapods (meaning ten feet), referring to the number of thoracic feet. Among the members of this division probably none are more familiar than the crayfishes, which occur in most of the larger rivers and their tributaries throughout the United States and Europe. It is their habit to remain concealed in crevices of rocks

or in the mouths of the burrows which they excavate, and from which they rush upon the small fish, the larvæ of

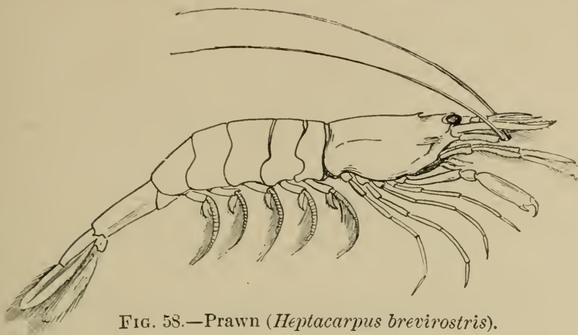

Fig. 58.—Prawn (*Heptacarpus brevirostris*).

many animals, and other equally defenseless creatures which constitute their bill of fare. In turn they are eagerly sought by certain birds and four-footed animals, and, especially in France, are extensively used for food by man.

Closely related to the crayfishes and differing but little from them structurally are the lobsters. In this country they are confined to the rocky coasts from New Jersey to Labrador, living upon fish, fresh or otherwise, various invertebrates, and occasionally seaweeds. Far more than the crayfish, the lobster is in demand as an article of food. By the aid of nets or various traps

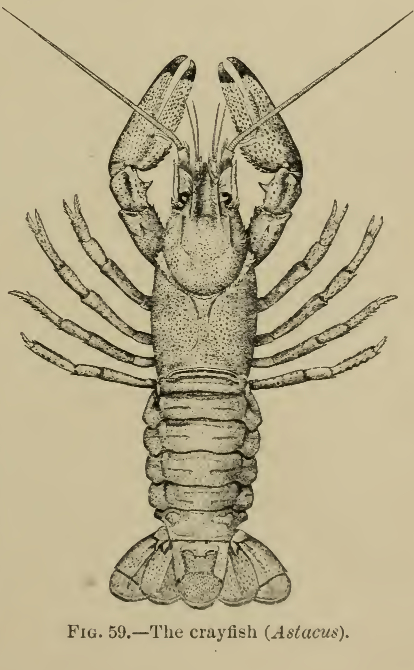

Fig. 59.—The crayfish (*Astacus*).

millions are caught each year, and to such an extent has their destruction proceeded that in many places they are well-nigh exterminated. At the present time, however, legislation, numerous hatcheries, and a careful study of their life habits is doing much to better matters and incidentally to put us in possession of many interesting zoological facts along this line, some of which will be mentioned later. Frequently the prawns, especially the larger ones, and a spiny lobster (*Palinurus*), are mistaken for crayfishes or lobsters, but they differ from them in the absence of the large grasping claws.

Along almost any coast some of these animals are to be found, often beautifully colored and harmonizing with the seaweeds among which they live, or so transparent that their internal organization may be distinctly seen. Farther out at sea other species swim in incredible numbers, feeding upon minute organisms, and in turn fed upon by numerous fishes and whales; and, especially on the Pacific coast, shrimp-fishing is an important industry.

103. **The hermit-crabs.**—The last of these long-tailed decapods is the interesting group of the hermit-crabs, which occur in various situations in the sea. In early life they take possession of the empty shell of some snail, and the protected abdomen becomes soft and flabby, while the appendages in this region almost completely disappear. The front part of the body, on the other hand, continually grows in firmness and strength, and is admirably adapted for the continual warfare which these forms wage among themselves. As growth proceeds the necessity arises for a larger shell, and the crab goes "house-hunting" among the empty shells along the shore, or it may forcibly extract the snail or other hermit from the home which strikes its fancy.

Many of the hermit-crabs enjoy immunity from the attacks of their belligerent relatives by allowing various hydroids to grow upon their homes. Others attach sea-anemones to their shells or to one of their large claws, which they poke into the face of any intruder. While the anemones or hydroids are made to do valiant service

FIG. 60.—Hermit-crab (*Pagurus bernhardus*) in snail shell covered with *Hydractinia*.

with their nettle-cells, they also enjoy the advantages of a large food-supply which is attendant upon the free ride.

104. **The crabs.**—The most highly developed Crustacea are the crabs or short-tailed decapods which abound between tide-marks alongshore, and in diminishing numbers extend to great depths. The cephalothorax is usually relatively wide, often wider than long, and the greatly reduced abdomen is folded against the under side of the thorax. Correlated with the small size of the abdomen, the appendages of that region disappear more or less, but the remaining appendages are similar to those of the crayfish or lobsters. All these different parts, however, are variously modified in each species to fit it for its own peculiar mode of life. In some forms, such as the common cancer-crab (Fig. 61), the legs are comparatively thick-set and possessed of great strength, enabling them to defend themselves against most enemies. On the other hand, there are the spider-crabs with small bodies and relatively long legs, withal weak, and

yet so harmonizing with their surroundings that they are as likely to survive as their stronger relatives. In this

FIG. 61.—Kelp-crab (*Epialtus productus*) in upper part of figure; to the right the edible crab (*Cancer productus*), and the shore-crab (*Pugettia richii*).

connection it is interesting to note that the giant crab of Japan, the largest crustacean, being upward of twenty feet from tip to tip of the legs, is a spider-crab, constructed on

FIG. 62.—The fiddler-crab (*Gelasimus*). Photograph by Miss MARY RATHBUN.

the same general pattern as our common coast forms. Between these two extremes numberless variations exist, some for known reasons, but more often not readily understood. And not only does the form vary, but the external surface may be sculptured or beset with spines or tubercles which frequently render the animal inconspicuous amid its natural surroundings. Such an effect is heightened by the presence of sponges, hydroids, and various seaweeds which the crab often permits to gather upon its body.

105. **Pill-bugs and sandhoppers.**—Finally there remain the groups of the pill- or sow-bugs (Isopods) and the sand-fleas or sandhoppers (Amphipods). In the first of these the body is usually small and compressed, the thorax more or less plainly segmented, and the seven walking (thoracic) legs are similar. In the female each leg bears at its base a thin membranous plate which extends inward and horizontally, thus forming on the under side of the body a brood-pouch (Fig. 63) in which the young develop. As one may readily discover in any of the common species, the abdominal segments are more or less fused, and bear appendages adapted for respiration and, in the aquatic forms, for swimming.

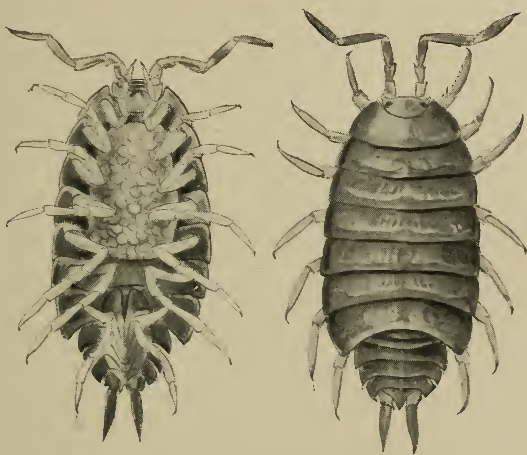

Fig. 63.—Isopod or pill-bug (*Porcellio laevis*).

The marine isopods occur in the sand, under rocks, and in the seaweeds; many are parasitic upon fishes; and the terrestrial forms (Fig. 63) are very common objects under old

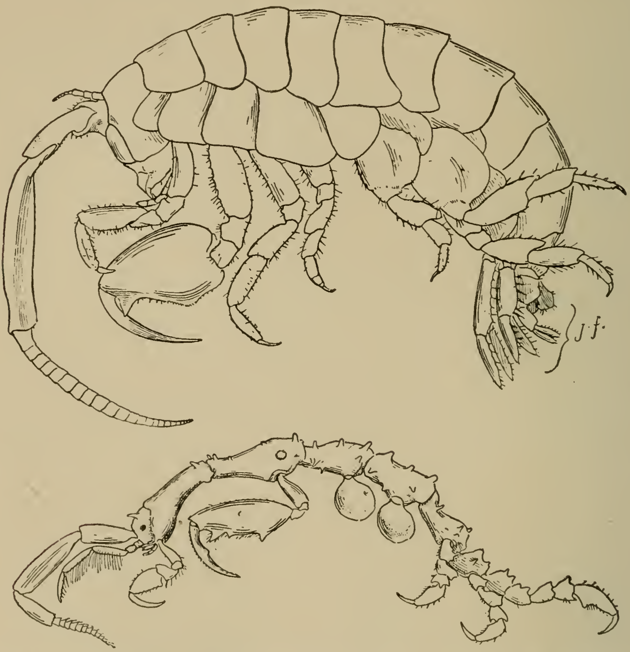

Fig. 64.—Amphipods or sand-fleas (*Gammarus*, upper species, and *Caprella*).

logs and in cellars, where they live chiefly on vegetable matter. In the sand-fleas the body is compressed from side to side, and while the thorax shows distinct segments, the legs are frequently dissimilar, and some may bear pincers. One of their most distinctive marks concerns the last three abdominal appendages, which are usually modified for leaping.

The sand-fleas (Fig. 64) are familiar objects to any one who has collected along the beach and has turned over the cast-up seaweeds, while numbers of small species often occur among the plants in our fresh-water ponds. Some most curious and highly modified forms, whose general appearance is shown in the lower part of Fig. 64, occur among hydroid colonies, with which their bodies harmonize in form and color. And, lastly, most bizarre creatures, known as "whale-lice," attach themselves to the skin of whales, of which each species acts as host for one or more kinds.

106. **Internal organization.**—Most Crustacea are carnivorous, preying upon almost any of the smaller animals within convenient reach; a much smaller number live on vegetable food; and there are many, such as the crayfishes, lobsters, and numerous crabs, which are also notorious scavengers. In these latter forms the food is held in one of the large pincers, torn into shreds by the other, and transferred to the mouth-parts, where, as in all Crustacea, it is soon reduced to a pulp by their rapid movements. In many species the food is now ready for the digestive process, but not so in the higher forms. If the stomach of any of these, for example, the crabs or crayfishes, be opened, three (Fig. 65, *s*) large teeth operated by powerful muscles will be noted, and beyond these a strainer consisting of many closely set hairs. In operation this "gastric mill" takes the food passed on from the mouth-parts, and crushes and tears it until fine enough to pass through the strainer, whereupon it is dissolved by the juices from the liver and is absorbed as it passes down the intestine.

The circulatory system is usually highly developed, and consists of a heart, in some species almost as long as the body, though usually shorter (Fig. 65), from which two or more arteries branch to all parts of the body. Here the blood, instead of emptying into definite veins, pours into a series of spaces or sinuses in among the muscles and other organs of the body, through which it makes its way back to the heart. During this return journey it is usually made to traverse definite respiratory organs, either situated upon the legs or, as feathery outgrowths, upon the sides of the body, and generally concealed under the carapace. A portion of the blood is also continually sent to the kidneys, which are located either at the base of the second antennæ (and known as green glands), as in the crayfishes or crabs, or on the second maxillæ (shell-glands) in many of the

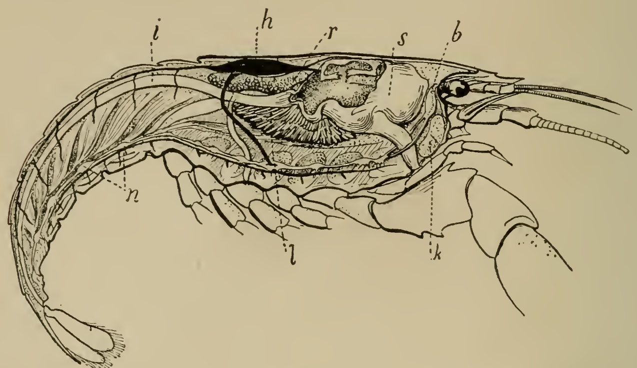

FIG. 65.—Dissection of crayfish. *b*, brain ; *h*, heart ; *i*, intestine ; *k*, kidney ; *l*, liver ; *n*, nerve-cord ; *r*, reproductive organ ; *s*, stomach, showing two teeth in position.

simpler crustaceans. Their method of operation is much like that of the kidneys in the earthworm.

107. **Nervous system and special senses.**—The nervous system also shows a decided resemblance to that of the annelids. The cerebral ganglia or brain is situated above the alimentary canal in the head, and connects with the ventrally lying cord by a collar. As in the earthworm, this ventral cord is double, and bears a pair of swellings or ganglia in each segment. In the crayfish, crabs, and other highly modified forms, where the segments tend to fuse, several of these ganglia may also unite, and except in early life their number cannot be determined.

Among the less specialized Crustacea the order of intelligence is low, though perhaps it may prove to be higher than is usually supposed when such forms have been more thoroughly studied. The following quotation relating to the lobster applies even more to the higher forms, the crabs : " Sluggish as it often appears when out of water and when partially exhausted, it is quite a different animal when free to move at will in its natural environment on the sea-bottom. It is very cautious and cunning, capturing its prey by stealth, and with weapons which it knows how to conceal. Lying hidden in a bunch of seaweed, in a crevice among the rocks, or in its burrow in the mud, it waits until its victim is within reach of its claws, before striking the fatal blow. The senses of sight and hearing are probably far from acute, but it possesses a keen sense of touch and of smell, and probably also a sense of taste."

Although enclosed in a horny and often very thick and strong armor, the sense of touch is very keen in the Crustacea and in arthropods generally. On many of the more exposed portions delicate hairs or pits connected with the nervous system occur in great abundance. Some of these, usually on the antennæ, undoubtedly serve in detecting odors, but the remainder are considered to be tactile. In the higher Crustacea, such as the crayfish, lobsters, and crabs, ears are usually found, consisting of sacs lined with similar delicate hairs, and containing several minute grains of sand, which in many cases make their way through the small external opening. Vibrations coming through the water gently shake the grains of sand, causing them to strike against the hairs which communicate with the nervous system—a very simple ear, yet sufficient for the needs of the animals.

The eyes of the Crustacea and arthropods in general are either simple or compound. The simple and frequently single eyes usually consist of a relatively few cells embedded in a quantity of pigment and connected with the nervous system. It is doubtful whether they perceive objects as anything more than highly blurred images, and perhaps they merely recognize the difference between light and darkness. The compound eyes, on the other hand, are remarkably complex structures, often borne on the tops of movable stalks, as in the common crabs and crayfishes. Each consists of an external transparent cornea, divided into numerous minute hexagonal areas corresponding to as many internal rods of cells, provided with an abundant nerve-supply. These latter elements may perhaps represent simple eyes grouped together to form the compound one; and it appears possible that each element may form a complete image of an object, as each of our eyes is known to do. On the other hand, many hold that the complete eye forms only one image, a mosaic, each element contributing its share.

108. **Growth and development.**—As we have seen, the simpler Crustacea hatch as minute larvæ (Fig. 56), and during their growth to the adult condition are especially subject to the attacks of multitudes of hungry enemies. In the higher forms, such as the crabs, some of these early transformations take place while the young are still within the egg and attached to the parent. Accordingly, the little ones are fairly similar to their parents, and their later history is very well exemplified by the lobster.

The eggs of the lobster are most frequently hatched in the summer months, usually July, after they have been carried by the parent for upward of a year. The young, about a third of an inch in length, at once disperse, undergo four or five moults during the next month, then, ceasing their swimming habits, settle to the bottom among the rocks. At this time, twice their original size, they closely resemble their parents, and their further development is largely an increase in size. "The growth of the lobster, and of every arthropod, apparently takes place, from infancy to old age, by a series of stages characterized by the growth of a new shell under the old, by the shedding of the outgrown old shell, a sudden increase in size, and the gradual hardening of the shell newly formed. Not only is the external skeleton cast off in the moult and the linings of the masticatory stomach, the esophagus, and intestine, but also the internal skeleton, which consists for the most part of a complicated linkwork of hard tendons to which muscles are attached."

109. **Peripatus (class Onychophora).**—It is generally believed that the Crustacea, insects, and spiders, together with their numerous relatives, trace their ancestry back to animals that bore a certain resemblance to the segmented worms. Most of these ancient types have long been extinct, but here and there throughout the earth we occasionally meet with them.

Among the most interesting of these are a few widely distributed species belonging to the genus *Peripatus* (Fig. 66), but as they are comparatively rare we shall dismiss them with a very brief description. They usually dwell in warm countries, under rocks and decaying wood, emerging at night to feed on insects, which they ensnare in the slime thrown out from the under surface of the head. Their external form, their excretory system, and various other organs are worm-like. On the other hand, the appendages are jointed, and one pair has been modified into jaws. The peculiar breathing organs characteristic of the insects are also present. *Peripatus* therefore gives us an interesting link between the worms and insects, and also affords an idea of the primitive insects from which the modern forms have descended.

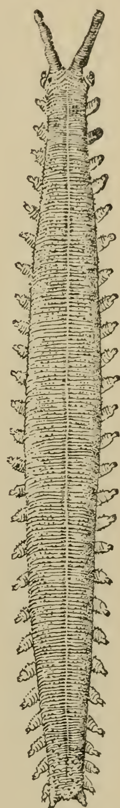

Fig. 66.—Peripatus (*Peripatus eiseni*). Twice the natural size.

110. **The centipeds and millipeds (class Myriapoda).**—Many of the myriapods—that is, the centipeds and thousand-legged worms—are familiar objects under logs and stones throughout the United States. The first of these (Fig. 67) are active, savage creatures, devouring numbers of small animals, which they sting by means of poison-spines on the tips of the first pair of legs. The bite of the larger tropical

species especially causes painful but not fatal wounds in man.

On the other hand, the millipeds (Fig. 68) or thousand-legs are cylindrical, slow-going animals, feeding on vegetable

Fig. 67.—Centiped. One-half natural size.

Fig. 68.—Thousand-legs or milliped (*Julus*). Natural size.

substances without causing any particular damage, except in the case of the "cutworms," which often work great injury to crops. When disturbed they make little effort to escape, but roll into a coil and emit an offensive-smelling fluid, which renders them unpalatable to their enemies.

All present a great resemblance to the segmented worms, as their popular names often testify; but, on the other hand, many points in their organization indicate a closer relationship to the insects. As in the latter, the head is distinct, and bears a pair of antennæ, the eyes, and two or three pairs of mouth-parts. The trunk is more worm-like, and consists of a number of similar segments, each bearing one or two pairs of jointed legs. In their internal organization the character of the various systems closely resembles that of the insects, and will be more conveniently described in that connection.

Among the myriapods the females are usually larger than the males. Some of the centipeds deposit a little mass of eggs in cavities in the earth and then abandon them, while others wrap their bodies about them and protect them until the young are hatched. The millipeds lay in the same situations, but usually plaster each egg over with a protective layer of mud. After several weeks the young appear, often like their parents in miniature, but in other species quite unlike, and requiring several molts to complete the resemblance.

CHAPTER X

ARTHROPODS (*Continued*). CLASS INSECTS

111. **Their numbers.**—It has been estimated that upward of three hundred thousand named species of insects are known to the zoologist, and that these represent a fifth, or possibly a tenth, of those living throughout the world. Many of these species, as the may-flies and locusts, are represented by millions of individuals, which sometimes travel in such great swarms that they darken the sky. With nearly all of these the struggle for existence is fierce and unrelenting, and it is little wonder that such plastic animals have changed in past times and are now becoming modified in order to adapt themselves to new situations where food is more abundant and the conditions less severe. Owing to such modifications we find some species fitted for flying, others for running and leaping, or for a life underground, and many for a part or all of their lives are aquatic in their habits.

112. **External features.**—The body of an insect—the grasshopper, for example—consists of a number of rings arranged end to end, as we have seen them in the Crustacea and the segmented worms. In the abdomen these are clearly distinct, but in the thorax, and especially the head, they have become so intimately united that their number is a matter of uncertainty. These three regions—head, thorax, and abdomen—are usually clearly defined in most insects, but they are modified in innumerable ways in accordance with the animal's mode of life.

The head usually carries the eyes, a pair of feelers (antennæ), and three pairs of mouth-parts which may be fashioned into a long, slender tube to be used in sucking, and frequently as a piercing organ ; or they may be constructed for cutting and biting. The thorax bears three pairs of legs and often one or two pairs of wings. The appendages of the abdomen are usually small and few in number, or even absent.

113. **Internal anatomy.**—The restless activity of insects is proverbial. Some appear to be incessantly moving about, either on the wing or afoot, and are endowed with comparatively great strength. Ants and beetles lift many times their own weight. Numerous insects are able to leap many times their own length, and others perform different kinds of work with a vigor and rapidity unsurpassed by any other class of animals. As is to be expected, the muscular system is well developed, and exhibits a surprising degree of complexity. Over five hundred muscles are required for the various movements of our own bodies, but in some of the insects more than seven times this number exist. The amount of food necessary to supply this relatively immense system with the required nourishment is correspondingly large. Many insects, especially in an immature or larval condition, devour several times their own weight each day. Their food may consist of the juices of animals or plants, which they suck out, or of the firmer tissues, which are bitten or gnawed off.

Not only do the mouth-parts stand in direct relation to the habits of the animal and to its food, but, as we have often noticed before, the internal organization is also adapted for the digestion and distribution of the nutritive substances in the most economical way. For this reason we find the alimentary canal differing widely in the various forms of insects. In each case it extends from the mouth to the opposite end of the animal, and ordinarily consists of a number of different parts. In the insect shown in

Fig. 69 the mouth soon leads into the esophagus, which in turn leads into the crop that serves to store up the food until ready for its entry into the stomach; or in some of the ants, bees, and wasps it may contain material which may be disgorged and fed to the young. In many cases the stomach is small and ill-defined as in Fig. 69, and again it may reach enormous dimensions, nearly filling the body. It may also bear numerous lobes or delicate hair-like processes, which afford a greater surface for the absorption of food. Behind the stomach are a number of slender outgrowths that are believed to act as kidneys. Beyond their insertion lies the intestine, which, like the stomach, is the subject of many modifications in the different kinds of insects.

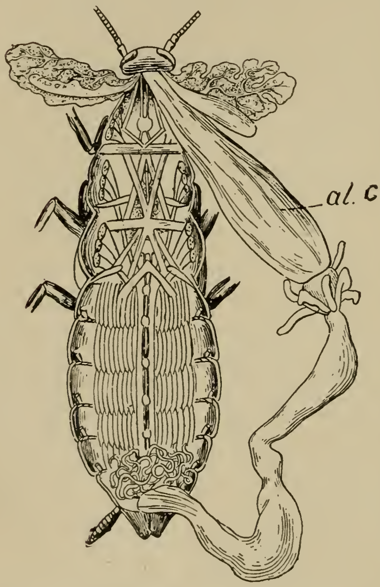

FIG. 69.—Cockroach, dissected to show alimentary canal, *al. c.*—After HATSELEK and CORI.

The digested food is rapidly absorbed through the coats of the stomach and intestine and enters a circulatory system which reminds us of what exists in many of the Crustacea. The heart is situated above the digestive tract, and from it arteries pass out to different parts of the body. Here the blood leaves the vessels and is poured directly into the spaces among the viscera, whence it is finally conducted through irregular channels to the heart by its pulsations.

In the Crustacea the blood is made to pass through a respiratory system usually in the form of definite gills, and the oxygen with which it is charged is distributed to all parts of the body. In the insects the blood serves almost entirely to carry the food, and the oxygen is conveyed through the animal by a remarkable contrivance found only in the insects, the spiders, and a few related forms.

114. **Respiratory system.**—If we examine an insect, the grasshopper for example, we find a number of small brown spots on each side of the abdomen, each of which under a magnifying-glass is seen to be perforated by a narrow slit. Carefully opening the body, we find that each slit is in communication with a white, glistening tube that rapidly branches and penetrates to all parts of the animal. When the body is expanded the air rushes into the outer openings, on through the open tubes, and is distributed with great rapidity to all the tissues of the body. In many insects some of these tubes connect with air-sacs which probably serve to buoy up the insect during its flights through the air.

115. **Wingless insects (Thysanura).**—The simplest of all insects are the fishmoths and springtails, relatively small organisms covered with shining scales or hairs. The first of these is occasionally seen running about in houses feeding upon cloth and other substances, while the latter live in damp places under stones and logs. They are without wings, but are able to run rapidly and to leap considerable distances. In addition to the ordinary appendages, the abdomen bears what are perhaps rudimentary legs, a fact which, together with their relatively simple structure, strengthens the belief that the insects have descended from centiped-like ancestors.

116. **Grasshoppers, crickets, katydids, etc. (Orthoptera).**—Rising higher in the scale of insect life, we arrive at the group of the cockroaches, crickets, grasshoppers, locusts, and other related insects. Four wings are present, the first pair thickened and overlapping the second thinner pair. The latter are folded lengthwise like a fan, which is said to have given the name *Orthoptera* (meaning straight-winged) to

this group of insects. These extend all over the world, being particularly abundant in the warmer countries, and their strong biting mouth-parts and voracious appetites render many of them dreaded pests to the farmer. The cockroaches are nocturnal in their habits, racing about at night, devouring victuals in the pantry and gnawing the bindings of books. During the day their flat bodies enable them to secrete themselves in crevices wherever there is sufficient moisture.

In the grasshoppers, locusts, katydids, and crickets the body is more cylindrical, and the hind pair of legs are often greatly lengthened for leaping. The crickets and katydids are nocturnal, the former remaining by day in burrows which they construct in the earth, the latter resting quietly in the trees. At night they feast upon vegetable matter principally, though some species are known to prey on small animals. Those insects we usually term grasshoppers (properly called locusts) are specially destructive to vegetation. Some species are strong fliers, and this, connected with their ability to multiply rapidly, renders them greatly dreaded pests. They have been described as flying in great swarms, forming black clouds, even hiding the sun as far as the eye could reach. The noise made by their wings resembled the roar of a torrent, and when they settled upon the earth every vestige of leaf and delicate twig soon disappeared.

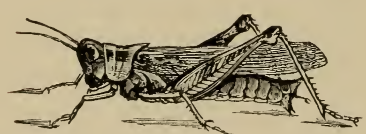

FIG. 70.—The Rocky Mountain locust.—After RILEY, from *The Insect World*.

The eggs of the majority of Orthoptera are laid in the ground, where they frequently remain through the winter. When hatched the young quite closely resemble the parents, and, after a relatively slight metamorphosis, assume the adult form.

117. **Dragon-flies, may-flies, white ants, etc. (Neuroptera).**—The dragon-, caddis-, may-flies, ant lions, and the white ants

possess four thin and membranous wings incapable of being folded. These possess a network of delicate nervures, giving the name Neuroptera (meaning nerve-winged) to the class. Of the forms mentioned above, all but the white ants lay their eggs in the water, and the developing larvæ

FIG. 71.—Dragon-fly (*Libellula pulchella*).

spend their lives in this medium until the time comes for their complete metamorphosis into the adult. The larvæ of the caddis-flies protect themselves within a tube of stones or sticks bound together with silken threads, which they usually attach to the under side of stones in running water. On the other hand, the young of the dragon- and may-flies, provided with strong jaws, are active in the search of food and very voracious. In time they emerge from their larval skin and the water in which they live, and after a life spent on the wing they deposit their eggs and perish. The adult ant-lion, which has somewhat the appearance of a small dragon-fly, lays its eggs in light sandy soil. In this the resulting larvæ excavate funnel-shaped pits, at the bottom of which they lie concealed. Insects stumbling into their pitfalls are pelted with sand, which the ant-lion throws at them with a jerky motion of the head, and are speedily tumbled down the shifting sides of the funnel to be seized and devoured.

While the white ants are not in any way related to the true ants, they possess many similar habits. Associated in great companies, they excavate winding galleries in old logs and stumps, and, further, are most interesting because of the division of labor among the various members. The wingless forms are divided into the workers, which excavate, care for the young, and otherwise labor for the good of the others; and into the soldiers, huge-headed forms,

Fig. 72.—Ant-lion larva plowing its way through the sand (upper figure) while another is commencing the excavation of a funnel-shaped pit similar to one on right. Photograph by A. L. Melander and C. T. Brues.

whose strong jaws serve to protect the colony. The remaining winged forms are the kings and queens. In the spring many of the royalty fly away from home, shed their wings, unite in pairs, and set about to organize a colony. The queen rapidly commences to develop eggs, and in some species her body becomes so enormously distended with these that she loses the power of locomotion and requires to be fed. A single queen has been known to lay eggs at the rate of sixty per minute (eighty thousand a day), and

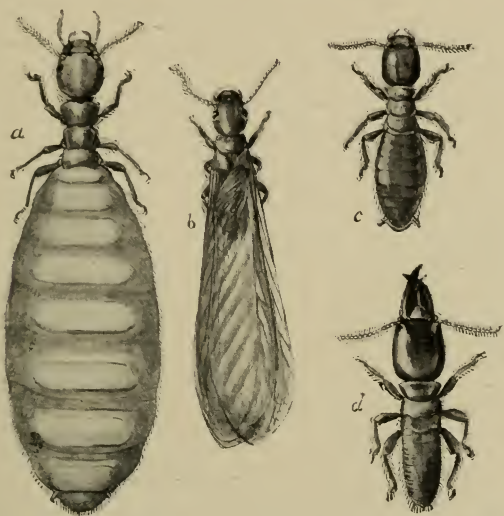

FIG. 73.—Termites or white ants. *a*, queen ; *b*, winged male ; *c*, worker ; *d*, soldier.

those destined to royal rank are so nursed that they advance farther in their development than the remaining sterile and wingless forms.

118. **The bugs (Hemiptera).**—The large and varied group of the bugs (*Hemiptera*) includes a number of semi-aquatic species, such as the water-boatmen, often seen rowing themselves along in the ponds by means of a pair of oar-shaped legs, in search of other insects. Somewhat similar at first sight are the back-swimmers, with like rowing habits, but unique in swimming back downward. Both of these bugs frequently float at the surface, and when about to undertake a subaquatic journey they may be seen to imprison a bubble of air to take along. Closely related are the giant water-bugs (Fig. 74), which often fly from pond to pond at night. In such flights they are frequently

attracted by lights, and have come to be called "electric-light bugs."

Among our most dreaded insect pests are the chinch-bugs—small black-and-white insects, but traveling in companies aggregating many millions. As they go they feed upon the stems and leaves of grain, which they devour with extraordinary rapidity. The squash-bug family is also extensive, and destructive to the young squash and pumpkin plants in the early spring.

Fig. 74.—Giant water-bug (*Serphus dilatatus*), with eggs attached.

The lice are small, curiously shaped bugs, which suck the blood of other animals. The plant-lice, also small, suck the juices of plants, and are often exceedingly destructive. This is especially true of the phylloxera, a plant-louse which causes annually the loss of millions of dollars among the vineyards of this and other countries. Even more destructive are the scale-insects, curiously modified forms, of which the wingless females may be found on almost any fruit-tree and on the plants in conservatories, their bodies covered with a downy, waxy, or other kind of covering, beneath which they remain and lay their eggs.

119. **The flies (Diptera).**—The group of the Diptera (meaning two-winged) includes the gnats, mosquitoes, fleas, house-flies, horse-flies (Fig. 75), and a vast company of related forms. Only a single pair of wings is present, the second pair being rudimentary or fashioned into short, thread-like appendages known as balancers, though they probably act as sensory organs and are not directly concerned with flight. The mouth-parts are adapted for piercing and sucking. The eyes, constructed on the same plan

as those of the Crustacea, are comparatively large, and are frequently composed of a great number of simple eyes united together, upward of four thousand forming the eye of the common house-fly.

Fig. 75.—Horse-fly (*Therioplectes*).

These insects are widely distributed throughout the world, where they inhabit woods, fields, or houses as best suits their needs. Their food is varied. Some suck the juices of plants, others attack animals, and, while many are troublesome pests, others, especially in the early stages of their existence, are of great benefit.

120. **Familiar examples.**—Owing to the widely different habits and structure of the members of this group, we shall briefly consider two examples, the mosquito and the house-fly, which will give us a fairly good idea of the characteristics of all. The eggs of the mosquito are laid in sooty-looking masses on the surface of stagnant pools. Within a very short time the young hatch, and, owing to their peculiar swimming movements, are known as "wrigglers." They are then active scavengers, devouring vast quantities of noxious substances and performing a valued service. They frequently rise to the surface, take air into the tracheal system, which opens at the posterior end of the body, and descend again. After an increase in growth and many internal changes resulting in a chrysalis-like stage, they rise to the surface, split the shell, and, using the latter as a float, carefully balance themselves and soon fly away.

The house-fly usually lays its eggs in decaying vegetable matter, and the young, maggot-like in form, are active scavengers. They too undergo deep-seated changes during the next few days, finally transforming into the adult.

Many of this great group of the flies spend their early life in the water or other medium acting as scavengers; but, on the other hand, numbers attack domestic and other animals, and throughout their entire lives are an intolerable plague.

121. **The beetles (Coleoptera).**—Owing to the ease of preservation and their bright colors, the beetles have probably been more widely collected than other insects. Fully ten

FIG. 76.—Long-horned borer (*Ergates*). Larva (left-hand figure), pupa, and adult insect.

thousand distinct species are known in North America alone. They are all readily recognized by the two firm, horny sheaths enclosing the two membranous wings, which alone are organs of flight. The mouth is provided with jaws, which are used in gnawing. Some prey on noxious insects or upon decaying vegetable or animal matter, and are often highly beneficial; but others attack our trees and domestic animals, and work incalculable damage.

In some of the stag- or wood-beetles (Fig. 76), which we may select as types, the adults are often found crawling about on or beneath the bark of trees, living on sap or small animals. The eggs laid in these situations develop into grub-like larvæ, which bore their way through living or dead wood, and in this condition sometimes live four or five years. They then transform into quiescent pupæ (Fig. 76), which finally burst their shells and emerge in the adult form. Others, like water-beetles and the whirligig-beetles, whose mazy motions are often seen on the surface of quiet streams, pass the larval period in the water. Under somewhat different conditions we find the potato-bugs, lady-bugs, fire-flies, and their innumerable relatives, but the changes they undergo in becoming adult are essentially the same as those described for the other members of the order.

122. **The moths and butterflies (Lepidoptera).**—The moths and butterflies occur all over the world. In their mature

FIG. 77.—Monarch-butterfly (*Anosia plexippus*). From photograph by A. L. MELANDER and C. T. BRUES.

state they are possessed of a grace of form and movement and a brilliancy of coloration that elicit our highest admiration. The mouth-parts are developed into a long proboscis, which may be unrolled and used to suck the nectar out of flowers, though in many of the adult moths, which never feed, it may remain unused. The wings, four in number, are covered with beautiful overlapping scales that adhere to our fingers when handled. This feature, and the general plan of the body, which is much the same

FIG. 78.—The silver-spot (*Argynnis cybele*). Photograph by A. L. MELANDER and C. T. BRUES.

throughout the group, enables us to recognize most of them at once.

123. **Development and metamorphosis.**—In some of the simplest insects, as in the bugs, the young at birth resemble their parents. In other insects the resemblance is not so close. The young grasshopper, for example, hatches, from an egg laid in the ground, with a ridiculously large head and staring eyes; still there is no difficulty in recognizing its relationships. During the next week internal changes take place. The shell is burst, and the grasshopper emerges, looking more like its parents than before. This process is repeated four or five times during the next few weeks, and the gradual changes thus produced finally bring the young insect to the adult form. This latter state has been attained by an *incomplete metamorphosis.*

In the flies, beetles, butterflies, and numerous insects the differences between the newly hatched young and the adult are vastly greater. No one looking on a caterpillar or a grub for the first time would suspect its origin, and the changes they undergo have attracted attention for centuries. Placing any of the ordinary caterpillars with their favorite food in a glass-covered box, we may readily watch their transformations. Provided with biting mouth-parts and a voracious appetite, they devour vast quantities of vegetation for several days. Finally they cease eating, and

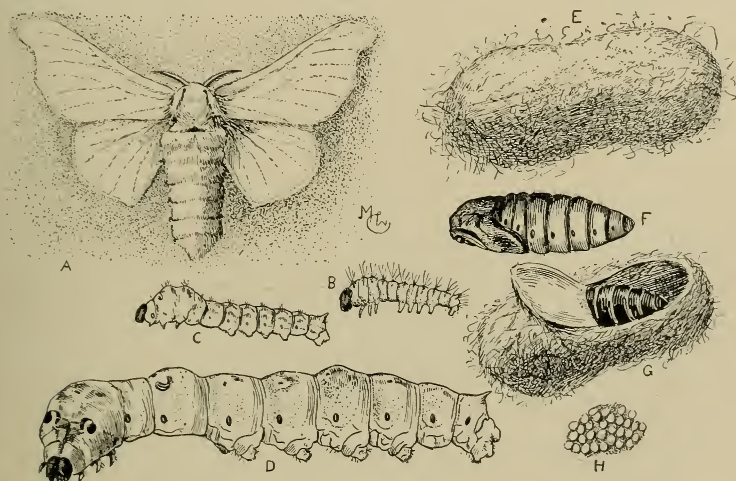

Fig. 79.—Life-history of silk-moth (*Bombyx mori*). A, adult; B, C, D, caterpillars of different ages; E, F, G, silken cocoon and pupa; H, eggs.

suspend themselves head downward by means of a kind of cobweb. After remaining quiet a few hours, they burst their skin, and within appears a chrysalis or pupa. In the moths, for example, the silk-moth (Fig. 79), the caterpillar or silk-worm, after eating the favorite mulberry leaves, spins a silken cocoon, in which the pupa is produced. The larvæ of beetles and many other insects excavate tunnels in wood or in the earth, and there undergo their transformations. Invariably the pupa remains quiet for days, months, or even years, but when the proper time arrives the fully formed insect emerges, and takes to the wing.

Wonderful internal changes have been taking place during this time. The organs fitted for the proper treatment of the vegetable food of the caterpillar or grub are destroyed, at least in part, and new systems are produced ready for the nectar and vegetable juices which are to be the food of the adult insect. All insects that pass through a pupal quiescent stage are said to undergo a *complete metamorphosis.*

124. **The ants, bees, wasps, etc. (Hymenoptera).**—The ants, bees, and wasps are the best-known insects belonging to this order. They are characterized by four membranous wings, by biting and sucking mouth-parts, and the female is often provided with a sting. All undergo a complete metamorphosis. The eggs may be laid in the bodies of other insects, many of which are pests, and are thus destroyed; or they may be deposited in the nests of other insects, the foster-parents being compelled to feed them; or they may be placed in marvelously constructed homes, and be the objects of the greatest attention, the parents or attendants often risking or losing their lives in their defense. The members of this order have long attracted attention, largely on account of their remarkable instinctive powers. They live in highly organized communities and certain of their characteristics may be illustrated by a study of some of the more familiar forms.

125. **The ants.**—The ants live in communities consisting of anywhere from a dozen to many thousands of individuals, according to the species. Each of these colonies contains the queen, several young winged males and females, destined as kings and queens to found new colonies, and of a far greater number of wingless sterile females, the workers. The workers construct the greater part of the nest, which often consists of extensive galleries, nurseries, and granaries, excavated in wood or in the earth. They also attend

to the acquisition of food, which consists of the sweet juices of plants, of other insects, or of leaves and seeds. These may be fed at once, or placed in storehouses until times of need.

Certain species of ants make carefully planned attacks upon other weaker forms. The young are carried off, at times only after a prolonged and fierce struggle, and all are soon eaten, or a few may be allowed to develop and act as slaves. Some species are unable to exist without servants, which feed them, wash them, and otherwise minister to their comfort.

In some of their raids numerous plant-lice (delicate, usually green, insects, such as occur on our household plants) are often captured and carried into the nest. These so-called "ant-cows" are carefully tended, and in return yield up a tiny drop of a sugary fluid to the hungry ant that solicits it.

The eggs laid by the queen develop into white worm-like creatures, which ordinarily spin cocoons when about to become pupæ. These are incorrectly called "ant-eggs." Many, probably on account of insufficient nourishment, never develop reproductive organs. They become the neuters or workers. The winged royalty fly away from the colony, pair and found homes of their own, and become surrounded by a numerous progeny.

126. **The bees.**—Among the bees we find a considerable number which lead solitary lives, excavating tunnels in earth or wood, as in the case of many of the wasps, but, unlike them, supplying the young with honey or pollen. Others may constitute a band of worthless insects which steal their food from their more industrious relations, in whose nests they also secretly deposit their eggs, leaving the young to be nourished with food rightly belonging to others.

But it is with the social bees we are most familiar—the bumble- and honey-bees. The former usually build in the ground, and form colonies consisting of the queen and from twenty to two hundred workers. Regular combs are not constructed, the young at first feeding on pollen masses or "bee-bread," and finally spinning cocoons. In the late summer males and females appear, but as winter comes on all perish except the queens, which seek a sheltered place, and in the spring revive to establish new colonies.

In a wild state the honey-bees dwell in cavities of trees and other protected places, where they form colonies, consisting of the queen, of perhaps two hundred males or drones if the nest be examined in the spring and summer, and of a hundred times as many sterile females, the workers. These form among the most highly organized insect societies known. All work for the good of the colony. To each worker is assigned a definite task, which is never shirked. It must collect the honey, supply the wax for making the comb, take care of the brood, or in other ways minister to the welfare of the community. On the queen devolves the entire task of egg-laying. She may lay three thousand eggs a day and be fully occupied during the three or four years that she lives. The drones, or males, fertilize most of the eggs, and are then driven out from the hive, after a stay of a month or two. The eggs unfertilized by the drones are placed in large cells, and the young fed on pollen develop into males. The fertilized eggs may produce queens or workers at the discretion of the queen. If the latter be desired, the eggs are placed in small cells with a scant amount of food, which apparently causes the reproductive system to remain undeveloped. The same eggs, if placed in the large queen cells and supplied with highly nutritious food, would have developed into queens. When these latter appear they are vigorously attacked and killed

Fig. 80.—Bumblebee (*Bombus*).

by the parent if not protected by the workers. If the young queen survive, the old queen departs with many of her subjects, and collects them into a dense swarm attached to a limb of a tree, where they remain until scouts return to conduct them to their new home.

127. **The wasps.**—The digger-wasps are frequently to be seen gnawing tunnels in the wood or earth, at the inner end

FIG. 81.—Nest of *Vespa*, a social wasp. Photograph by A. L. MELANDER and C. T. BRUES.

of which an egg is laid. In some species the developing young is nourished by food carried in to it day by day. In other cases the parent may never see her child, dying or abandoning it before its birth; but before departing she is careful to place within reach a sufficient supply of spiders, caterpillars, beetles, or locusts that shall nourish the little one until it becomes a motionless pupa. This stage is soon over, and the adult wasp now digs its way to the surface.

Passing by the familiar mud-wasps or mud-daubers, whose nests are common objects under stones or against the rafters of barns and houses, we arrive at the social wasps. As the name indicates, these insects, such as the yellow-jackets and hornets, live together in companies which consist, as in the ants and bees, of males, females, and workers. They also are fond of the juices of fruits, and many of them destroy insects which may be fed to the young. Their nests are variously situated and constructed, but all of them agree in being composed, at least in part, of a grayish substance which is in reality a kind of paper. With their jaws they scrape off from old logs and fences small particles of wood, which they probably mix with saliva, and rolling the mass into a ball set out for home. These pellets are then flattened out into thin sheets, and worked up into hexagonal cells, in which the eggs are laid.

Along with the nests of the mud-daubers one frequently notices the nests of some of the familiar wasps (*Polistes*), which build cake-like nests composed of thirty or forty hexagonal cells attached by a stalk. Somewhat similar nests, though usually more extensive, are constructed by the yellow-jackets in cavities in the ground. The numerous combs of the hornet are surrounded by several sheets of wood-pulp, and the whole structure is attached generally to the limb of a tree.

In the spring the nests of all these species of wasps are commenced by a single female, who has lived in a dormant condition through the winter. She builds a small nest and in time is surrounded by numerous workers, which live in perfect harmony, enlarging the nest and rearing the young. As autumn approaches the young males and females leave the nest; but the males, together with the workers, all succumb to the cold, and none but the females persist to found a new colony the following spring.

CHAPTER XI

ARTHROPODS (*Continued*). CLASS ARACHNIDA

128. **General characters.**—In this group, comprising the spiders, mites, and a large assemblage of related species, we again meet with great differences in form and structure which fit them for lives under widely different conditions. The three regions of the body, head, thorax, and abdomen, so clearly marked in the insects, are here less plainly defined. The head and thorax are usually closely united, and in the mites the boundaries of the abdomen are also indistinct. The appendages of the head are two in number, and probably correspond to the antennæ and mandibles of other Arthropods. In the scorpions and some species of mites these are furnished with pincers for holding the prey, and in other forms they act as piercing organs. Usually the thorax bears four pairs of legs, a characteristic which readily separates such animals from the insects.

The internal organization differs almost as much as does the external. In many species it shows a considerable resemblance to that of some insects, but in others, especially those of parasitic habits, it departs widely from such a type. Respiration is affected by means of tracheæ, or lung-books, which consist of sacs containing many blood-filled, leaf-like plates placed together like the leaves of a book.

Usually, as in the insects, the young hatch from eggs which are laid, but in the scorpions and some of the mites the young develop within the body and at birth resemble the parent. Almost all of these organisms live either as parasites or as active predaceous animals upon other animals. For this purpose many are provided with keen senses for detecting their prey and poisonous spines for despatching it.

129. **The scorpions.**—Owing to the stout investing armor, the strong pincers, and the general form of the body, the scorpions might at first sight be mistaken for near relatives of the crayfish or lobster. A more careful examination will show that the two pairs of pincers probably correspond to the antennæ and mandibles of the Crustacea that have become modified for seizing the food. The swollen part of the animal lying behind the four pairs of legs is a part of the abdomen, of which the slender "tail" constitutes the remainder. On the tip of the tail is a curved spine supplied with poison glands. Several pairs of eyes are borne on the dorsal surface of the head and thorax, while on the under side of the animal several slit-like openings lead into as many small cavities containing the lung-books.

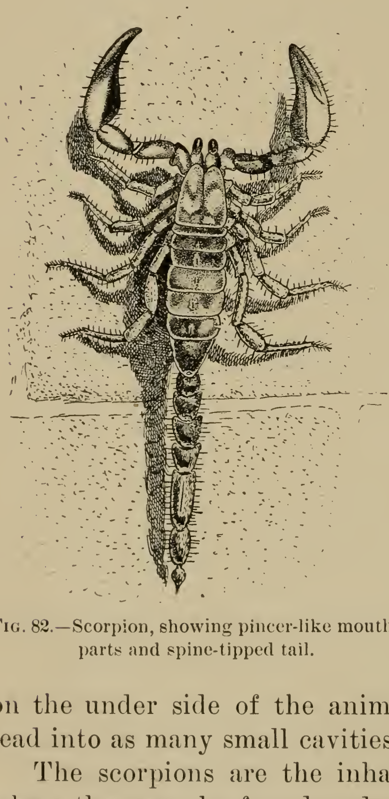

FIG. 82.—Scorpion, showing pincer-like mouth-parts and spine-tipped tail.

The scorpions are the inhabitants of warm countries, where they may be found under sticks and stones throughout the day. At night they leave their homes in search of food, which consists chiefly of insects and spiders. These are seized by means of the pincers, and the sting is driven into them with speedily fatal results. It is doubtful if the poison causes death in man, but the sting of some of the larger species, which measure five or six inches in length, may produce certain disorders chiefly affecting the circulation. In this country there are upward of thirty species, most of which are comparatively small.

130. **The harvestmen.**—The harvestmen or daddy-long-legs are small-bodied, long-legged creatures which resemble in general appearance several of the spiders. They differ from them, however, in the possession of claws corresponding to the smaller ones of the scorpion, and in their method of respiration, which is similar to that of insects. During the day they conceal themselves in dark crevices or stride slowly about in shaded places; but at night they emerge into more open districts and capture small insects, from which they suck the juices.

131. **The spiders.**—The spiders are world-wide in their distribution, and are a highly interesting group, owing chiefly to their peculiar habits. Examining any of our familiar species, it will be seen that the united head and thorax are separated by a narrow stalk from the usually distended abdomen. To the under side of the former are attached four pairs of long legs, a pair of feelers, and the powerful jaws supplied with poison-sacs, while eight shining eyes are borne on the top of the head. On the abdomen, behind the last pair of legs, are small openings into the lung cavities which contain a number of vascular, leaf-like projections known as lung-books. In some species a well-marked system of tracheæ are also present. At the hinder end of the body are four or six little projections, the spinnerets, each of which is perforated with many holes. Through these the secretion from the glands beneath is squeezed out in the form of excessively delicate threads, often several hundred in number, which harden on exposure to the air. According to the use for which these are intended, they may remain a tangled mass or become united into one firm thread; and according to the habits of the animal, they may be used for enclosing their eggs,

for lining their burrows, or for the construction of webs of the most diverse patterns.

132. **The habits of spiders.**—Many species of spiders, some of which are familiar objects in fields and houses, construct sheets of cobweb with a tube at one side in which they may

FIG. 83.—A tarantula-spider (*Eurypelma lentzii*). Natural size. Photograph by A. L. MELANDER and C. T. BRUES.

lie in wait for their prey or through which they may escape in times of danger. In the webs of the common orb- or wheel-weavers several radial lines are first constructed, and upon these the female spider spins a spiral web. Resting in the center of this or at the margin, with her foot on some of the radial threads, she is able to detect the slightest tremor and at once to rush upon the entangled captive.

Some of the bird-spiders and their allies, living in tropical America, and attaining a length of two inches, construct web-lined burrows in the ground. From these they stalk their prey, which consists of various insects and even small birds. These are almost instantly killed by the poison-fangs, and are then carried to the burrow, where the juices of the body are extracted.

The trap-door spiders of the southwestern section of the United States also dig tunnels, which they cover with a closely fitting lid composed of earth. Raising this they come out in search of insects, but if sought in turn, they dash into the burrow, closing the door after them, and holding it with such firmness that it is rarely forced open. If this should happen, there are sometimes blind passage-ways, also closed with trap-doors, which usually baffle the pursuer.

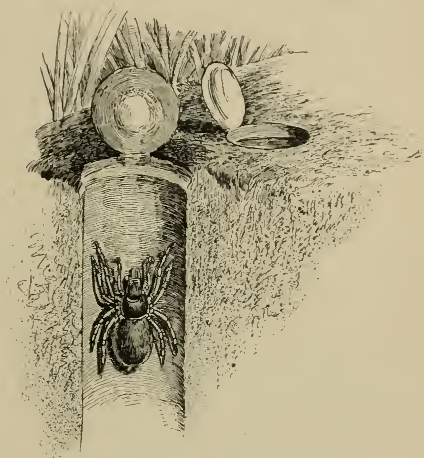

Fig. 84.—Trap-door spider and burrow (*Ctenizа*).

Finally, there are among the thousand species of spiders in the United States a considerable proportion which construct no definite web. Many of these may be seen darting about in the sunshine on old logs and fences, often trailing after them a thread which may support them if they fall in their active leaping after insects.

133. **Breeding habits.**—The male spiders are usually much smaller than the females, and some species are only one-fifteenth as long as the female and one one-hundredth of its weight. They are usually more brilliantly colored, more active in their movements, yet rarely spinning their own webs and capturing their own food, preferring to live at the expense of the female. At the breeding season the males of several species make a most interesting display

of their colors, activity, and gracefulness before the females; and the latter, after watching these exhibitions, are said to select the one who has "shown off" in the most pleasing fashion. The life after this may be stormy, resulting in the death of the male; but ordinarily the results are not so disastrous, and in a little while the female deposits her eggs in cases which she spins. In these the young develop, sometimes wintering here, and emerging in the spring to scamper about in search of food, or to drift through the air to more favorable spots on fluffy masses of cobweb.

Few groups of animals are more interesting objects of study and more accessible. Their bites are rarely more serious than those of the mosquito—never fatal; and a careful study of any species, however common, will undoubtedly bring to light many interesting and unknown facts.

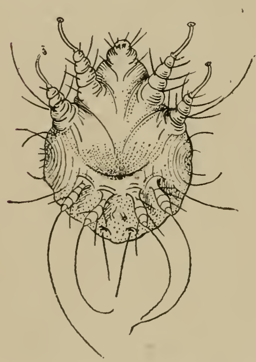

Fig. 85.—The itch-mite (*Sarcoptes scabei*).

134. **The mites and ticks.**—The mites and ticks are the simplest and among the smallest of the animals belonging to this group. To the attentive observer they are rather common objects, with homes in very different situations. Some occur on living and decaying vegetation, in old flour and unrefined sugar, while others live in fresh water and a few in the sea. Almost all tend toward parasitism. Some of the insects which they pierce and destroy are a pest to man, but on the other hand some are intolerable owing to the diseases they produce.

As to other parasitic organisms, degradation of structure is manifest. The respiratory system, so important to the active life of the insects, may be absent, the animal breathing through its skin. The circulatory system may be wanting, the blood occupying spaces among the various organs being swept about by the animal's movements. And many other peculiarities have arisen which fit them for their different modes of life.

135. **The king crab (Limulus).**—The king crab may be found crawling over the bottom or plowing its way through the sand and mud in many of the quiet bays from Maine to Florida. The large head and thorax of these animals are united into a horseshoe-shaped piece, behind which lies the triangular abdomen. On the curved front surface of the former are a pair of small median eyes, and farther outward are two larger compound ones. On the ventral side are six pairs of appendages, instrumental in capturing and tearing the small animals that serve as food, and functioning in connection with the terminal spine as locomotor organs. On the ventral surface of the abdomen are numerous plate-like flaps which serve in respiration, and in the imperfect swimming movements in which these animals occasionally indulge.

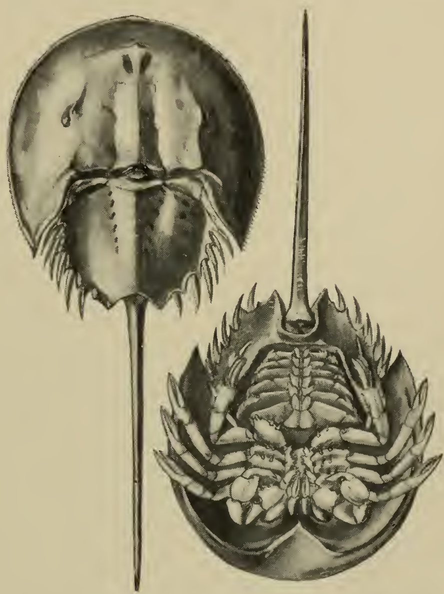

Fig. 86.—The king or horseshoe crab (*Limulus polyphemus*).

These relatively large and clumsy creatures are the remnant of a great number of strange, uncouth animals that inhabited the earth in past ages. Many of them show a close resemblance to the scorpions. The anatomy and development also show certain points of resemblance, and by some are thought to give us an idea of the ancient type of spider-like animal from which the modern forms have descended.

CHAPTER XII

ECHINODERMS

136. **General characters.**—The division of the echinoderms includes the starfishes, sea-urchins, serpent- or brittle-stars, sea-cucumbers, and crinoids or sea-lilies. All are marine forms, and constitute a conspicuous portion of the animals along almost any coast the world over. From these shallow-water situations they extend to the greatest depths of the ocean, and the bodily form possesses a great number of variations, adapting them to lives under such diverse conditions; and yet there is perhaps no group of organisms so clearly defined or exhibiting so close a resemblance throughout. At one time it was thought that their radial symmetry was an indication of a close relationship to the cœlenterates, but more careful study has shown them to be much more highly developed than this latter group, and widely separated from it. A skeleton is almost always present, consisting of a number of calcareous plates embedded in the body-wall, and often supporting numbers of protective spines, which fact has given to the group the name Echinoderm, meaning hedgehog skin.

137. **External features.**—The body of a starfish (Fig. 87) consists of a more or less clearly defined disk, from which the arms, usually five in number, radiate like the spokes of a wheel. At the center of the under side the mouth is located, and from it a deep groove, filled with a mass of tubular feet, extends to the tip of each arm. Innumerable calcareous plates firmly embedded in the body-wall serve

for the protection of the internal organs, and at the same time admit of considerable movement.

In the brittle-stars (Fig. 88) the central disk is much more sharply defined than in the preceding forms, and the long snake-like arms are capable of a very great freedom of movement, enabling the animal to glide over the sea-bottom, or through the crevices of the rocks, at a surprising rate.

In several species, otherwise closely resembling those

Fig. 87.—Starfish (*Asterias ocracea*), ventral view. One-half natural size.

in Fig. 88, the arms divide repeatedly. These are the so-called basket-stars, living in the deeper waters of the sea, where they, like other brittle-stars, act as scavengers and devour large quantities of decomposing plant or animal remains.

At first sight the globular spiny sea-urchins (Fig. 90) would scarcely be recognized as close relatives of the star-fishes. A closer examination, however, shows the mouth to be located on the under side of the body; from it five rows of feet radiate and terminate close to the center of the dorsal side, and the arrangement of the plates forming the skeleton indicate that the sea-urchin is comparable to a starfish, with its dorsal surface reduced to insignificant proportions.

In the sea-urchins the calcareous plates possess a great regularity, and are so closely interlocked that they prevent

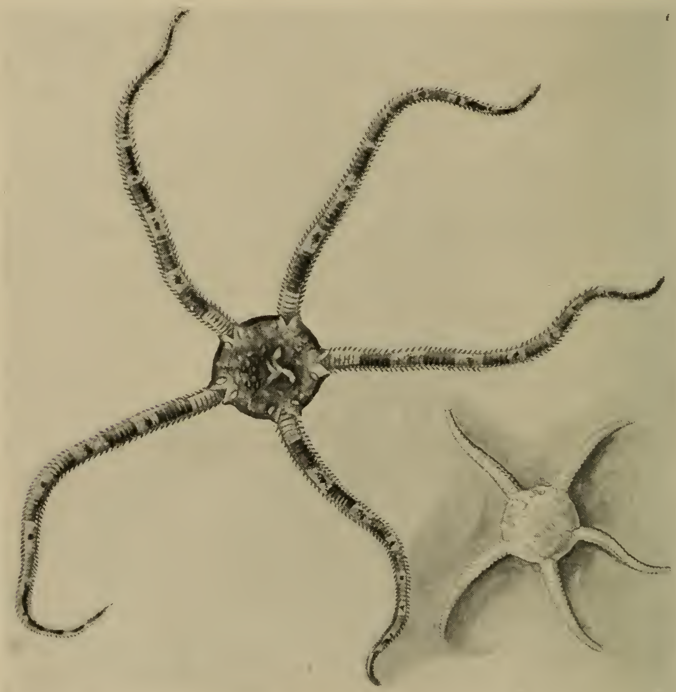

FIG. 88.—Brittle- or serpent-stars (species undetermined). Natural size.

any motion of the body-wall. Also, each plate is usually provided with highly developed spines, movable upon a ball-and-socket joint. These spines serve for locomotion, and, in some instances, for conveying food to the mouth. A considerable number of sea-urchins show an irregularity in form which destroys to a corresponding degree the radial symmetry. This is due to various causes, but especially to a compression of the body, which, in the "sand-dollars," has resulted in the production of a thin, cake-like form (Fig. 91).

If the spherical body of a sea-urchin were to be stretched in the direction of a line joining the mouth and the center

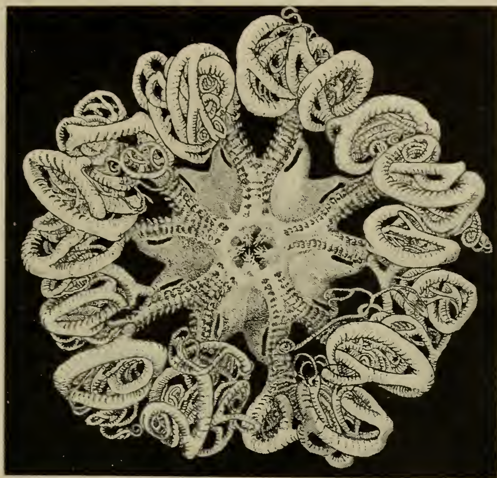

FIG. 89.—Basket-star (*Astrophyton*). One-half natural size.

of the dorsal surface, a form resembling a sea-cucumber (Fig. 92) would be the result. These latter organisms live among crevices of the rocks, embedded in the mud or burrowing in the sand at the bottom of the sea. In such situations they are well protected, and a highly developed skeleton, such as that of the sea-urchin, would not only be of little value, but a positive hindrance to locomotion. The skeleton, therefore, is much reduced, consisting of a few scattered calcareous plates embedded in the fleshy body-wall. Another peculiar feature is almost universally present, in the form of a circlet of tentacles surrounding the mouth, which serve either for the purpose of respiration, for locomotion, or to convey food to the mouth.

A very good imitation of the general plan of a sea-lily or crinoid (Fig. 93) could be made by attaching a serpent-star, especially one of the basket-stars, by its dorsal side to a stalk. In the crinoids the numerous branches of the arms are comparatively short, and in the arrangement of the internal organs there are numerous differences, but for all that the resemblance of these organisms to the other echinoderms is undoubted.

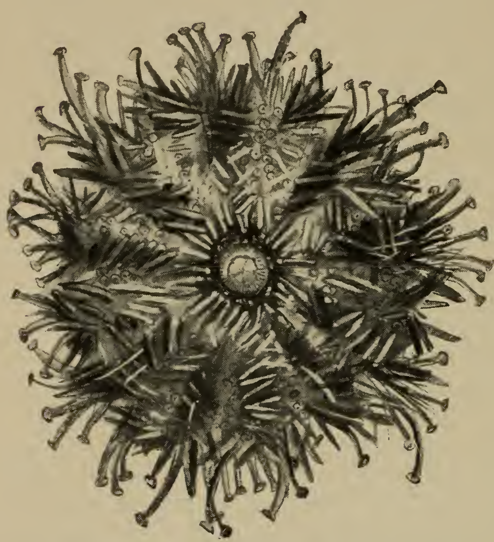

FIG. 90.—Sea-urchin (*Strongylocentrotus purpuratus*). Natural size.

138. **Haunts.** — The greater number of starfishes occur alongshore, slowly crawling about in search of food, or concealed in dark crevices of the rocks, where they may often be found as the tide goes out, and we know that in gradually lessening numbers other species lead similar lives at different levels far down in the dark and gloomy depths. In these same locations the sea-urchins occur, sometimes singly, but more usually associated in great numbers, several species excavating hollows in the rocks, within which they obtain protection. The brittle-stars and sea-cucumbers may also be found occasionally in open view, but more often they make their way about in search of food buried in the sand. The crinoids are usually inhabitants of deeper water, where they are found associated often in great numbers. A few species upon attaining the adult condition separate from the stalk, and are able to move about (Fig. 95), but the remaining species never shift their position.

139. **The organs of defense and repair of injury.**—As we have seen, the body-wall of the echinoderms is provided with a series of plates, often bearing spines which serve as organs of defense, and to protect the internal organs. The starfishes and sea-urchins also possess numerous modified spines (*pedicellaria*) scattered over the surface of the body, which have the form of miniature birds' beaks, fastened to slender muscular threads. During life these jaws continually open and close, and it is said they clean the body of *débris* that settles on it; but on the other hand there are several reasons for the belief that they also act as organs of defense. Thus protected, the natural enemies of echinoderms appear to be relatively few, and are confined chiefly to some of the fishes whose teeth are especially modified for crushing them. In this way, and owing to the action of the breakers, they suffer frequent injury, but many species exhibit to a remarkable degree the ability to regenerate lost parts. Experiments show that if all the arms of a starfish be separated from the disk the latter will within two or three months renew the arms; and a single arm with a part of the disk is able to renew the missing portions in about the same length of time.

Fig. 91.—Sand-dollar, a flat sea-urchin. Natural size.

The brittle-stars, as their name indicates, are usually excessively delicate, often dropping all of their arms upon the slightest provocation; but here again the ability is present to develop the lost portions.

Sea-cucumbers resent rough treatment by vigorously contracting their muscular walls and removing from the body almost the entire digestive tract, the respiratory tree, and a portion of the locomotor system; but some species, at least, renew them again. In some of the starfishes and brittle-stars portions of the body appear to be voluntarily detached and to develop into new individuals, and it is thought that such self-mutilation is a normal method of reproduction.

FIG. 92.—Sea-cucumber (*Cucumaria* sp.). Natural size.

140. **Locomotor system.**—One of the most characteristic and remarkable features of the echinoderms is the water-vascular system, a series of vessels containing water which serve in the process of locomotion. Their arrangement and mode of operation are, with slight modifications, the same throughout the group, and may be readily understood from their study in the starfish.

On the dorsal surface of a starfish, in the angle between two of the arms, is a round, slightly elevated, calcareous plate, the *madreporic body* (Fig. 95, *m.p.*), which under the microscope appears full of holes, like the "rose" of a watering-pot. This connects with a tube that passes to the opposite side of the body, where it enters a canal completely encircling the mouth. On this ring-canal a number of sac-like reservoirs with muscular walls are attached, and from it a vessel extends along the under surface of each arm from base to tip. Each of these radial water-mains gives off numerous lateral branches that open out into small reservoirs similar to those located on the ring-canal, and a short distance beyond communicate through the wall of the body with one of the numerous tube-feet, which, as we have seen, are slender tubular organs, many in number, filling the grooves on the ventral surface of each arm. This entire system of tubes and reservoirs is full of water, taken in, it is said, through the perforated plate, and, when the starfish wishes to advance, many of the little reservoirs contract, forcing water into the cavity of the feet, with which they are in communication, thus extending the extremity of the tubes a considerable distance. The terminal sucker of each foot, acting upon the same principle as those on the cuttlefish, attaches firmly to some foreign object, whereupon the muscles of the foot contract, drawing the body toward the point of attachment. This latter movement is similar to that of a boatman pulling himself to land by means of a rope fastened to the shore. When the shortening of the tube-feet has ceased, the sucking disks release their attachment, project themselves again, and this process is repeated over and over. At all times some of the feet are contracting, and a steady advance of the body is the result.

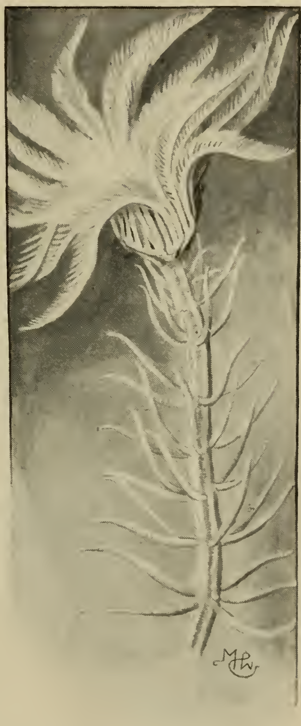

FIG. 93.—Sea-lily or crinoid.

This method of locomotion also obtains in the sea-urchins and cucumbers, but in the serpent-stars the tube-feet have become modified into feelers, and the animal moves, often rapidly, by means of twisting movements of the arms. The feet have this character also in the crinoids, where the animal is generally without the power of locomotion. In some of the sea-cucumbers five equidistant rows of tube-feet extend from one end of the body to the other, and the animal crawls worm-like upon any side that happens to be down; but certain species living in the sand, where tube-feet will not work satisfactorily, have lost all traces of them, and creep like an earthworm from place to place. In all the sea-cucumbers the feet, situated near the mouth, have been curiously modified to form a circlet of tentacles, which range in form from highly branched to short and thick structures, and in function from respiratory organs and those of touch to contrivances for scooping up sand and conveying it to the mouth.

Fig. 94.—An unattached crinoid (*Antedon*). One-half natural size.

141. **Food and digestive system.**—In the echinoderms the body-wall is comparatively thin (Fig. 95), and encloses a great space, the body-cavity, in which the digestive and reproductive organs are contained. As the former in various species is adapted for acting upon very different kinds of food, it shows many modifications; but there are a few principal types which may be briefly considered.

In the starfishes the mouth enters almost directly into the cardiac division of the stomach, a capacious, thin-walled sac, much folded and packed away in the disk and bases of the arms (Fig. 95, *b*). This in turn leads into the second pyloric portion (*a*), with thicker walls and dorsal, to the first, from which a short intestine leads to the exterior, near the center of the disk. Another conspicuous and important feature is the so-called liver, consisting of a pair of closely branched, fluffy glands (*l*), extending the entire length of each arm and opening into the pyloric stomach.

The starfishes are carnivorous and highly voracious, devouring large numbers of barnacles and mollusks which happen in their path. If these are small and free they are taken directly into the stomach, but when one of relatively large size is encountered the starfish settles down upon it, and, slowly pushing the cardiac stomach through the mouth, envelops it in the folds. Digestive fluids are now poured over it, and the victim is speedily despatched and in a partly digested condition is gradually absorbed into the body, leav-

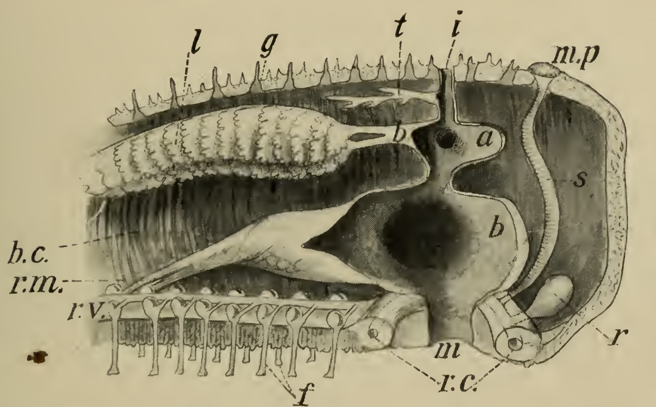

Fig. 95.—Dissection of starfish to show: *a*, pyloric stomach; *b*, bile-ducts (above), cardiac stomach (below); *b.c.*, body-cavity; *f*, feet; *g*, spines; *i*, intestine; *l*, liver; *m*, mouth; *m.p.*, madreporic plate; *r*, reservoir; *r.c.*, ring canal; *r.m.*, stomach retractor muscle; *r.v.*, radial vessel; *s*, stone canal; *t*, respiratory tree.

ing the shell and other indigestible matters upon the exterior. Oysters and clams close their shells when thus attacked, but a steady, continuous pull on the part of the starfish finally opens them, and the stomach is spread over the fleshy portions with speedily fatal results. In the interior of the body the food is transferred to the pyloric stomach, subjected to the action of the liver, and when completely dissolved is borne to all parts of the body.

The digestive system of the starfishes, with its various subdivisions and appendages, is in some respects more complicated than in the other classes. This is most strikingly the case with the serpent-stars, where the entire system for disposing of the minute animals and plants on which it feeds consists of a simple sac communicating with the exterior by a single opening—the mouth.

In the sea-cucumbers large quantities of sand are taken into the body, and the minute organisms and organic matter are digested from it. In the sea-urchins the mouth is provided with five teeth, and the food consists of minute bits of seaweeds, which these snip off. Such diets evidently require a comparatively simple digestive apparatus, for in both it consists throughout its whole extent of a tube of equal caliber, in which the various divisions of esophagus, stomach, and intestine are little, if at all, defined. This is usually somewhat longer than the body, and therefore thrown into several loops; and in the sea-cucumbers its last division is expanded and furnished with more highly muscular walls, which aid in respiration.

142. **Development.**—With but a few exceptions, the eggs of the echinoderms are laid directly in the surrounding water, and for many days the exceedingly minute young are borne great distances in the tidal currents. During this period they show no resemblance to their parents, and only after undergoing remarkable transformations do they assume their permanent features. In every case they have a five-rayed form in early youth, but in several species of starfishes additional arms develop until there may be as many as twenty or thirty.

CHAPTER XIII

THE CHORDATES

143. **General characters.**—Up to the present time we have been studying the representatives of a vast assemblage of animals whose skeletons, if they have any at all, are located on the outside of the body. In the corals, the mighty company of arthropods, and the echinoderms, it is external. On the other hand, we shall find that the animals we are now about to consider, the fishes, frogs, lizards, birds, and mammals, are in possession of an internal skeleton. In some of the simpler fishes and in a number of more lowly forms (Fig. 96) it is exceedingly simple, and consists merely of a gristle-like rod, the *notochord* (Fig. 98, *nc*), extending the length of the body and serving to support the nervous system, which is always dorsal. This is also the type of skeleton found in the young of the remaining higher animals, but as they grow older the notochord gives way to a more highly developed cartilaginous or bony, jointed skeleton, the vertebral column.

In the young of all these back-boned or chordate animals, the sides of the throat are invariably perforated to form a number of gill-slits. In the lower forms these persist and serve as respiratory organs, but in the higher animals they disappear in the adult. The chordates are thus seen to be distinguished by the possession of a dorsal nervous cord supported by an internal skeleton and by the presence of gill-slits, characters which separate them widely from all invertebrates.

The chordates may be divided into ten classes, seven of which (the lancelets, lampreys, fishes, amphibians, reptiles, birds, and mammals) are true vertebrates, while the others embrace several peculiar animals of much simpler organization.

144. **The ascidians.**—Among the latter are a number of remarkable species belonging to the class of ascidians or sea-squirts (Fig. 96). These are abundantly represented along our coasts, and are readily distinguished by their sac-like bodies, which are often attached at one end to shells or rocks. On the opposite extremity two openings exist, through which a constant stream of water passes, bearing minute organisms serving as food. When disturbed they frequently expel the water from these pores with considerable force, whence the name "sea-squirt." While many lead solitary lives, numerous individuals of other species are often closely packed together in a jelly-like pad attached to the rocks, and others not distantly related are fitted to float on the surface of the sea.

Fig. 96.—Ascidian or sea-squirt.

The young when hatched resemble small tadpoles both in their shape and in the arrangement of some of the more important systems of organs. For a few hours each swims about, then selecting a suitable spot settles down and adheres for life. From this point on degeneration ensues.

The tail disappears, and with it the notochord and the greater part of the nervous system. The sense-organs vanish, the pharynx becomes remodeled, and numerous other changes occur, leaving the animal in its adult condition, with little in its motionless, sac-like body to remind one of a vertebrate.

145. **The vertebrates.**—Since the remainder of this volume is concerned with the vertebrates it will be well at the outset to gain some knowledge of their more important characteristics. One of the most apparent is the presence of a jointed vertebral column, composed of cartilage or bone, which supports the nervous system. To it are also usually attached several pairs of ribs, two pairs of limbs, either fins, legs, or wings, and in front it terminates in a more or less highly developed skull. In the space partially enclosed by the ribs, the body-cavity, a digestive system is located, which consists of the stomach and intestine, together with the attached liver and pancreas. The circulatory system is also highly organized, and consists of a muscular heart, arteries, and veins which ramify throughout the body. Breathing, in the aquatic animals, is carried on by means of gills, and in the air-breathing forms by means of lungs, which, like the gills, effect the removal of carbonic-acid gas and the absorption of oxygen. The nervous system, consisting of the brain situated in the head and the spinal cord extending through the body above the back-bone, even in the lower vertebrates, is far more complex than in the invertebrates. The sense-organs also attain to a high degree of acuteness, and in connection with the highly organized nervous system enable these forms to lead far more varied and complex lives than in any of the animals heretofore considered.

CHAPTER XIV

THE FISHES

146. **General characters.**—In a general way the name fish is applied to all vertebrates which spend the whole of their life in the water, which undergo no retrograde metamorphosis, and which do not develop fingers or toes. Of other aquatic chordates or vertebrates the ascidians undergo a retrograde metamorphosis, losing the vertebral column, and with it all semblance of fish-like form. The amphibians, on the other hand, develop jointed limbs with fingers and toes, instead of paired fins with fin rays. A further comparison of the animals called fishes reveals very great differences among them—differences of such extent that they cannot be placed in a single class. At least three great groups or classes must be recognized: the Lancelets, the Lampreys, and the True Fishes. The general characters of all these groups will be better understood after the study of some typical fish, that is one possessing as many fish-like features as possible, unmodified by peculiar habits. Such an example is found in the bass, trout, or perch. In either fish the pointed head is united, without any external sign of a neck, to the smooth, spindle-shaped body, which is thus fitted for easy and rapid cleaving of the water when propelled by the waving of the powerful tail (Fig. 97). A keel also has been provided, enabling the fish to steer true to its course. This consists of folds of skin arising along the middle line of the body, supported by numerous bony spines or cartilaginous

rays. These are the unpaired fins, as distinguished from the paired ones, which correspond to the limbs of the higher vertebrates. In the bass or perch the latter are of much service in swimming, and are also most important organs in directing the course of the fish upward or downward, or for

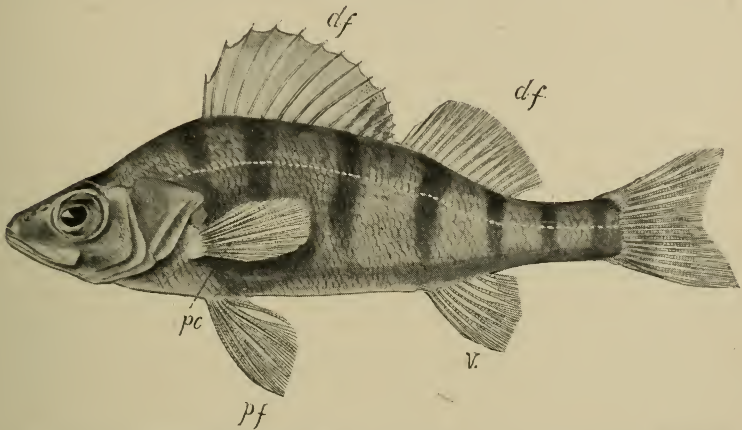

FIG. 97.—Yellow perch (*Perca flavescens*). *df*, dorsal fins ; *pc*, pectoral fin ; *pf*, pelvic fin ; *v*, ventral fin.

aiding the tail in changing the course from side to side; or they may be used to support the animal as it rests upon the bottom in wait for food ; and, finally, they may serve to keep the body suspended at a definite point.

In addition to an internal skeleton the bass or perch, like the greater number of fishes, is more or less enclosed and protected by an external one, consisting of a beautifully arranged series of overlapping scales, which afford protection to the underlying organs, and at the same time admit of great freedom of movement. These usually consist of a horny substance, to which lime is sometimes added, and are peculiar modifications of the skin, something like the feathers, nails, and hoofs of higher forms.

147. **The air-bladder.**—Naturally a fish's body is heavier than the water in which it lives, and there are reasons for thinking that the air-bladder (Fig. 106, *a.bl.*) acts in the

bass and perch and many other fishes as a float to enable them, without much effort, to remain suspended at a definite level. By compressing this sac, partly by its own muscles and partly by those of the body-wall, the bulk of the fish is made less, and it sinks; upon the relaxation of these same muscles the body expands and rises again. Deep-sea fishes, when brought to the surface, where the pressure is relatively slight, are found with their air-bladders so distended that they can not sink again, and the float of surface fishes would be as useless if they were to be carried into the depths below, so that such fishes are compelled to keep within tolerably definite limits of depth. Morphologically considered, the air-bladder is a modified or degenerate lung, and in many fishes it is lost altogether.

148. **Respiration.**—Looking down the throat of the perch, or any other fish, a series of slits (the gill-openings), usually four or five in number, may be seen on each side communicating with the exterior. In the sharks these outer openings are readily seen, but in the bony fishes they open into a chamber on each side of the head, covered by a bony plate or gill-cover that is open behind. On raising these flaps the gills may be seen composed of great numbers of bright-red filaments attached to the bars between each slit. During life the fish may be seen to open its mouth at regular intervals, and, after gulping in a quantity of water, to close it again, contracting the sides of the throat to force it out of the gill-openings and over the gill-filaments to the exterior. During this process the blood traversing the excessively thin filaments extracts the oxygen from the water and carries it to other parts of the body.

With this information, let us return to the study of the three classes of fishes.

149. **The lancelet (Branchiostoma).**—The lancelet, sometimes called amphioxus (Fig. 98), the type of the class *Leptocardii*, is a little creature, half an inch to four inches long, in the different species, transparent and colorless, living in the

sand in warm seas, the nine species known being found in as many different regions. A lancelet may be regarded as a vertebrate reduced to its lowest terms. Instead of a jointed back-bone, it has a cartilaginous notochord, running from the head to the tail. A nervous cord lies above it, enclosed in a membranous sheath. No skull is present, and the nerve-cord does not swell into a brain. There are no eyes and no scales. The mouth is a vertical slit, without jaws. There is no trace of the shoulder-girdle (shoulder-blade and collar-bone) or pelvis (hip-bone) from which

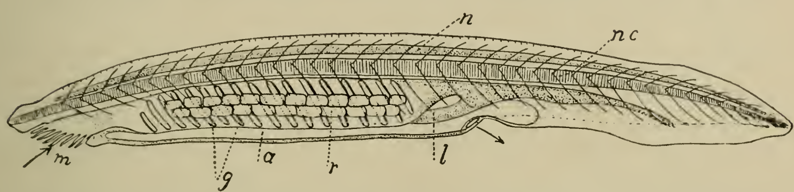

FIG. 98.—The California lancelet (*Branchiostoma californiense*). Twice the natural size. *g*, gills ; *l*, liver ; *m*, mouth ; *n*, nerve-cord ; *nc*, notochord.

spring the paired fins, which, in true fishes, correspond to arms and legs. The circulatory system is fish-like, but there is no heart, the blood being driven about by the contraction of the walls of the vessels. Along the edge of the back and tail is a rudimentary fin, made of fin-rays connected by membrane. In the character and arrangement of its organs the lancelet is certainly like a fish, but in degree of development it differs more from the lowest fish than the fish does from a mammal.

150. **Lampreys (or Cyclostomes).**—The class of lampreys stands next in development (Fig. 99). The notochord gives way anteriorly to a cartilaginous skull, in which is contained the brain, of the ordinary fish type. There are eyes, and the heart is developed, and consists of an auricle and a ventricle. As distinguished from the true fish, the lampreys show no trace whatever of limbs or of the bones which would support them. The lower jaw is wholly wanting, the mouth being a roundish sucking disk. The fins

are better developed, but of the same structure as in the lancelet. There is no bony matter in the skeleton, and there are no scales. The nasal opening is single on the top of the front of the head.

There are about twenty-five species in this class. Some of them, called lampreys, ascend the streams from the sea

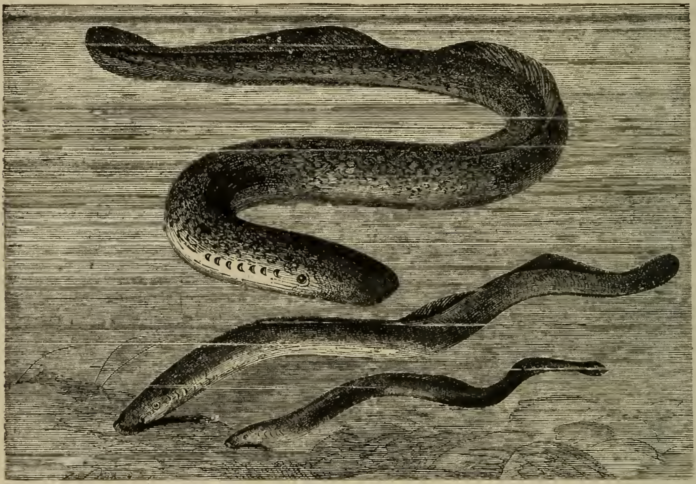

Fig. 99.—Lampreys.

in the spring for the purpose of spawning. The young undergo a metamorphosis, at first being blind and toothless. The adults feed mostly on the blood of fishes, which they suck after scraping a hole in the flesh with their rasp-like teeth. The others, called hag-fishes, live in the sea and bore into the bodies of other fishes, whose muscles they devour. All are slender, smooth, and eel-shaped.

From their structure and a few fossil remains we suppose that these eel-like forms existed long ago, probably before the more highly developed sharks and bony fishes made their appearance, but it is difficult to determine whether their simple organization is of such long standing or is not in part the result of semiparasitic habits, or a life spent largely in burrowing. Like the lancelet and other simple chordates, they are of the greatest interest to the zoologist who gains from them some idea of the lowly vertebrate forms that peopled the earth long ago.

151. **True fishes.**—The third class, Pisces or true fishes, to which the shark as well as the bass and perch belong has a well-developed skeleton, skull, and brain. The lower jaw is developed, forming a distinct mouth, and there is at least a shoulder-girdle and pelvis; although the fins these should bear are not always developed, the general traits are those we associate with the fish. Of the true fishes, there are again several strongly marked groups, usually called subclasses. Of these, three chiefly interest us.

152. **The sharks and skates.**—Very early in the life of the sharks (Fig. 100) and skates (*Selachii* or *Elasmobranchii*)

Fig. 100.—Dogfish (*Squalus acanthias*). One-seventh natural size.

a notochord appears, similar to that in the lancelet and the lampreys. As growth proceeds its sheath becomes broken up into a series of cartilaginous rings, which thus appear like spools strung on a cord. As the fish grows older these "spools" or vertebræ grow solid, cutting the notochord into little disks, and great flexibility is thus secured. Cartilaginous appendages also grow up and cover the spinal nerve-cord lying above, and give strength to the unpaired fins; the paired fins also have their supports. The shoulder-girdle is placed behind the skull, leaving room for a distinct neck; strong bars of cartilage bear the gills; others form jaws to carry the teeth; and a complex skull protects the brain and sense-organs, which are of a relatively high state of development. Throughout life the skeleton is of cartilage, with perhaps here and there a little bone where greater strength is required. Besides these, there are numerous minor characters which the student will readily find for himself.

The sharks and skates or rays live chiefly in the sea, and some reach an enormous size, the largest of all fishes. Some are very ferocious and voracious; others are very mild and weak, and the development of teeth is in direct proportion to their voracity of habit. In earlier geologic times there were many more species of them than now exist.

153. **The lung-fishes.**—The lung-fishes (Dipnoi) are peculiar forms living in some of the rivers of Australia and the tropical regions of Africa and South America. In these the air-bladder is developed as a perfect lung. During the wet season they breathe like other fishes by means of gills, but as the rivers dry up they burrow into the wet mud and breathe by means of lungs which are spongy sacs of which the air-bladder of other fishes is a degenerate representative. As we shall see, they resemble in this respect the tadpoles and some adult Amphibia (frogs and salamanders). The paired fins are also peculiar in structure, having an elongate jointed axis, with a fringe of rays along its length, a structure almost as much like that of the limbs of a frog as that of a fish's fin. In fact the Dipnoi must be regarded as an ancestral type, an ally of the generalized form from which Amphibia and bony fishes have descended. Only four living species of dipnoans are known, but great numbers of fossil species are found in the rocks.

154. **The bony fishes (Teleostei).**—The bony fishes, or Teleosts, are distinguished by the bony skeleton, the symmetrical tail, and by the development of the air-bladder as a more or less completely closed sac, useless in respiration.

Often this organ is altogether wanting, as in the common mackerel. About ten thousand kinds of bony fishes are known. The species swarm in every sea, lake, or river throughout the earth, and some form or another among them is familiar to every boy in the land. These fishes are divided into about two hundred families, and these may be arranged in fifteen to twenty orders. As these are mostly distinguished by features of the skeleton, we need not name them here. In Jordan and Evermann's Fishes of North and Middle America, as well as in various other books, the student of fishes can find the characters by which orders may be distinguished.

155. **Sturgeons and garpikes (Ganoidea).**—While the great majority of the typical fishes possess a bony skeleton, there are a few quaint types—the ganoid fishes, such as the sturgeons (Fig. 101) and garpikes—in which it is cartilaginous or partly bony. In past ages these were probably the highest type of fishes, and from their fossil remains we may conclude that they flourished in vast numbers; but at present they are almost extinct. In this country the ganoids are represented by several species, the best known being the sturgeons which inhabit the Great Lakes, the Mississippi, and its tributaries; while on the East coast the common sturgeon (*Acipenser sturio*) often leaves the sea and ascends rivers. They are the largest fishes found in fresh water, attaining a length of ten or twelve feet, and a weight of five hundred pounds. Their food consists of small plants and animals, which they suck in through their tube-like mouth. The garpikes live in the larger lakes and rivers throughout the East and Mississippi Valley. Their bodies, from three to ten feet in length, according to the species, are covered with comparatively large regularly arranged square scales, and the upper jaw is elongated to form a kind of beak, abundantly supplied with teeth. They are carnivorous, voracious fishes, working great havoc among the more defenseless food-fishes.

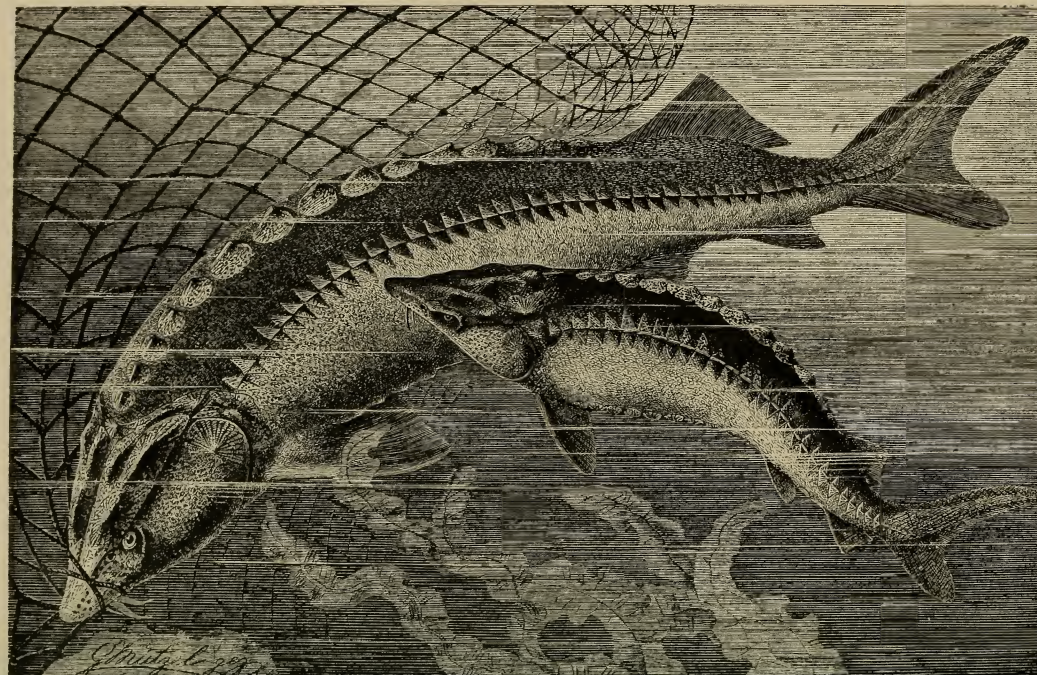

Fig. 101.—Sturgeon (*Acipenser sturio*).

156. **The catfishes.**—Lowest of all the bony fishes we may place the great group to which almost all fresh-water fishes belong. In this group the four vertebræ situated next the head are firmly united, and by means of certain small lever-like bones a connection is formed between the air-bladder and the ear of the fish, which is sunk deep in the skull. The air-bladder thus becomes a sounding organ in the function of hearing. The family of catfishes possesses this structure, and the student should look for it in the first one he catches. The catfishes are remarkable for the long feelers about the mouth, with which they pick their way on the bottom of a pond. There are many kinds the world over. The small ones are known as horned pout or bullhead. In these the dorsal and pectoral fins are armed each with a strong, sharp spine, which is set stiff when the fish is disturbed, and makes them very troublesome to handle. The catfishes have no scales.

157. **The carp-like fishes.**—The still greater carp family includes all the carp, dace, minnows, and chubs. They have the air-bladder joined to the ear, just like the catfish, but they lack the long feelers and the fin spines, while the soft body is covered with scales, and there are no teeth in the mouth. In the throat are a few very large teeth, which the ingenious boy should find. In the sucker family these throat teeth are like the teeth of a comb, and the mouth is fitted for sucking small objects on the river bottom.

158. **The eels.**—In the great order of eels the body is long and slim, scaleless, or nearly so, with no ventral fins. The shoulder-girdle has slipped back from the head, so as to leave a distinct neck, while ordinary fishes have none. Of eels there are very many kinds—some large and fierce, some small as an earthworm; and one kind comes into fresh water.

159. **Herring and salmon.**—In the great order which includes the herring and salmon the vertebræ are all alike, the ventral fins far from the head, and the scales smooth to

the touch. The herring and shad are examples, as also the salmon and trout. Some live in the great depths of the sea, even five miles below the surface. These are very soft in body, being under tremendous pressure. They are inky black—for the sea at that depth seems black as ink—and most of them have luminous spots which give them light in the darkness. Some species have the forehead luminous, like the headlight of an engine. Most of these deep-sea fishes are very voracious, for there is nothing for them to feed on save their neighbors.

160. **The pike, sticklebacks, etc.**—Several small orders stand between these soft-rayed, smooth-scaled fishes and

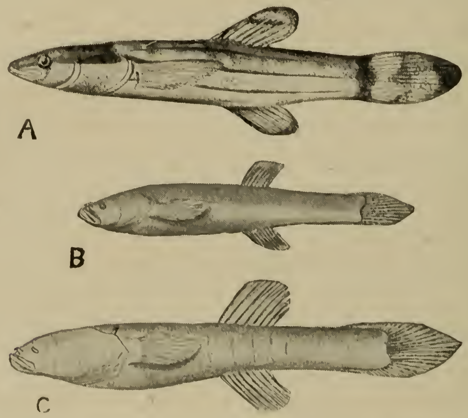

FIG. 102.—The blindfish and its parentage. A, Dismal Swamp fish (*Chologaster avitus*), the ancestor of (B) Agassiz's cave fish (*Chologaster agassizi*) and (C) cave blindfish (*Typhlichthys subterraneus*).

the form, like the perch and bass, which has many spines in the dorsal fin. Among these transitional forms is the pike (Fig. 103)—long, slender, circumspect, and voracious, lying in wait under a lily-pad; the blindfish, which lost its eyes through long living in the streams of the great caves; the stickleback, small, wiry, malicious, and destructive, stealing the eggs and nibbling the fins of any larger fish; the sea-horse, clinging with its tail head downward to floating

Fig. 103.—The pike (*Esox*). From photograph by R. W. Shufeldt.

seaweed, the male carrying the eggs about in his pocket until they hatch; the mullet, stupid, blundering, feeding on minute plants, crushing them in a gizzard like that of a hen, but withal having soft flesh, good for the table; the flying-fishes, which sail through the air with great swiftness to escape their enemies.

161. **The spiny-rayed fishes.**—In the group of spiny-rayed fishes the ventral fins are brought forward and joined to the shoulder-girdle. The scales are generally rough to the touch, and the head is usually roughened also. There are many in every sea, ranging in size from the Everglade perch of Florida, an inch long, to the swordfish, which is thirty. These are the most specialized, the most fish-like of all the fishes. Leading families are the perch, in the fresh waters, the common yellow perch, familiar to all boys in the Northeastern States; the darters, which are dwarf perches, beautifully colored and gracefully formed, living on the bottoms of swift rivers; the sunfishes, with broad bodies and shining scales, thriving and nest-building in the quiet eddies; the sea-bass of many kinds, all valued for the table; the mackerel tribe, mostly swimming in great schools from shore to shore. After these come the multitude of snappers, grunts, weakfishes, bluefishes, rose-fishes, valued as food. Then follow the gurnards, with bony heads; the sculpins, with heads armed with thorns, the small ones in the rivers most destructive to the eggs of trout; and at the end of the long series a few families in which the spines once developed are lost again, and the fins have only soft and jointed rays. It is a curious law of development that when a structure is once highly specialized it may lose its usefulness, at which point degeneration at once sets in. Among fishes of this type are the codfishes, with spindle-shaped bodies, and the flounders, with flat bodies. The flounders lie on the sand with one side down, and the head is so twisted that the eyes come out together on the side that lies uppermost. This side is col-

Fig. 104.—Long-eared sunfish (*Lepomis megalotis*).—From photograph by R. W. Shufeldt.

ored like the bottom—sand colored or brown or black—and the under side is white. When the flounder is first hatched, the eyes are on each side of the head, and the animal swims upright in the water like other fishes. But it soon rests on the bottom; it turns to one side, and as the body is turned over the lower eye begins to move over to the other side. Finally, we may close the series with the anglers (Fig. 105), in which the first dorsal spine is transformed into a sort of fishing-pole with a bait at the end, which may sometimes serve to lure the little fishes, which are soon swallowed when once in reach of the capacious mouth.

162. **Internal anatomy.**—A few fishes are vegetarians, but the greater number are carnivorous. Some swallow large quantities of sand of the sea-bottom and absorb from it the small organisms living there. Others are provided with beaks for nipping off corals and tube-dwelling worms. Huge plate-like teeth enable others to crush mollusks, sea-urchins, and crabs, and many are adapted for preying upon other fishes. The latter are often able to escape, owing to the presence of numerous spines, sometimes supplied with poison-glands; or their colors are protective, and a vast number of devices are present which enable them with some degree of surety to escape their enemies and capture food.

Usually, without mastication, the food passes into the digestive tract (Fig. 106), which in the main resembles that of the squirrel, but varies considerably according to the nature of the food it is required to absorb. As in other animals, it is usually longer in the vegetable feeders. In most fishes the walls of the canal are pushed out at the junction of the stomach and intestine, to form numerous processes like so many glove-fingers (the pyloric cœca, Fig. 106, *py.c.*), which probably serve to increase the absorptive surface. The same result is obtained in other ways, chiefly by numerous folds of the lining of the canal.

The blood-system is much more complex in the fishes than in any of the invertebrates. It also differs in its general plan from that of most adult vertebrates, owing to the peculiar method of respiration. In almost every case the

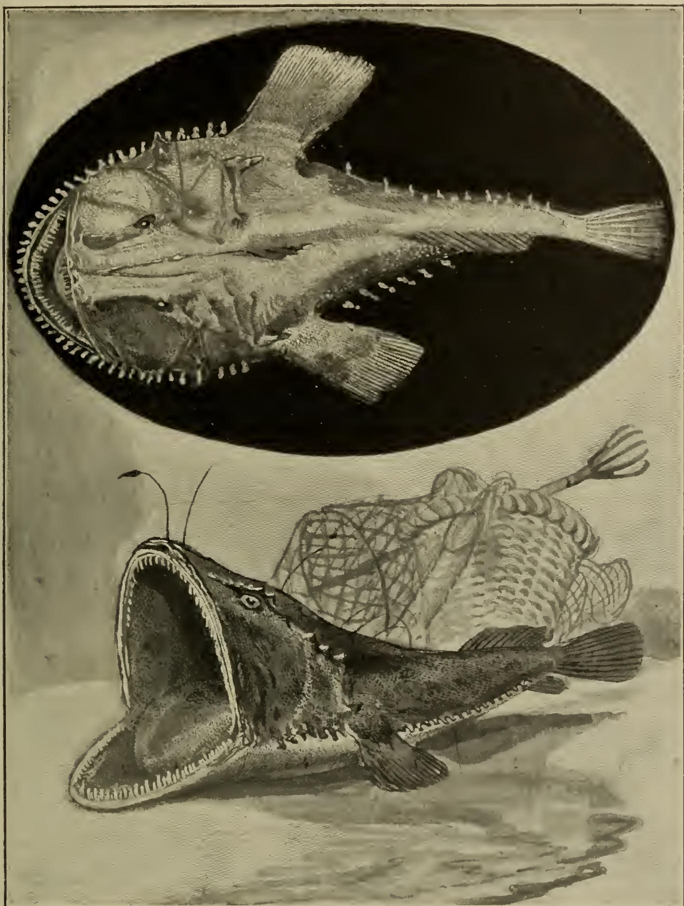

Fig. 105.—Angler or frogfish (*Lophius piscatorius*). One-tenth natural size.—After Baskett.

vessels returning from all parts of the body unite into one vein leading into the heart, which consists of only one auricle and ventricle (Fig. 106). From the heart the blood is forced through the gills, with all their delicate filaments, and now, laden with oxygen and nutritious substances already absorbed from the coats of the digestive tract, it

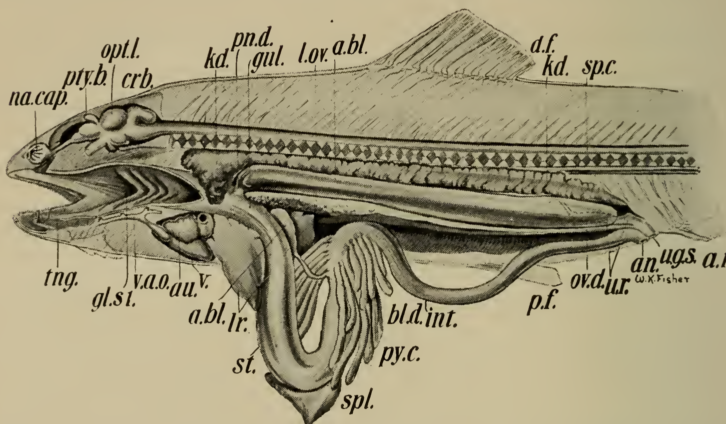

FIG. 106.—Dissection of a bony fish, the trout (*Salmo*). *a.bl.*, air-bladder; *an.*, anal opening; *au.*, auricle; *gl.st.*, gills; *gul.*, esophagus; *int.*, intestine; *kd.*, kidney; *lr.*, liver; *l.ov.*, ovary; *opt.l.*, brain; *py.c.*, pyloric cœca; *sp.c.*, spinal cord; *spl.*, spleen; *st.*, stomach; *v.*, ventricle.

travels on to all parts of the body, continually unloading its cargo in needy districts and waste matters in the kidneys before returning once more to the heart.

163. **The senses of fishes.**—The habits of fishes indicate that they know considerable of what is going on in the outside world, and their well-developed sense-organs show the degree of their sensitiveness. A share of this information comes through the sense of touch, which is distributed all over the surface of the body, chiefly in the more exposed regions sometimes especially provided with fleshy feelers, like those on the chin of the catfish.

The sense of smell appears to be fairly developed, as is that of hearing; but there is no evidence of a sense of taste. A few fishes chew their food, and may possibly taste it, but there are others that swallow it whole, and in all there are relatively a few nerves going to the tongue or floor of the mouth.

The eyes of most fishes are highly developed, and are of the greatest use at all times. Exceptions to the rule are found in certain species which live in caves or in the dark abysses of the ocean. In some of these the eyes have disappeared almost completely, and the sense of touch becomes correspondingly more acute ; in other deep-sea forms they have grown to a large size, enabling them to distinguish objects in the gloom, like the owls and other nocturnal animals. Embedded in the skin of some of these deep-sea fishes, and certain nocturnal ones, are peculiar spots, composed of a glandular substance, which produces a bright glow like that of the fireflies. These may be located on the head or arranged in patterns over various parts of the body, and may serve to light the fish on its way and enable it to see its food to better advantage, or it may act as a lure to many fishes that become victims to their own curiosity. In those fishes which are active most of the time the eyes are located on the sides of the head, and in those which remain at or near the bottom they are turned toward the top; in every case where they can be used to the best advantage.

164. **Breeding habits.**—Among fishes the egg-laying time usually comes with the spring, when the males of several species become more resplendent, and sometimes engage in struggles for their respective mates. In others this ceremony is performed without show of hostility. Some make nests, while others lay their eggs loosely in the water.

In all the salmon family the young fishes are born in the colder fresh-water rivers, and later make their way into the sea, where they spend the greater part of their lives. When the time comes for them to lay their eggs they migrate in great companies, and make their way hundreds, perhaps thousands, of miles to the rivers in which they spent their youth. Up these streams they rush in crowds, leaping waterfalls and rapids, and, dashed and battered on the rocks, many, and in some species all, die from injuries or exhaustion after the breeding season is passed. The eggs, like those of the chubs, suckers, sunfishes, and catfishes, are usually buried in shallow holes in the sand, and the males of most fishes keep a faithful watch over the young until they are able to live in safety. In some of the sticklebacks and several marine species elaborate nests are composed of grass or seaweeds; some of the catfishes carry the eggs until they hatch in their mouths or else in folds of spongy skin on the under side of the body; in the pipefishes and sea-horses a slender sac along the lower surface of the male acts as a brood-pouch, in which the female places the eggs to remain until developed; and some fishes, such as the surf-fishes and a number of the sharks, bring forth their young alive. On the other hand, the young of many of the herrings, salmon, cod, perch, and numerous other fishes are abandoned at their birth, and fall a prey to many animals, even their parents often included.

In the former cases, where the young are protected, only a relatively few eggs are produced: where they are abandoned the female often lays many millions. In every case the number of eggs is in direct relation to the chances the young have of reaching maturity, a few out of each brood surviving to perpetuate the race.

165. **Development and past history.**—The eggs of the higher bony fishes are usually small (one-tenth to one-third of an inch in diameter), and the young when they hatch are accordingly little; in the sharks the eggs are larger, the size of a hen's egg or even larger, and the young when born are relatively large and powerful. These differences, however, do not greatly affect the early development, for in every case the head and then the trunk soon become formed, gills arise, the nervous system appears, which is invariably supported by a skeleton in the form of a gristly rod—the notochord. In the lower forms of fishes this persists throughout life; but in the sharks and skates it becomes replaced in the adult by another and higher type of

skeleton, which is much more specialized with the bony fishes.

Those who study the fossils on the rocks tell us that the first fishes were very simple, and many believe that their skeleton, like that of the little growing fish, consisted only of a notochord. Many of these old forms died out long ago, while others gradually changed in one way and another to adapt themselves to their surroundings, the constant need of adaptation having resulted in the multitude of present-day types. Some, such as the lamprey, have probably changed relatively only to a slight extent; others, like the sharks and skates, are much more altered; and the bony fishes are far from their original low estate, though their development has been rather toward a greater specialization for aquatic life than an advance upward. The little fish in its growth from the egg thus repeats the history of its ancestral development; but as though in haste to reach the adult condition, it omits many important details. Moreover, the record in the rocks is not complete, and we have many things yet to learn of the ancient fishes and their development from age to age to the present day.

CHAPTER XV

THE AMPHIBIANS

In many respects the amphibians—toads, frogs, and salamanders—resemble the fishes, especially the lung-fishes (Dipnoi). The modern amphibians are essentially fishes in their early life, but in developing legs and otherwise changing their bodily form they become adapted for a life on land under conditions differing from those of the fishes. Judging from this class of facts, we may assume that fish-like ancestors, by the development of the lungs, became fitted for a life on land, and that from these the amphibians of our times have been derived.

166. **Development.**—The eggs of the Amphibia are laid during the spring months in fresh-water streams and ponds. They are globular, about as large as shot, and are embedded in a gelatinous envelope (Fig. 107). They are either deposited singly or in clumps, or festooned in long strings over the water-weeds. During the next few days development proceeds rapidly under favorable conditions, resulting in an elongated body with simple head and tail. In this condition they are hatched as tadpoles. As yet they are blind and mouthless, but lips and horny jaws soon appear, along with highly developed eyes, ears, and nose. External fluffy gills arise on the sides of the head, and slits form in the walls of the throat, between which gills are attached, and over which folds of skin develop, as in the fishes. A fin-fold like that of the lancelet or lamprey appears on the tail. The brain and spinal cord, extending along the line of the back, are supported by a gristly notochord, and complete and com-

plex internal organs adapt the animal to a free-swimming existence for days to come.

The tadpole is now, to all intents and purposes, a fish—a fact most clearly recognized in its form, method of locomotion, the arrangement of the gills, and the general plan of the circulatory system.

FIG. 107.—Metamorphosis of the toad.—Partly after GAGE, from *Animal Life*.

167. **Further growth.**—In the course of the next few weeks hind limbs develop beneath the skin, through which they finally protrude. In the same manner, fore limbs arise at a later date. In position these organs are like the paired fins of fishes, but they are intended for crawling or leaping on land, and are modified in accordance with this need. As in the higher vertebrates, the limbs develop as arms and legs, with long fingers and toes, between which are stretched webs of skin, which serve in swimming.

In the meantime large internal changes are also taking place. The wall of the esophagus has gradually pouched out to form the lungs. They are richly supplied with blood-vessels, closely resembling in their general features the lungs of the lung-fishes. The animal now rises to the surface occasionally to gulp in air, and it also continues to breathe by means of gills. At this stage of its existence, therefore, the larva is amphibious (two-living), and we have the interesting example of an animal extracting oxygen from both the water and the air. The diet of the tadpole at this time changes from vegetable to animal substances, and horny teeth give way to the small teeth of the frog, and the digestive system undergoes an entire remodeling to adapt it to its new duties. The young amphibian—whether frog, toad, or salamander—is now a four-legged creature, with well-developed head and tail, with lungs and gills, though the latter are usually fast disappearing, and is rapidly assuming those characters which will fit it for a terrestrial or semiaquatic existence.

168. **The salamanders.**—The changes which now ensue in such a larva in reaching the adult condition are relatively slight in the lower salamanders. The external gills often persist (Fig. 110), the lungs are also functional, and the changes are largely those of increase of size. In the larger number of species the gills disappear more or less completely (Fig. 108), such species often abandoning the water for homes in damp soil or under stones and logs, returning to it only when the time comes for their eggs to be laid. The limbs are always relatively weak, never supporting the body from the ground, but serving in a clumsy way to push it from place to place. In the aquatic forms the tail continues to serve as a swimming organ. In some species the hind legs become rudimentary, or even entirely lacking. A still further modification occurs in a few burrowing species, which move by wrigglings of the body, and are without either pairs of legs.

In geological times many of the salamanders were of great size, several feet in length, and some were enclosed in an armor consisting of bony plates. All now living have the skin naked, and with the exception of the giant species of Japan, three feet in length, and a few similar forms in America, the modern representatives are comparatively

FIG. 108.—Blunt-nosed salamander (*Amblystoma opacum*). Photograph by W. H. FISHER.

feeble and measure their length by inches. Only a few, on account of their bright colors, are particularly attractive, while the others are usually shunned and considered repulsive, chiefly because of their supposed poisonous character, though in reality few animals are more harmless.

169. **Tailless forms.**—In the frogs and toads the metamorphosis which the young undergo is almost as profound as that which takes place with the insects. The gills, together with their blood-vessels, disappear completely. The tail, with its muscles, nerve-supply, and skeleton, is absorbed. The cartilaginous notochord gives way to a jointed back-bone. A skull is developed; numerous bones form in the limbs, affording an attachment for the powerful muscles which make the toad, and especially the frog, expert swim-

mers and leapers, and thus equipped they hereafter lead a wholly terrestrial or semiaquatic life.

170. **Distribution and common forms.**—All the Amphibia are dependent upon moisture. Almost all are hatched and developed in fresh water, and those which leave the water return to it during the breeding season. So we find representatives of the group all over the world having much the same range as the fresh-water fishes. The great majority of the salamanders are confined to the northern hemisphere, but the toads and frogs are almost universally distributed.

Among the salamanders in this country only a relatively few species completely retain their external gills. This is the case with sirens and mud-puppies or water-dogs (Fig. 110), which may occasionally be seen in the clear waters of our lakes and rivers crawling slowly about in search of food, and every now and then rising to the surface to gulp in air. The remainder lose their gills more or less completely, and usually leave the water for damp haunts on land. One of the blunt-nosed salamanders, known as the tiger salamander (*Amblystoma tigrinum*), is found in moist localities in most parts of the United States. Besides these are numerous small species, among them the newts (*Diemyctylus*), ranging widely over the United States, living under logs and stones and feeding upon the small insects and worms inhabiting such situations. In several species of salamanders the lungs disappear with age, and respiration is performed solely through the surface of the skin.

The tailless amphibians are much more abundant and familiar objects than the salamanders, and from the opening of spring until late in the fall they are met with on every hand. With few exceptions the frogs live in or about ponds and marshes, in which they obtain protection in troublous times and from which they derive the store of worms and insects that serve as food. On the other hand, the tree-frogs, as their name indicates, usually abandon the water and repair to moist situations in trees and other vegetation. Their shrill, cricket-like calls are often heard in the summer. The fingers and toes are more or less dilated into disks at their tips, enabling them to climb with considerable facility; and they are further adapted to their surroundings on account of their protective colors. The toads undergo their metamorphosis while very small, and approach only the water at the breeding season. During the day they remain concealed in holes and crevices, but at the approach of evening come out in search of food.

171. **Means of defense.**—The food of the members of this group consists chiefly of small fishes, insect larvæ, snails, and little crustaceans, which are swallowed whole. On the other hand, many Amphibia prey on each other, while most of them are eagerly sought by birds and fishes. Some, as the toads, stalk their food only during the night-time or depend upon their agility to escape their enemies. Others are colored protectively, the markings of the skin resembling the foliage of the earth upon which they rest, and in some species, as the tree-toads, this color-pattern changes as the animal shifts its position. A few species are most brilliantly colored with red, green, yellow, or combinations of these, in striking contrast to their surroundings. They have apparently few enemies, possibly because of an unpleasant odor or taste, and it has been suggested that their gorgeous tints are danger-signals, warning their would-be captors from attempting a second time to devour them. At the same time it is well known that the somber-hued toads emit a milky secretion from the warty protuberance of their skin which is intensely bitter, irritating to delicate skin, and poisonous to several animals.

172. **Skeleton.**—As in all vertebrates, the skeleton of the amphibian first arises as a cartilaginous rod, the notochord, which is afterward replaced by a jointed back-bone, to which the limbs are attached. The back-bone is anteriorly modified into a flat, usually complex, skull. In the salamanders the number of vertebræ is sometimes very large,

and the body correspondingly long and snake-like; but in other cases parts of the vertebræ are reduced in number, and the body is rather short and thick. In the frogs and toads this reduction reaches its culmination, for only nine distinct vertebræ are present, the tail vertebræ, corresponding to those of the salamanders, being represented by a rod-like bone, the urostyle, made of segments grown together.

173. **Digestive and other systems.**—In its main characters the digestive tract of the amphibian (Fig. 109) resembles

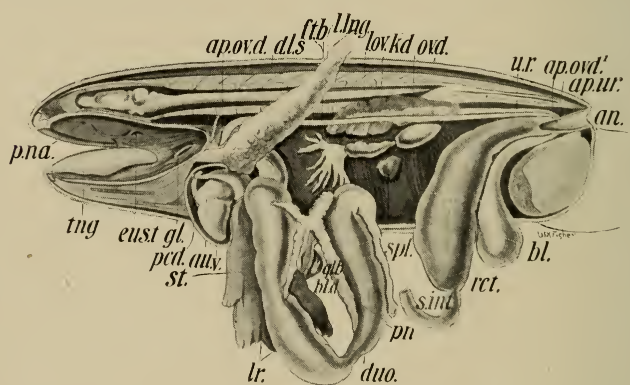

FIG. 109.—Dissection of toad (*Bufo*). *an.*, anal opening; *au.*, auricle; *bl.*, bladder; *duo.*, duodenum; *lng.*, lung; *lr.*, liver; *pn.*, pancreas; *rct.*, rectum; *spl.*, spleen; *st.*, stomach; *v.*, ventricle.

that of the fishes and the squirrel. The mouth is usually large, and the teeth are very small, as in the frog or salamander, or are lacking completely, as in the common toad. In many salamanders the tongue, like that of a fish, is fixed and incapable of movement. In most of the frogs and toads it is attached to the front of the mouth, leaving its hinder portion free, and capable of being thrown over and outward for a considerable distance. In the throat region gill-clefts may persist, but they usually close as the lungs reach their development. The succeeding portions of the canal are comparatively straight in the elongated forms, or more or less coiled in the shorter species. In some cases no well-marked stomach exists, but ordinarily the different portions, as they are shown in Fig. 109, are well defined.

As noted above, the circulation in the tadpole is the same as in fishes, then lungs arise, and for a time respiration is effected both by gills and lungs, and the circulation resembles in its essential points that of the lung-fishes. This may continue throughout life, but more frequently the gills and their vessels disappear, and the circulation approaches that of the reptiles. In such forms the heart consists of two auricles and one ventricle. Into the left auricle pours the pure blood from the lungs; into the right the impure blood from the body. To some extent these mix as they are forced into the general circulation by the single ventricle. The amount of oxygen carried is therefore smaller than in the higher air-breathers, the amount of energy is proportionately less, and hence it is that all are cold-blooded and of comparatively sluggish habits.

In some species of salamanders the lungs may also disappear, and breathing is carried on by the skin, as it is to a certain extent in all amphibians. In the frogs and toads lungs are invariably present, and vocal organs are situated at the opening of the windpipe in the throat. These produce the characteristic croaking or shrilling, which in many species are intensified through the agency of one or two large sacs communicating with the mouth-cavity.

Although the brain is small in the amphibians, it is more complex in several respects than it is in fishes. The eyes are also usually well developed, but in some of the cave and burrowing salamanders they are concealed beneath the skin, and are rudimentary. The ear varies considerably in complexity in the different species, but in the possession of semicircular canals and labyrinth resembles that of the fishes. In the frogs and toads, as one may readily discover, the drum or tympanum is external, appearing as a smooth circular area behind the eye. Organs of touch, smell, and taste are likewise developed in varying degree of perfection.

174. **Breeding-habits.**—While the great majority of amphibians mate in the spring and deposit their eggs in the water, often to the accompaniments of croakings and pipings almost deafening in intensity, several species, for various reasons, have adopted different methods. Some of the salamanders bring forth young alive, and several species of toads and frogs are known in which the young are cared for by the parent until their metamorphosis is complete. In one of the European toads (*Alytes*) the male winds the strings of eggs about his body until the tadpoles are

Fig. 110.—Salamanders. The axolotl (the larva of *Amblystoma tigrinum*) and the newt (*Diemyctylus torosus*).

ready to hatch ; and in a few species of tree-toads the eggs are stored in a great pouch on the back of the parent until the early stages of growth are over. In the Surinam toad of South America the eggs are placed by the male on the back of the female, and each sinks into a cavity in the spongy skin. Here they pass through the tadpole stage without the usual attendant dangers, and emerge with the form of the adult.

Sunlight and warmth are apparent necessities for speedy development. Tadpoles kept in captivity where the conditions are generally unfavorable may require years to assume the adult form. As mentioned above, the tiger salamander (*Amblystoma tigrinum*) occurs in most parts of the United States and Mexico. In the East this species drops its gills in early life as other salamanders do, and assumes the adult form, but in the cold water of high mountain lakes, in Colorado and neighboring States, it may never become adult, always remaining as in Fig. 110. This peculiar form is locally known as axolotl. In this condition it breeds. It is thus one of the very few examples of animals whose undeveloped larvæ are able to produce their kind. Owing to this trait it was at first considered a distinct species, and many years elapsed before its relationship to the true adult form was discovered.

CHAPTER XVI

THE REPTILES

175. **General characteristics.**—In all the reptiles the general shape of the body, and to some extent the internal plan, is not materially different from that seen among the amphibians. In spite of external resemblance the actual relationship is not very close. It appears to be true that ages ago the ancestors of the modern reptiles were aquatic animals, possibly somewhat similar to some of the salamanders; but they have become greatly changed, and are now, strictly speaking, land animals. At no time in their development after leaving the egg do we find them living in the water and breathing by gills. Some species, such as the turtles, lead aquatic or semiaquatic lives, but the modifications which fit them for such an existence render them only slightly different from their land-inhabiting relatives. The skin bears overlapping scales or horny plates, united edge to edge, as in the turtles, enabling them to withstand the attacks of enemies and the effects of heat and dryness. Indeed, it is when heat is greatest that reptiles are most active. In no other class of vertebrates, and very few invertebrates, do normal activities of the body appear to be so directly dependent upon external warmth. In the presence of cold they rapidly grow sluggish, and sink into a dormant state.

As in the case of all animals, habits depend upon structure, and accordingly among the reptiles we find many remarkable modifications, enabling them to lead widely different lives. Nevertheless all are constructed upon much the same plan.

176. **The lizards (Sauria).**—As in the amphibians, especially the salamanders, the body (Fig. 111) consists of a relatively small head united by a neck to the trunks,

FIG. 111.—Common lizard or swift (*Sceloporus undulatus*). Photograph by W. H. FISHER.

which, in turn, passes insensibly into a tail, usually of considerable length. Two pairs of limbs are almost always present, and these exhibit the same skeletal structure as in the amphibians; but in their construction, as in the other divisions of the body, we note a grace of proportion and muscular development which enable the lizards to execute their movements with an almost lightning-like rapidity. The mouth is large and slit-like, well armed with teeth, and the eyes and ears are keen. Scales of various forms and sizes, always of definite arrangement, cover the body. The scales are always colored, in some species as brilliantly as the feathers of birds, and usually harmonize with the surroundings of the animal, enabling it to escape the attacks of its many enemies. Altogether the lizards are a very attractive group of animals. As in the salamanders, the vertebral column is usually of considerable length, but it too presents a lighter appearance and a greater flexibility. Slender ribs are present, and a breast-bone and the girdles which support the limbs. Although more ossified than in the amphibians, the skull still continues to be composed here and there of cartilage. The roof also is yet incomplete, but with the firm plates on the surface of the head ample protection is afforded the small brain underneath. As above mentioned, the limbs are slender and insufficient to support the body, which accordingly rests upon the ground, and by its wrigglings and the pushing of the limbs is borne from place to place. It will be recalled that some of the salamanders living in subterranean haunts and burrowing in the soil have no need of limbs, and the latter have accordingly disappeared. This condition is paralleled by certain species of lizards. The blindworms (which are neither blind nor worms, but true lizards, though snake-like in appearance) are devoid of limbs, as are also the "glass-snakes." In some species the hinder pair arise in early life, but they remain small, and ultimately disappear. In almost all lizards the tail is very brittle, breaking at a slight touch. In such case the lost member will grow again after a time.

177. **The snakes (Serpentes).**—The snakes are characterized by a cylindrical, generally greatly elongated body, in which the divisions into head, neck, trunk, and tail are not sharply defined. As we have seen, this is also true of certain lizards, but the naturalist finds no difficulty in detecting the differences between them. Another peculiarity of the snakes is in the great freedom of movement of the bones

not concerned with the protection of the brain. In the reptiles the lower jaw does not unite directly with the skull, as in the higher animals, but to an intermediate bone, the quadrate, which is attached to the skull. In the snakes these unions are made by means of elastic ligaments. The two halves of the lower jaw are also held

Fig. 112.—Blacksnake (*Bascanion constrictor*). Photograph by W. H. Fisher.

together by a similar band, so that the entire palate and lower jaw are loosely hung together. This enables the snake to distend its mouth and throat to an extraordinary degree, and to swallow frogs and toads but slightly smaller than itself. Where the prey is of relatively small size, the halves of the lower jaw alternate with each other in pulling backward, thus drawing the food down the throat. The food is never masticated. The teeth are usually small and recurved, and serve only to hold the food until it may be swallowed. The latter process is facilitated by the copious secretion of the salivary glands, which become very active at this time.

A further character of the snakes is the absence externally of any trace of limbs. However, in some of the pythons and boas hind limbs are present in the form of small groups of bones embedded beneath the skin and terminating in a claw. There thus appears to be no doubt that the ancestors of the modern snakes were four-footed, lizard-like creatures, which have assumed the present form in response to the necessity of adaptation to new conditions.

More than any other order of vertebrates do the snakes deserve the name of creeping things, and yet their method of locomotion enables them to crawl and swim with a rapidity equal to that of many of the more highly developed animals. This depends chiefly upon certain peculiarities of the skeleton, which consists merely of a skull, vertebral column, and ribs. The vertebræ, usually two or three hundred in number, are united together by ball-and-socket joints, and each attaches by similar joints a pair of slender ribs. These in turn are attached to the broad outer plates upon which the body rests, and the whole system is operated by a powerful set of muscles. Upon the contraction of the muscles the ventral plates are made to strike backward upon the ground or other rough surface, which drives the body forward. Also, the ribs may be made to move backward and forward, and the snake thus progresses like a centiped or "thousand-legs."

178. **The turtles (Chelonia).**—In many respects the turtles are the most highly modified of all the reptiles. The body (Fig. 113) is short and wide and enclosed in a shell or heavy armor, consisting of an upper portion, the carapace, and a flat ventral plate, the plastron. The shape of the carapace varies greatly from a low, flat shield to a highly vaulted dome, remaining cartilaginous throughout life, as in the soft-shelled turtles, or becoming bony and of great strength. These two portions of the shell form a box-like armor, through whose openings the head, tail, and limbs may be extended. The latter organs are superficially unlike those of any other order of animals. The head is generally

thick-set and muscular, and provided with horny jaws entirely destitute of teeth, like those of the birds. The limbs also are usually short and thick and variously shaped, and adapted for aquatic or terrestrial locomotion. The number of vertebræ in the body and tail are relatively few, and the thick and heavy body is devoid of the elements of grace and agility of movement characteristic of the other reptiles. On the other hand, the former enjoy a freedom from the attacks of enemies not accorded to animals in general.

At first sight the appearance of a turtle does not indicate a close relationship to the other reptiles, but a more

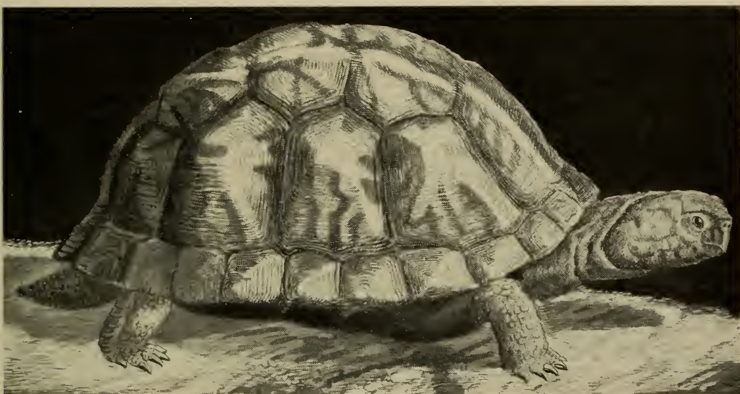

FIG. 113.—Box-turtle (*Terrapene carolina*).

careful examination, and especially of their development, discloses a remarkable resemblance. The head, tail, and limbs are essentially similar to those of the lizards, but in the trunk region peculiar modifications have taken place. The ribs at first separate, as in other animals, flatten greatly, and unite with a number of bones embedded in the skin, thus forming one great plate overlying the back of the animal. About the circumference of the shield other dermal or skin-bones are added, which increase the area of the carapace, and at the same time still others have arisen and united on the ventral surface to form the plastron. In this process the shoulder- and hip-girdles which attach the limbs come to be withdrawn into the body, and we have the curious example of an animal enclosed within its back-bone and ribs. This is even more the case with the box-turtles (Fig. 113), common in the eastern United States, whose ventral plate is hinged so that after the limbs, head, and tail have been withdrawn it may be made to act like a lid to completely enclose the fleshy parts of the body.

Scales and horny plates are present, as in other reptiles, the former covering all parts of the body except the carapace and plastron, which support the plates. In nearly all species the latter are of considerable size, and in the tortoise-shell turtles are valuable articles of commerce. They also are sculptured in a fashion characteristic of each species, and may, like the colors of other animals, render them more like their surroundings, and consequently inconspicuous.

179. **Crocodiles and alligators (Crocodilia).**—The alligators (Fig. 114) and crocodiles are much more complex in structure than the lizards, though their general form is much the same. The body is covered with an armor of thick bony shields and horny scales. These, along the median line, are keeled, and extending along the length of the laterally compressed tail form an efficient swimming organ and rudder. The mouth is of large size, and is bounteously supplied with large conical teeth, which are set in sockets in the jaw, and not fused with it, as in many of the lizards. The nose and ears may be closed by valves to prevent the entrance of water, and a similar structure blocks its passage beyond the throat while the mouth is open. When large animals, such as hogs or calves, are captured as they come to drink, these devices enable the alligator or crocodile to sink with them to the bottom and hold them until drowned. The limbs, short and powerful, are efficient organs of locomo-

tion on land, and together with the general shape of the body, are also well adapted for swimming.

FIG. 114.—Alligator (*Alligator mississippiensis*).

180. **Distribution of the lizards.**—In a general way the number of reptiles is greatest where the temperature is highest. The tropics therefore abound in species, often of large size, and usually of bright coloration. As one travels northward the numbers rapidly diminish, their size is smaller, and the tints less pronounced. In all probability not less than four thousand known reptiles exist, whose haunts are of the most varied description.

In North America the lizards are almost exclusively confined to the southern portions, only a very few species extending up to the fortieth parallel. Among these the skinks (*Eumeces*) are most widely distributed. The blue-tailed skink is probably the most familiar, a small lizard eight or ten inches in length, dark green with yellowish streaks and a bright-blue tail. On sunny days it may sometimes be seen darting about on the bark of trees in search of insects, upon which it feeds.

One of the most familiar lizards in this country is the "glass-snake," found burrowing in the drier soil of the southern half of the United States east of the Mississippi.

Both pairs of limbs are absent, but by wriggling movements of the body this lizard is able to force its way through light soil with considerable rapidity. It is a matter of some difficulty to secure entire specimens, for with other than the gentlest handling the tail severs its connection with the body, as the vertebræ in this portion are extremely brittle. This peculiarity, together with its shape, has given it the popular name of glass-snake. Many species of lizards will thus detach the tail, a habit which is a means of protection, enabling the animal to scamper away into a place of safety while its enemy is concerning itself with the detached member. Later on a new tail develops, though usually of a less symmetrical form.

181. **Horned toads.**—The horned toads (*Phrynosoma*) are lizards peculiar to the hot, sandy deserts and plains of

FIG. 115.—Gila monster (*Heloderma suspectum*). One-third natural size.

Mexico and the western United States. The body is comparatively broad and flat, almost toad-like, and is covered with scales and spines of brownish and dusky tint, so like dried sticks and cactus spines in form and color as to render them difficult of detection. In captivity they readily adapt themselves to their new surroundings, become tame, and feast on flies, ants, and other insects, which they capture by the aid of their long tongue. The horned toads are perfectly harmless creatures, but when irritated sometimes perform the remarkable feat of spurting a stream of blood from the eye toward the intruding object for a distance of several inches. This has been regarded by some as a zoological fable; but there are many who have watched the horned toad in its natural state and in captivity, and they assure us that it is a fact.

In the hot deserts of Arizona and Sonora is another peculiar species of lizard known as the Gila monster (*Heloderma*) (Fig. 115), having the distinction of being the only poisonous lizard known. Further protection is afforded by bony tubercles on the head and by scales over the remainder of the body, all of which are colored brown or various shades of yellow, giving the animal a peculiar streaked and blotched appearance.

182. **Distribution of the snakes.**—The snakes are much more common than the lizards. All over the United States one meets with them, especially the garter- or water-snakes. Of less wide distribution are the black-, grass-, and milk-snakes, and a number of less known species, all of which are perfectly harmless and often make interesting pets. Some of them when cornered show considerable temper, flatten the head and hiss violently, and imitate poisonous forms, but venomous snakes are comparatively few in number in northern and eastern United States. In the southern portions of the country they become more abundant. Along the streams and in the swamps the copperheads, and especially the water-moccasins, often lie in wait for frogs and fish. Both these species are especially dreaded, as they strike without giving any warning sound, but the name and bad reputation of the moccasin is often, especially in the South, transferred to perfectly harmless water-snakes. On higher ground are the rattlesnakes (*Crotalus*), once

abundant but now in many regions well-nigh exterminated. In these species the tail terminates in a series of horny

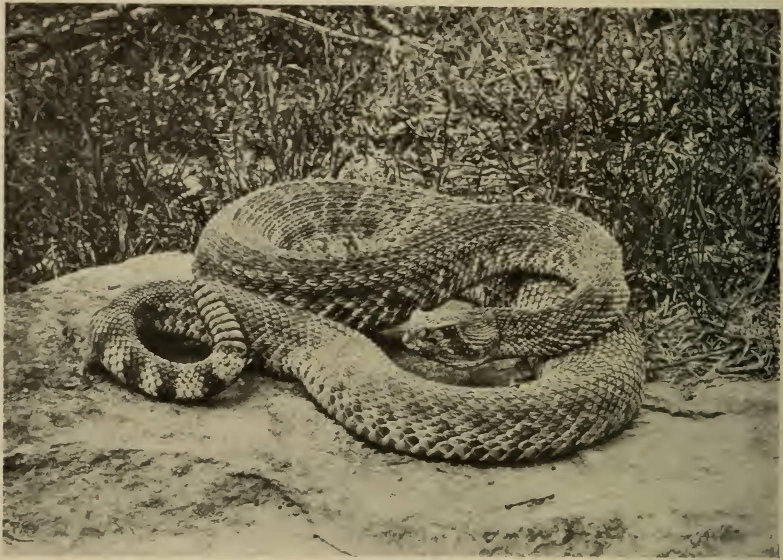

Fig. 116.—Diamond-rattlesnake (*Crotalus adamanteus*). Photograph by W. H. Fisher.

rings that produce a buzzing sound like that of the locust when the tail is rapidly vibrated.

183. **Distribution of the turtles.**—The turtles are perhaps somewhat less dependent upon warmth than other reptiles, yet they too delight to bask in the sunshine, and soon grow sluggish in its absence. In all our fresh-water streams and ponds they are familiar objects, and several species extend up into Canada. Among the turtles the soft shell, the painted and the snapping turtles have the widest distribution, scarcely a good-sized stream or pond from the Gulf of Mexico to Canada, and even farther north, being without one or more representatives. All are carnivorous and voracious, and the snapping turtles are especially ferocious, and "for their size are the strongest of reptiles." In the woods and meadows the wood-tortoise and box-turtles are occa-

sionally met with, and at sea several turtles exist, some of them of great size. Among these is the leather-turtle, found in the warmer waters of the Atlantic, lazily floating at the surface or actively engaged in capturing food. They attain a length of from six to eight feet, and a weight of over a thousand pounds, and are sometimes captured for food when they come ashore to bury their eggs in the sand. By this same method the loggerheads, the hawkbills, and the common green turtles are also captured in considerable numbers. These are of smaller size, and the second named is of considerable value, as the horny plates cover-

FIG. 117.—Hawkbill turtle (*Eretmochelys imbricata*).

ing the shell furnish the tortoise-shell of commerce. These plates are removed after the animal is killed, by soaking in warm water or by the application of heat.

184. **Food and digestive system.**—Some reptiles, among which are a number of species of lizards and the box- and green turtles, are vegetarians, but the great majority are

carnivorous, and usually very voracious. The lizards especially devour large quantities of insects and snails, together with small fishes and frogs. The latter figure largely in the turtle's bill of fare, and in that of the snakes, which also capture birds and mammals. On the other hand, many of the reptiles prey upon one another; and they are the favorite food of hawks and owls and numerous water-birds, of skunks and weasels and many other animals, which look for them continually. Many of the turtles, owing to their protective armor, and the snakes because of their poisonous bite or great size and strength, are more or less exempt, but this is not true of their eggs and young. The smaller species depend upon keenness of sense, agility, and inconspicuous tints. These latter may undergo changes according to the character of the surroundings, but usually only to a slight extent. The chameleons of the tropics and a similarly colored green lizard on the pine-trees in the Southern States are able to change with great rapidity from green, through various shades, to brown.

185. **Respiration and circulation.**—While still in the egg the young lizard develops rudimentary gills, and thus bears

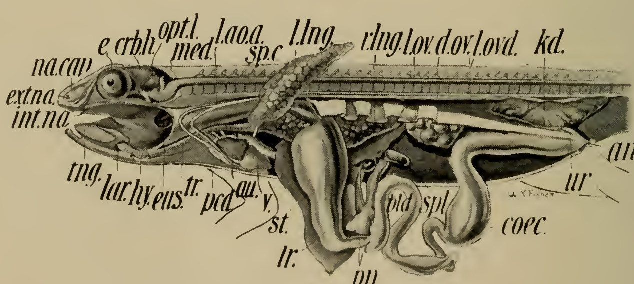

FIG. 118.—Dissection of lizard (*Sceloporus*). *an.*, anal opening; *au.*, auricle; *crb.h.*, brain; *coec.*, intestine; *kd.*, kidney; *l.lng.*, left lung; *lr.*, liver; *pn.*, pancreas; *sp.c.*, spinal cord; *spl.*, spleen; *st.*, stomach; *v.*, ventricle of heart.

evidence to the fact that its distant ancestors were aquatic; but before hatching they disappear, and lungs arise, which remain functional throughout life. Corresponding to the shape of the body, these are usually much elongated and ordinarily paired (Fig. 118, *l.lng.*). The snakes are peculiar in having the left lung rudimentary or even lacking completely, while the right one becomes greatly elongated and extends far back into the body. In nearly all the reptiles the amount of oxygen brought into the lungs is relatively large and the activity of the animal is proportionately great. The circulation of reptiles shows an advance beyond that of the Amphibia. As in the latter, there are two distinct auricles; but the chief difference arises from the fact that the ventricle is more or less divided by a partition which to a considerable degree prevents the blood returning from the lungs from mixing with the impure blood as it returns from its journey over the body. In the crocodiles and alligators the partition is complete, and the circulation thus approaches close to that of the higher animals.

186. **Hibernation.**—Attention has already been called to the fact that reptiles are very susceptible to cold, rapidly growing less active as the temperature lowers. When winter comes on they seek protected spots, and either alone or grouped together hibernate. The various activities of the body during this period are at very low ebb. The blood barely circulates, breathing is imperceptible, and stiff and insensible to the world about them they remain until the warmth again stirs them to their former activity. Some of our common turtles must also pass a somewhat similar sleep while embedded far down in the mud during the disappearance of the ponds in summer. At such times no food is taken, but owing to their loss in weight it is probable that a slow consumption of the body supplies the small amount of necessary energy.

187. **Nervous system and sense-organs.**—At first sight one is struck with the small size of the brain of fishes, Amphibia, and reptiles. Their intelligence likewise is at low

ebb. Almost all the movements and operations of the body appear to be carried on by the animal with little apparent thought. Their acts, like most of the animals below them, are said to be instinctive; yet they are sufficiently well done to enable the animal to procure its food, avoid its enemies, and lead a successful life. As is true of other animals, the ability of the reptile to cope with its surroundings depends to a great extent upon the keenness of one or all of its organs of special sense. In the reptiles the sense of sight is perhaps sharpest, but there is considerable variation in this respect. Eyelids are present in all except the snakes, together with a third, known as the nictitating membrane, a thin, transparent fold located at the inner angle of the eye, over which it is drawn with great rapidity. In the snakes eyelids are absent, giving the eye its characteristic stare. Furthermore, their sense of sight, except in a few tree-dwelling species, appears to be defective, the majority depending largely upon the sense of touch.

In all the vertebrates a very peculiar organ known as the pineal gland or eye is situated on the roof of the brain. In several lizards its position is indicated by a transparent area in one of the plates of the head, and by an opening in the bones of the roof of the skull. In young reptiles, and especially in one of the New Zealand lizards (*Hatteria*, Fig. 119), its resemblance to an eye is decidedly striking. Lens, retina, pigment, cornea, are all present much as they are in some of the snails, but they finally degenerate more or less as the animal reaches maturity. It is a general belief that it represents the remnant of an organ of sight, a third eye, which looked out through the roof of the skull in some of the ancient vertebrates.

With the possible exception of the few species of reptiles which produce sounds, probably to attract their mate, the sense of hearing is not particularly well developed. The senses of smell and taste are also comparatively feeble. The latter sense is located in the tongue, which is also popularly supposed to serve for the purpose of defense, and that it is in some way related to the poison-glands. This, however, is an error. The tongue is used primarily as an organ of

FIG. 119.—Tuatera (*Sphenodon punctatus*).

touch, and in snakes especially it is almost continually darted in and out to determine the character of the animal's surroundings.

188. **Egg-laying.**—The eggs of the reptiles are relatively large and enclosed in a shell like a bird's egg, the shell, however, being leathery rather than made of lime. These are deposited in some warm situation, and generally left to themselves to hatch. Under stones, logs, and leaves, or buried lightly in the soil, are the positions most frequently chosen by the lizards and snakes. The turtles almost invariably select the warm sand at the edge of the water, and after scooping a hole lay several perfectly spherical eggs, usually at night. The alligators lay upward of a hundred eggs about the size of those of a goose, and guard them jealously until and even after they hatch. On the other hand, the young of many lizards and snakes are born alive, the eggs being hatched within the body.

Many reptiles are surprisingly slow in attaining maturity, and live to an age attained by few other animals. It is a well-known fact that turtles live fully a hundred years, and probably the same is true of the crocodiles and alligators and some of the larger snakes. Their enemies are few, and death usually results when the natural course is run.

Throughout life all reptiles periodically shed their skin, as birds do their feathers and mammals their fur. In the snakes and some of the lizards the skin at the lips loosens, and the animal gradually slips out of its old slough, bright and glossy in the new one which previously developed. In the others the old skin hangs on in tatters, gradually coming away as they scamper through the grass.

CHAPTER XVII

THE BIRDS

189. **Characteristics.**—Birds form one of the most sharply defined classes in the animal kingdom, and the variations among the different species are relatively small. "The ostrich or emu and the raven, for example, which may be said to stand at opposite ends of the series, present no such anatomical differences as may be found between a common lizard and a chameleon, or between a turtle and a tortoise," and these we know to be relatively slight.

In many respects the birds resemble the reptiles, and long ago in the world's history the relationship was much closer than now, as we know from certain fossil remains in this country and in Europe. One of the earliest of these fossil birds, that of the Archæopteryx, is a most remarkable combination of bird and lizard. Unlike any modern bird, the jaws were provided with many conical reptile-like teeth. The wings were rather small, and the fingers, tipped with claws, were distinct, not grown together, as in modern birds. The tail was as long as the body, and many-jointed, like a lizard's, each vertebra carrying two long feathers. The bird was about the size of a crow, and it probably could not fly far. Other ancient types have been discovered—principally sea-birds—many of which existed when the Pacific extended over the region now occupied by the Rocky Mountains. These were all of the same generalized type, intermediate between reptile and bird. This fact leads us to the belief that birds descended from reptilian ancestors, and in becoming more perfectly adapted for an aerial life have developed into our modern forms.

In the modern birds the most important peculiarities, those which separate them from all other animals, are correlated with the power of flight. The body is spindle-shaped, for readily cleaving the air. The fore limbs serve as wings. The hind limbs, supporting the weight of the body from the ground, are usually well developed. A series of air-chambers usually exists in powerful fliers. This serves a purpose analogous to that of the air-bladder of a fish, giving buoyancy. But the most characteristic mark of a bird, as above stated, is its feathers, universally present and never found outside the class. Like the scales of lizards, and probably derived from similar structures, they are of different forms, and serve a variety of purposes. The larger ones, with powerful shafts, and forming the tail, act as a rudder. Those of the wings give great expanse with but little increase in weight, and are so constructed that upon the down-stroke they offer great resistance to the air, and push the bird forward, while in the reverse direction the air slips through them readily. In flight these movements of the wing may be too rapid for us to follow, as in the humming-birds, though they are usually much slower, two to five hundred a minute in many powerful fliers, such as the ducks, and frequently long-continued enough to carry them many hundreds of miles at a single flight. The remaining feathers are soft and downy, giving roundness to the body and enabling it to cleave the air with greater ease, and, being poor conductors of heat, they aid in keeping the body at the high temperature characteristic of birds. In most birds the body is not uniformly clothed in feathers. Naked spaces, usually hidden, intervene between the feather tracts, and on the feet and toes scales exist.

190. **Molting.**—As we all know, the growth of feathers, unlike that of hair and nails, is limited, and after they have become faded and worn out they are shed, and new ones

arise to take their place. This process of molting is usually accomplished gradually, without diminishing the powers of flight; but in the ducks and some other birds all the wing- and tail-feathers drop out simultaneously, leaving the bird to escape its enemies by swimming and diving. The molting-process usually takes place in the fall, after the nesting and care for the young is over, and often when the need for a heavy winter coat commences to be felt. Many birds also don what are called courting colors, ruffs, crests, and highly colored patches, in the spring, previous to the mating season, doubtless for the purpose of attracting or impressing their mates. In other cases the change appears to be related to the bird's surroundings. A most beautiful example of this is the ptarmigans—grouse-like birds living far to the north. During winter they are perfectly white and are almost invisible against the snow; but in the spring, as the snow disappears, the white feathers gradually fall out and new ones arise. The latter so harmonize "with the lichen-colored stones among which it delights to sit, that a person may walk through a flock of them without seeing a single bird."

There are also numerous birds, chiefly those that go in flocks, which possess what are known as color-calls or recognition-marks. These may consist of various conspicuous spots or blotches on different parts of the head or trunk, such as we see in the yellowhammer or meadow-lark; or one or more feathers of the wings or tail may be strikingly colored, as in many sparrows and warblers. During the time the bird remains at rest these usually are concealed under neighboring feathers, but during flight they are strikingly displayed. It may possibly be true, as many have urged, that these color-signals are for the purpose of enabling various members of the flock to readily follow their leader; but this and many other interesting questions regarding the color of birds and other animals have not yet received final answers.

In very many animals, fishes as well as birds, the tints on the under side of the body are usually relatively light colored, shading gradually into a darker tint above. This is in all probability a protective device, as was recently shown by Mr. A. H. Thayer, an American artist. His experiments show that the light from above renders the back less dark, and that the shadow beneath is neutralized by the light color. The bird thus appears uniformly lighted, and this effect, together with streaks and blotches, renders them invisible at surprisingly short distances.

191. **Skeleton.**—Turning now to the internal organization of birds, we find many points in common with other vertebrates, especially the reptiles, but many interesting modifications are also present that adapt them for flying and for collecting their food. According to the nature of the food, the beak may have a great variety of forms. The skull may be thick and heavy, or thin and fragile, but these are matters of proportion of the various parts possessed by all birds. The neck also is of differing length; but it is in the trunk region that the greatest changes have arisen, as we may see in any of our ordinary birds. For example, the vertebræ of this part of the body are more or less fused together into rigid framework, to which are attached the ribs that in turn unite with the breast-bone. In the fliers the latter bears a vertical plate or keel, to which the great muscles that move the wings are attached. The tail consists, like that of the old-fashioned birds, of several vertebræ, but these are of small size and fused together into a little knob that supports the tail-feathers. The fore limbs are used for flight, but there are the same bones that exist in the fore limbs of other vertebrates—one for the upper arm, two for the lower, a thumb carrying a few feathers, and known as the bastard wing, and indications of several bones that form the hand. In the hind limb the resemblance is equally apparent, though its different parts are of relatively large size to support the body. It is interest-

ing to note that the knee has been drawn far up into the body, and that the joint above the foot is in reality the ankle.

We thus see that the bird's skeleton presents the same general plan as that of the lizard, for example; but in order to combine the elements of strength, lightness, and compactness essential to successful flight, it has been necessary to remodel it to a considerable degree.

192. **Other internal structures.**—The lungs of birds consist of two dark-red organs buried in the spaces between the ribs along the back. Each communicates with extensive thin-walled air-sacs extending into the space between the

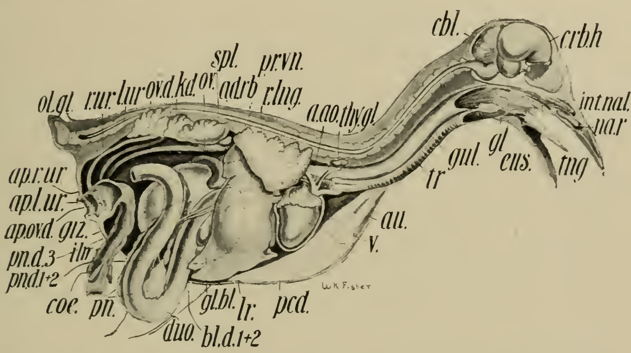

Fig. 120.—Anatomy of a bird. *au.*, auricle; *cbl.* and *crb.h.*, cerebellum and cerebral hemispheres (divisions of the brain); *duo.*, intestine (with portion removed); *giz.*, gizzard; *kd.*, kidney; *r.lng.*, lung; *tr.*, trachea or windpipe; *vent.*, ventricle.

various organs, and in many birds of flight they even extend into the bones of the body, and thus decrease their weight. "The enormous importance of this feature to creatures destined to inhabit the air will be readily understood when we learn that a bird with a specific gravity of 1.30 may have this reduced to only 1.05 by pumping itself full of air."

As we know, air is taken into the body in order that the oxygen it contains may combine with the tissues of the body to liberate the energy necessary for the work of its life. The deeper and more frequent the breathing the greater the amount of energy produced. Birds habitually breathe deeper breaths than other animals. The air passing into the body traverses the entire extent of the lung on its way back to the air-sacs, with the result that large quantities of oxygen are taken into the body. This is distributed by a circulatory system of a more highly developed type than in any of the preceding groups of animals. The ventricles of the heart no longer communicate with each other, and the pure and impure blood never mingle. Furthermore, the beating of the heart is comparatively rapid, rushing the oxygen as fast as it enters the blood to all portions of the body. The result is that everywhere heat is being generated, so necessary to life and activity.

In the lower animals no special means are employed to husband the energy thus produced, but in the birds the body is jacketed in a non-conducting coat of feathers which prevents its dissipation. For this and other reasons the birds, summer and winter, maintain an even and relatively high temperature (102°–110°). Like the mammals, birds are warm-blooded animals, full of energy, restlessly active to an extent realized in few of the cold-blooded animals.

193. **Digestive system.**—This life, at high pressure, demands a relatively large amount of food to make good the losses due to oxidation. The appetites of some growing birds is only satiated after a daily meal equal to from one to three times their own weight, and after reaching adult size the amount of daily food required is probably not less than one-sixth their weight. The nature of the food is exceedingly varied, and the digestive tract and certain accessory structures are obviously modified in accordance with it. The beak, always devoid of teeth in the living form, varies extremely according to the work it must perform. The same is true of the tongue, and many correlated modifications exist in the digestive apparatus. In the birds of prey and the larger seed-eating species, such as the

pigeons and the domestic fowls, the esophagus dilates into a crop, in which the food is stored and softened before being acted upon by the gizzard. The latter is the stomach, provided with muscular walls, especially powerful in the seed-eaters, and with an internal corrugated and horny lining which, in the absence of teeth, serves to crush the food. In some species, such as the domestic fowls and the pigeons, this process is aided by the grinding action of pebbles swallowed along with the food. The remaining portions, with pancreas and liver, vary chiefly in length, and are sufficiently shown in Fig. 120 to require no further description.

194. **Nesting-habits.**—A few birds, such as the ostriches and terns, merely scoop a hollow in the earth, and make no further pretense of constructing a nest. On the other hand, some birds, such as the humming-birds and pewees, build wonderful creations of moss, lichens, and spider-webs, lining it with down, and concealing it so skilfully that they are not often found. Every bird has its own particular ideas as to the fitness of its own nest, and the results are remarkably different, and form an interesting feature in studying the habits of birds. Usually the female takes upon herself the choice of the nest and its construction; but these duties are in some species shared by the male. After the eggs are laid, the male may also aid in their incubation, or may carry food to the female. In other species—for example, the pigeons and many sea-birds—the parents take turns in sitting upon the eggs and in the subsequent care of the young. Finally, there are certain birds, such as the cuckoo and cowbirds, which take advantage of the industry of other species and deposit an egg or two in the nests of the latter. All the work of incubation and care of the young is assumed by the foster-parents, which sometimes neglect their own offspring in their desperate attempts to satisfy the appetites of the rapidly growing and unwelcome guests.

The eggs of birds are relatively large, and are often delicately colored. In some species the blotches and streaks of different shades are probably protective, as in the plovers and sandpipers, whose eggs blend perfectly with their surroundings, but many other cases exist not subject to such an explanation.

The young require a high degree of heat for their development, and this is usually supplied by the parent. In a very general way the length of sitting, or incubation, is proportional to the size of the egg, being from eleven to fourteen days in the smaller species, to seven or eight weeks in the ostriches. Before hatching, a sharp spine develops on the beak, and with this the young bird breaks its way through the shell. Among the quails, pheasants, plovers, and many other species, the young are born with a covering of feathers, wide-open eyes, and the ability to follow their parents or to make their own way in the world. Such nestlings are said to be *precocial*, in distinction to the *altrical* young of the more highly specialized species, such as the sparrows, woodpeckers, doves, birds of prey, and their allies, which are born helpless and depend for a considerable time on the parents for support.

Some of the owls, crows, woodpeckers, sparrows, quails, etc., remain in the same localities where they are bred. They are resident birds. The greater number, at the approach of winter, migrate toward the southern warmer climes, some species traveling in great flocks, by day or night, and often at immense heights. In some cases this movement appears to be directly related to the food-supply; but there are many apparent exceptions to such a theory, and it is possible that many birds migrate for other reasons. Certain species migrate thousands of miles, along fairly definite routes, the young, sometimes at least, guided by the parents, which in turn appear to remember certain landmarks observed the year before. Sea-birds, in their journeys northward or southward, keep alongshore, occasionally veering in to get their bearings or to rest, especially in the presence of fogs.

195. **Classification.**—Most zoologists make two primary divisions of the living types of birds—those like the ostrich with flat breast-bones, and the other the ordinary birds, in which the breast-bone has a strong keel for the attachment of the powerful muscles used in flight. This distinction is not of high importance, but we may use it as a convenience in the description of a few typical forms belonging to several orders into which these two divisions are subdivided.

196. **The ostriches, etc. (Ratitæ).**—From specimens introduced or from pictures we are doubtless familiar with the ostriches and with some of their relatives. The African ostrich (*Struthio camelus*, Fig. 121) is the largest of living birds, attaining a height of over seven feet, and is further characterized by a naked head and neck, two toes, and fluffy, plume-like feathers over parts of the body. They are natives of the plains and deserts of Africa, where they travel in companies, several hens accompanying the male. When alarmed, they usually escape by running with a swiftness greater than that of the horse, but if cornered they defend themselves with great vigor by means of their powerful legs and beaks. Their food consists of insects, leaves, and grass, to which is added sand and stones for grinding the food, as in the domestic fowl. The American ostriches or rheas, are smaller ostrich-like birds, living on the plains of South America. Their habits are essentially the same as those of the African species.

197. **The loons, grebes, and auks (Pygopodes).**—The birds in this and some of the following orders are aquatic in their habits. All have broad, boat-like bodies, which, with the thick covering of oily feathers, enables them to float without effort. The legs are usually placed far back on the body—a most favorable place for swimming, but it renders such birds extremely awkward on land. The grebes are preeminently water-birds. The pied-billed grebe or dab-

FIG. 121.—African or two-toed ostrich (*Struthio camelus*). Photograph by WILLIAM GRAHAM.

chick (*Podilymbus podiceps*), for example, found abundantly on the larger lakes and streams throughout the United States, captures its food, sleeps, and breeds without leaving the water. The loons living in the same situations as the dabchick are also remarkable swimmers and divers. Of the three species found in this country, the common loon or diver (*Gavia imber*) attains a length of three feet, and is otherwise distinguished by its black plumage, mottled and barred with white, which is also the color of the under parts. The auks, murres (see frontispiece), and puffins are marine, and, like their inland relatives, are expert swimmers and divers, strong fliers, and spend much of their time on the open sea. During the breeding-season they assemble in vast numbers on rugged cliffs along the shore, and lay their eggs on the bare rock or in rudely constructed nests.

198. **The gulls, terns, petrels, and albatrosses (Longipennes).**—The birds belonging to this group are among the most abundant along the seacoast, and several species make their way inland, where they often breed. All are characterized by long, pointed wings and pigeon or swallow-like bodies, which are carried horizontally as the bird waddles along when ashore. Many are excellent swimmers and powerful fliers, especially the petrels and albatrosses, which sometimes travel hundreds of miles at a single flight.

The gulls are abundantly represented along our coasts, where they frequently associate in companies, usually resting lightly on the surface of the water, or wheeling lazily through the air on the lookout for food. The terns are of lighter build than the gulls and are more coastwise in their habits, and are further distinguished by plunging like a kingfisher for the fishes on which they live. Both the gulls and terns breed in colonies, every available spot over acres of territory being occupied by their nests, which are usually built of grass and weeds placed on the ground.

The petrels and albatrosses are at home on the high seas, rarely coming ashore except at the breeding-season. Some species of the former are abundant off our shores, especially the stormy petrel (*Procellaria pelagica*) or Mother Carey's chickens (*Oceanites oceanicus*), which are often seen winging their tireless flight in the wake of ocean vessels. Among the dozen or so albatrosses few reach our shores. The wandering albatross (*Diomedea exulans*), celebrated in story and as the largest sea-bird (fourteen feet between the tips of its outstretched wings), is an inhabitant of the southern hemisphere, and only rarely extends its journeys to more northern regions.

199. **Cormorants and pelicans (Steganopodes).**—The cormorants and pelicans are comparatively large water-birds

FIG. 122.—White pelicans (*P. erythrorhynchus*) and whooping-crane (*Grus americana*). Photograph by W. K. FISHER.

usually abundant along the seashore and in many sections of the United States. The cormorants or shags are glossy black in color, with hooked bills, long necks, and short wings, which give them a duck-like flight. The much larger pelicans (Fig. 122) are at once distinguished by long bills, from which is suspended a capacious membranous sac. All these birds are sociable in their habits, breeding, roosting, and fishing in great flocks. Their food consists of fishes, which the shags pursue under water and capture in their hooked beaks; while the pelicans, diving from a considerable height or swimming rapidly on the surface, use their pouches as dip-nets. The nests, usually built of seaweed or of sticks, are placed on rocky cliffs or on the ground in less elevated places.

200. **Ducks, geese, and swans (Lamellirostres).**—The birds of this order, with their broad, flat, serrated beaks, short legs, and webbed feet, are well known, for in a wild or domesticated state they extend all over the earth. All are excellent swimmers, many dive remarkably well, and are strong on the wing. While a considerable number breed within the United States, their nesting-grounds are generally farther north, and in the early spring it is not unusual to see them migrating in flocks from their warmer winter homes. Among the ducks, the mergansers, mallards (from which our domestic species have been derived), the teals, and the beautiful wood-duck remain with us the year round, dwelling on quiet streams and shallow ponds, living on fish, Crustacea, and seeds. In the more open waters of the larger lakes and along the seacoast we find the canvasback, the scaup-ducks, and the eiders (Fig. 123) which supply the famous down of commerce. Of the few species of geese which inhabit the United States, the Canada goose (*Branta canadensis*) is perhaps the most familiar. During their migrations to the nesting sites they fly in V-shaped flocks, their "honks" announcing the opening of spring. The brant (*B. bernicla*) is also common in the eastern part of the country, where it, like its relations, lives on vegetable substances entirely. The swans are familiar in their semi-

Fig. 123.—American eider-duck (*Somateria dresseri*).

domesticated state, but the two beautiful wild swans found in this country are rarely seen.

201. **The herons and bitterns (Herodines).**—The herons and bitterns are also aquatic in their habits, but, unlike the swimming-birds, they seek their food by wading. Adapting them for such an existence, the legs and neck are usually very long, and the bill, longer than the head, is sharp and slender. Among the relatively few species in the United States, the great blue heron (*Ardea herodias*) is widely distributed, and may often be seen standing motionless in some shallow stream on the lookout for fish, or it may wander away into the meadows and uplands to vary its diet with frogs and small mammals. Even more familiar is the little green heron or poke (*Ardea virescens*), which also is seen widely over the country. The night-herons, as their name indicates, stalk their prey by night, and during the day roost in companies—a characteristic common to most herons. The bitterns or stake-drivers are at home in reedy swamps, where they live singly or in pairs, and throughout the night, during times of migration, utter a booming noise resembling the driving of a stake into boggy ground. As a rule, the herons breed as they roost—in companies—building bulky platforms, usually in trees. The bitterns, on the other hand, secrete their nests on the ground in the rushes of their marshy home.

202. **Cranes, rails, and coots (Paludicolæ).**—In their external form the cranes and rails resemble the herons, but in their internal organization they differ considerably. They likewise inhabit marshy lands, but usually avoid wading, picking up the frogs, fish, and insects or plants along the shore or from the surface of the water. The cranes are comparatively rare in this country, yet one may occasionally meet with the whooping-cranes (*Grus americana*) and sand-hill cranes (*Grus mexicana*), especially in the South and West. They are said to mate for life, and annually repair to the same breeding-grounds, where they build their

nests of grass and weeds on the ground in marshy places. The rails are more abundant, though rarely seen on account of their habit of skulking through the swamp grasses. Only rarely do they take to the wing, and then fly but a short distance, with their legs dangling awkwardly. Closely related to them are the coots or mud-hens (*Fulica americana*), which may be distinguished, however, by their slaty color, white bills, and lobed webs on the toes, and consequent ability to swim. All over the United States they may be seen resting on the shores of lakes or quiet streams, or swimming on the surface gathering food. The nest consists of a mass of floating reeds, which the young abandon almost as soon as hatched.

203. **The snipes, sandpipers, and plovers (Limicolæ).**—The snipes, sandpipers, and plovers are usually small birds, widely scattered throughout the country wherever there are sandy shores and marshes. In most species the legs are long, and in connection with the slender, sensitive bill fit the bird for picking up small animals in shallow water or probing for them deep in the mud. During the greater part of the year they travel in flocks, but at the nesting-season disperse in pairs and build their nests in shallow depressions in the earth. The eggs are usually streaked and spotted, in harmony with their surroundings, as are the young, which leave the nest almost as soon as hatched.

Fully fifty species of these shore-birds live within the confines of the United States. Among these the woodcock (*Philohela minor*) and snipe (*Gallinago delicata*) are abundant in many places inland, where they probe the moist soil for food, and in turn are eagerly sought by the sportsman. Even more familiar are the sandpipers and plovers, which are especially common along the seacoast, and are also abundantly represented by several species far inshore. Among the latter are the well-known spotted sandpiper or "tip-up" (*Actitis macularia*) and the killdeer plover (*Ægi-*

alitis vocifera), which inhabit the shores of lakes and streams throughout the country.

204. **Quail, pheasants, grouse, and turkeys** (**Gallinæ**).—The quail, grouse, and our domestic fowls are all essentially

Fig. 124.—California quail (*Lophortyx californicus*). Two-thirds natural size.

ground-birds, and their structure well adapts them to such a life. The body is thick-set, the head small, and the beak heavy for picking open and crushing the seeds and berries upon which they live. The legs and feet are stout, and fitted for scratching or for running through grass and underbrush. Protective colors also prevent detection, but if close pressed they rise into the air with a rapid whirring of their stubby wings, and after a short flight settle to the ground again. During the breeding-season the male usually mates with a number of hens, which build rough nests in hollows in the ground, where they lay several eggs. The young are precocial.

The quail or bob-white (*Colinus virginianus*) and the ruffed grouse (*Bonasa umbellus*) occur throughout the Eastern States. Over the same area the wild turkey (*Meleagris gallopavo*) once extended, but is now almost extinct. The prairies of the middle West support the prairie-hen (*Tympanuchus americanus*), and the valleys and mountains of the far West are the home of several species of quails, some of which are beautifully crested.

205. **Pigeons and doves (Columbæ).**—The pigeons and doves belong to a small yet well-defined order, with upward of a dozen representatives in the United States. They are of medium size, with small head, short neck and legs, and among other distinguishing characters frequently possess a swollen, fleshy pad in which the nostrils are placed. In former years the passenger-pigeon (*Ectopistes migratorius*), inhabiting eastern North America, was probably the most common species in this country. Their flocks contained thousands, at times millions, of individuals, which often traveled hundreds of miles a day in search of food, to return at night to definite roosts—a trait which enabled the hunter to practically exterminate them. At present the mourning- or turtle-dove (*Zenaidura macroura*) is the most familiar and wide-spread of the wild forms. The domestic pigeons are all descendants of the common rock-dove (*Columba livia*) of Europe, the numerous varieties such as the tumblers, fantails, pouters, etc., being the product of man's careful selection. In the construction of the nest, usually

a rude platform of twigs, and in the care of the young both parents have a share. The young at hatching are blind, naked, and perfectly helpless, and are fed masticated food from the crops of the parents until able to subsist on fruits and seeds.

206. **Eagles, hawks, owls, etc. (Raptores).**—The birds of prey, all of which belong to this order, are carnivorous, often of large size and great strength, and are widely distributed throughout this country. The vultures live on carrion, some of the small hawks and owls on insects, while the majority capture small birds and mammals by the aid of powerful talons. In every case the beak is hooked, and the perfection of the organs of sight and hearing is unequaled by any other animal, man included. They live in pairs, and in many species mate for life. As a rule, the female incubates the eggs, and the male assists in collecting food.

Among the vultures, the turkey-buzzard (*Cathartes aura*) is most abundant throughout the United States, especially in the warmer portions, where it plays an important part as a scavenger. Of the several species of hawks, the white-rumped marsh-hawk (*Circus hudsonius*), the red-tailed hawk (*Buteo borealis*), the red-shouldered hawk (*Buteo lineatus*), and above all the bold though diminutive sparrow-hawk (*Falco sparverius*) are the most abundant and familiar. In the more unsettled regions live the golden eagle (*Aquila chrysaetus*) and bald eagle (*Haliaetus leucocephalus*). The owls are nocturnal, and not so often seen as the other birds of prey, yet the handsome and fierce barn or monkey-faced owl (*Strix pratincola*), and the larger species, such as the great gray owl (*Scotiaptex cinereua*), and the beautiful snowy owl (*Nyctea nyctea*), are more or less common, and occasionally seen. Much more abundant is the little screech-owl (*Megascops asio*), and in the Western States the burrowing-owl (*Speotyto cunicularia*), which lives in the burrows of the ground-squirrels and prairie-dogs. Fiercest and strongest of the tribe is the great horned owl (*Bubo virginianus*).

FIG. 125.—Bald eagle (*Haliaetus leucocephalus*).

207. **Cuckoos and kingfishers (Coccyges).**—Omitting the order of parrots (*Psittaci*), whose sole representative in this country is the almost exterminated Carolina parrakeet

(*Conurus carolinensis*), we next arrive at the cuckoos and kingfishers, which differ widely in their habits. The black- or yellow-billed cuckoos or rain-crows are shy, retiring birds, with drab plumage, and though seldom seen are often fairly abundant, and are of much service in destroying insects. Unlike their shiftless European relatives, which lay their eggs in the nests of others birds, they build their own airy homes in some bush or hedgerow, and raise their brood with tender care. The belted kingfisher (*Ceryle alcyon*) is also of a retiring disposition, and spends much of its time on some branch overlooking the water, occasionally varying the monotony by dashing after a fish, or flying with rattling cry to another locality. Their nests are built in holes in banks, and six or eight young are annually reared.

208. **The woodpeckers (Pici).**—The woodpeckers are widely distributed throughout the world, and are preeminently fitted for an arboreal life. The beak is stout for chiseling open the burrows of wood-boring insects, which are extracted by the long and greatly protrusible tongue. The feet, with two toes directed forward and two backward, are adapted for clinging, and the stiff feathers of the tail serve to support the bird when resting. Almost all are bright-colored, with red spots on the head, at least in the males, which may further attract their mates by beating a lively tattoo with their beaks on some dry limb. The glossy white eggs are laid in holes in trees, and both parents are said to share the duties of incubation and feeding the young. Among the more abundant and well-known species is the yellowhammer or flicker (*Colaptes auratus*), which extends throughout the United States. Somewhat less widely distributed is the red-headed woodpecker (*Melanerpes erythrocephalus*), and the small black-and-white downy woodpecker (*Dryobates pubescens*). This is often called sapsucker, but incorrectly so, as, like all but one of our other woodpeckers it feeds on insects. The yellow-bellied wood-

pecker (*Sphyrapicus varius*) is a real sapsucker, living on the juices of trees. A close relative of the red-headed woodpecker, the California woodpecker (*Melanerpes formicivorus*), is renowned for its habit of boring holes in bark and inserting the acorns of the live oak. Subsequently the bird returns, and breaking open the acorns, devours the grubs which have infested them, and apparently eats the acorns also.

209. **Swifts, humming-birds, etc. (Macrochires).**—The birds of this order are rapid, skilful fliers, and their wings are very long and pointed. The feet, on the other hand, are

FIG. 126.—Night-hawk (*Chordeiles virginianus*) on nest. Photograph by H. K. JOB.

small, relatively feeble, and adapted for perching or clinging. Accordingly, the insects upon which they feed are taken during flight by means of their open beaks. The night-hawk (*Chordeiles virginianus*), roosting lengthwise on a branch by day, at nightfall takes to the wing, and high in the air pursues its food after the fashion of a swallow. In the same haunts throughout the United States the whippoorwill (*Antrostomus vociferus*) occurs, sleeping by day, but active at night. Neither of these birds constructs nests, but lays its streaked and mottled eggs directly on the ground. The chimney-swifts (*Chætura pelagica*), swallow-like in general form and habits, but very unlike the swallows

Fig. 127.—Anna hummers (one day old), showing short bill and small size of body. Compare with last joint of little finger.

in structure, frequent hollow trees or unused chimneys, to which they attach their shallow nests. The nearly related humming-birds are chiefly natives of tropical America, only a few species extending into the United States. Of these the little, brilliantly colored, and pugnacious ruby throat (*Trochilus colubris*) is the most widely distributed. Its nest, like that of other hummers, is composed of moss and lichens bound together with cobweb and lined with down.

210. **Perching birds (Passeres).**—The remaining birds, over six thousand in all, belong to one order, the *Passeres* or perchers. They are characterized by great activity, interesting habits, frequently by exquisite powers of song, and in addition to several other structural arrangements have the feet adapted for perching. Their nesting habits

differ widely, but in every case the young are helpless at the time of hatching, and require the care of the parents.

The perchers constitute the greater number of the birds living in the meadows and woods, and are more or less

FIG. 128.—Anna hummer (*Calypte anna*) on nest.

common, and consequently familiar everywhere. Among the families into which the order is divided that of the fly-catchers (*Tyrannidæ*), the crows and jays (*Corvidæ*), the orioles and blackbirds (*Icteridæ*), the finches and sparrows (*Fringillidæ*), the swallows (*Hirundinidæ*), the warblers (*Mniotiltidæ*), the thrushes, robins, and bluebirds (*Turdidæ*), are the more familiar, though the others are equally interesting.

CHAPTER XVIII

THE MAMMALS

211. **General characteristics.**—The mammals, constituting the last and highest class of the vertebrates, comprise such forms as the opossum and kangaroo, the whales and porpoises, hoofed and clawed animals, the monkeys and man. All are warm-blooded, air-breathing animals, having the skin more or less hairy. The young are born alive, except in the very lowest forms, which lay eggs like reptiles, and for some time after birth are nourished by milk supplied from the mammary glands (hence the word *mammals*) of the mother. The skeleton is firm, the skull and brain within are relatively large, and, with few exceptions, four limbs are present.

Most of the mammals inhabit dry land. A number, however, such as the whales and seals, are aquatic; while others, such as the beavers, muskrats, etc., though not especially adapted for an aquatic life, are, nevertheless, active swimmers, and spend much of their time in the water.

Mammals tend to associate in companies, as we may witness among the ground-squirrels, prairie-dogs, rats, mice, and the seals and whales. In many cases they band for mutual protection, and often fight desperately for one another. Claws, hoofs, and nails are efficient weapons, and spiny hairs, as on the porcupines, bony plates, such as encircle the bodies of the armadillos, and thick skin and hair, serve as a protection. The hair is also frequently colored to harmonize the animal with its surroundings.

Some rabbits and hares in the far north don a white coat in the winter season.

212. **Skeleton.**—As in other vertebrates, the external form of mammals is dependent in large measure upon the internal skeleton. This consists of relatively compact bones, the cavities of which are filled with marrow. Those forming the skull are firmly united, and, as in other vertebrates, afford lodgment for several organs of special sense and for the brain, which, like that of the birds, completely fills the cavity in which it rests. The vertebral column to which the skull is attached differs considerably in length, but it invariably gives attachment to the ribs, and to the basal girdles supporting one or two pairs of limbs. Generally speaking, the number of bones in the head and trunk of all mammals is the same, so the variations we note in the species about us, for example, are simply due to differences of shape and proportion. As we are aware, there is a great dissimilarity between the length of the neck of man and that of the giraffe, yet the number of bones in each is precisely the same. On the other hand, the variations occurring in the limbs are often due to the actual disappearance of parts of the skeleton. Five digits in hand and foot is the rule, and yet, as we well know, the horse walks on the tip of its middle finger and toe, the others being represented by small, very rudimentary, splint bones attached far up the leg. The even-hoofed animals walk on two digits, two smaller hoofed toes being often plainly visible a short distance up the leg, as in the pig. In the whales the hind limbs have completely disappeared, and in the seals, where the fore limbs are modified, as in the whales, into flippers, the hind limbs show many signs of degeneration.

213. **Digestive system.**—Some mammals, such as man, monkeys, and pigs, are omnivorous; others, like the cud-chewers and gnawers, are vegetarians; and still others, like the foxes, weasels, and bears, are carnivorous. In

every case the food substances are acted on by a digestive system constructed on the same general plan as that in man, yet modified according to the specific work it is required to perform. The teeth especially afford a valuable indication of the animal's feeding habits, and, as we may notice later, are also of much value in classification. They consist of incisors used in biting, canines for tearing, and premolars and molars for crushing and grinding.

The remaining portions of the digestive tract, esophagus, stomach, and intestine, with their appended glands, are usually not unlike those possessed by the squirrel (Fig. 1). The chief differences are in the size of the various regions. The stomach, for example, may be long and slender or of great dimensions, and its surface may further be increased by several lobes, which are especially well developed in the ruminants or cud-chewers. The intestine, relatively longer in the mammals than in any other class of vertebrates, also exhibits great differences in length and size. In the flesh-eating species its length is about three or four times the length of the body, while in the ruminants it is ten or twelve times the length of the animal.

214. **Nervous system and sense-organs.**—As before noted, the nervous system of mammals is characterized by the large size and great complexity of the brain. Even in the simpler species the cerebral hemispheres (large front lobes of the brain, Fig. 1) are well developed, and in the higher forms of the ascending series they form by far the larger part of the brain. The sense-organs also are highly developed, and are constructed and located much as they are in man. The greatest variations occur in the eyes. In some of the burrowing animals they are usually small, and in some of the moles and mice may even be buried beneath the skin and very rudimentary. On the other hand, they are large and highly organized in nocturnal animals; more so, usually, than in those which hunt their prey by day. The ears also have different grades of perfection, which

appear to be correlated with the habits of the animal. Among the species of subterranean habits the sense of hearing is largely deficient; but, on the other hand, it is exceedingly keen in the ruminants, and enables them to detect their enemies at surprisingly great distances. In these creatures the outer ears are of large size and great mobility, and, placed as they are on the top of the head, serve to concentrate the sound-waves on the delicate apparatus within. In the mammals the sense of smell reaches its highest development, especially among the carnivores which scent their prey. On the other hand, it is said to be absent in the whales and very deficient in the seals. The sense of taste, closely related to that of smell, is located in taste-buds on the tongue, and is also more acute than in any other class of animals. The sense of touch, located over the surface of the body, is especially delicate on the tips of the fingers, the tongue, and lips, which often bear long tactile hairs, called whiskers or *vibrissæ*.

215. **Mental qualities.**—Correlated with the high degree of perfection of the brain and sense-organs the mammals show a higher degree of development of the intellectual faculties than any other class of animals. In many cases their acts are instinctive, and not the result of previous training and experience. Just as the duck hatched in an incubator instinctively takes to the water and pecks at its food, or as the bee builds its symmetrical comb, many of the mammals perform their duties day by day. On the other hand many other mammals are also undoubtedly intelligent. They possess the faculty of memory; they form ideas and draw conclusions; they exhibit anger, hatred, and self-sacrificing devotion for their companions and offspring that is different from that in man only in degree and not in kind. In fact, intelligence differs from instinct primarily in its power of choice among lines of action.

216. **Classification.**—Of the eleven orders into which the mammals have been divided eight are represented in this

FIG. 129.—Three-toed sloth (*Bradypus*). About one-tenth natural size.

country. Of the other three the first (*Monotremes*) and simplest of the eleven is represented by the duck-mole

FIG. 130.—Australian duck-mole (*Ornithorhynchus paradoxus*). One-fifth natural size.

(*Ornithorhynchus*) living in the Australian rivers. Its general appearance and mode of life are represented in

Fig. 130. The duck-moles are the only mammals which lay eggs. One egg a year is deposited in a carefully constructed nest where the young are hatched. Another order (*Edentata*) includes a number of South and Central American forms, among which are the ant-eaters, armadillos, and tree-inhabiting sloths (Fig. 129). Still another order (*Sirenia*) includes the fish-shaped marine dugong and sea-cows or manatees, of which one species is found occasionally on the Florida coast. The remaining orders are described in the succeeding sections.

217. **The opossums and kangaroos (Marsupialia).**—The lowest order of mammals represented in the United States

Fig. 131.—Opossum (*Didelphys virginiana*). One-tenth natural size. Photograph by W. H. Fisher.

is that of the marsupials. It includes the opossums and kangaroos, together with a number of comparatively small and unfamiliar animals living chiefly in and about Australia.

The opossums, fairly abundant throughout the warmer portions of this country, are rat-like creatures, with scaly tails, yellowish-white fur, large head, and pointed snout. Except at the breeding season they lead solitary lives, sleeping in the holes of trees by day and at night feeding on roots, birds, and fruits.

The kangaroos, familiar from specimens in menageries or museums, chiefly inhabit the plains of Australia. The giant gray kangaroos (*Macropus giganteus*), attaining a height of over six feet, go in herds, and owing to the great development of their hind limbs and tails are able, when alarmed, to travel with the swiftness of a horse. Several smaller species, some no larger than rabbits, live among the brush, and like their larger relatives crop the grass and tender herbage with sharp incisor teeth.

While the marsupials do not lay eggs as does the duck-mole, they allow them to develop within the body for a very short time only. Hence the young, when born, are scarcely more than an inch in length, and are blind, naked, and perfectly helpless. At once they are placed by the mother in the pouch of skin, or *marsupium*, on the under side of her body. In this the young are suckled and protected until able to gather their own food and fight their own way.

218. **Rodents or gnawers (Glires).**—The rodents are a large group of mammals, including such forms as the rats, mice, squirrels, gophers, and rabbits. They are readily distinguished by their clawed feet adapted for climbing or burrowing, and by large curved incisor teeth. Unlike ordinary teeth, they grow continually, and, owing to the restriction of the hard enamel to their front surfaces, wear away behind faster than in front, thus producing a chisel-like cutting edge.

The largest of our native rodents is the porcupine (*Erethizon dorsatus*), which ranges from Maine to Mexico, and attains a length of nearly three feet. Many of the hairs of the body have the form of stiff, barbed spines (Fig. 132), readily dislodged so that the animal requires no other weapon of defense. The rabbits and hares are of smaller size, and the cottontails especially are widely distributed. West of the Mississippi the jack-rabbits are familiar, and are

FIG. 132.—Porcupine (*Hystrix cristata*). One-tenth natural size.—After BREHM.

famous for their great speed. Like the porcupines, they feed on leaves and grass, and are often very destructive. The mice, especially the field and white-footed mice, are abundant in woodland and meadow throughout the United States. The house-mouse (*Mus musculus*) is a native of Europe, as is the common rat (*M. decumanus*), which was imported over a century ago. The wood-rat (*Neotoma*), however, is native, and may be found in many localities from east to west. The muskrat (*Fiber zibethicus*), beaver (*Castor canadensis*), and woodchuck (*Arctomys monax*) were also more or less plentiful formerly, but in many localities are well-nigh exterminated. The squirrels, on the other hand, continue to exist in large numbers. The prairie-dogs, ground-squirrels, and chipmunks of the terrestrial species are of frequent occurrence, and of the tree-dwellers the fox, gray and red squirrels are well known in many sections of the United States.

219. **Insect-eating mammals (Insectivora).**—The shrews and moles belonging to this order are representatives of a large group of small animals, which, unlike the major number of rodents, live on insects. The shrews, of which there are several species in this country, are small, mouse-like creatures, nocturnal in their habits, and hence rarely seen. The moles are of much larger size, and owing to their burrowing proclivities scarcely ever appear above ground, but excavate elaborate burrows with their shovel-like feet, devouring the insects which fall in their way. The common mole (*Scalops aquaticus*) extends from the eastern seaboard to the Mississippi River, where it is replaced by the prairie-mole (*S. argenteus*), which extends far to the west, into a country inhabited by other species.

220. **The bats (Cheiroptera).**—The bats are also insectivorous, but their habits are widely different from those of the shrews and moles. The forearm and the fingers of the fore limbs are greatly elongated, and are connected by a thin papery membrane, which also includes the hind limbs and tail, and serves as an efficient organ of flight. During the day they remain suspended head downward in some dark cranny, awakening at nightfall to capture flying insects. Several species are found in this country, the most common being the little brown bat (*Vespertilio fuscus*), with small, fox-like face, large erect ears, and short olive-brown hair. The red bat (*Lasiurus borealis*) is also plentiful everywhere throughout the United States, and is distinguished from the preceding by its somewhat larger size and long reddish-brown fur.

221. **The whales and porpoises (Cete).**—The animals belonging to this order, the whales (Fig. 133), porpoises, and dolphins, are aquatic animals bearing a resemblance to fishes

only in external form. The cylindrical body has no distinct neck, the comparatively large head uniting directly with

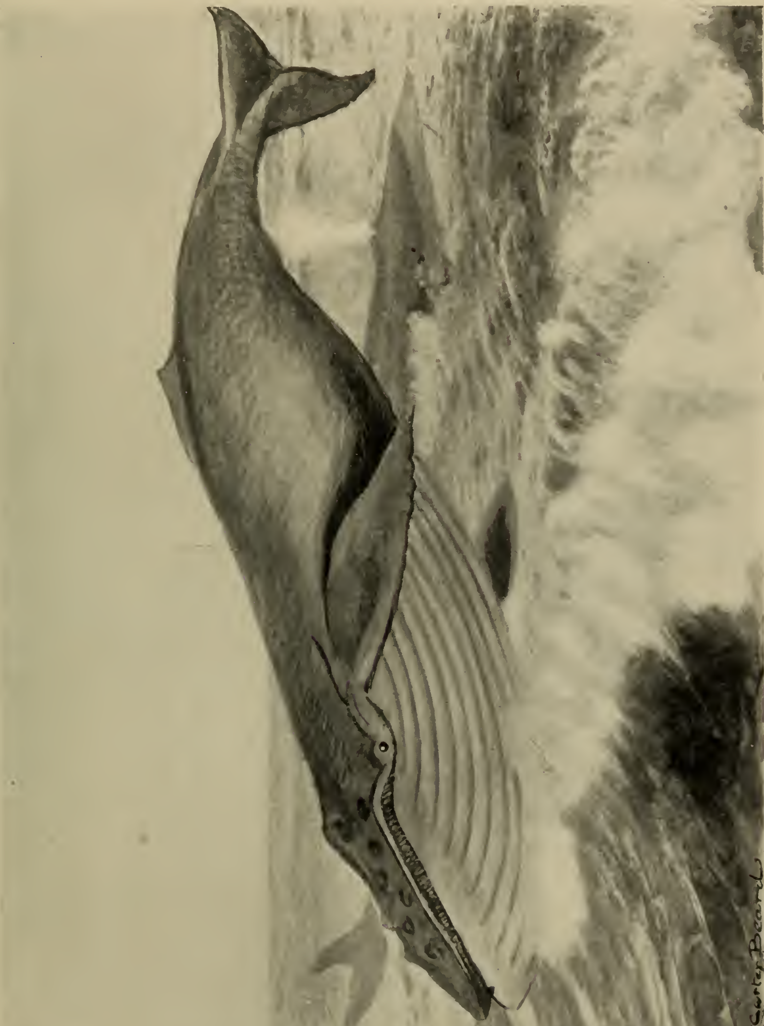

FIG. 133.—Humpback whale (*Megaptera versabilis*). Attains a length of seventy feet.

the cylindrical body, which terminates in the tail with horizontally placed fins. No external signs of hind limbs exist, while the fore limbs are short and capable of being moved only as a whole. External ears are also absent. The eyes are exceedingly small, those of individuals attaining a length of from fifty to eighty feet, being in some species, at least, but little larger than those of an ox. These are often placed at the corners of the mouth. The nasal openings, often known as blow-holes, are situated on the forehead, and as the whale comes to the surface for air afford an outlet for the stream of breath and vapor often blown high in the air—a process known as spouting. In some of the whales, such as the dolphin, porpoise, and sperm-whales, the teeth persist throughout life, but in most of the larger species they never "cut" the gum, but early disappear, and their place is taken by large numbers of whalebone plates with frayed edges which act as strainers. The smaller-toothed forms (porpoises, dolphins, and several species of grampus) are frequently seen close to the shore, where they are usually actively engaged in capturing fish. On the other hand, the larger species, such as the humpback, right whale, and sulfurbottom, not uncommon along our coasts, especially to the northward, live on much smaller organisms. With open mouth these whales swim through the water until they collect a sufficient quantity of jelly-fishes, snails, and crustacea, then closing the mouth strain out the water through the whalebone fringes and swallow the residue.

As noted above, the animals of this order are almost wholly devoid of hair, but the heat of the body is retained by a thick layer of fat beneath the skin. This "blubber" also gives lightness to the body (as do the voluminous lungs), and, furthermore, yields large quantities of oil, which in former times made "whale-fishing" a profitable industry. The whales bear one, rarely two offspring, which are solicitously attended by the mother for a long time. The smaller species grow to a length of from five or eight feet (porpoises, dolphins) to twice this size (grampuses); while the larger whales, by far the largest of animals, range from thirty to over a hundred feet in length with a weight of many tons.

222. **Hoofed mammals (Ungulata).**—The order of hoofed animals or ungulates includes a large number of forms like the zebra, elephant, hippopotamus, giraffe, deer, and several other wild species, some of which are domesticated, such as horses, sheep, goats, and cattle. All of these animals walk on the tips of their toes, and the claws have become developed into hoofs. The order is divided into the odd-toed forms (perissodactyls), such as the rhinoceros with three toes and the horse with one, and the even-toed (artiodactyls), as the pigs with four, and the ox, deer, etc., with two toes. The even-toed forms are again divided into those which chew the cud (ruminants) and those which do not (non-ruminants). No living native odd-toed mammal exists in this country, and of the wild even-toed species all are ruminants. In the members of this latter group the swallowed food passes into a capacious sac (the paunch), is thoroughly moistened, and passed into the second division (the honeycomb), later to be regurgitated and ground by the powerful molars. It is then reswallowed, and undergoes successive treatment in the other two divisions of the stomach (the manyplies and reed) before entering the intestine.

Among the North American ruminants, the deer family (*Cervidæ*) is the best represented. In the more unsettled regions of the East the red deer is still common, and the same may be said of the white-tailed, black-tailed, and mule-deer of the West. Among the woods and lakes to the northward live the reindeer and caribou, and the largest of the deer family, the moose, which attains the size of the horse. Of nearly the same size is the wapiti or elk, whose general characters are shown in Fig. 134. In all of the above-mentioned species the horns, if present, are confined to the male (except in the reindeer), and are annually shed after the breeding season.

Fig. 134.—American elk (*Cervus canadensis*).

The native hollow-horned ruminants (*Bovidæ*) are at present confined to the Western plains, and comprise the pronghorn antelope (*Antilocapra americana*), the wary big-horn or Rocky Mountain sheep (*Ovis canadensis*), living in mountain fastnesses, and the buffalo or bison (*Bison bison*). All of these species were formerly abundant, especially the pronghorn and buffalo, which roamed the plains by thousands, but their extermination has been nearly complete, small herds only persisting in a few wild, inaccessible regions, or protected in parks.

Our domestic sheep and cattle are probably the descendants of several wild species living in Europe and other portions of the world. Of the domesticated even-toed ungulates the horse is the direct descendant of Asiatic wild breeds; while the pig traces its ancestry back to the wild boar (*Sus scrofa*) of Europe, and probably a native species (*S. indicus*) of eastern Asia.

223. **Flesh-eating mammals (Feræ).**—The order of *Feræ* or Carnivora is typically exemplified by such animals as the lions, tigers, bears, dogs, cats, and seals, forms which differ from all other mammals by the large size of the canine teeth (often called dog-teeth) and the molars, which are adapted for cutting, not crushing. The limbs, terminated by four or five flexible digits, bear well-developed claws, which, together with the teeth, serve for tearing the prey. While the bears shuffle along on the soles of their feet, the greater number of species, as illustrated by the dog and cat, tread noiselessly on tiptoe. Almost all are fierce and bold, with remarkably keen senses and quick intelligence, and are the dreaded enemies of all other orders of mammals.

The largest land-inhabiting carnivora are the bears, of which the brown or cinnamon bear (*Ursus americanus*), inhabiting North America generally where not exterminated, and the huge grizzly (*Ursus horribilis*) of the Western mountains, are the best-known species. The former lives on berries and juicy herbs, while the grizzly prefers the flesh of animals which it kills. The raccoon (Fig. 135) (*Procyon lotor*) is found in wooded districts all over the United States, and its general appearance and thieving propensities are well known. Almost everything is accept-

FIG. 135.—Raccoon (*Procyon lotor*). Photograph by R. W. SHUFELDT.

able as an article of food, and its fondness for poultry and vegetables makes it an unmitigated nuisance. The otters, skunks, badgers, wolverenes, sables, minks, and weasels, while differing considerably in general appearance and habits, nevertheless belong to one family (the weasel family, *Mustelidæ*), and are more or less valued for their fur. Almost all are characterized by a fetid odor, especially the skunk, which is notoriously offensive, and in consequence is avoided by all other animals.

The dog family is represented by several widely distributed varieties of the red fox (*Vulpes pennsylvanicus*) and gray fox (*Urocyon cinereo-argentatus*), and by the coyotes

FIG. 136.—Silver fox (*Vulpes pennsylvanicus*, var. *argentatus*). Photograph by W. K. FISHER.

(*Canis latrans*) and wolves (*Canis nubilus*). The domestic dog (*Canis familiaris*) is probably the descendant of the wolf, and owing to man's careful breeding during thousands of years has formed several widely differing varieties.

The cat family, comprising the most powerful, savage, and keenest-scented carnivora, is represented by the lion, tiger, jaguar, and hyena. In this country the group is represented by the lynx (*Lynx canadensis*), the wildcat (*Lynx rufus*), and the panther or puma (*Felis concolor*), which attains the length of nearly five feet. The domestic cat has, like the dog, been domesticated for centuries, and has possibly descended from an African species (*Felis

Fig. 137.—Panthers (*Felis concolor*) and peccaries (*Dicotyles torquatus*).

caffra), which was held sacred by the Egyptians, who embalmed them by thousands.

224. **Man-like mammals (Primates).**—The last and highest order of mammals, the Primates, includes the lemurs, monkeys, and man. The first of these are strange squirrel-like forms living chiefly in trees in Madagascar and neighboring regions where they feed on insects. The apes and monkeys are divided into Old and New World forms, which differ widely from each other. The American species are marked by flat noses, with the nostrils far apart. All are arboreal, many have long prehensile tails, and the digits bear nails, not claws. Among them are several species of marmosets, the howling monkeys (*Myocetes*), the spider-monkeys (*Ateles*), and the capuchins (*Cebus*), all of which are more or less common in captivity. In the Old World apes, on the other hand, the nostrils are close together and are directed downward, the tail is never prehensile, and in some cases is rudimentary, and may even disappear. The lowest species (the dog-like apes) include the large, clumsy baboons, among them the familiar blue-nosed mandrill (*Cynocephalus maimon*) and several other species of lighter frame, such as the long-tailed monkey (*Cercopithecus*) (Fig. 139), the tailless *Macacus*, common in menageries, and the Barbary ape, inhabiting northern Africa and extending over into Spain.

FIG. 138.—Baby orang-utan. From life.

The remaining anthropoid or man-like apes include the gibbons (*Hylobates*), orang-utan (*Simia*), gorilla (*Gorilla*), and chimpanzee (*Anthropo-*

Fig. 139.—A monkey (*Cercopithecus*) in a characteristic attitude of watchfulness.

pithecus). The gibbons, inhabiting southeastern Asia, possess arms of such length that they are able to touch their hands to the ground as they stand erect. They are thus adapted for a life in the trees, where they spend most of their time feeding on fruit, leaves, and insects. In the same district the orang occurs, walking when on the ground on its knuckles and the sides of its feet. It prefers the life in the trees, however, in which it builds nests serving for rest and concealment. The gorilla (Fig. 140), the largest of apes, attaining a height of over five feet and a weight of two hundred pounds, is a native of Africa, where it lives in families and subsists on fruits. The same region is the home of the chimpanzee, which in its various characteristics approaches most nearly to man.

Fig. 140.—Gorilla (*Gorilla*).

Man (*Homo sapiens*) is distinguished by the inability to oppose the big toe as he does his thumb—a feature associated with his erect position—and by the relatively enormous size of the brain. Even in an average four-year-old child or an Australian bushman the brain is twice as large as in the gorilla. With this relatively great development of the nervous system is correlated superior mental faculties, which together with social habits and powers of speech exalt man to a position far above the highest ape.

As usually understood, the family of man (*Hominidæ*) contains but a single species, cosmopolitan and highly variable. This species is "now split up into many subspecies or races, the native man of this continent, or 'American Indian,' being var. *americanus*. Other races now naturalized in America are: the Caucasian race, var. *europæus*; the Mongolian race, var. *asiaticus*; and the negro race, *afer*. The first of these is an immigrant from Europe, the second from Asia, and the third was brought hither from Africa by representatives of var. *europæus* to be used as slaves."

CLASSIFICATION OF ANIMALS

The following table of classification is designed to show the systematic position of the more important animals mentioned in the text.

ANIMAL KINGDOM

ONE-CELLED ANIMALS:

BRANCH I. **PRŌTŌZO'A** (*protos*, first; *zoon*, animal)

Class I. **Rhīzop'oda** (*rhiza*, root; *pous*, foot).
Amœ'ba, Difflū'gia.

Class II. **Infusō'ria** (organisms found in infusions).
Order 1. **Flagellā'ta** (*flagellum*, a whip).
Euglēn'a, Cōdōsig'a, Păndōrī'na, Vŏl'vŏx.
Order 2. **Cĭlĭā'ta** (*cilium*, an eyelash).
Păramœ'cium, Vorticĕl'la.

MANY-CELLED ANIMALS (**Metazoa**):

BRANCH II. **PORĬF'ERA** (*porus*, pore; *fero*, to carry)

Class I. **Porifera** (or sponges).

BRANCH III. **CŒLĔNTERĀ'TA** (animals with combined body and stomach cavity)

Class I. **Hȳdrozō'a** (*hydra*, water-serpent; *zoon*, animal).
Hȳ'dra, Gōnionē'mus, Hȳdrăctin'ia, Portuguese man-of-war.

Class II. **Scȳphozō'a** (*scyphos*, cup; *zoon*, animal).
Rhīzŏs'toma, Hălіclȳs'tus.

Class III. **Actinōzo'a** (*actis*, a ray; *zoon*, animal).

BRANCH IV. **PLĀTYHĔLMĬN'THES** * (*platus*, flat; *helminthos*, a worm)

Class I. **Plătō'da** (*platus*, flat; *eidos*, likeness).
Plăna'ria, Lĕptōpla'na.

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* For purposes of convenience, the flatworms (Platyhelminthes), roundworms (Nematelminthes), and segmented worms (Annelids) are combined in one branch (The Worms) in the text.

Class II. **Trĕmatō'da** (*trematodes*, pierced with holes, from the erroneous belief that the suckers are holes into the body).
Liver fluke, *Epidĕl'la.*
Class III. **Cĕstō'da** (*cestos*, a girdle; *eidos*, likeness).
Tapeworm.

Branch V. **NEMATELMINTHES** (*nema*, thread; *helminthos*, a worm)
Class I. **Nĕmatō'da.**
Vinegar eel (Anguillula), *Trĭchī'na*, horsehair snake (*Gordius*).

Branch VI. **NĒMERTĬN'EA** (*nemertes*, a sea-nymph)

Branch VII. **ROTĬF'ERA** (*rota*, a wheel; *fero*, to carry)

Branch VIII. **ANNĔL'IDA** (*annelus*, a ring)
Class I. **Chætŏp'oda** (*chaite*, bristle; *pous*, foot).
Order 1. **Polychæ'te** (*polus*, many; *chaite*, bristle).
Ner'eis, Polynō'e, Sĕr'pula, Sabĕl'la.
Order 2. **Oligōchæ'te** (*oligos*, few; *chaite*, bristle).
Earthworm (*Lŭm'brĭcus*).
Class II. **Hĭrudĭn'ea** (*hirudo*, a leech).
Leeches.
Class III. **Gĕphyrea** (*gephura*, a bridge, because these animals were once supposed to bridge the gap between the worms and sea-cucumbers).

Branch IX. **MŎLLUSCOI'DA**
Class I. **Pŏlyzō'a** (*polus*, many; *zoon*, animal—colonial animals).
Polyzoa, sea-mats.
Class II. **Brăchiŏp'oda** (*brachion*, arm; *pous*, foot).
Lamp-shells (brachiopods).

Branch X. **MŎLLŬS'CA** (*mollis*, soft)
Class I. **Lămēllibranchiā'ta** (*lamella*, a plate; *branchia*, gill).
Clams, mussels, oysters, ship-worm (*Terē'do*).
Class II. **Gastrŏp'oda** (*gaster*, stomach; *pous*, foot).
Snails, slugs, armadillo snails, naked snails, nudibranchs.
Class III. **Cĕphalŏp'oda** (*cephale*, head; *pous*, foot).
Squids, cuttlefishes, devil-fishes (*Oc'tŏpus*), nautilus.

Branch XI. **ĔCHĬNŌDĔR'MATA** (*echinos*, a hedgehog; *derma*, skin)
Class I. **Asteroi'dea** (*aster*, star; *eidos*, likeness).
Starfishes.

Class II. **Ophiuroi'dea** (*ophis*, serpent; *oura*, tail: *eidos*, likeness).
Serpent- or brittle-stars, basket-stars.

Class III. **Hŏlothuroi'dea** (*holothurion*, a kind of water polyp; *eidos*, likeness).
Sea-cucumbers.

Class IV. **Crīnoi'dea** (*crinon*, lily; *eidos*, likeness).
Sea-lilies or crinoids.

Class V. **Ĕchinoi'dea** (*echinos*, hedgehog; *eidos*, likeness).
Sea-urchins.

BRANCH XII. **ARTHRŎP'ODA** (*arthron*, joint; *pous*, foot)

Class I. **Crustā'cea** (*crusta*, a crust or shell).
Fairy-shrimp (*Brănchĭp'us*), water-fleas (*Daph'nia*), cōp'epod, *Cȳ'clops*, goose barnacle, acorn barnacle, *Săccŭlī'na*, opossum-shrimp, prawn, lobster, crayfish, cancer-crab, rock-crab, pill-bug or i'sopod, sand-hopper or amphi'pod.

Class II. **Ŏnycŏph'ora** (*onyx*, claw; *phero*, to carry).
Pĕrĭp'atus).

Class III. **Myrĭŏp'oda** (*myrios*, numberless; *pous*, foot).
Cent'iped, thousand-legs.

Class IV. **Insĕc'ta** (*insectum*, cut in, owing to the grooves surrounding the body).
Fishmoth, springtail, cockroach, grasshopper, cricket, katydid, locust, dragon-fly, caddis-fly, may-fly, white ants or termites, ant-lion, water-boatman, water-bug, back-swimmer, chinch-bug, squash-bug, lice, plant-lice, *Phȳllŏx'era*, scale-insect, gnat, mosquito, flea, house-fly, stag-beetle, wood-beetle, water-beetle, potato-beetle, ladybug, firefly, moth, butterfly, ants, honey-bees and bumblebees, wasps, hornets, yellow-jackets.

Class V. **Arăch'nida** (*arachne*, spider).
Garden-spider, tărăn'tula, bird-spider, trap-door spider, mite, tick, king-crab or horseshoe crab.

BRANCH XIII. **CHORDATA** (*chorda*, a cord, referring to the notochord)

SUBBRANCH I. **Adelochor'da.** Class **Adelochorda.**

SUBBRANCH II. **Urochor'da.** Class **Urochorda.**
Sea-squirts, Tunicā'ta, Ascĭd'ians.

SUBBRANCH III. **Vertebrā'ta** (*vertebratus*, jointed).

Division A. Acrā'nia (*a*, without; *cranion*, skull). Class **Leptocardii.**
Lancelet (Brănchiŏs'toma = Amphiox'us).

Division B. Crāniā'ta.

Class I. **Cyclostŏm'ata** (*cyclos*, circle; *stoma*, mouth).
  Hagfishes, lamprey.

Class II. **Pĭs'ces** (*piscis*, fish).
  Shark, skate or ray, lung-fish, sturgeon, garpike, catfish, horned pout, bullhead, carp, dace, chub, minnow, eel, herring, shad, salmon, trout, pike, stickleback, blindfish, sea-horse, mullet, flying-fish, perch, darter, sunfish, sea-bass, mackerel, snapper, grunt, weakfish, bluefish, rose-fish, gurnard, sculpin, codfish, flounder, angler.

Class III. **Amphĭb'ia** (*amphi*, double; *bios*, life).
  Siren, mud-puppy, water-dog, tiger salamander, axolotl, toad, frog, tree-frog.

Class IV. **Reptĭl'ia** (*reptans*, creeping).
  Skink, "glass-snake," swift, chameleon, horned toad, Gila monster, blacksnake, grass-snake, milk-snake, rattlesnake, copperhead, water-moccasin, soft-shell turtle, snapper, painted turtle, box-turtle, leather-turtle, loggerhead, hawkbill, crocodile, alligator.

Class V. **A'ves** (*avis*, bird).
  Ostrich, loon, grebe, auk, murre, puffin, gull, tern, petrel, albatross, cormorant, pelican, duck, goose, swan, heron, bittern, crane, rail, mud-hen or coot, snipe, woodcock, sandpiper, killdee plover, quail, grouse, wild turkey, prairie-chicken, pigeon, dove, eagle, hawk, owl, turkey-buzzard, cuckoo, kingfisher, woodpecker, sapsucker, swift, humming-bird, night-hawk, whippoorwill, crow, jay, swallow, warbler, thrush, robin, bluebird.

Class VI. **Mammăl'ia** (*mamma*, breast).
  Duck-mole, ant-eater, sloth, armadillo, sea-cow, opossum, kangaroo, porcupine, mouse, rat, muskrat, woodchuck, beaver, rabbit, squirrel, chipmunk, prairie-dog, shrew, mole, bat, whale, grampus, dolphin, porpoise, zebra, elephant, giraffe, deer, antelope, goat, sheep, horse, cow, pig, buffalo, bear, raccoon, otter, skunk, badger, wolverene, sable, mink, weasel, dog, fox, wolf, cat, lynx, panther, monkey, ape, baboon, gibbon, orang-utan, gorilla, chimpanzee, man.

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(1)

THE END