AMERICAN SCIENCE SERIES

ELEMENTARY COURSE

ZOOLOGY

PACKARD

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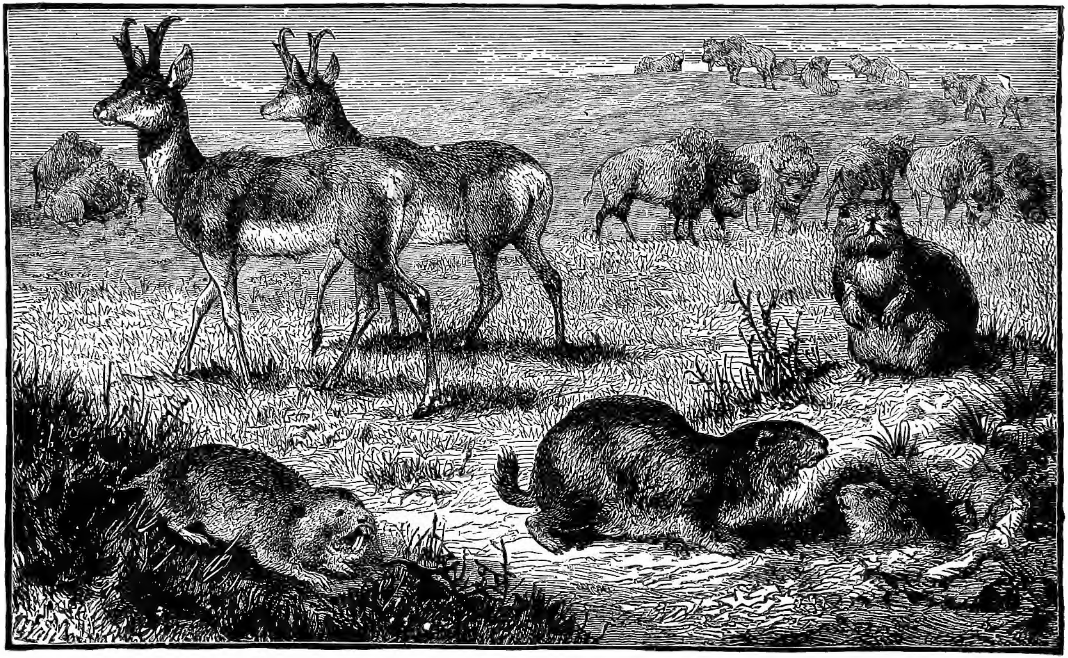

CHARACTERISTIC MAMMALIA OF THE AMERICAN PRAIRIES.—*After Wallace.*

AMERICAN SCIENCE SERIES, ELEMENTARY COURSE

FIRST LESSONS

IN

ZOOLOGY

ADAPTED FOR USE IN SCHOOLS

BY

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FIFTH EDITION, REVISED

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PREFACE.

In our larger museums there have been formed what are called "epitome collections," a single apartment containing a series of examples of the principal classes of the animal kingdom, so that, before entering the museum itself, the visitor may obtain some idea of the principal forms of animal life.

This excellent plan has been kept in view in the preparation of these "First Lessons," and followed out as well as circumstances would allow.

It differs from the author's two other text-books in Zoology—1. In treating of still fewer examples or types, omitting representatives of a number of orders and classes described in his larger Zoology. 2. In using fewer technical terms and names. 3. In rendering the book an elementary guide to the principles of Biology, leading the student from facts to the principles, without tiring him with formal, general statements; the latter usually being printed in italics. 4. The subject, as a whole, is given in somewhat smaller compass. No boy or girl should leave school without at least as much knowledge of the life about us and of our own relations to the animal world, as should be found in a book of this sort. The teacher can carry a class through it in thirty days, or extend its use through a term, as the case may require. But this or any other book should not be used without specimens. This involves the use of such fresh, living animals as can be easily and cheaply obtained, and of a small school museum of prepared objects for illustration. The school library of reference should be supplemented by a small select museum which can be formed at less expense than the library itself.

The success of class-work in Zoology depends mainly on the teacher and the proper use of specimens.

While the book begins with the simplest forms and ends with the most complicated, the first lesson should be, as suggested in the prefaces to the author's more advanced books of this series, devoted to the examination of a fish with the aid of Chapter XXI., so that the student may have before him a standard by which to compare the lower forms.

Younger scholars or readers might omit the purely anatomical descriptions, which are in small type. Indeed, class-work in Zoology may be made easy or difficult, simply amusing and yielding useful information, or as disciplinary as the study of mathematics or the languages. To become in any way disciplinary, the student should be required to rigidly observe, compare, dissect, draw, and write out descriptions of the specimens or dissections, thus becoming an original observer and recorder.

But the student of modern Zoology needs something more than a knowledge of the structure of a few types; he should watch them while alive, observe their habits, see how they grow, learn how each kind of creature is adapted to its peculiar life; learn, so far as is possible, how and why certain groups have been successful in the struggle for existence, and why others have failed. Something can be done in this respect by young students. For valuable hints in this direction the author acknowledges his indebtedness to Miss Buckley's interesting "Winners in Life's Race," an excellent book for collateral reading in connection with the class-work.

Of the 265 wood-cuts, 111 have not appeared in the author's other books; of these 24 are original, having been prepared expressly for this book, 16 of them (Figs. 16, 58, 60, 78, 80, 177–8, 195, 199, 207–11, 240–1) having been drawn from nature by Prof. H. C. Bumpus, of Olivet College, under the author's direction. A few (8) have been drawn by the author. From Miss Buckley's "Winners in Life's Race," and "Life and Her Children" (D. Appleton & Co., publishers), Figs. 51, 137, 217, 219, 247, and 251 have been copied by electrotypy. Figs. 40 and 46–49 are copied from Romanes' "Jelly-fish, Starfish, and Sea-urchins;" Figs. 265 and 266 from Hartmann's "Anthropoid Apes," both works published by the Messrs. Appleton. Figs. 223–28, 230–32, have been copied from Mivart's "The Cat," by permission of the publishers, Messrs. Charles Scribner's Sons. Figs. 216, 250, 252, and 253 have been copied from Claus' "Text-book of Zoology;" Fig. 126 from Harris' "Treatise on Insects," and Figs. 127–9, 132–3, from S. H. Scudder's "Butterflies." From Graber's "Die äusseren mechanischen Werkzeuge der Thiere" have been copied Figs. 76, 77, 100, 101, 108, and 212–15; from Dr. G. Dimmock's essay on the mouth-parts of flies, Fig. 117, and from W. H. Edwards' great work on the butterflies of the United States, Fig. 126 A–D.

For collateral reading, the teacher or student is referred to the works of Huxley, Gegenbaur, Claus, Darwin, and Brooks' "Invertebrate Zoology;" for more special works, Woodward's "Manual of Mollusca," Packard's "Guide to the Study of Insects," Coues' "Key to North American Birds," Baird, Brewer, and Ridgway's "Birds of North America;" and for a magazine of natural history to the "American Naturalist," Philadelphia, and "Nature," London. A further list of works of reference is given in the author's larger "Zoology."

The author is well aware of the difficulty and limitations in carrying out the plan of such a book as this, and hopes to be dealt with leniently by the critics. He would be thankful for suggestions and for corrections of errors.

PROVIDENCE, R. I., May, 1886.

PREFACE TO THE SECOND EDITION.

BESIDES a number of minor corrections, this edition has been, it is hoped, improved by the addition of four brief chapters, with illustrations, relating to the centipedes, etc. (*Myriopoda*), the spiders (*Arachnida*), the net-veined insects without, and those with, a complete metamorphosis, representing several of the smaller orders of the class Insecta. Additional sections on the ctenophores, and on the horseshoe crab and its allies the trilobites (*Podostomata*), have also been inserted.

PROVIDENCE, July, 1887.

PREFACE TO THE FIFTH EDITION.

THE chief changes made in the present edition are three: first, the transfer of the chapter on Echinoderms to follow the chapter on Worms, since the former now appear to have been derived from some worm-like form, and agree in some details of structure with, and are on nearly the same plane of organization as, the higher worms. The second change is in the arrangement of the orders of Crustacea, the Branchiopoda being now regarded as the earliest and most generalized group. The third change is the addition of lists of and references to the most authoritative text-books and treatises both on general zoology and the special classes, and it is hoped that both teachers and pupils will use such works, many of which are well illustrated, for reference or study.

PROVIDENCE, May 26, 1892.

CONTENTS.

FIRST LESSONS IN ZOOLOGY.

INTRODUCTION.

THE study of nature is the study of everything about us which we can perceive by our senses. Every object which we can see on the earth is either a mineral or a living body. Mineral bodies are not only stones, crystals, or sand, but they include the air, water, and gases. Minerals do not live; they are lifeless bodies, while plants and animals are living bodies. The study of natural history is the study of minerals and rocks, of plants and animals; or, in other words, of our earth and the minerals composing it, and of the plants and animals which have either once lived or are now living on its surface.

Minerals sometimes appear to grow like plants, as in the frost which forms the delicate leaf-like tracery on our windows, and if we watch under a microscope the evaporation of a few drops of salt water, we can see the solid particles of salt in the water arrange themselves in delicate crystals, which actually grow, becoming larger by adding particle after particle to the outside. Thus small crystals may grow and become large ones. We see, then, that growth in minerals consists in the addition of particle after particle of solid matter to the outside of the growing body.

The Difference between Mineral and Living Bodies.—Now how do living bodies differ from minerals? The earth and sea teem with plants and animals each after their kind, and yet all these myriad forms are alike and differ from minerals in one respect: their bodies are composed of a substance like a clear jelly or the "white" of an egg. This jelly-like substance is called *protoplasm,* and it is contained in sacs of microscopic size, called cells (Fig. 1). Our bodies are made up of cells, and so far as we know there is no living being, whether plant or animal, which is not formed of this all-important living substance. Hence we are led to believe that this living jelly is the basis of life. The lowest one-celled plants and animals are composed of nothing but this fundamental jelly-like matter; and the seeds and eggs of the higher many-celled plants and animals are mostly made up of it.

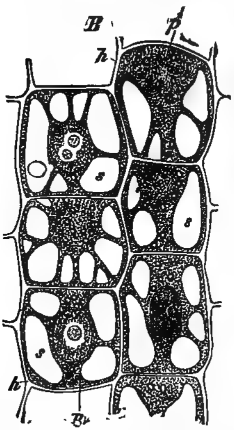


FIG. 1.—Cells of a lily, showing protoplasm (*p*); *s*, vacuoles, and *h*, the cell-walls. (Magnified 550 times.)

This living matter or protoplasm consists of mineral matter, to be sure, but so combined as to form a substance not found in the mineral world.

The most important materials composing protoplasm are gluten, a sticky substance made from flour and like macaroni, and albumen, which can be made either from vegetable starch or from the white of an egg, by heating them in water. In the protoplasm of plants are starch, cellulose, and many other substances, while in that of animals are gelatine, fibrin, etc.; but fundamentally they are alike, for when analyzed by the chemist they are both found to be formed of proteids, which are complex compounds of the elements carbon, hydrogen, oxygen, nitrogen, sulphur (and sometimes phosphorus), combined in very nearly the same proportions. Moreover the simplest one-celled plants and animals look alike, act in the same way, move in the same manner, so that in some cases we cannot say which is an animal and which a plant. Also some animals have in their bodies starch and cellulose, while some animals have no substance from which gelatine may be made.

While, then, living bodies, even the simplest, differ from minerals in manufacturing protoplasm and other substances, such as starch, fat, etc., within their bodies; unlike minerals, they grow by additions from within. Besides this, they multiply or reproduce, i.e., they set apart a portion of their bodies, as a seed or egg, which may grow up to be an oak or a bird; they have also the power of waste and repair.

Moreover living things "go." A watch "goes," but such a machine soon stops unless the spring is wound up. When it stops, however, we do not say that the watch dies. When, however, a plant stops going, i.e., when the sap ceases to flow, the leaves wither and the root dries, it dies; when a dog's heart stops beating and the blood ceases to flow, it dies. Minerals do not die.

So we see that living bodies differ from minerals in four respects: 1. Their bodies contain and are built up of protoplasm; 2. They grow from within; 3. They reproduce from seeds, germs, or eggs; and 4. All living bodies die.

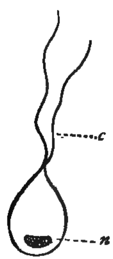


FIG. 2.—Red-snow, a plant. *c*, cilia; *n*, nucleus. (Highly magnified.)

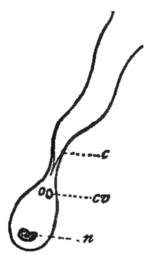


FIG. 3.—A Monad. *c*, cilia; *n*, nucleus; *cv*, contractile vesicle.

The Differences between Plants and Animals.—Any child can see that a fern, or lily, or elm-tree are very unlike a fish or dog. Such animals as these differ from lilies or trees in being able to move about, in having a stomach, heart, eyes, ears, a nose, nerves and muscles. But when we place under the microscope the red-snow or a similar plant (Fig. 2) and compare it with a monad (Fig. 3), which is one of the lowest animals, it is difficult to tell which is vegetable and which animal. Both are formed of protoplasm, both move about by little thread-like appendages, and both

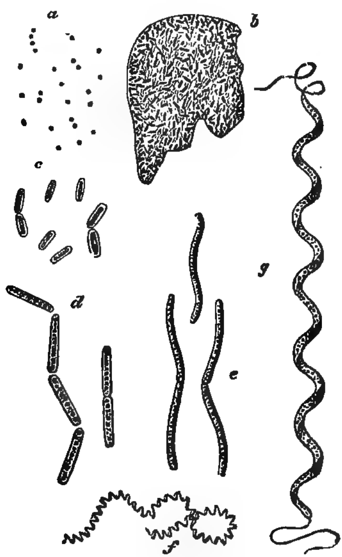


FIG. 4.—Forms of Bacteria, or disease-germs. (Highly magnified.)

multiply in the same manner. The slime-moulds, and even the disease-germs (Fig. 4), are by some authors regarded as animals.

It is only by a study of the connecting links between these lowest beings, leading up to what are undoubted animals or plants, that we are enabled to refer them to their proper kingdom.

As a rule, plants have no special organs of digestion or circulation, and nothing approaching to a nervous system. Most plants absorb inorganic food, such as carbonic-acid gas, water, nitrate of ammonia, and some phosphates, silica, etc., all of these substances being taken up in minute quantities. Low plants live on dead animal matter, and promote the process of putrefaction and decay, but the food

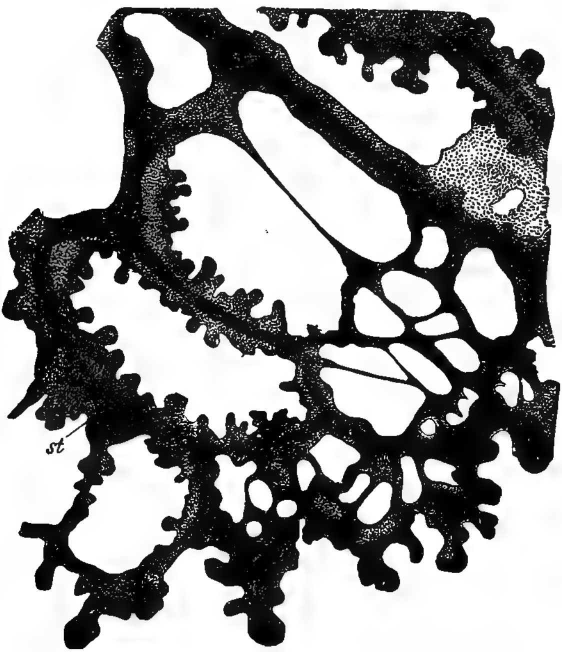


FIG. 5.—Part of a Slime-mould. (Magnified 350 times.)

of these organisms is inorganic particles. The slime-moulds (Fig. 5), however, envelop the plant or low animals, much as an *Amœba* throws itself around some living plant, and absorbs its protoplasm; but slime-moulds, in their manner of taking food, are an exception to other moulds. The lowest animals swallow other living animals whole or in pieces; certain forms near *Amœba* bore into minute plants and absorb their protoplasm; others engulf silicious-shelled plants (diatoms and desmids) and absorb the protoplasm filling them. No animal swallows silica, lime, ammonia, or phosphates as food. On the other hand,

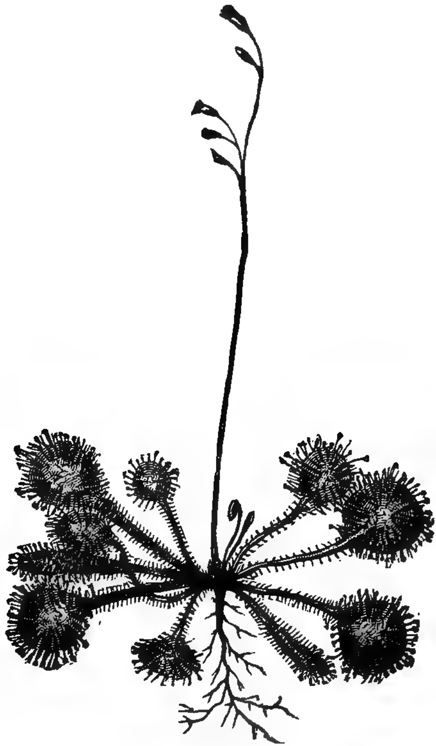


FIG. 6.—A Sun-dew plant. (Natural size.)

plants manufacture or produce protein in the shape of starch, albumen, sugar, etc., which is animal food. Plants during the assimilation of their food, absorb carbonic acid, and in sunlight exhale oxygen; but while they are growing and performing other functions, they, like animals, consume oxygen and exhale carbonic acid.

Animals move and have special organs of locomotion; few plants move, though minute forms have thread-like processes or vibratile lashes (cilia) resembling the flagella of monads, and flowers open and shut; but these motions of the higher plants are purely mechanical, and not performed by special organs controlled by nerves.

Certain plants, as the sun-dew (Fig. 6), can move the slender-stalked sensitive glands on their leaves, which secrete a sticky substance. When a fly alights on the leaf the glands slowly bend toward the fly, and the leaf rolls over so as to entrap it. The fly thus caught finally dies, and its body is dissolved and digested by an acid fluid formed in the leaf, whose tissues absorb the digested fly, which serves as food for the plant. We thus notice in some plants a process like digestion, which is peculiar to animals.

Finally, animals are guided by instinct; many insects and higher animals exhibit traces of a reasoning power, and lastly man, though with an animal body, possesses intellectual, moral, and spiritual faculties.

Definition of Zoology.—Plants form the Vegetable Kingdom, and animals the Animal Kingdom. The study of plants is called *Botany*, and the study of animals *Zoology;* while the study of living beings in general, whether plants or animals, is termed *Biology*, which means the science of living beings.

How to Study Animals.—We study an animal, a fish for example, by observing its form, noticing its head, trunk, its fins, etc. After a long and patient examination of the outside of the body we dissect it, examining the heart, stomach, brain and nerves, etc., and the skeleton. After a thorough study of a single specimen we should then compare it with a frog, and thus make our studies comparative. As the result of such an examination we shall obtain a fair idea of the form and structure of the back-boned or vertebrate animals.

Before studying this book we earnestly advise the student to read the account of the anatomy of the fish, and also study the skeleton and dissect a perch or any common fish. The student will thus have a standard of comparison, a standpoint from which to survey the animal world as a whole. He will thus learn the relations of the skeleton or solid framework of an animal to the muscles, etc., and learn what a heart, lung, or eye is. Then he can the better understand the structure of the lower animals.

Moreover we should study how the fish swims, how its heart beats, or its eyes see. This is studying the *Physiology* of the animal. Then we should learn how the animal grows or develops from the egg, and this is called *Embryology*, the germ of an animal being called an embryo. The bodies of animals are made up of *cells*. A cell is a microscopic mass of protoplasm. Animalcules are composed of but a single cell; such creatures are said to be *unicellular*, but most animals are formed of bone, cartilage, muscles, nerves, etc. These parts are made up of cells. Hence these animals are many-celled. The cells form *tissues*, such as muscular or nervous tissue. The study of cells and tissues is called *Histology*. Finally, we should acquaint ourselves with the habits and mental traits of the animal, and this is called *Psychology*.

A fish is the most convenient vertebrate for use in ordinary school laboratory work. The object of these lessons is to induce the scholar to depend as far as possible upon the use of his own eyes and brain. He should observe with care some of the common animals here described, most of which he can readily obtain, and then study their form, habits, and the leading features of their anatomy. After examining a jelly-fish, star-fish, clam, lobster, insect and fish, and reading about their mode of growth, he will obtain a knowledge, however elementary, of the principal groups of the animal kingdom which he will remember throughout life.

Classification.—There are estimated to be upward of 250,000 species of animals now living on the surface of the earth. How all these forms are related and how they differ comprises what is called the classification of animals, or SYSTEMATIC ZOOLOGY.

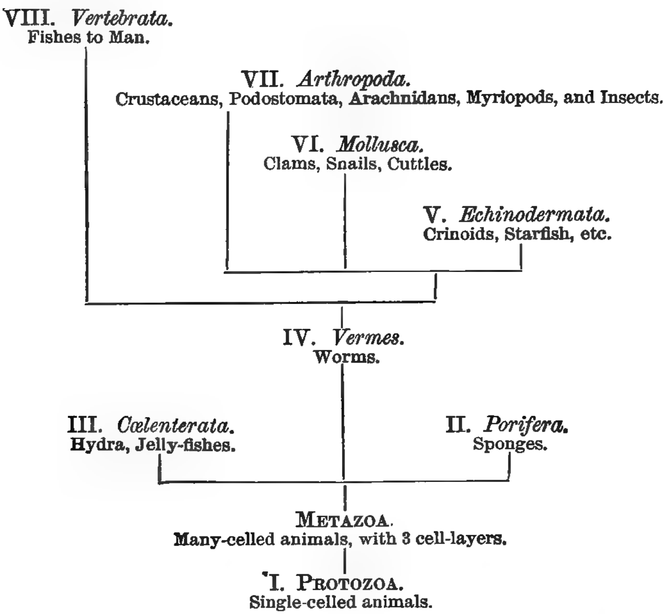
When Linnæus, the father of natural history, undertook to classify animals, he divided the animal kingdom into classes, orders, genera, and species. Thus at present all animals, such as fishes, birds, or mammals, which have a backbone are placed together in the branch or sub-kingdom of Vertebrates; those vertebrates, such as the cat, horse, or cow, which suckle their young are placed in the class of Mammals; those mammals which have claws and teeth adapted for seizing and chewing flesh are carnivorous, i.e., belong to the order of *Carnivora.* The order of Carnivora is composed of a number of families, such as the cat family, the dog family, etc. A family is composed of one or more genera, and a genus is made up of species and varieties, the latter being composed of individuals.

Thus the principle of zoological classification consists in placing animals which are alike by themselves into distinct groups. The following table expresses the zoological position of the cat:

Kingdom of Animals;
Sub-kingdom, or *branch,* Vertebrates;
Class, Mammalia;
Order, Carnivora;
Family, Felidæ;
Genus, Felis;
Species, Felis domesticus Linnæus;
Variety, Felis domesticus Angorensis.

The animal kingdom is divided into two series of branches: those for the most part composed of a single cell are represented by a single branch, the *Protozoa* (animalcules). Those animals whose bodies are formed of many cells are called *Metazoa*. The series of *Metazoa** comprises the seven higher branches, i.e., the *Porifera*, *Cœlenterata*, *Vermes*, *Echinodermata*, *Mollusca*, *Arthropoda*, and *Vertebrata*. Their relationship may be expressed by the following

TABULAR VIEW OF THE EIGHT BRANCHES OF THE ANIMAL KINGDOM.



Paleontology.—The existing animals were preceded in the earth's history by multitudes which are now extinct. Their remains in the shape of bones, teeth, or shells, etc., are called fossils, and the study of fossil animals and plants is called Paleontology.

* In the latter group the cells are arranged in two, mostly three, fundamental cell-layers. Of these cell-layers, the outermost is called the *ectoderm;* the middle, the *mesoderm;* the innermost, the *endoderm.*

Geographical Distribution.—Animals are not arbitrarily scattered over the earth's surface, but form assemblages of species which people any given spot or country. Such an assemblage of animals inhabiting a given place or area is called a *fauna*. Thus we may speak of the fauna of New York, or of the United States, or of North America. The animals of the arctic region belong to the arctic fauna; those of the tropics constitute the tropical fauna. We may also speak of the fauna of the land or of the ocean.

Where the physical geography—i.e., the contour of the surface, the plains, valleys, and hills—is similar in character and the climate the same, the fauna is much the same; but when these characteristics of soil and climate change, as in passing from lowlands to highlands, or from south to north, the assemblage of animals will be found to change in a corresponding ratio. And as there are no definite limits to any large area of the earth's surface, the physical features of one area merging insensibly, as a rule, into adjoining districts, so adjoining faunæ merge into one another, and a certain proportion of the species may range through two or more faunal areas.

At almost any point in temperate North America the fauna is found to consist of three elements—i.e., mainly a temperate, with a certain percentage of boreal or subarctic, and of southern or semi-tropical forms; and if the point be situated near some lofty range of mountains, a fourth element—i.e., a purely arctic or alpine feature—is superadded.

Marine animals are also assorted into faunæ, which are nearly as well marked as land-faunæ. Below a depth of a thousand feet, where the temperature is from 32° to 40° F., deep-sea animals occur, forming the abyssal fauna.

General Works on Zoology.—*T. H. Huxley:* A Manual of the Anatomy of the Invertebrated Animals, 1877; A Manual of the Anatomy of the Vertebrated Animals, 1871.—*C. Gegenbaur:* Elements of Comparative Anatomy, 1878.—*C. Claus:* Elementary Text-book of Zoology, 2 vols., 1884–85.—*A. Lang:* Text-book of Comparative Anatomy, Pt. I., 1891.—*Coues and Kingsley's* Standard Natural History, 6 vols., 1884–85. Also, Darwin's Origin of Species, and the works of Lamarck, Semper, Haeckel, Wallace, Eimer, and Weismann.

CHAPTER I.

THE AMŒBA AND OTHER ROOT-ANIMALCULES.

THIS book begins with the lower, simpler, one-celled animals and ends with the more complex, i.e., birds and beasts, since this is the most natural method. The lower forms of animal life, such as worms, shell-fish and insects, appeared in the earth's history before the back-boned creatures. It is therefore better to lead the student from the simpler and earlier to the more complex and later animal forms, just as in studying history we begin with that of uncivilized or barbarous peoples, and study their progress upward to civilization. To begin the study of zoology by first taking up the beasts and birds is like reading history backwards.

We will begin our lessons, then, with the simplest being we can readily find, and that is the Amœba (Fig. 7). It is to be sought for in standing pools, where it lives on the leaves or stems of submerged plants, or in the mud or ooze at the bottom. Taking up a drop of water from the bottom of such a pond and placing it under high powers of the microscope, we may, after close examination, detect a very small, moving mass of jelly-like substance or protoplasm. As it glides over the glass the sides of its body bulge out, or it suddenly throws out lobes or projections from various parts of its body as if it were falling apart; then it retracts these transparent root-like processes, which are called *pseudopodia*, or false feet, and becomes smooth and rounded, like a drop of thick syrup. Throughout the body-mass are granules which have a rude sort of circulation. There is also in or near the middle a clear round body called the *nucleus*. In all respects the Amœba is a *cell*, i.e., a bit of protoplasm with a nucleus in the middle.

Besides the nucleus, a clear, round, pinkish space which enlarges and contracts is usually present. This is called the "contractile vesicle."

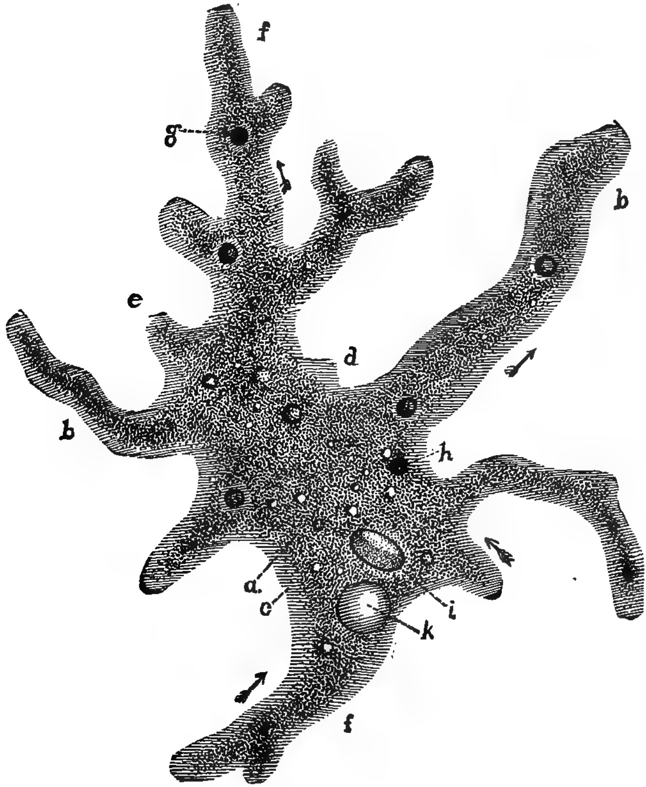


FIG. 7.—*Amœba proteus.* *a*, inner granular portion; *c*, outer clear portion of the body; *d*, a simple pseudopod; *f*, a branched pseudopod; *g*, food-vacuole; *d*, a pseudopod beginning to grow out; *e*, one a little more developed; *h*, food-ball; *i*, nucleus; *k*, contractile vesicle. (Magnified 200 diameters.)

The food of the Amœba consists of minute plants, or of animalcules. After selecting its food, as for example a minute plant, it engulfs or swallows it by moving toward the object and gradually closing around it, until the object is enveloped within the body, which is so transparent that the food-object can be seen through it. The Amœba has the power of digesting and of distributing and absorbing the food (Fig. 7, *h*, food-ball) when digested.

The Amœba reproduces its kind by simply dividing into two portions, as seen in Fig. 8. After becoming encysted or forming a round mass as at *B*, it breaks out of the cell-wall and becomes free and irregular in shape as at *A*. Self-division then begins as at *C*, the nucleus dividing into two, until at *Da* and *Db* two separate individuals are formed.

When the Amœba is touched it (1) contracts its body—

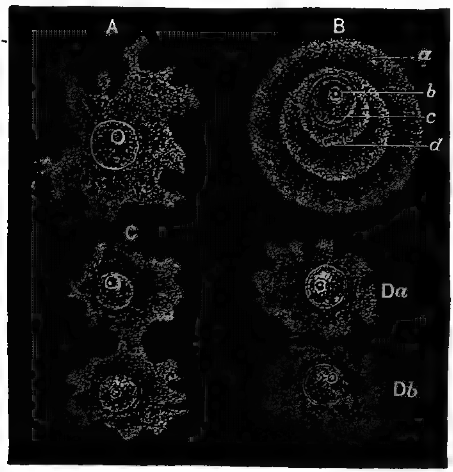


Fig. 8.—*Amœba.* *A*, before division. *B*, the same in its resting stage; *a*, cyst or cell-wall; *d*, body-mass; *c*, nucleus; *b*, nucleolus. *C*, Amœba, nearly divided. *D*, two young Amœbæ, the result of division. (Highly magnified.)

it is thus said to be contractile—and (2) performs automatic movements; also, like the higher animals (3), it swallows food; (4) chemical changes in the food take place: in other words, it digests its food, i.e, separates or secretes the portion necessary to nourish its body from those portions which it excretes or rejects as waste; (5) it may also be said to breathe, the changes involved in taking food, especially oxygen, causing the production and excretion of carbonic acid; (6) and finally, it can reproduce its kind. Thus we have foreshadowed in this exceedingly simple being all the important functions of animal life. Besides the *Amœba,* which is a representative of this class, there are a number of fresh-water forms which are protected by simple, silicious shells; but in the sea there are thousands of species whose shells are partitioned into chambers, and are usually perforated with holes like a sieve, through which

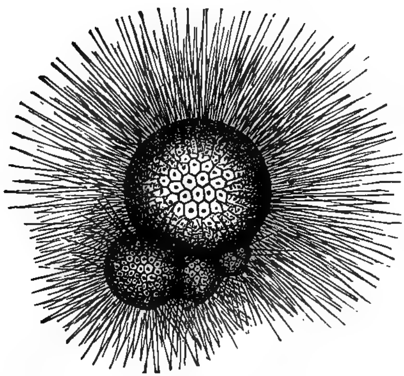


Fig. 9.—A Foraminifer. *Globigerina*, **magnified 70 diameters.**

the animal protrudes its false feet or pseudopods. These shelled Rhizopods are called Foraminifera (Latin, *foramen,* a hole or aperture; *ferens,* bearing. Figs. 9 and 10). They have the same power as snails and clams to separate or secrete from the sea-water the lime or silica dissolved in it, and to build up a shapely, graceful, and strong shell; while others gather with their finger-like processes grains of sand or bits of shell and form them into houses of stone-work. Many Foraminifera float in calm weather on the surface of the sea, and when they die their shells slowly sink to the bottom. They are exceedingly abundant, and the shells at the bottom accumulate in such quantities as to make a gray mud or ooze, forming the bottom of the ocean at great depths: this soft, deep mud is called Globigerina ooze. Chalk is largely made up of the calcareous shells of Foraminifera; before it became hardened into rock-masses it was a kind of Foraminiferous ooze.

Certain root-animalcules secrete a silicious shell; a few live in fresh-water ponds,* but the majority live in the sea.

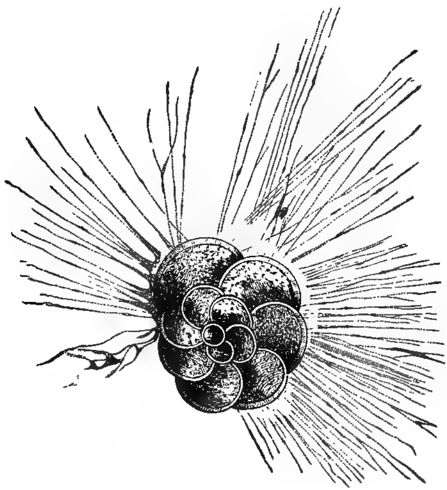


FIG. 10.—*Rotalia.* A Rhizopod, showing the pseudopodia.

Their shells possess wondrous beauty and variety of ornamentation.

A few root-animalcules have been seen to develop from little monad-like germs, which move about by means of two little threads or tails.

All the root-animalcules form the class of Protozoa known as *Rhizopoda, since all move by root-like pseudopods, and nearly all, except Amœba, are protected by shells.**

* *Leidy:* Fresh-water Rhizopods of North America, 1879.—*Haeckel:* Die Radiolarien, 3 vols., Berlin, 1862–88 ; Report on the Radiolaria of H.M.S. Challenger, 1887. With the works of Schulze, Hertwig, Carpenter, J. Müller, etc.

CHAPTER II.

THE MONAD AND OTHER INFUSORIANS.

If we allow a little dried grass or hay or a piece of fish oı flesh to stand in a glass of water for a day or two, thus making what is called an infusion, and then examine a drop of this water, it will be found to teem with myriads of microscopic creatures, called Infusorians, because they are found in infusions. The simplest and minutest form of infusorian is the monad (Fig. 11).

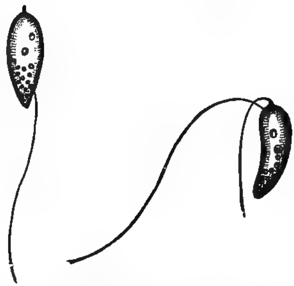


Fig. 11 —Monad from an infusion of decayed flesh. *Heteromita putrina* Stokes. (Magnified 1500 diameters.)

In swimming, the monad stretches out the whip-lash-like appendage called the flagellum, which vibrates with an undulating, whirling motion, and produces a peculiar graceful rolling motion of the monad. When the monad is fixed, the flagellum is used to convey food to the mouth, which lies between the base of the flagellum and beak, or "lip." The food is thrown by a sudden jerk, and with precision, directly against the mouth.

Ascending a step higher, we come to Infusoria which are covered with *cilia*, or hair-like processes, by which they glide about over submerged leaves, etc. One of the largest and commonest Infusorians is the *Paramecium* (Fig. 12). This animalcule is a mass of protoplasm, representing a single cell. In the body-mass are excavated a rude mouth, and a throat leading to a so-called stomach or digestive cavity. Three hollows in the body form the contractile vesicles.

A solid central mass constitutes the nucleus (N). A smaller form is called *Chilodon* (Fig. 13).

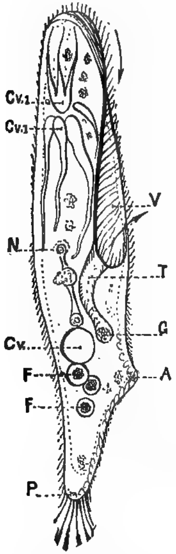


Fig. 12.—*Paramecium caudatum.* A view from the dorsal side magnified 150 diameters. P, the tail; T, the throat; A, the posterior opening of the digestive cavity; Cv^1, the anterior, and Cv, posterior contractile vesicles; N, a solid central mass or nucleus; V, the large vibratile cilia at the edge of the mouth; F, masses of food.

The trumpet-animalcule (*Stentor*) is large enough to be detected with the unaided eye. This Infusorian attaches itself at one end by a stalk, and builds up a slight tube, into which it contracts when disturbed. The Stentor may be sometimes observed multiplying by self-division.

The process of self-division takes place in two hours. Fig. 14, *f*, represents the final stage when the two individuals swim away separately, each assuming the original adult form, *a*.

We have thus seen that in the one-celled animals there is a considerable range of form. Their organs are few and of the simplest kind, and yet primitive as the Protozoans are, they vary greatly in form and in habits, and certain kinds which grow in compound assemblages partially bridge over the gap separating the one-celled from the many-celled

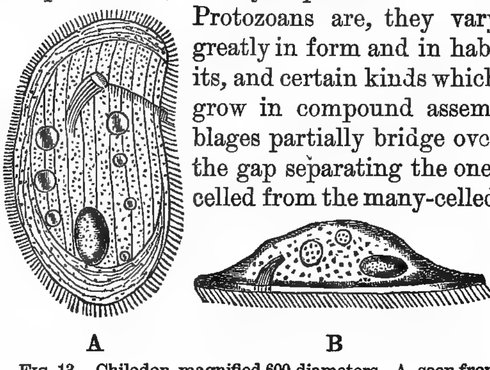


Fig. 13.—Chilodon, magnified 600 diameters. A, seen from beneath; B, seen sideways.

animals. The one-celled animals form a branch of the animal kingdom called *Protozoa*, from the Greek words *protos*, first, and *zoon*, animal, meaning primitive or simplest animals. *They differ from all other animals in being formed of a single cell.* Nature is greatest in her smallest things, and of these inconceivably minute beings there are many thousand species which act as scavengers to purify the sea and fresh waters. Certain kinds live in the bodies of insects, etc., and are called *Gregarinida* (Fig. 15).

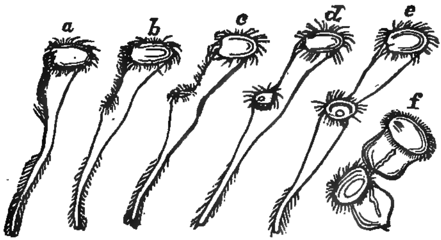


Fig. 14.—Process of fission in *Stentor*. *b*, a new Stentor budding out; *e*, ready to separate from the original one; *f*, the two in a contracted state.

Classes of Protozoa.

1. Body jelly-like, formless, usually shelled.... *Rhizopoda.*
2. Body cylindrical; parasitic................ *Gregarinida.*
3. Body ciliated....................... ..... *Infusoria.*

These beginnings of life, simple as they appear, seem to find food, to overcome the perils of life and to survive the attacks of their enemies, though they have no outer organs, such as legs, jaws, eyes; or organs of defence. Their strength lies in their wonderful plasticity of form, mobility, and minuteness, hence their striking power of adapting themselves to untoward circumstances. They flourish in such hosts that were their growth not checked there would be no room in the waters of the land or the sea for other animals. They serve as food for sponges, worms, shell-fish, and the smaller shrimps, which swallow thousands of them at a single mouthful; and thus, though millions are born each hour, millions die each hour, and hence their numbers are kept within due limits. As it is, the Protozoans are wonderfully

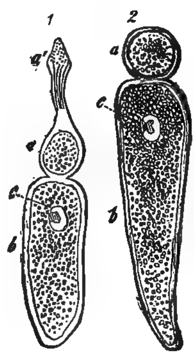


Fig. 15. – Gregarina from the alimentary canal of a beetle. 1, younger state, with a beaklike continuance (*a′*) of the head; 2, older: *a*, anterior end; *b*, hinder part of the body; *c*, nucleus. (Highly magnified.)

adapted each to its peculiar abiding-place or habitat. The soft shelless kinds live in the mud or on the leaves of plants in quiet pools or lakes; they people drops of water in the gutters of our houses, flourish in the dew-drops by the wayside, in the dampness of moss; while certain monads live in the blood and other fluids of our bodies. Certain venturesome kinds go about more freely in their one-chambered shells, while those living on the high seas are protected from the force of the waves by their many-chambered shells, and there are larger kinds with heavy lime shells, which live on coral-reefs, where they are exposed to the beating of the surf. Everywhere do we find a harmony between the form and mode of life of these humble beings and the world about them.

From the study of the simplest animals, as well as plants, which are without complicated organs to do special kinds of work, we realize that life is not the *result* of organization, but rather the *cause* of it.

While we do not, and may never, know what life is, we can yet understand that the protoplasm which forms the bodies of the simplest beings is only the vehicle or material in and through which the life-forces act. The ultimate origin of what we call life is thus far an inscrutable mystery.

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CHAPTER III.

THE SPONGES.

It is a great step from an infusorian to a sponge—from a one-celled to a many-celled animal. Formerly sponges were supposed to be plants, but they are now known to be composed of numerous cells, arranged in three layers, and to develop from eggs like the higher animals.

A sponge, then, is a cellular sac (Fig. 16) with digestive

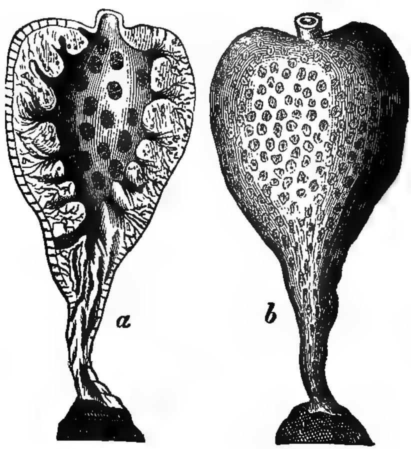

FIG. 16.—A longitudinal section through a simple calcareous sponge, showing the simple central cavity; *b*, showing a single osculum at the top, and the many mouths over the surface.

chambers or minute rude stomachs lined with ciliated cells, the whole sponge-mass being supported by an irregular basket-work of needle-like bodies called spicules (Fig. 17).

Upon cutting a dry sponge in half there are to be seen large canals which have large openings called *oscula;* these are really openings for the exit of waste matters. Among these large openings are multitudes of minute openings which serve as mouths. These mouths lead by branching canals

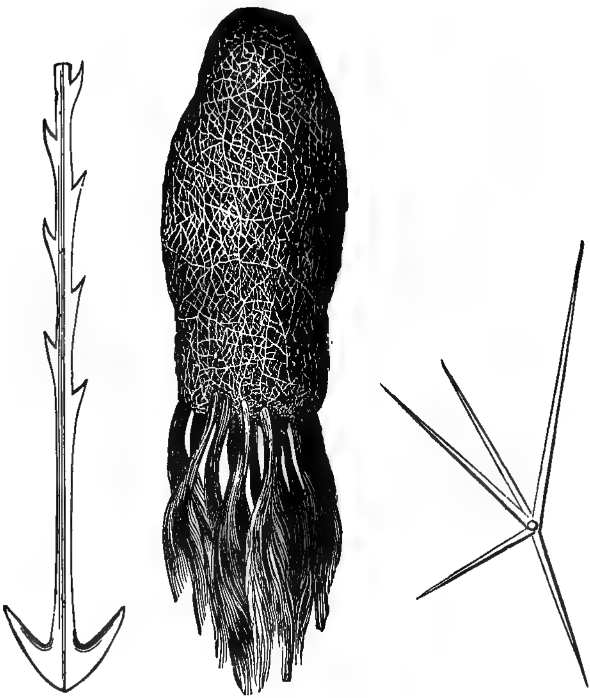

FIG. 17.—*Pheronema Annœ*, half natural size, with stellate and anchor-like spicules, much enlarged.

into little pockets or chambers which are lined with digestive, ciliated cells; the sponge, then, has myriads of mouths and stomachs (Fig. 18).

Sponges develop, like all the higher animals, from true eggs. The egg, after fertilization, begins to grow, and divides into two, four, eight, sixteen, and more spheres, until it looks like a mulberry (Fig. 19, *C*). The cells further multiply, and arrange themselves into an outer (ectoderm) and inner layer (endoderm). Some of the cells are ciliated, and in this state the germ (*E*) leaves the parent sponge and swims about in the sea, finally fixing itself to some seaweed or rock.

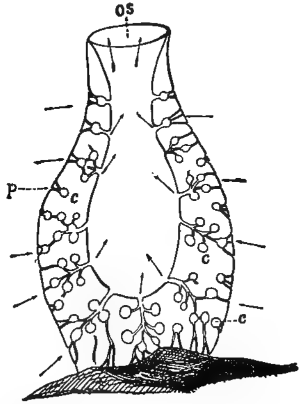

FIG. 18.—*os*, osculum; *p*, pore or mouth, towards which the outer arrows point; *c*, ciliated chambers.

Of the marketable sponges there are six species, with numerous varieties. They are available for our use from being simply horny or fibrous, having few flinty or silicious spicules. The Mediterranean sponges are the best, being the

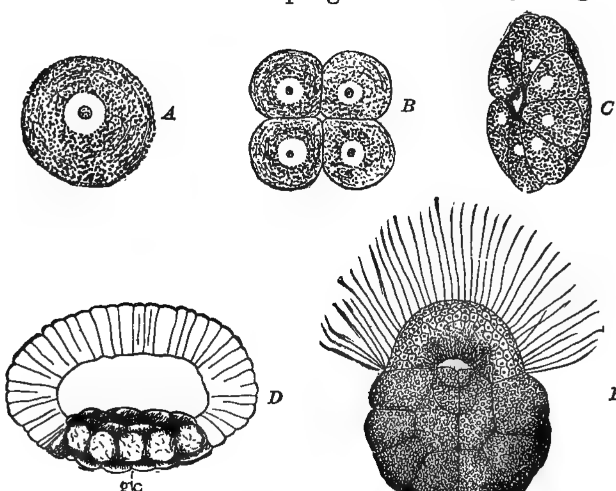

FIG. 19.—Development of a sponge (*Sycon raphanus*). *A*, ripe egg; *B*, stage with four segmentation-cells; *C*, morula stage; *D*, blastosphere, with large dark granular cells (*gc*) at the open pole; *E*, free-swimming larva, one half of the body (endodermal) being formed of long ciliated cells, the other (ectodermal) of large granular cells. The mesoderm develops later. (All highly magnified.)

softest; those of the Red Sea are next in quality, while our West Indian species are coarser and less durable. Our West Indian glove-sponge corresponds to the Turkish cup-sponge and Levant toilet-sponge of the Mediterranean. The wool-sponge of Florida and the Bahamas is used as a horse- or bath-sponge.

The sponges are so unlike other many-celled animals that they form a branch by themselves called *Porifera.*

We see, then, that *the sponge is composed of numerous cells, which are arranged in layers and form tissues, but it has no single definite mouth or stomach, and the shape of the body is indefinite.*

Cells grow by absorbing or taking in cell-food—i.e., by the assimilation of nutritious matter from without, and this food may be in masses of considerable size when seen under the microscope. Cells multiply by self-division. The egg-cell of the sponge, and indeed of all the higher animals, undergoes division of the yolk into two, four, eight, and afterward many cells; the cells thus formed become arranged into two layers or sets called germ-layers. The outer is called the *ectoderm,* and the inner the *endoderm.* A third germ-layer arises between them, called the *mesoderm,* or middle germ-layer. From these germ-layers, or cell-layers, the *tissues* of the body are formed, such as muscle, bone, nerve, and glandular tissue. These tissues form *organs,* hence animals (as well as plants) are called *organisms,* because they have certain parts formed of a particular kind of tissue set apart for the performance of a special sort of work or physiological labor. This separation of parts for particular or special functions is called *differentiation ;* and the highest animals are those whose bodies are most differentiated, while the lowest are those whose bodies are least differentiated; hence *high* animals are *specialized,* and, on the other

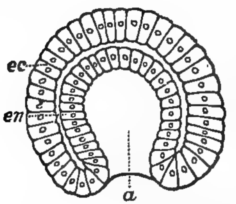

FIG. 20.—A two-layered germ. *ec*, ectoderm; *en*, endoderm; *a*, mouth opening into the digestive cavity.

hand, *low* animals are *simple*. Thus differentiation of organs involves the division of physiological labor.

For example, an Amœba has but a single organ, a nucleus; but still it moves. A more varied amount of work is done by the infusorian with its cilia, its incipient mouth, and its contractile vesicle. Sponges with their distinct cells, mouths, digestive chambers, eggs, and spicules do a still greater amount of varied work. The jelly-fish, with its nervous system, muscles, stomach and eyes, each performing its separate duties, affords an instance of still greater differentiation of parts, and consequent division of labor; while in the lobster, butterfly, or fish or bird, the subdivision of the parts of the body and of the work done by each separate organ is still greater and more wonderful.

The sponges are found in all parts of the sea, in shallow or deep water, and in very different circumstances; some grow in mud; others, like the colossal Neptune's cup, stand boldly up in the water on the coral-reef, and others grow in flat patches over the surface of stones and shells. Still others bore tunnels into shells and lime-rock, where, safe from harm, they do much good in causing the shells and stones to break up into gravel and sand, thus making a soft bed for worms and other creatures to live in. Sponge-life is spread throughout the ocean, in its abysses as well as its shallows, in fresh-water lakes and in sluggish streams, and everywhere it touches that of many other creatures. Yet, owing to their tough, flinty skeleton, few sponges are eaten by fishes and other large animals; but when they die the slime is devoured by the one-celled animals.

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CHAPTER IV.

THE HYDRA AND JELLY-FISH.

THE common Hydra (Fig. 21) may be found in fresh-water ponds attached by its base to the under side of the leaves of aquatic plants. It is not fixed permanently, but can move freely about. It is very small, just large enough to be seen without a magnifying-glass; it is usually pale green, but is sometimes brown. The mouth, which is surrounded with from five to eight tentacles or feelers, opens into the central cavity or stomach. The Hydra, attached to some leaf, reaches its tentacles out in all directions; a minute insect or young snail or Infusorian passing by will, if touched by these feelers, be instantly paralyzed, and then the feelers close over the helpless victim and it is drawn into the stomach and digested. This power of paralyzing and thus easily capturing active living creatures is due to the presence in the skin of the tentacles and body of what are called lasso-cells or nettling organs (Fig. 23, *c, d, e*), which are minute cells containing a long barbed thread coiled up within the cell. When the Hydra touches an animal swimming near it, thousands of these little barbed cords are darted into the

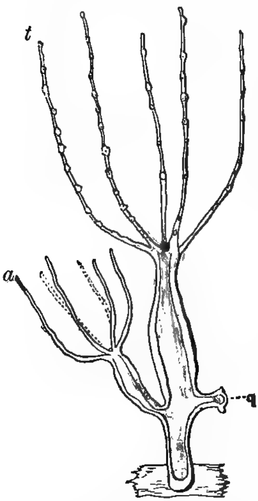

FIG. 21.—*Hydra*, with two young (*a*, *q*) budding from it; *t*, tentacles surrounding the mouth. (Much magnified.)

victim, which is instantly paralyzed, and thus falls an easy prey to its captor. These nettling organs are found in all Hydras, jelly-fishes and polyps.

The Hydra, like some other animals of simple structure, is capable to a wonderful degree of reproducing itself when cut into pieces. Trembly, as early as 1744, not only cut Hydras into two, each part becoming a perfect Hydra, but on slicing them across into thin rings he found that from each ring grew out a crown of tentacles; he split them into longitudinal strips, each portion becoming eventually a well-

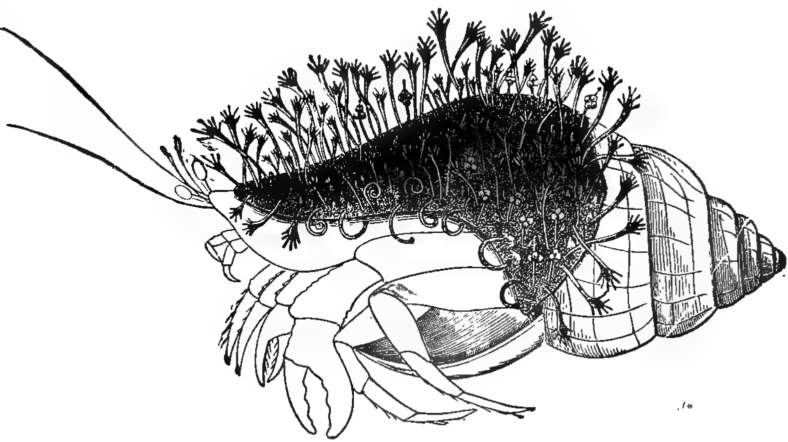

Fig. 22.—Colony of *Hydractinia* on a shell tenanted by a hermit-crab. (Natural size)

shaped Hydra, and finally he turned some inside out, and in a few days the Hydra swallowed and digested bits of meat, its former stomach-lining having now become its skin. The Hydra reproduces by budding as well as by eggs.

The process of budding is but a modification of that involved in natural self-division, and it is carried on to a great extent in Hydra, a much larger number of individuals being produced in this way than from eggs. Our figure (21) shows two individuals budding out from the parent

Hydra; the smaller bud (*q*) is a simple bulging out of the body-walls, the bud enveloping a portion of the stomach, until it becomes constricted and drops off, the tentacles meanwhile budding out from the farther end, and a mouth-opening arising between them, as at *a*. Budding in the Hydra, the Actinia, and other polyps, and in fact all the lower animals, is simply due to the division and consequent multiplication of cells at a special point at or near the outside of the body.

The simplest form next to Hydra is *Hydractinia*, a Hydroid encrusting shells (Fig. 22). In this form the indi-

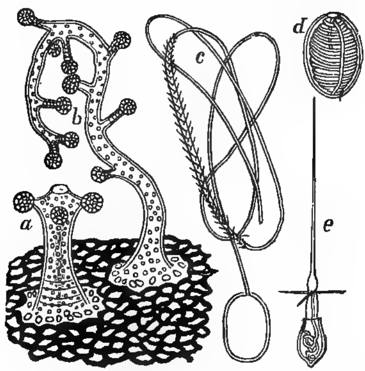

FIG. 23.—Animal of *Millepora nodosa*. *a*, nutritive zooid; *b*, tentaculated zooid; *c*, lasso- or nettling thread; *d*, the same coiled up in its cell; *e*, a third form. (All highly magnified.)

vidual is composed of three parts, each endowed with different functions and called *zooids*. These are, *a*, hydra-like, sterile or nutritive zooids; *b* and *c*, the reproductive zooids, both being much alike externally, having below the short rudimentary tentacles several round sacs, or "medusa-buds" which produce either male or female medusæ. These medusa-buds correspond to the free medusæ of *Coryne* (Fig. 25).

The minute animals of *Millepora* secrete large coral-like masses on the reefs of Florida and the Pacific Ocean. The name is derived from the numberless minute holes or pores scattered over the surface in which the nutritive (Fig. 23, *a*) and tentaculated zooids (Fig. 23, *b*) live. On breaking off pieces of the living coral one's hand is stung and made sore for days by the stings from the lasso-cells (Fig. 23, *c*, *d*, *e*), so poisonous is this coral-like growth.

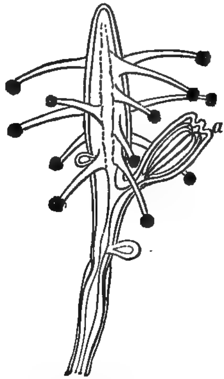

FIG. 24.—The polyp of *Coryne mirabilis*, with a medusa-bud at *a*. (Much enlarged.)

A common Hydroid on our northern shores is the *Coryne* (Fig. 24), which differs from the foregoing kinds in producing a free bell-like form called a *medusa*, or jelly-fish (Fig. 25). Most jelly-fishes are more or less bell or umbrella-shaped, and are delicate transparent creatures which move about in the water, by opening and closing the edge of the disk-like body. From the centre of the body hangs down a hollow proboscis-like tube, the stomach, from the base of which radiate four canals or passages which open into a circular passage around the edge of the disk. This is the *water-vascular* system, and the fluid it contains is sea-water mixed with the digestive fluid; this fluid thus rudely corresponds to the blood of higher animals. Four long thread-like tentacles in the Coryne hang down from the edge of the disk. These delicate jelly-fishes possess a nervous ring passing around the edge of the disk, and also eyes and usually ears situated at intervals on the edge of the disk. We thus find for the first time a true nervous system.

FIG. 25.—Free Medusa of *Coryne*, with the four long tentacles. (Enlarged.)

The medusæ arise from little bud-like swellings on the young or Hydroid (Fig. 24, *a*); these enlarge, and finally become detached and swim about as at Fig. 25.

The growth of a jelly-fish from the Hydra-stock is a very striking fact. It will be seen that the offspring of the Hydra is unlike its parent, but exactly like its grand-parent. There is a generation of Hydras, and a generation of jelly-fish, and these alternate, the Hydra not producing young Hydras, but young jelly-fishes.

Our common large jelly-fish or "sun-fish" so often thrown ashore on sandy beaches is the *Aurelia* (Fig. 29). It grows

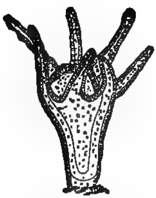

Fig. 26.—Larva or Scyphistoma of Aurelia. (Much magnified.)

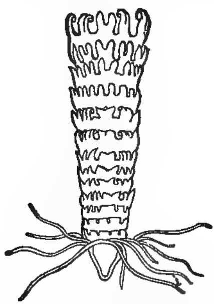

Fig. 27.—Strobila of Aurelia. (Magnified.)

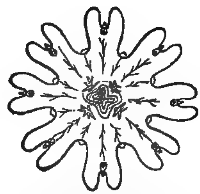

Fig. 28.—Ephyra or earliest free condition of Aurelia. (Magnified.)

eight or ten inches in diameter. Its tough, jelly-like, convex disk is smooth above, but hollowed out beneath into a broad stomach with a square mouth, the edge of which is minutely fringed, and bears four fringed broad, short tentacles. On the fringed margin are eight covered eyes situated in indentations, which divide the disk into eight slightly marked lobes. The four main water-vascular canals subdivide, as seen in Fig. 29, into numerous branches, which connect with the marginal vessel.

The Aurelia spawns late in the summer. The eggs pass out of the mouth into the water along the channelled arms, and in October the ciliated sac becomes pear-shaped and attaches itself to rocks, dead shells, or sea-weeds, and then assumes a Hydra form, with often twenty-four very long tentacles. This stage was originally described as a distinct animal under the name of *Scyphistoma.* In this Scyphistoma stage (Fig. 26) it remains about eighteen months. Toward the end of this period the body increases in size and divides into a series of cup-shaped disks. These saucer-like disks are scalloped on the upturned edge; tentacles bud out, and the animal assumes the Strobila stage (Fig. 27). Finally the disks separate, the upper one becomes

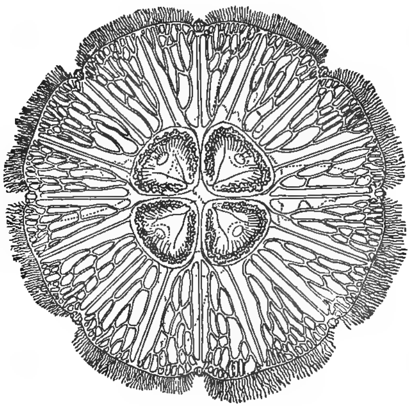

FIG. 29.—Aurelia, one-third of the natural size.

detached and dies, but the others swim away in the *Ephyra* form (Fig. 28) when about a fifth of an inch in diameter, and toward the middle or end of summer each becomes an adult *Aurelia* (Fig. 29).

In the wonderful changes of the Aurelia we have what is called a *metamorphosis ;* it is like the change of a caterpillar into a chrysalis and afterward a butterfly. The Scyphistoma may be compared to the caterpillar, the Strobila to the chrysalis, and the free jelly-fish to the butterfly. (See *Agassiz:* Contributions to the Natural History of the U. S., III, 1860; and *A. Agassiz:* Seaside Studies.)

CHAPTER V.

THE POLYPS AND CORAL-MAKERS.

The polyps are represented by the common Actinia of our coast (*Metridium marginatum*, Fig. 30), which is to be found between tide-marks on rocks under sea-weeds, or in

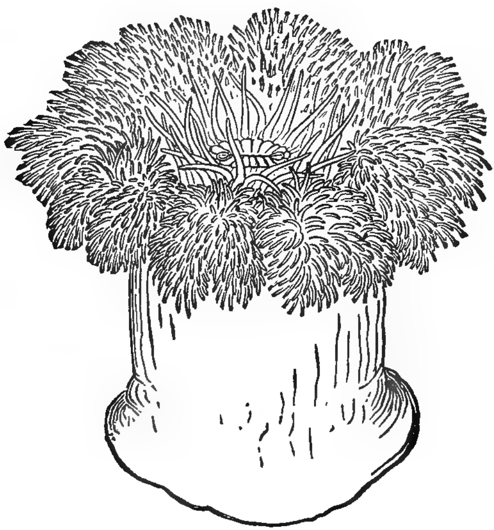

Fig. 30.—Common Sea-anemone. Natural size, with the tentacles expanded.

tidal pools, but grows most luxuriantly on the piles of bridges. It readily lives in aquaria, where its habits may be studied. An aquarium may be improvised by using a preserve-jar or glass globe, covering the bottom with sand, with a large flat stone for the attachment of the sea-anemone. By placing a green sea-weed attached to a stone in the jar, and filling it with sea-water, the animal may be kept alive a long time.

After observing the movements of the crown of tentacles as they are thrust out or withdrawn, and the eye-spots at the base of some of the tentacles, specimens may be killed expanded by the gradual introduction of fresh water, or by plunging them into picric acid. They should then be transferred to the strongest alcohol, and allowed to soak in it for two or three days until the tissues become hard enough to cut well. Then vertical and transverse sections may be made with a sharp knife. The first fact to observe is that the animal has an alimentary canal, there being a distinct digestive sac (*s*), separate from the body-walls, hanging suspended from the mouth-opening, and held in place by six partitions which divide the body-cavity into a number of chambers. The digestive sac is not closed, but is open at the bottom of the body, connecting directly with the chambers, so that the chyme, or product of digestion, passes down to the floor of the body, and then into each of the chambers. Fig. 31 shows at the base of the body the free edges of the partitions (*m*) of different heights, with the spaces between them through which the chyme passes into the body-cavity. For the complete passage of the circulating fluid the six primary partitions are perforated by a large orifice (*op*) more or less oval or kidney-shaped in outline. The digestive sac is divided into two divisions, the mouth and stomach proper, the latter when the animal is contracted being much shortened, and with the walls vertically folded, as seen in the cut.

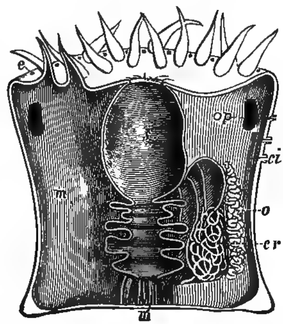

FIG. 31. — Partly diagrammatic sketch of the anatomy of an Actinia (*Metridium*) with the tentacles disproportionately enlarged. *s*, throat; *m*, mesenteries, or partitions; *o*, egg-gland; *cr*, mesenterial filaments; *e*, eyes; *op*, orifice through the septa.

In the tentacles are lodged the lasso-cells, and the tentacles are hollow, communicating directly with a chamber or space between the partition, and are open at the end. When a passing shrimp, small fish, or worm comes in contact with these tentacles, the lasso-threads are thrown out, the victim is paralyzed, other tentacles assist in dragging it into the distensible mouth, where it is partly digested, and the process is completed in the second or lower division of the digestive canal. The bones, shells, or hard covering of the animals which may be swallowed by the Actinia are rejected from the mouth after the soft parts are digested.

Sea-anemones have been found to have a slight sense of smell. Nearly all sea-anemones, besides arising from eggs, increase by budding, new individuals growing out at or near the base of the large one.

The coral polyps only differ from the sea-anemones in

FIG. 32.—Coral polyps, some expanded and others shut up within the hollow of the coral-stock.

secreting a limestone support or "coral-stock." Corals are either cup-shaped and single, or are compound, forming branching or rounded masses. The soft parts are supported by limestone partitions secreted in the chambers of the polyp.

All polyps develop from eggs, and at first appear as little oval, ciliated, free-swimming embryos (*gastrulæ*), which eventually become attached to the bottom of the sea.

Before the embryo becomes fixed and the tentacles arise, the lime destined to form the partitions begins to be deposited. Fig. 33, *C*, shows the twelve rudimentary partitions. These, after the young polyp has become stationary, finally enlarge and become joined to the external walls of the coral now in course of formation (Fig. 33, *C*), forming a foundation on which the polyp rests. *D* represents the young polyp resting on the limestone pedestal, with the tentacles well developed.

But little is positively known as to the rate of growth of

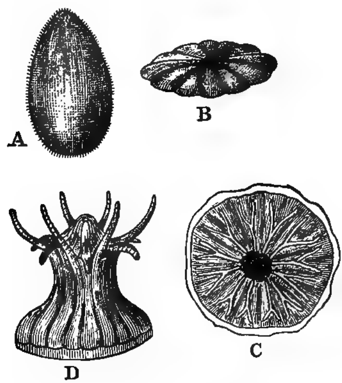

FIG. 33.—Development of a coral polyp. *A*, ciliated gastrula; *B*, young polyp with twelve partitions; *C*, *D*, young polyp farther advanced, with twelve tentacles; *C*, the corallum and limestone septa beginning to form. (Magnified.)

corals. A common brain-coral (*Mœandrina labyrinthica*), measuring a foot in diameter and four inches thick in the most convex part, attained its growth in twenty years.

The common red coral (*Corallium rubrum*) of the Mediterranean Sea is worked into various ornaments. The coral-fishery is pursued on the coasts of Algiers and Tunis, where assemble in the winter and spring from two hundred to three hundred vessels. The coral-fishermen, with large rude nets, break off the coral from the submerged rocks. About half a million dollars' worth of coral is annually gathered.

Of the larger corals the *Madreporaria* in the main are the true reef-builders. They are confined to waters in which through the coldest winter month the temperature of the water does not fall below 68° F., though usually the waters are much warmer than this, the mean annual temperature being about 73½° F. in the North Pacific and 70° F. in the South. Coral-reefs are abundant in the West Indies, but still more so in the Central Pacific, where there are a much greater number of species of corals. Along the Brazilian coast, as far south as Cape Frio, are coral-reefs. In depth living coral-reef-builders do not extend more than fifteen or twenty fathoms below the surface.

Fig. 34.—High volcanic island with a barrier and fringing reef.

Coral-reefs are divided into outer or barrier reefs and inner reefs (Fig. 34). The barrier-reefs are formed from the growth of corals exposed to the open seas, while the inner or fringing reefs are formed in quiet water, between a barrier-reef and the island.

Upon comparing a polyp with a sponge it will be seen that *the polyp has a more definite shape; it is a rude hollow cylinder; the mouth at the upper end, and sur-*

*rounded with one or more circles of tentacles.** We thus come in our ascent up the scale of animal life to creatures

Fig. 35.—Coral-island or atoll.

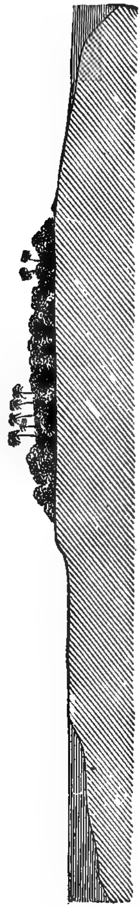

Fig. 36.—Section of a reef.

with a single, definite stomach or digestive sac, opening outward by a definite mouth.

* See the works of Darwin on Coral Reefs, Dana's Corals and Coral Islands, A. Agassiz's Seaside Studies in Natural History, 1871.

Besides the class of jelly-fishes or hydroids, and that of polyps, there is a third class, called *Ctenophora,* of which our *Pleurobrachia rhododactyla* is the commonest example. It is like a ball of transparent jelly, moving through the sea by means of eight rows of minute paddles, and throwing out from a sac on each side of the body two long ciliated tentacles.

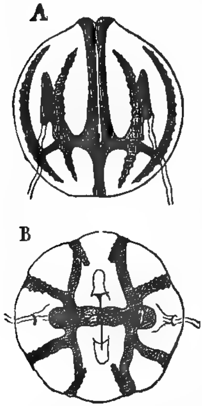

FIG. 36*a*.—View, of the gastro-vascular canals of a *Pleurobrachia*, from which the two retractile arms have been removed. *A*, from one side, the mouth-opening above; *B*, seen from the mouth end.—After Gegenbaur.

These beautiful animals derive their class name from the vertical rows of comb-like paddles (ctenophores) situated on eight meridional bands of muscles which serve as locomotive organs. They have a true digestive canal passing through the body. Like other animals of the class the food nourishes the body by means of canals passing off from the stomach, and called gastro-vascular canals.

Reviewing our steps up the scale of life, we see that we have come to *radiate animals, with a distinct mouth surrounded by tentacles containing thread-cells, opening into a gastric cavity which is used both for digestion and respiration; that they have a distinct nervous system, often eyes and ears; and that in the jelly-fishes there is a series of changes of form called a metamorphosis.*

All polyps, jelly-fishes, and Ctenophora are called Cœlenterata in allusion to their rudimentary digestive cavity.

CLASSES OF CŒLENTERATA.

1. Hydra-like; adults free-swimming, bell- or umbrella-shaped animals with a nervous system. *Hydrozoa* (Hydra).
2. A digestive sac held in place by partitions; polyp often forming coral................*Actinozoa* (Actinians).
3. Body round or oval, swimming by series of comb like paddles........................*Ctenophora.*

CHAPTER VI.

THE WORMS.

THE path which led up to the branch of Cœlenterates passed naturally, so to speak, by way of the group Gastræads,* and the sponges; we must now retrace our steps and take a new path, which will lead us to the worms. This path has not been very clearly pointed out by our studies of nature, but certain of the young of the lowest worms are so simple that it is difficult to tell them from some of the larger Infusoria. Hence the entrance to the path leading to the simplest worms seems pointed out by the higher Infusorians, though perhaps a Dicyema-like form may be the signpost to the vermian track. But we first should understand the structure of a true or typical worm.

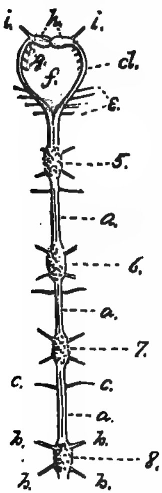

FIG. 37.—"Brain" and part of the nervous or ganglionated cord of the earth-worm. *h*, brain, or first pair of ganglia; *g*, nerves to pharynx; *d*, œsophageal collar; *f*, space occupied by the pharynx; 5–8, the ganglia of the 5th to 8th segments respectively; *i*, nerves to first segment; *a*, nerve-threads or commissures.

In order to obtain an idea of worms in general, the student may dig up in the garden a common earth-worm, and then place it on the table or desk in a flat dish and watch its movements and appearance. The body will be seen to be formed of numerous joints or segments; these are due to infoldings of the muscular skin at regular intervals. Though both ends of the long, slender, cylindrical body are much alike, the observer will soon be able to distinguish the head-end from the tail-end; he will also notice that both sides of the body repeat each other, and that there is an upper (dorsal) and lower (ventral) side, the worm lying on the latter side. The student will now be able to understand the following definition of the branch of worms, to which there are some exceptions, which need not, however, be here mentioned. A

* Gastræads (Dicyema) are without pores, and are simpler than sponges.

typical worm is bilateral, with a well marked dorsal and ventral side and a head-end and tail-end, with the body divided into segments.

By dissecting the body and tracing with needles the internal anatomy, and also by cross-sections of the body, the following relation of the most important internal organs will be observed. The digestive tract is a slender tube lying free in the body-cavity, and extending from the mouth to the vent. Above it lies a long delicate pulsating tube called the dorsal vessel or heart. The brain is small, and is situated in the upper part of the head, while behind the throat on the floor of the body lies the main nervous system, a double white cord with swellings called *ganglia* (Fig. 37), one for nearly each segment. A worm may or may not have eyes. The flat-worms have two (Fig. 38), or many scattered all over the body; others have eyes both in the head and tail; many worms have ears—i.e., organs of hearing. All worms grow from eggs, and the sea-worms have free-swimming young entirely unlike the parent worm, which pass through a metamorphosis.

The common earth-worm is cylindrical and many-jointed. The small mouth opens on the under side of the first seg-

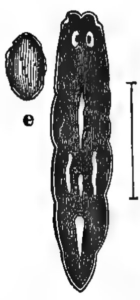

Fig. 38. — *Planaria torva* (enlarged); and *e*, egg-capsule. (Natural size.)

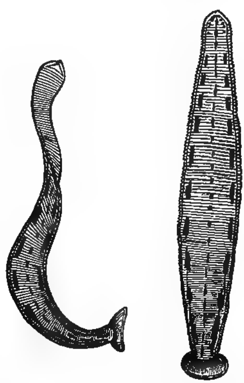

Fig. 39.—*Macrobdella*, or pond-leech. (Natural size.)

ment. The earth-worm is able to climb perpendicularly up boards or the sides of buildings by minute, short, curved bristles, which are deeply inserted in the muscular walls of the body, and arranged in two double rows along each side of the body. In burrowing it thrusts the pharynx into the end of the head, causing it to swell out, and thus push the earth away on all sides, while it also swallows the dirt, which passes through the digestive canal. In this way it may descend from three to eight feet in the soil.

While earth-worms are in the main beneficial, from their habit of boring in the soil of gardens and ploughed lands, bringing the subsoil to the surface and allowing the air to get to the roots of plants, they occasionally injure young seedling cabbages, lettuce, beets, etc., drawing them during the night into their holes, or uprooting them.*

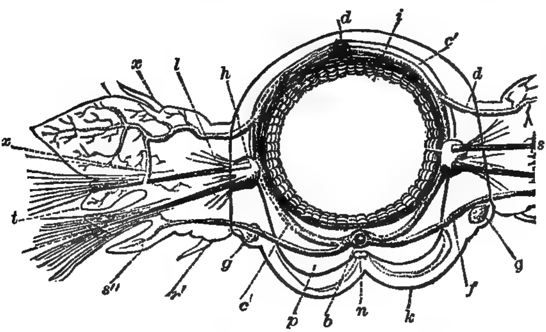

FIG. 40.—Transverse section through the body of a Nereis. *d*, dorsal vessel or heart; *c'*, circular blood-vessel; *b*, ventral vessel; *n*, nervous cord or ganglia; *f*, artery to swimming appendage *s''*; *i*, intestine; *s*, setæ or bristles.

The leeches (Fig. 54) are allied to the earthworm, but are adapted to a life in fresh-water ponds.

Our commonest sea-worm, sometimes called the "clam-worm," is *Nereis virens*. It lives between tide-marks in holes in the mud, and can be readily obtained. The body, after the head, eyes, tentacles, and bristle-bearing feet have been carefully studied, can be opened along the back by a pair of fine scissors, and the dorsal and ventral red blood-vessels with their connecting branches observed, as well as the alimentary canal and the nervous system.

This worm is very voracious, thrusting out its pharynx and seizing its prey with its two large pharyngeal teeth

**Darwin.* Formation of vegetable mould through the action of worms.

(Fig. 56). It secretes a viscid fluid lining its hole, up which it moves, pushing itself along by its bristles. At night it leaves its hole, swimming on the surface of the water.*

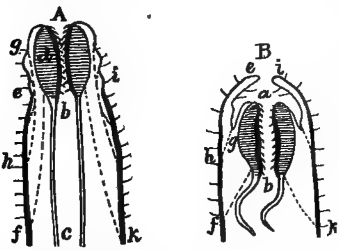

FIG. 41.—A, Head of worm, with the proboscis (pharynx) protruded; B, the same retracted; *a*, mouth; *d*, pharyngeal teeth; *b*, stomach; *ega*, pharynx; *geh*, muscles for everting the pharynx; *df*, for retracting it.

The body consists of from one hundred to two hundred segments. The head consists of two segments, the first with four eyes and two pairs of tentacles. The second segment bears four tentacles. Each of the other segments bears a pair of paddle-like appendages, which may be best studied by examining one of the middle segments (Fig. 40).

Some sea-worms are beautifully phosphorescent. The young of all sea-worms (Fig. 42) are ciliated, and swim on the surface of the sea. Thus, young or larval worms differ entirely from their parents in shape, size, and habits, leading different lives, and exposed to greater danger than the full-grown animals.

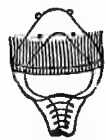
FIG. 42.—Ciliated larva of a sea-worm.

CLASSES OF VERMES (Worms).

1. Body flat, no body-cavity.........*Platyhelminthes* (Flat worms).
2. Body round, with a body-cavity...*Nematelminthes* (Round worms).
3. Body microscopic, moving by two ciliated flaps..................*Rotatoria* (Wheel animalcules).
4. Body minute, in a solid cell... ..*Polyzoa* (Moss animals).
5. Two shells, upper and lower, attached by stalk, with two arms.*Brachiopoda* (Shelled worms).
6. Body jointed, usually with feelers, eyes, bristles, oars, and gills..*Annulata* (Earth-worms, Sea-worms).

* See *Verrill's* works in U. S. Fish Commission Reports, etc.—*Verrill and Smith's* Report upon the Invertebrate Animals of Vineyard Sound, 1874.—Also *Trumbull:* Anatomy and Habits of Nereis virens (Transactions Connecticut Academy, III, 1876, 265–280); *Sedgwick and Wilson:* Biology (Chapters 7–10); and *Whitman:* External Morphology of the Leech (Proc. Amer. Acad. Arts and Sc., 1884).

CHAPTER VII.

STARFISH, SEA-URCHINS, AND SEA-CUCUMBERS.

We now come to animals more like worms than the jelly-fish, and in which the body is star-like, the parts radiating from the middle, forming either five arms, as in the starfish, or five wedge-shaped portions, as in the sea-urchin. As the body is more or less covered with spines or prickles, they are called Echinoderms, or spiny-skinned.

The student may first examine a common starfish (*Asterias vulgaris*), which is the most common and accessible Echinoderm to be found on the New England shores. A starfish may be placed in some sea-water and its motions watched. It will be seen to move by thrusting out the numerous feet or suckers by which it pulls or warps its clumsy body over the mussel-beds, rocks, or weeds, the arms being capable of slightly bending. The eyes are the little red spots at the end of each arm or ray. The numerous spines are attached by a sort of ball-and-socket joint to the calcareous framework of the body-walls.

First, as to the calcareous crust or external support of the starfish. In order to study this, a transverse section should be made through an arm, and a vertical one through the body and along the middle of a single arm, and finally the animal should be divided into two halves, an upper and lower. It will then be seen that the calcareous framework or so-called skeleton consists of a great number of limestone plates or pieces attached by a tough membrane and covered by the skin. Between the plates are small openings by which the water enters the body-cavity. These plates are arranged so as to give the greatest strength and lightness to the body. The mouth is situated on the under side in the middle, at the base of the arms. Each arm or ray is deeply channelled by a furrow containing four rows of suckers or "ambulacral feet," which are tentacle-like protrusions of the skin, growing out through orifices in the ambulacral plates, and are a continuation of the water-sacs or "ampullæ" within. The "madreporic plate" is a flattened hemispherical, red, sieve-like body situated on the disk between two of the arms.

We are now ready to examine the internal organs and to study their relations to one another and to the body-walls. The nervous system may be seen without dissection. By closely examining the mouth a pentagonal ring is seen surrounding it, each angle slightly enlarging

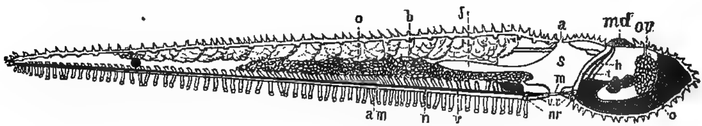

FIG. 43.—Longitudinal section through the body and one arm of *Asterias vulgaris*. *m*. mouth; *s*, stomach; *l*, lobe of stomach extending into the arm; *a*, anus; *nr*, nervous ring; *n*, radial nerve; *vr*. water-vascular ring, sending a radial vessel (*v*) into the arm; *md*, madreporic plate: *t*, stone-canal; *h*. hæmal canal; *ov*, oviduct; *o*, ovary; *am*, ampullæ, the ambulacral feet projecting below; *b*, cœca or liver.

and sending off a nervous cord to the eye at the end of the ray. It may be discovered by pressing apart the ambulacral feet along the median line of each arm. Fine nerves are sent off to each sucker,

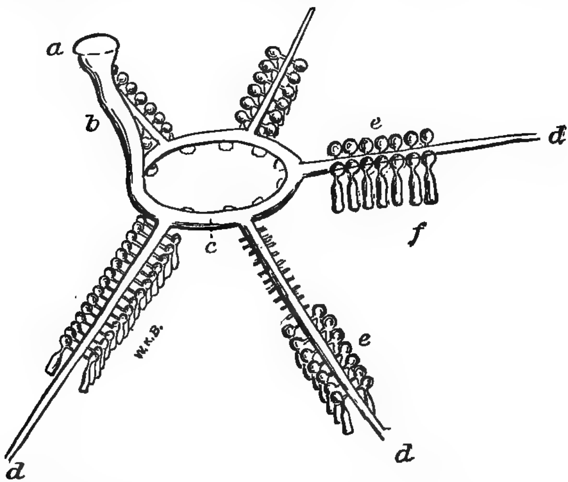

FIG. 44.—Diagram of the water-system of a starfish. *a*, madreporic body; *b*. stone-canal; *c*, circumoral water-tube; *d*, water-tubes to the arms; *e*, ampullæ; *f*, feet or suckers.

passing through the opening between the calcareous plates and extending to each ampulla, thus controlling the movements of the ambulacral feet. The skin is also underlaid by a sheet of nervous tissue.

The mouth (Fig. 43, *m*) is capacious, opening by a short œsophagus into a capacious stomach (Fig. 43, *s*) with thin distensible walls, and sending a long lobe or sac (Fig. 43, *l*) into the base of each arm; each sac is bound down by two muscles attached to the median ridge lying between the two rows of water sacs (ampullæ, see also Fig. 44). The stomach ends in a short intestine, the limits between the two not distinctly seen. Appended to the intestine are the "cœca" or "liver" (Fig. 43, *b*), consisting of two long tree-like masses formed of dense branches of from four to six pear shaped follicles, connecting by a short tube with the main stem. The two main tubes unite to form a short common opening into the intestine. The cœca are usually dark, livid green, and secrete a bitter digestive fluid, representing probably the bile of the higher animals.

The water-vascular system consists of the madreporic body, the "stone canal" (Fig. 43, *t*), the ring or circumoral canal (*vr*), and the radial vessels (*v*) ending in the water-sacs (*am*) and the feet. The stone-canal begins at the outer and under side of the sieve-like madreporic body, passing directly forward and downward in a sinuous course to the edge of the mouth. The sea-water in part enters the body-cavity through the fissures in the madreporic body, while most of it enters the stone-canal, which is a slender tube scarcely one fourth the diameter of the entire madreporic body. The water entering the stone-canal (Fig. 44, *b*) passes directly into the water-vascular ring (Fig. 44), and then into the ten Polian vesicles and the five radial canals, whence it is conveyed to each water-sac or ampulla (Fig. 44, *c*; compare also Fig. 43). These pear-shaped water-sacs, when contracted, are supposed to press the water into the long slender suckers or ambulacral feet, which are distended, elongated, and, by a sucker-like arrangement at the end, act in conjunction with the others to warp or pull the starfish along. Besides locomotion, the ambulacral feet serve for respiration and perception

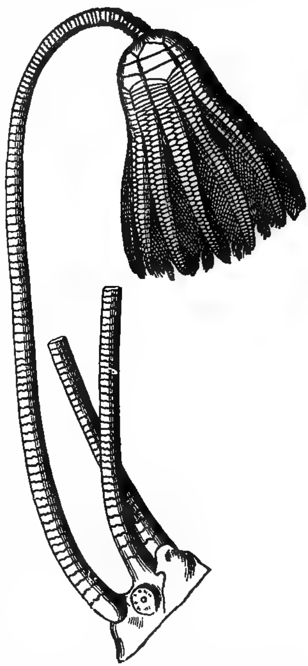

FIG. 45.—Encrinus or Stone-lily.

It will thus be seen that the water-vascular system in the starfish is in its functions partly respiratory and partly locomotive, while it is in connection with the vascular system, and thus partly aids in circulating the blood and chyle. There is, besides, a complicated system of true blood-vessels, which are, however, difficult to discover.

By placing a living starfish in a tank of water one can see how it moves by means of its suckers. When turned upon its back, it can right itself in the following manner:

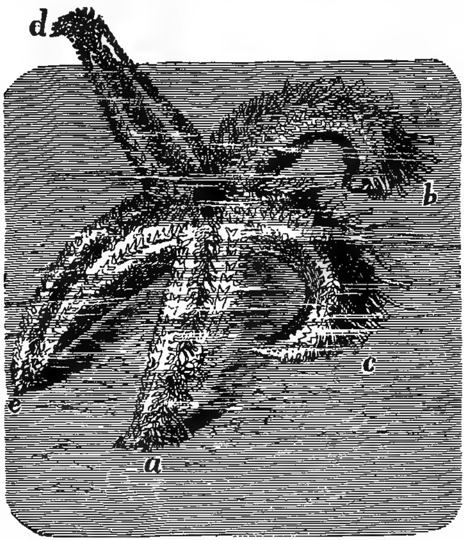

FIG. 46.—A starfish, which has been placed on its back, righting itself.

it twists round the tip of one or more of its rays (Fig. 46) until the feet there situated are able to get a firm hold of the floor of the tank (*a*); then, by a successive and similar action of feet farther back in the row, the whole ray is twisted round (*b*), so that the ambulacral surface of the end is applied flat against the floor of the tank (*c*); the other rays or arms then turn, and the starfish is right side up. Mr. Romanes, from whom we have taken the foregoing account, has also proved that the little red spots at the ends of the arms are true eyes, since, when shut up in a dark tank, it will crawl towards the light admitted by a crack. The starfish can also smell its food, for if a bit of a clam is held with a pair of forceps near the creature and slowly withdrawn, the starfish, if very hungry, will crawl after it. The sense of smell is distributed along the lower side of the arms. It is also thought that little bodies on the shells of Echini, called "Sphæridia," have the combined sense of taste and smell.

The Starfishes.—These include the snake-star (Fig. 47), and the common five-finger, *Asterias vulgaris* (Fig. 48). This and allied kinds are abundant on mussel and oyster beds, being very injurious to the latter, which serve them as food. The starfish projects its capacious stomach between the open valves of the oyster, and sucks in the soft parts, in this way doing much damage to the oyster-beds of the southern coast of New England.

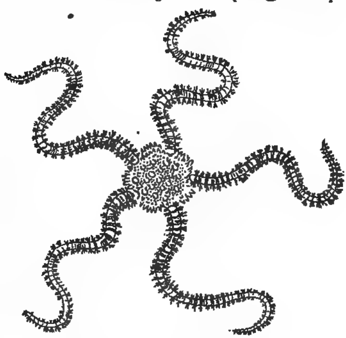

FIG. 47.—Snake-starfish.

All starfishes grow from eggs. After swimming about as a little ciliated sac (*gastrula*), arms grow out, and it appears much as in Fig. 49.

The young or larva has now both sides of the body alike. At this time two lobes arise from each side of the mouth. These separate from their attachment and form two distinct hollow cavities; and by the time the larva attains what is called the *Brachiolaria* stage, the development of the body of the starfish begins, for these two cavities subsequently develop into two water-tubes. On one of these cavities the back of the starfish is afterward developed, while on the other the under side with the feet or tentacles. Fig. 49 shows the young starfish growing on the posterior end of the larva or young, whose body it is now beginning to absorb; finally, the larval body disappears. At this time the starfish is still minute, conical, disk-shaped, with a crenulated edge. In this condition it remains probably two or three years before the arms lengthen and it becomes of full size.

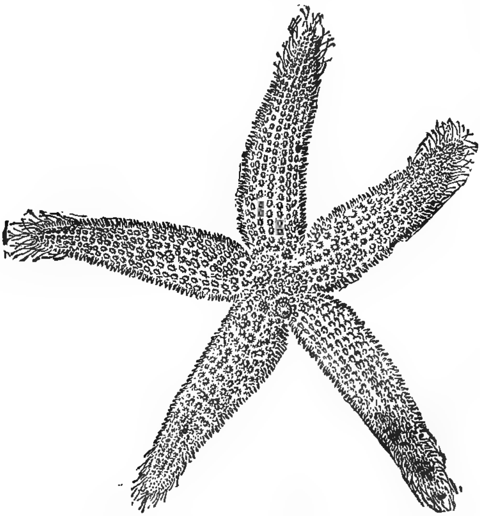

FIG. 48.—*Asterias vulgaris.* (Natural size.)

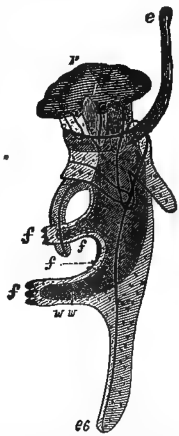

FIG. 49.—Brachiolaria of *Asterias vulgaris*, enlarged, with the starfish (r) developing at the aboral end; e, median anal arm; e^6, odd terminal oral arm; f, brachiolar arm; f^1, branch of water-tube (ww') leading into f'', odd brachiolar arm.

The changes or transformations of the starfish as well as other Echinoderms are intimately connected with the preservation of the species. Full-grown starfish are heavy, slow, inert creatures, and do not move far away from their homes among oysters, mussels, and under stones or seaweed; but in their infant or larval stages they are, as we have seen, entirely different creatures, swimming as transparent, animated bits of pinkish jelly at the top of the water, and borne about in vast numbers by the ocean currents hundreds of miles from their birthplace. Perhaps they would be snapped up by fishes and other animals were their bodies not so transparent; as it is, were all the adult starfishes and sea-urchins exterminated over a given region, the species would survive, as the young might be hundreds of miles away, and in safety at the surface of the ocean.

Sea-urchins.—Another example of Echinoderms is the

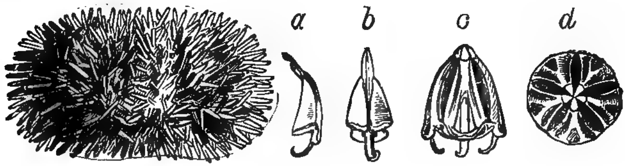

FIG. 50.—The common Sea-urchin, *Echinus*. *d*, framework of mouth and teeth seen in front; *c*, the same seen sideways; *a*, *b*, side and external view of a single tooth (pyramid). (All natural size.)

Echinus, which is more like a starfish than one would at the first glance think. A good idea of the general structure of sea-urchins may be obtained by an examination of the common *Echinus* (Fig. 50).

It is common among rocks, ranging from low-water mark

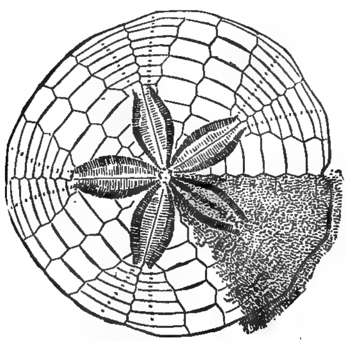

FIG. 51.—*Echinarachnius*, common Sand-cake. (Natural size.)

to fifty or more fathoms. It eats sea-weeds, and is also a scavenger, feeding on dead fish, etc.

The shell consists of five double rows of limestone pieces called *ambulacral plates*, which are perforated for the exit of the suckers or feet, which are like those of star-fish. There are also five double rows of *interambulacral plates*, to which the spines are attached. The sand-cake urchin (Fig. 51) is very flat, with minute spines.

On placing an Echinus in sea-water the movements of the animal, especially its mode of drawing itself along by

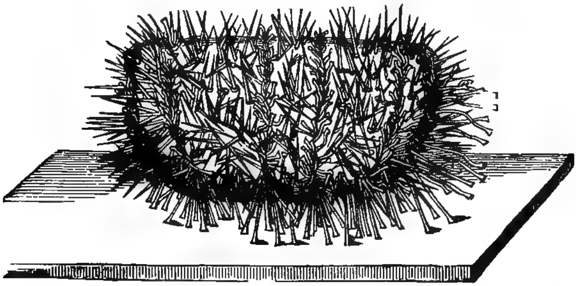

FIG. 52.—Echinus on its back.

its numerous long suckers, and how it covers itself by drawing together bits of sea-weed and gravel, may be observed.

Of course the sea-urchin is a heavier, clumsier creature than the starfish, and when turned over on its back feeble

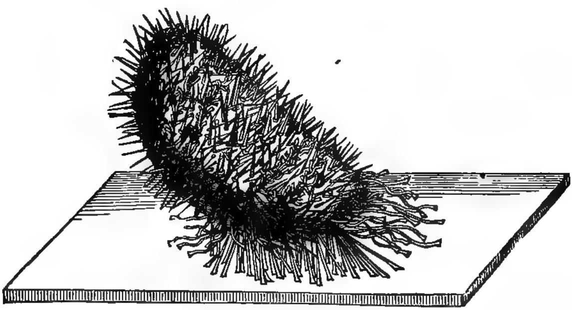

FIG. 53.—Echinus extending its suckers on beginning to right itself.

ones cannot right themselves; but a fresh, vigorous urchin can turn itself over in the manner indicated by Figs. 52–55.

Sea-urchins live in nooks and crannies in the rocks, away from the wash of the waves, as they are clumsy creatures, and if exposed would be easily rolled out of place. They are eaten in great numbers by cod and other large fish,

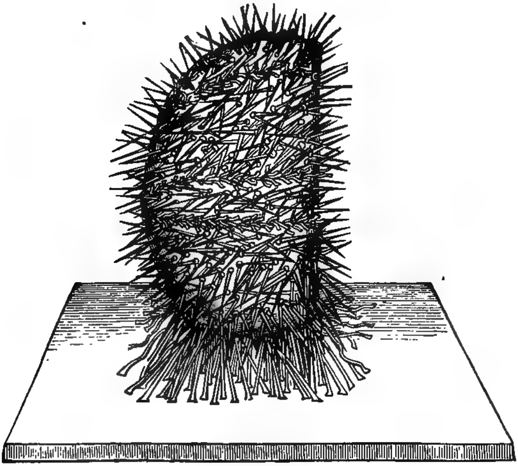

FIG. 54.—Echinus half way over.

which gulp them down whole, their prickly shell seeming to make little difference to their captors.

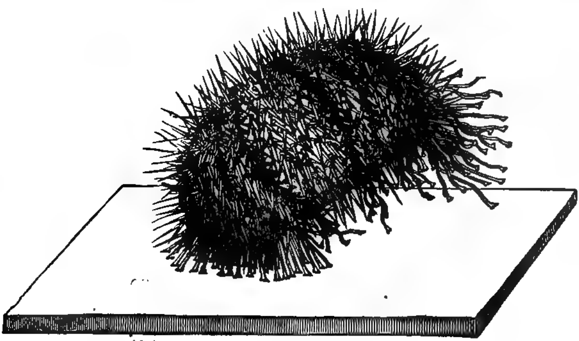

FIG. 55.—Echinus nearly righted.—After Romanes.

The Sea-cucumbers.—While the earliest Echinoderms are the stalked starfish or crinoids (Figs. 45 and 56), the highest class comprises the sea-cucumbers or Holothurians. In the sea-cucumber, as its name implies, the body is usually long, cylindrical, with a tendency to become worm-like. The skin is not solid, and is muscular. Around the mouth are situ-

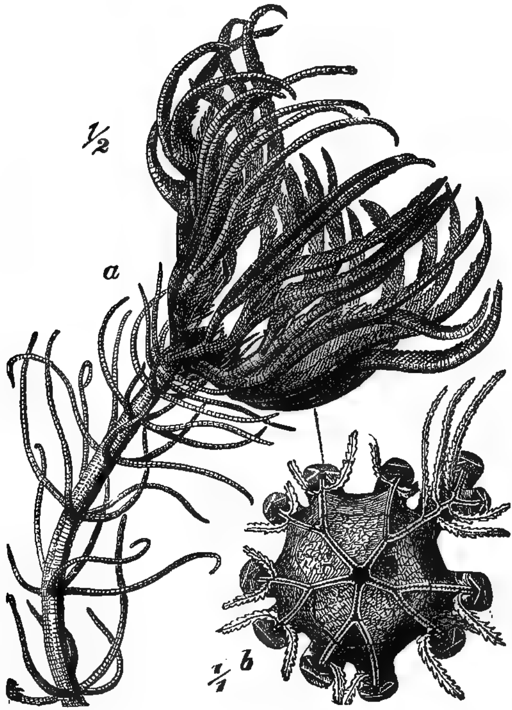

FIG. 56.—Pentacrinus. *b*, disk with mouth. (Natural size.)

ated the ten branching gills, while there are usually suckers arranged in five rows along the body.

The trepang or bêche-le-mer (*Holothuria edulis*) is collected in the Moluccas and Australian seas, and when dried is sold for soups in Chinese markets.

The infant Holothurian (Fig. 57, A) is a transparent, barrel-shaped creature, which usually has ciliated bands or zones around its body; the Holothurian grows up in it, in nearly the same way as the starfish grows from the larva.

On review, we see that *the Echinoderms differ from the worms in the body being very distinctly star-like or radiated; that the skin is usually filled with solid limestone plates, forming a shell; that they all have a tube-like digestive canal, which lies loose and free in the body-cavity; that in the sea-urchin there are five teeth for cutting up the food; that Echinoderms can see and smell, and that most of them pass through a metamorphosis.* They are very complicated animals compared with a sponge, a polyp, or even a jelly-fish, having a body-cavity, blood-vessels, and often gills.

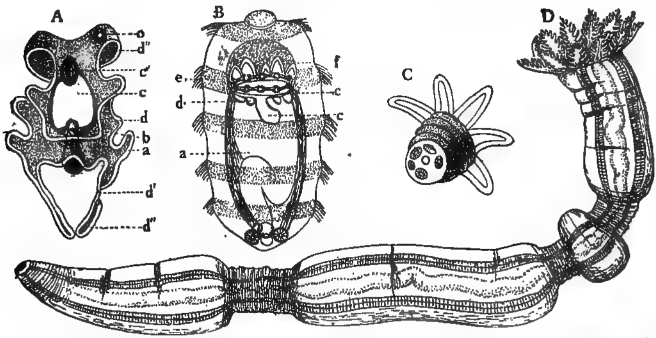

FIG. 57.—Sea-cucumber (*Synapta*). *A*, larva. *B*, Young farther advanced, with the Synapta (*f*, *d*) growing within. *C*, young become free (after Müller). *D*, adult Synapta. (Kingsley del.)

CLASSES OF ECHINODERMATA.

1. Body mounted on a stalk.......... *Crinoidea* (stalked starfish).
2. Body with five arms; free.......... *Asteroidea* (starfish, etc.).
3. Body spherical, with long spines.... *Echinoidea* (sea-urchins).
4. Body elongated; skin soft, hardened by minute plates .... *Holothuroidea* (sea-cucumbers).

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CHAPTER VIII.

THE CLAM AND OTHER BIVALVED SHELL-FISH.

In walking along the sea-shore, the commonest shells one picks up are the long clam, the round clam or quohog, the mussel, and perhaps scallop- and oyster-shells; and if one lives inland and walks by the river-bank, one is apt to meet with pretty mussel-shells, brown outside and of a deep pearly purple within. The sea shell-fish can be also bought fresh in the market; and we will suppose that we are addressing a class of boys and girls, sitting around the table, each with a shell in his or her hand. We will begin with empty clam-shells. Now, what shall we observe? Look first at the two shells, which may be held with the two sides or valves closed. Each shell is called a valve, and as the soft animal or clam is protected from harm by two solid valves of lime, it is called a bivalve. The two valves are alike, whether seen from without, from above, or below, or from either end. If, however, we look at the whole shell from the side, we see that the two ends are unlike, that it is somewhat wedge-shaped, one end being less rounded than the other. As the head of the animal lies in the rounder end, this is called the anterior or front end. When the clam burrows in the mud, the anterior end sinks down first. The sharper end is called the posterior end: it is this end which remains uppermost in the clam's hole.

If we now open the two valves and look at their inner sides we shall see that they are unlike. One of them has a large projection on the edge; this is called the "tooth," in the other shell there is a cavity corresponding to the tooth. This cavity and the hollow on the inner side of the large tooth is, if the shell is a fresh one, filled with a dark-brown substance called the "ligament" (Fig. 58, *lig*). When the clam is alive this ligament is slightly elastic, so as to allow the valves, aided by the two great muscles within, to open and shut. The tooth in the one valve and the cavity in the opposite valve, together with the ligament, form the "hinge" of the shell. The edges of the valves are also thickened to support the hinge, and this side of the shell is called the upper or dorsal side; hence the opposite edge of the shell is called the lower or ventral side. Thus the clam-shell has an upper and lower side, and a front and hinder end, and each side is for the most part like its opposite. We shall also see that the animal within has a dorsal and

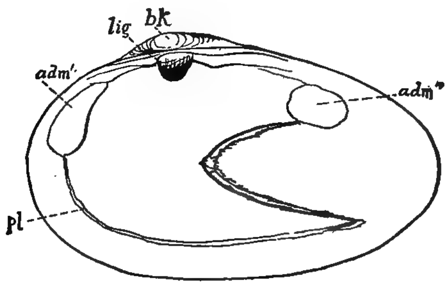

FIG. 58.—Inside view of the clam-shell (natural size). *Pl*, pallial line, made by the mantle; *adm'*, impression of the anterior; *adm''*, of the posterior adductor muscle; *lig*, ligament; *bk*, beak.

ventral side, a head-end and hinder-end, and that both sides of the animal are alike.

Moreover, we notice over the hinge, outside of the shell, that each valve is full and swollen over the site of the hinge. Each swelling is somewhat like a bird's beak; hence they are called collectively "the beaks."

We also observe that the surface of the valves is rough and marked with lines nearly parallel to the outer edge of the valves. These are the lines of growth. They are not at equal distances apart, for the clam probably does not grow steadily at all times of the year, but by fits and starts. If we pick up some very young clams, however, we shall see that in outline they correspond to the concentric lines of growth near the beaks.

We also notice in shells which are not too much beach-worn that the outside is covered with a thin skin or scurf, which easily peels off when dry; this is called the "epidermis."

Now, turning the valves over, we see that the inside is smoother and more shiny than the outside; it is lined with a thin layer of pearl, while the outside is dull chalk-white.

We also see near the upper or hinge side of the shell, near each end, two rounded spots which shine or glisten more than the others; these are called the "muscular impressions," because the two great thick muscles which open and close the shell are attached to the valves at these points. The muscular impressions are connected by a narrow, rather irregular line, which sends a great sharp loop along and near the lower edge to a point opposite the front muscular impression; this is the "pallial line."

Having learned something about the clam's shell, we will now look at the clam itself, for the shell is to the clam what scales are to the fish or our finger-nails are to our bodies; they are dead parts, produced by certain organs of the body to protect it from harm, and are not essential, vital, living parts. If the shell is broken, the animal repairs it by secreting* from the surface of its mantle limy matter to mend the hole or crack.

We will now look at the clam. To do this we should remove one valve, and then immerse the clam in a dish or small tin-pan of water. The clam should be carefully opened so as not to injure the animal or to hurt it, though the sense of pain, slight as it is, is only felt in the black "head," or siphon, as it is called. If a knife be thrust into the opening of the shell at each end and close to one valve, so as to sever the two "adductor" muscles, one shell can be

* i.e., separating from the blood sent to the mantle.

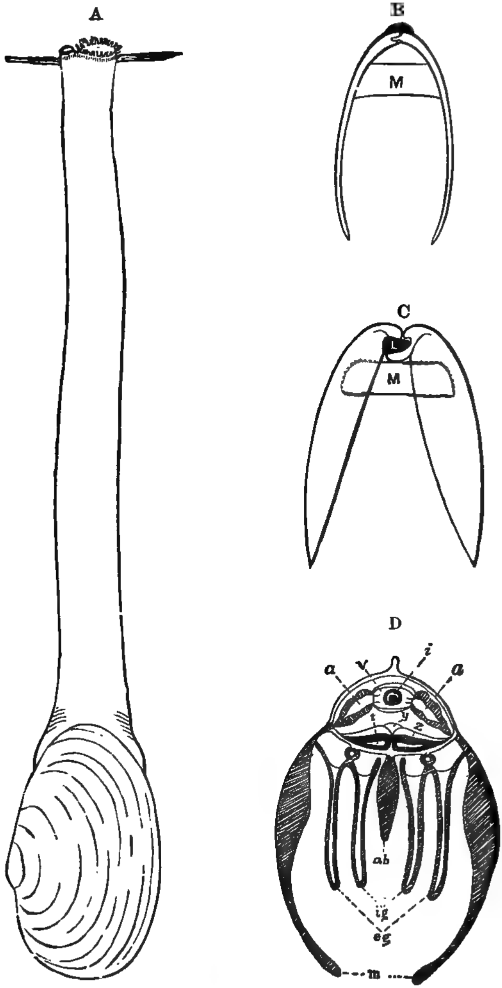

Fig. 59.—A, the clam with its siphon extended: in its natural position in the mud, head downwards. B, *Unio*, or fresh-water mussel; transverse section of the shell, showing the position of the spring opening the shell; *m*, adductor muscle. C, clam: *l*, ligament. D, transverse view of animal of *Unio* (after Brooks); *ab*, abdomen or visceral mass; *a*, auricles; *v*, ventricle; *i*, intestine; *t*, glandular part of kidney; *z*, non-glandular part of kidney; *y*, sinus venosus; *ig*, inner, *eg*, outer, gills; *m*, mantle.

lifted up, and then the "mantle" taken up with it can be carefully, and without injuring the clam, pressed away from the shell, and allowed to fall down over the exposed side of the clam in its former, natural position. The upper valve, thus partly removed, can be now pulled away from the other by tearing apart the ligament which holds it to its fellow-valve.

Now we can obtain some idea, without further injuring or materially displacing the parts of the body of the clam. In the first place, we see that the creature has no head; what is commonly called the "head" or "neck" because it projects out of the shell, sometimes to a distance greater than the length of the whole shell, is a double tube, rather sensitive to the touch and very extensible, like india-rubber. This is called the "siphon" (Fig. 60, *si*). On looking at the black end we see that there are two openings, surrounded by a fringe of finger-like feelers or "tentacles." The lower opening allows the sea-water laden with the clam's food, i.e., animalcules, perhaps even young clams when too small to be seen with the naked eye, and other young swimming sea-animals, to pass into the interior of the body. After entering the body, a current of sea-water, thus teeming with life, enters the mouth.

To see where the mouth is, and the foot and gills as well as other parts, we shall have to lift up a thin fleshy veil which conceals them. This veil is a part of the fleshy walls of the body, called the "mantle." It is very thick and muscular at the edge of the shell.

Upon removing the thin mantle from over the body, we see the gills. These are broad wrinkled sheets, two on each side of the animal, which are free at the edge, hanging down like a double curtain on each side of the body, when the animal is held with its dorsal side uppermost.

In front of the gills, i.e., towards the front part of the shell, are two pairs of delicate lappets (Fig. 60, *p*), which are called feelers. Now, the mouth is a small irregular opening, situated between and at the base of these feelers, or *palpi.* It is quite hard to find, as the lips are very soft and movable. Just below the mouth, and attached to the body, is a tongue-shaped fleshy mass, called the "foot." This is used in burrowing, as it projects through a round or oval hole in the mantle in front.

How the clam moves and burrows into the mud, and the use of the siphon, can be observed by placing a living clam in a dish of fresh sea-water. If allowed to remain in perfect quiet for a while, the clam will open its shell a little way, and gradually thrust out its siphon; then one can,

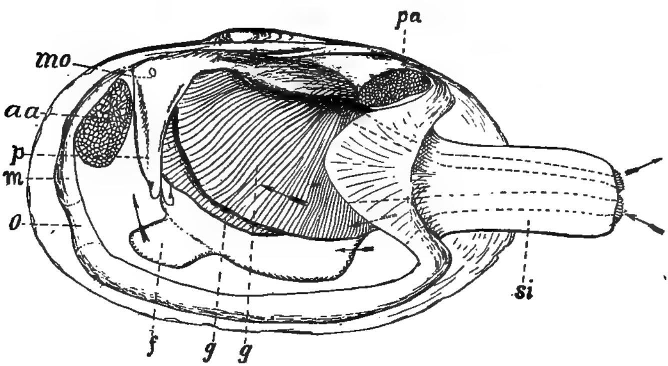

FIG. 60.—One valve of the clam removed to show the siphon (*si*), the gills (*g*), feelers (*p*), foot (*f*), and position of the mouth (*mo*); *aa*, anterior, *pa*, posterior, adductor muscle; *o*, orifice in the mantle (*m*) for the protrusion of the foot; the arrows pointing inwards mark the course of the currents of water from the siphon to the mouth; the single outward pointing arrow marks the exit of waste matter out of the upper division of the siphon.

with a lens, observe the two openings at the end, and the tentacles guarding them; also, perhaps, the current of water passing into the lower opening in the siphon, and a current passing out of the upper opening, as through this passage are expelled the hard and other indigestible parts of the animals it has swallowed.

The clam burrows deep in the mud by means of its foot. This is very strong and muscular, and swells so that it can be thrust out from between the valves of the shell into the mud; then, by movements somewhat like those of a spade in digging, it makes a hole, down which the clam rapidly sinks. After digging its way down for nearly a foot, out of harm's way (for the clam has many enemies), it remains with its head end downwards, and its siphon greatly extended, straight upward in its hole, which is partly open, at least enough to allow the water to trickle down (Fig. 59, A).

In walking over mud flats we see little pits in the mud; these are the holes of the clam. Sometimes when we step near the hole a jet of water shoots into the air. This is spurted out by the clam. Alarmed by the approach of a supposed enemy, the clam suddenly closes its shell, draws in its siphon, and, as the latter contracts, ejects the water from its shell. How does the clam know that any one is coming? It can hear. There is in the middle of the foot a little yellowish-white ear, connected by a nerve with the brain in the foot. Nerves run from the foot-brain to the upper brain, and thence nerve-threads extend to the siphon, and branch out in each tentacle; so that when a noise is heard the news is sent to the brain, and the latter repeats the message to the muscles of the siphon and shell, so that the valves close and the siphon is drawn in, while the clam remains quiet until the disturbance is over.

The clam breathes, digests its food, and circulates its blood throughout its body in the same manner as the oyster, which we will describe farther on.

The clam has a very large family. From early in September to the middle of October, or about forty days, it lays each year hundreds of thousands of eggs. Some of the eggs are probably eaten by other animals, or become in some way spoiled; but the larger proportion hatch, and the little clams swim about in the water, where most of them, however, are eaten by other animals, and few out of the original numerous brood get to be full-grown clams. Hence, though it has myriads of young, they are exposed to so many dangers that few clams survive, and there are no more clams now than there were hundreds of years ago.

In fact, there are not so many, for the Indians used to be fond of clams. This is proved by the multitude of clam-shells forming heaps along our shores from Nova Scotia to New Jersey; and now the white man is a great lover of clams, eating them all the year round, not even giving the clams a chance to breed during the forty days in early autumn; so that, upon the whole, the poor clam is in danger, through our ignorance and carelessness, of dying out. Its life in its hole seems an easy one; but between human

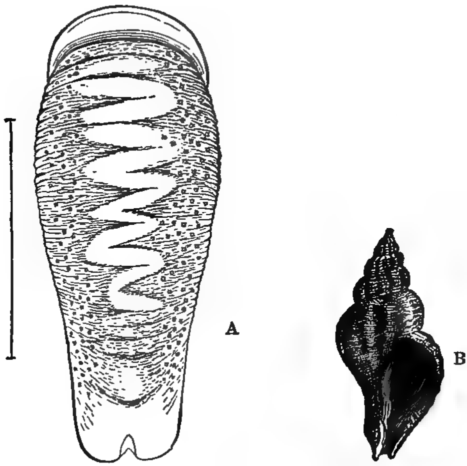

FIG. 61.—The enemies of the clam. A, the clam-worm (the line by the side represents the length). B, the drill (natural size).

clam-diggers and certain fish, such as flounders and eels and skates, which also dig them out of their holes, or snap them up if found away from home, and various other enemies, some of which live in their shells, or at least are troublesome boarders, the clam of late years, at least, has had a hard time of it.

One of these boarders which may be a great nuisance is the clam-worm, which is sometimes found within the shell. But the most deadly foes of the clam are certain snails, like the oyster-drill (Fig. 61), which bores holes through the shell, and kills the animal, feeding on its flesh.

Having seen and examined the clam, the student should compare some other common bivalves with it. Beginning with the round clam, or quohog, its Indian name, the pupil should compare every part with corresponding parts in the clam. It will be seen that the shell is much thicker and more solid. As the quohog is more active in its habits, with a much larger foot (Fig. 62), it is more likely to be swallowed by flounders or pollock and other fish; hence

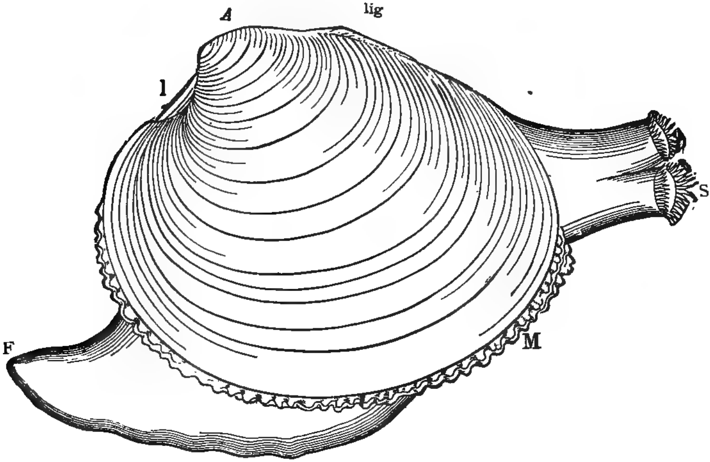

FIG. 62.—The round clam, or quohog (natural size), with the siphon (*s*) thrust out, showing the tentacles; also the scalloped edge of the mantle (*M*), and the large foot (*f*); *l*, lunule; *lig*, ligament; *A*, beak.

its shell is thicker, and thus more of a protection from its enemies.

We see that the shell is also wedge-shaped, the more rounded end being the head-end, which goes into the sand first.

If we look at the shell from in front, we see the distinct large beaks, and below it a heart-shaped hollow, called the "lunule;" also on the upper edge the large "ligament" (Fig. 62, *lig*). Opening the valves, we see that there are three teeth in the right and two in the left valve, while the hinge-margin is very solid. We also see the muscular impressions, which are connected by the "pallial line." The edge of each valve is purple. This part of the shell was

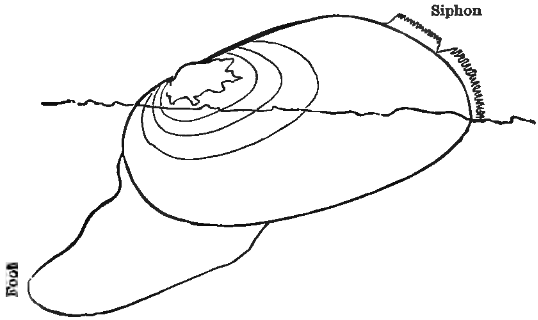

FIG. 63.—*Unio*, or fresh-water mussel, with its large foot partly buried in the sand, the siphonal openings above the level of the river-bottom.

used by the Indians in making beads for money, or "wampum."

The inland student who cannot readily obtain live sea-clams should pick up the mussels from the edge of ponds and rivers, carry them home, put them into pans of water,

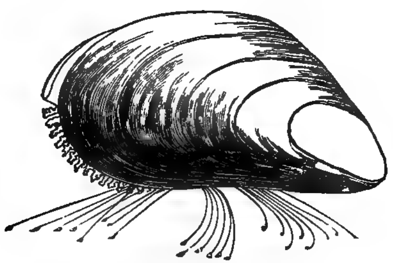

FIG. 64.—*Mytilus edulis*, common mussel, with its siphons expanded, and anchored by its byssus.

with plenty of sand on the bottom, and then after a while watch their motions.

The mussel will be seen to thrust its large foot out, dig and burrow into the sand, until it buries itself out of sight.

Here it will lie, with its short siphon extended at the level of the sand, as in the sketch.

The shell is lined with a thick nacre, or pearl, and often good salable pearls will be found inside the shell.

The common edible sea-mussel (*Mytilus*, Fig. 64) should also be examined, as it can be easily obtained attached to wharves, or at low water, where it grows in such great

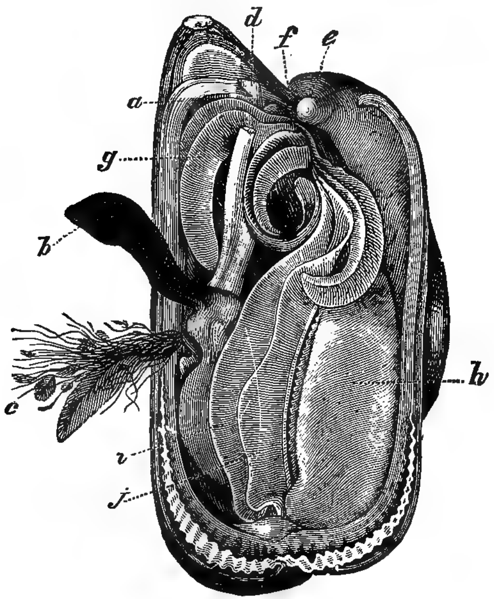

FIG. 65.—Common mussel. *a*, mantle; *b*, foot; *c*, byssus; *d* and *e*, muscles retracting the foot; *f*, mouth; *g*, palpi; *h*, visceral mass inclosing the stomach and liver; *i*, inner gill; *j*, outer gill.

quantities as to form "mussel-banks," attached to one another or to stones, etc., by threads called the "byssus."

The mussel's shell is rather a simple affair. It has a very slight hinge, with no teeth, while the beaks are large, but not distinct from the rest of the shell.

The shell is easily opened by cutting the muscles at the anterior or smaller end of the shell, and the different parts within can be named by reference to Fig. 65. The attention of the student should be drawn to the byssus, which arises from the base of the foot (*b*). The gills (*i j*) and large feelers (*g*) should also be noticed.

The pearl-mussel should be noticed here, and every school museum should have a specimen. It is very large, with a straight, broad, thick hinge-edge, but with no teeth. The shell is rough enough outside, but within is lined very thickly with mother-of-pearl, which is cut into paper-cutters, pen-handles, and various ornaments.

Pearls are often produced in these shells by particles of sand getting in between the mantle and the shell. This irritates the soft flesh and deforms the shell, so as to give rise either to a little bunch on the surface of the shell, or the particle remains free from but next to the mantle, and thus a round mass or pearl is formed. This may occur in almost any bivalve shell, but the largest and most perfect are formed in the pearl-mussel or pearl-oyster of Ceylon and Panama, and other places in the tropical seas, where extensive pearl-fisheries are carried on. The largest pearl known is two inches long, four round, and weighs 1800 grains.

Now we come to the oyster; and while the animal is delicious to the taste, the shell is thick, solid, rough, and homely, and of various shapes, though usually oval. The hinge is without a tooth, and, like the scallop, has a hollow in each valve containing the ligament. There is a single large dark muscular impression. The edge of the shell is sometimes scalloped, though usually plain. One valve is a little smaller than the other.

The grown-up oyster cannot go about in the world. It lies attached by one valve to some stone, or its fellow-oysters. Fixed immovably to the bottom, it opens the smaller upper valve, so as to admit the sea-water bearing its food. It therefore needs no siphon, and has none; neither does it have a foot, as it needs none. The oyster gets along well enough without these organs; they would be in its way. The animal is thus adapted to a mode of life quite different from that of many other shell-fish; and though it is less highly developed (i.e., some of its organs less fully formed) than they, yet they need not therefore despise the oyster, which is superior to them in numbers and usefulness to man. Happily oysters are not generally useful to fishes for food, as their shells are rough and thick, so that skates, sharks, and other fish find it "doesn't pay" to bother with them, but burrow in the sand or mud after clams, mussels, and other shells which they can get with less trouble. A good many prettily painted bivalves, as the scallop, for example,

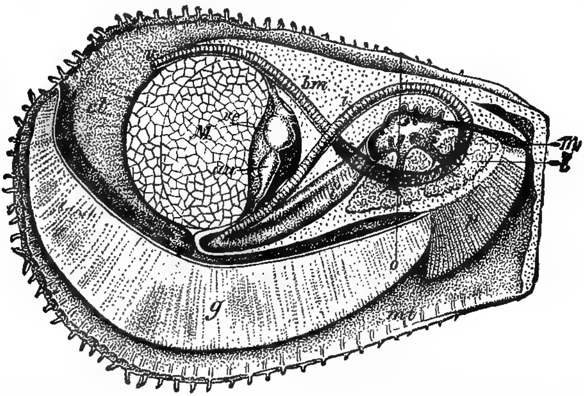

FIG. 66.—Anatomy of the oyster. *au*, auricle; *ve*, ventricle; *bm*, body-mass; *cl*, cloaca; *g*, gills; *i* and *i'*, intestine; *l*, liver, with its ducts opening into the stomach; *M*, adductor muscle; *m*, mouth; *mt*, mantle; *o*, the line of section of Fig. 67 passing through the stomach; *p*, outer wrinkled surface of inner or lower palpi; *v*, vent.—After Ryder.

"look down" upon the lowly oyster; but as the latter has no eyes, it probably has no pride, and is contented with its rough exterior, and hides away from common observation, mimicking rough stones and bits of shells, and in doing this it is farther protected from the attacks of prowling fish. So we see that the oyster, if it has no eyes, no foot, and probably no ears, and even if its shell be, so to speak, rough and carelessly made, without regard to looks, yet it fills a large and important place in the economy of the ocean-world. Nothing which lives has been made in vain. The world would not be what it is without oysters.

We can procure oysters at the fish-market which have been opened, and placing one remaining in the lower shell in water, we can, with the aid of Figs. 66–68, examine its structure. Fig. 66 shows the outline of the animal. We can see the edge of the mantle, which sends tentacles out at quite regular intervals. We also see the large single muscle (*M*) which keeps the shell closed. As we said, the oyster has no siphon, but the water enters in through the open shell, and passes in towards the mouth (*m*). The water is set in motion by the moving to and fro of the tentacles. The oyster's food consists of very minute plants and animals, and the minute young of sponges, worms, shell-fish, etc., all too small to be seen without a microscope. The water thus laden with food flows into the mouth, and the food is digested in the stomach (Fig. 67, *st*), aided by the secretions of the large dark liver (*l*). The sand and mud in the sea-water and the minute shells and other refuse pass out through the intestine (*i*), a very long tube which ends at *v*.

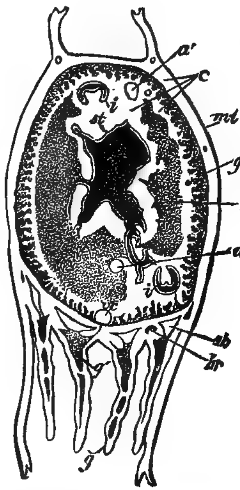

FIG. 67.—Section through the oyster along the line *o* of Fig. 66 (enlarged twice). *a'a''*, dorsal and ventral branches of the anterior aorta in section; *br*, artery to gills; *c*, connective tissue; *g*, gills in section; *g'*, internal cavities of the gills; *ge*, egg-gland; *ii*, cross-sections of the intestinal tube; *l*, liver; *mt*, mantle; *sb*, suprabranchial or water spaces above the gills; *st*, stomach; *vc*, vena cava.—After Ryder.

The fresh sea-water also bathes the gills (*g*), which are the breathing organs. The water passes up between the leaves of the gills, entering the upper gill-cavity through a large number of openings or canals between the gills, and then passes out into an open space above the gills (Fig. 67, *sb*). The object of breathing is to freshen the blood; and the heart, which is composed of two chambers (*ve* and *au*) collects the blood by three blood-vessels (*bc*) on each side. The blood thus freshened enters the auricle of the heart (*au*), and then passes into the ventricle (*ve*), to be distributed through two arteries which branch out all over the body.

Now we will see how the oysters grow. Many millions of eggs are laid by the oyster, and they pass directly out

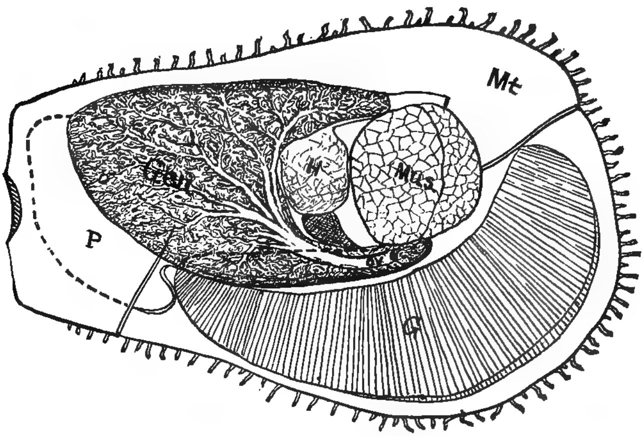

FIG. 68.—Oyster. *Gen*, gland in which the eggs are formed; *ov*, oviduct, from which the eggs are discharged; *mus*, adductor muscle; *H*, heart; *mt*, mantle; *P*, palp; *G*, gills.—After Ryder.

into the sea-water. A very large proportion come to naught. Mr. Ryder tells us that probably only a fraction of 1 per cent of all that are laid ever develop or fix themselves, even under favorable conditions.*

* A German naturalist (Professor Moebius) estimates that each European oyster which is born has $\frac{1}{1145000}$ of a chance to survive and reach adult age, so numerous and effective are the adverse conditions which surround the millions of eggs; and Mr. Ryder adds that those of the American oyster, whose yield of eggs is much greater, have, on account of their smaller size, probably still fewer chances of survival. This is the case with most of the lower animals.

We will for a moment look at the life of an oyster. It may be divided into three periods. 1. The fry. In about six hours after life begins the germ swims about in the water, and in a few hours more looks as represented in Fig. 69, 1.

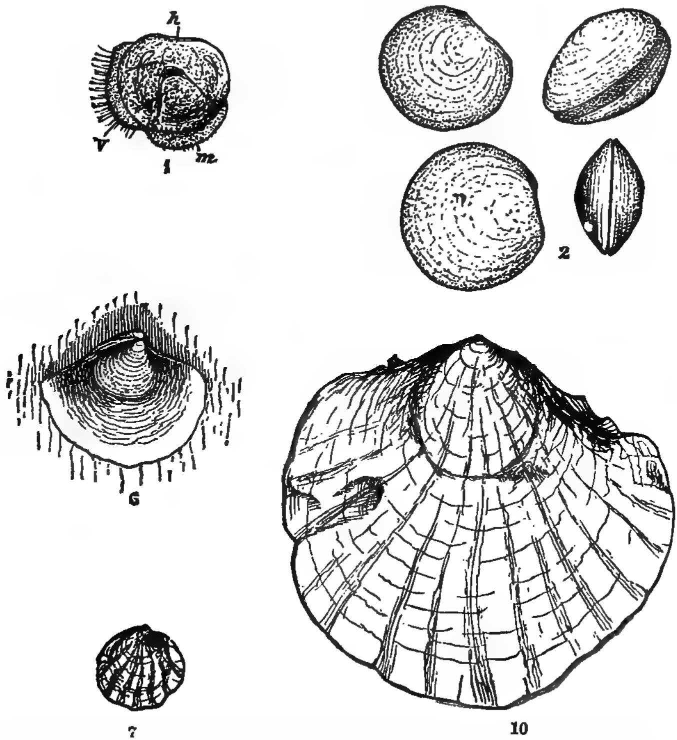

FIG. 69.—1. Young oyster seen from the side immediately after fixation by the mantle border (*m*); *v*, ciliated velum, or paddle; 2, four young European oysters taken from the beard of the parent, enlarged 96 times; 6, very young spat, showing the peculiar form of the true larval shell and that of the spat ×35 times; 7, twenty-days-old spat (natural size); 10, young oyster, 2½ to 3 months old.—After Ryder.

It now has a minute shell, and swims about by means of two little flaps, fringed with minute, slender hair-like processes called "cilia." It swims near the surface of the ocean, and is borne about by the currents, and it is in this way that the oyster is spread almost all over the world. In its babyhood it is a great traveller. 2. The spat. When the shell becomes thicker and heavier the young oyster sinks to the bottom and settles down to a quiet life. In this stage the spat fixes itself, with the head or hinge end downward, usually to the old oyster-shells; and thus a natural oyster-bank is formed; and there may be seen in any bed of oysters four sets of shells, i.e., the dead shells buried in the sand, etc., at the bottom; a second set partly living and partly dead; a third set in which all are living, and to whose shells the spat are attached, though some of the spat live attached in the holes between the dead shells.

At the time the fry is large enough to be fixed (Fig. 69) it is $\frac{1}{80}$ of an inch in diameter. The shells are now somewhat like those of a quohog, and both valves are alike, as in that shell (3). As soon as the oyster ceases to be active and becomes fixed it ceases to be symmetrical, the lower shell being unlike the upper, and thus takes a backward step.

The oyster grows rapidly after it is fixed. Fig. 69, 7, represents an oyster not over twenty days old, and Fig. 69, 10, one not over three months old. The oyster gets its growth and lays eggs by the time it is a year old, while most of the oysters sold in the markets have reached the age of two or three years. How many years the oyster can live is unknown, but probably ten or fifteen; some bivalves are thought to live nearly a century.

Many animals prey upon the oyster. It also takes in, whether willingly or not, as a boarder or messmate, a little yellowish crab; the oyster crab, which seeks shelter between its shells. Upon the shell of the crab, at times, grow multitudes of animalcules, whose young are swept into the oyster's mouth, and thus the crab may involuntarily be quite useful in purveying for its host the oyster.

The two more deadly enemies of the oyster are the "drill" and starfish. The drill is a snail which carries in its head a sort of slender rasp, by which it drills a hole through the oyster's shell, and feeds upon the animal until it kills it (Fig. 70). The starfish also destroys hundreds of thousands of dollars' worth of the oysters. The starfish protrudes its capacious stomach, turning it inside out between the open valves of the oyster, and sucks in the soft parts. They are so numerous and destructive that they kill great numbers of oysters. Mussels also suffer from their attacks. When the oyster is dead, its shells are bored in all directions by a sponge, which causes the shell to break up and thus aid in forming the sand or mud of the sea-bottom.

FIG. 70.—The Drill.

We thus see how varied is the life of the oyster, and, in fact, of all shell-fish. Early in life they have a different appearance, different habits, different enemies, and are, so to speak, different animals from what they are when grown up. Were it not for their power of adapting themselves to their different surroundings they would probably all die out. We also see that nothing about them is wasted. The surplus oyster population serves as food for other animals, and even the fragments of their dead shells are used to build up the sea-bottom, to aid in forming layers of sand and mud; and thus through past ages the shells of shell-fish, whether whole or broken into pieces, have been used to build up the rocks which form a part of our earth.

Indeed, a large part of the earth's population consists of the bivalves. There are about 14,000 different species of these shell-fish; of these, however, from 8000 to 9000 are extinct or fossil. The species differ from one another in various ways, *but nearly all agree in having two valves, while the animal is headless, with a small foot,—though this may be occasionally, as in the oyster, wanting,—and there are usually two pairs of leaf-like gills.* By examining the kinds we have described as examples or types, the student can get a good idea of the appearance of all the members of the class *Lamellibranchiata,* which means "shell-fish with leaf-like gills."

CHAPTER IX.

SNAILS AND OTHER UNIVALVE SHELL-FISH.

SNAILS can be picked up anywhere on the seacoast, in ponds and rivers, or in damp places on land under sticks or leaves. Our common large land-snail is called *Helix albolabris* (Fig. 71), and Fig. 72 represents the shell of a pond-snail.

In examining such a shell we see that it consists of but one piece or valve; hence this and all such shells are called "univalves." We also see that the shell is twisted in a spiral, and the twists are called "whorls;" the crease between any two of the whorls is called the "suture." The first whorl forms the body

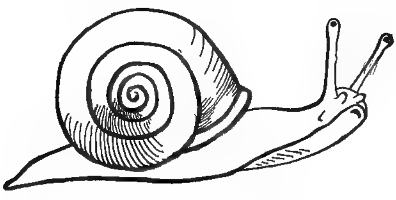

FIG. 71.—Snail, *Helix albolabris*. (Natural size.)

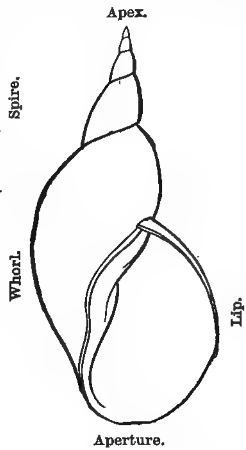

FIG. 72.—Univalve shell.

of the shell, and the other smaller whorls form the "spire," the end of which is called the "apex." The animal or snail itself lives within the shell, but pushes its head and foot out of the opening or "aperture" of the shell. The outer edge of the aperture is called the lip; the inner edge is thickened, and is called the "columella," which means a little column.

If we keep a land-snail in a slightly moist box or jar we can observe its movements. As seen in Fig. 71, when undisturbed it will push a great fleshy mass out of the aperture of the shell, and soon the head and foot will unfold; the feelers or tentacles will be thrust out, and the snail will walk off on its "foot," which is a broad, creeping disk, very different from the clam's foot. The foot can be best seen by allowing the snail to creep up the glass; the outline of the foot can be observed, as well as the peculiar gliding motion of the snail as it moves about. Also the mouth, which is situated at the front end of the foot; as well as the opening (Fig. 76), which leads into the lung-cavity or gill-like organ. In the land-snail the spire of the shell is very short, while the lip is usually very thick and white. Nothing is more interesting than to collect a lot of pond-snails, which may be found anywhere in roadside ditches or in pools in swampy places, and to watch their movements. Our commonest kind is the *Physa*, Fig. 73 representing on the right an empty shell, and on the left the animal in the act

FIG. 73.—*Physa*, common pond-snail.

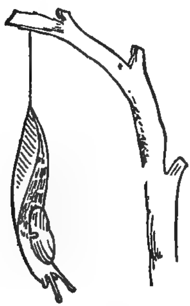

FIG. 74.—Slug (natural size), hanging by a slimy thread from a branch.

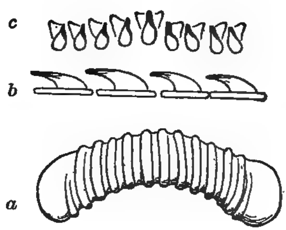

FIG. 75.—*a*, jaw; *b* and *c*, side and top view of teeth of lingua ribbon of the snail, *Helix albo labris*.

of creeping on its long pointed foot, its two tentacles extended out in front.

It will be seen that the land-snails have four tentacles and the pond-snails only two. The eyes of the land-snails are situated at the end of the tentacles; in the sea-snails the eyes are not on the end, but on the head near the base of the tentacles, and some kinds have no eyes. Indeed, some snails have no shells. In the slug (Fig. 74), which

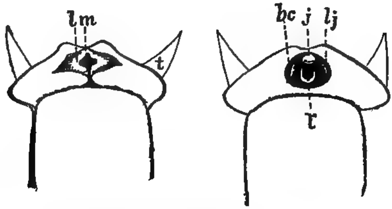

FIG. 76.—Under side of head of pond-snail. *bc*, mouth open showing the buccal cavity; in the left-hand figure the mouth (*m*) is closed by the lip (*l*); *j*, jaw; *lj*, lateral teeth; *r*, lingual ribbon; *t*, tentacle.

is common under stones and sticks on land, the shell is only a thin scale on the back, and covered by the skin. If they climb a twig or spear of grass, they let themselves down by a slimy thread. In fact, the body is covered with

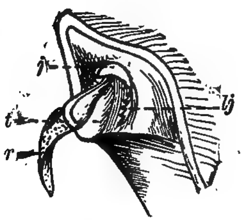

FIG. 77.—Mouth-parts of the pond - snail protruded. *t*, tongue; *lj*, lateral teeth; *j*, jaw; *r*, rasp, or lingual ribbon.

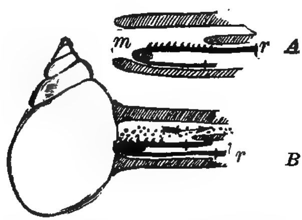

FIG. 78.—Sea - snail (*Sycotypus*) boring into a shell. *A*, mouth (*m*) at rest, the rasp (*r*) retracted; *B*, mouth pressed against a shell, *r*, the rasp gliding over a tendon like a pulley, and filing a hole into the shell; the arrow points into the throat.

slime, and where a snail walks it leaves behind it a glistening slimy track, which soon dries.

One can easily see how pond-snails eat, by watching them in a glass vessel of water, as they move about either on their backs at the surface of the water, or glide up the side of the jar. The mouth continually opens and closes. Now within the mouth is a plate forming the "jaw" (Figs. 77 and 78); and also a slender rasp, armed with rows of minute teeth, called the lingual ribbon, which grows on the "tongue." By means of this rough rasp or minute saw, which can be thrust rapidly out and then withdrawn, the snail can cut off bits of leaves, which it swallows, while with it the drill, etc., can bore holes in other shells (Fig. 78).

The snail can be killed by throwing it into hot water. It can then be pulled out of its shell by means of a pin or bent wire, and it will be seen that the animal fills up the whole shell to the top of the spire.

The land-snails lay their eggs in little packets under leaves, etc., while the pond-snails deposit their eggs in the spring on leaves. When a number are kept in glass jars or in an aquarium, the eggs will be seen in little jelly-like masses on the sides of the vessel, and it is interesting to watch the young develop, until they leave the egg-mass and shift for themselves.

The common *Purpura*, which lives on the seashore under sea-weed, lays its eggs in capsules like a vase, which may be found attached to rocks (Fig. 79). Those of the common whelk (Fig. 80) are laid in conical masses, sometimes two inches high, composed of flattened capsules.

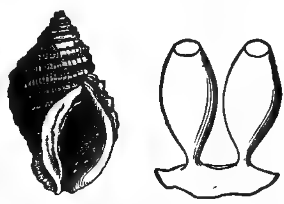

Fig. 79.—*Purpura* and its egg-capsules; the latter enlarged.

There are about 15,000 different species of snails known, besides 7000 species which are extinct or fossil; and yet, varied as are their forms, by examining the few common shells we have noticed we can obtain an idea of the general appearance of nearly all. With comparatively few exceptions, *all have a head, with feelers or tentacles; they all creep on a foot or disk, and nearly all are protected by a one-valved, more or less spiral shell.*

In the squid or cuttle-fish there is no external shell, and the mouth is surrounded with ten arms, provided with suckers, while the mouth is furnished with a pair of jaws somewhat like a parrot's bill. The squids are very active, and can dart rapidly backward by ejecting the water from their siphon or funnel. They have large, well-developed eyes, and the brain is large, and protected by an imperfect gristly brain-box. The Octopus has eight arms. To this

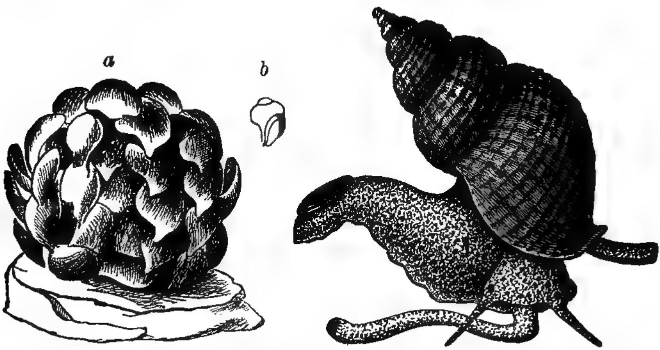

FIG. 80.—The whelk. Its tentacles and proboscis extended; *a*, egg-capsules; *b*, embryo shell. (Natural size.)

class, called *Cephalopoda*, also belong the chambered Nautilus, and the paper Nautilus.

Since their bodies are so soft, all univalve and bivalve shell-fish, and certain other animals allied to them, together with the cuttles, etc., are called "molluscs," from the Latin *mollis*, meaning soft. Molluscs, then, are *soft-bodied animals, with a foot or creeping disk, and usually protected by a shell.*

CLASSES OF MOLLUSCA.

1. Shell bivalved………… *Lamellibranchiata.* Oyster, clam, etc.
2. Shell univalve………… *Cephalophora.* Snails.
3. Shell when present coiled;
   8–10 arms………… *Cephalopoda.* Cuttle-fish.

LITERATURE.—Article *Mollusca*, by E. R. Lankester, in Encyclopædia Britannica.—Woodward's Manual of the Mollusca, 1868, With the writings of Brooks, Ryder, Dall, Jackson, etc.

CHAPTER X.

THE LOBSTER AND OTHER CRUSTACEANS.

THE lobster is so large an animal, so easily procured and examined, that its study affords material for a series of excellent object-lessons for young students. Boiled lobsters, which can be purchased for a few cents apiece in our seaboard towns, are as good for our present purpose as living or alcoholic specimens. If the student lives inland, especially in the Central and Southern States, a large crayfish* will answer the purpose equally well as the lobster.

The lobster lives from below low-water mark to the depth of from 50 to 100 feet, on a rocky bottom, where it hides under rocks, its long antennæ extended out of its retreat. If disturbed when walking about over the bottom on its sprawling legs, it will suddenly bend its tail under its body, thus shooting backwards several feet. Its food is fish and other animals, and it is also a scavenger. In life it is dark-green, with some reddish tints; when boiled it turns a bright brick-red.

We will now draw the pupil's attention to the more obvious points in the appearance and external structure of the lobster, and the student should have a specimen for dissection.

In the first place, notice that there is a well-marked head, with feelers and eyes, as well as a hinder end, or tail; there are also an upper and an under side. Moreover, if an imaginary line be drawn along the middle of the back from head to tail, it will divide the lobster into two equal halves. To use two rather long words, the lobster is bilaterally symmetrical, each half exactly repeating the other.

The body is protected by a solid crust, formed mostly of

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* Huxley's The Crayfish, 1880. Dana's Crustacea, U. S. Expl. Exp., 1852. Packard's Monograph of N. A. Phyllopod Crustacea. 1883.

lime; hence the lobster is called a "crustacean." But the creature has feelers and legs, and the body must be movable in its different parts; hence the crust and the legs, etc., are divided into rings or joints called "segments." Were not the lobster thus ringed or segmented, it would be inclosed in the straitest sort of jacket. Thus the body is composed of a certain number of segments.

Now let us see how the segments and their appendages look, and finally we may estimate how many there really are, while we may also discover a fundamental similarity in all the appendages. With the point of a knife separate one of the middle segments of the hind body (Fig. 81, *E* or *F*). It forms a complete ring (*D'*), with the legs attached to the under side. The pupil may next separate all the segments of the hind body and lay them upon the table in the order given in Fig. 81, *B* to *G*. Each segment will be seen to be much like the other, and each to bear a pair of two-branched limbs. Each limb, as in *D'*, consists of three parts, i.e., a stalk (*b*), supporting an inner (*en*) and an outer branch (*ex*).

But the sixth ring (*G*) will be somewhat of a puzzle to the beginner. What are the broad, flat, fan-like appendages? Are they true legs? Yes; they may be directly compared with the legs immediately in front. They form broad paddles, which move up and down, and propel the creature backwards.

Still a greater puzzle is the piece *H*. Is this a part of the segment *G* or not? It is in reality a partly formed separate segment, without any legs, and is the last segment in the body.

On counting the segments of the hind body the pupil will find that there are in all seven, the last not bearing any legs.

Now, before we try to find out how many more rings or segments there are, let us look carefully at the head and chest (thorax). We see that it is protected by a large shield (*A*), which ends in front in a spiny beak (*r*). In little hollows on the front edge are the eyes (*e*), which are very movable, being mounted on stalks. The eyes are black; and when the creature is undisturbed they are held straight out, but if frightened they are folded back in the cavity, and thus

FIG. 81.—External anatomy of the lobster. *A*, carapace; *e*, eyes; *r*, rostrum; a^1, first pair of antennæ; a^2, second pair; *h*, outlet of green gland; *m*, mandible, and *p*, its palpus; *mx–mx'*, maxillæ; *mp*, first maxillipede; mp^2, second maxillipede; mp^3, third maxillipede: with *ep*, epipodite, and *g*, gill; *i–d*, first leg; *B–G*, six abdominal segments; *H*, telson; *B* ♂, first pair abdominal legs of male; *B* ♀, of female; *D*, section of abdomen, with *en*, endopodite; *ex*, exopodite; *b*, basipodite; *S*, section of eye; *f*, cornea; *e*, cone; *n*, rod.

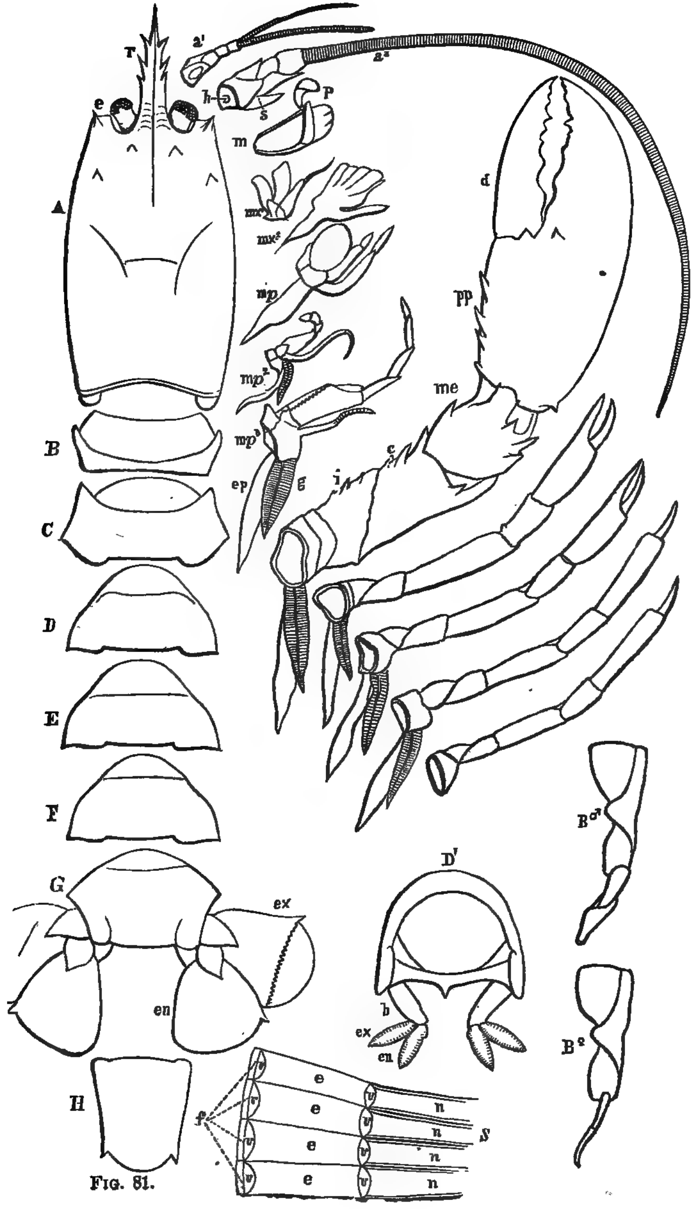
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FIG. 81.

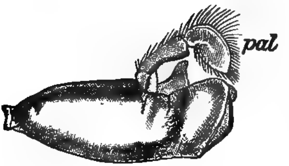

FIG. 82.—Mandible of the lobster. *pal*, palpus. (Natural size.)

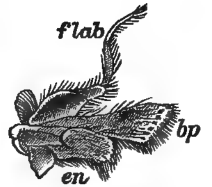

FIG. 83.—*A*, first maxilla of lobster. (Natural size.)

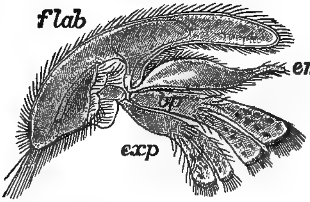

FIG. 84.—Second maxilla of lobster. (Natural size.)

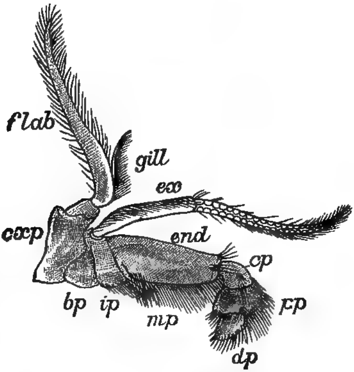

FIG. 86.—Second maxillipede. *ex*, outer, *end*, inner, division, with the gill and gill-paddle.

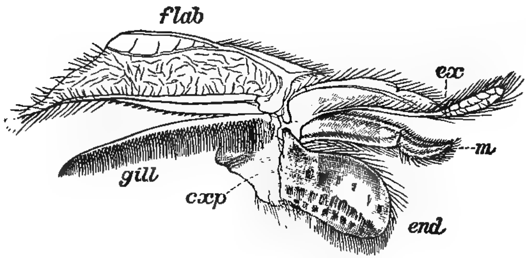

FIG. 85.—First maxillipede of lobster. (Natural size.)

protected from injury. It is interesting to watch a live lobster when it feels at home in an aquarium, and to see the lively motions of its eyes, feelers, and jaws, as well as to watch it crawl over the bottom. But the lobster is seldom to be seen in confinement. Shrimps, however, which are much like lobsters, can be easily procured, and kept in saucers, and also the crayfish, if the pupil lives far from the sea-shore.

Behind the eyes are two pairs of feelers, called antennæ; each antenna is composed of many small joints. It will be seen that the first pair of antennæ is small, and ends in two slender branches; but the second pair is very large, and over half as long as the body. In life the antennæ are kept in constant motion, as a blind man uses his cane while walking, and they serve as feelers to detect the presence of food or of enemies. The pupil should remove the antennæ and lay them on the table.

And now for the jaws and other mouth-parts* and legs. For convenience we will begin with the latter. The five pairs of legs should be removed and laid upon the table, one behind the other, beginning with the pair of great claws. It will be seen that the three front pairs of legs end in claws or nippers, and that each leg is composed of seven joints.

We are sorry to say that the lobster is a quarrelsome fellow; with its great powerful claws it bites whatever comes in its way; and in duels with each other, which are only too frequent, they will not only pinch and bite each other, but even go so far as to pull each other's claws off. Fortunately, however, for the sufferer, a new claw will grow out after a few weeks.

If the class is a large one and there are a good many lobsters on the table, it will be seen that one claw is always larger than the other, and that sometimes it is the left and sometimes the right; there is no rule about it.

If the legs have been removed, not roughly pulled off, but carefully dissected with the point of a knife, the gills will come off with them. These are well worth examination. They consist of three branches, each with hundreds of little slender cylindrical tubes. They are packed away under the shield against the sides of the body. The gills are bathed by the fresh sea-water which passes in between the shield and the side of the body; and in order to cause the water to flow forward over the gills, a set of large paddles, which we may call gill-paddles, by their movements keep the water in motion.

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* It is not necessary for the pupil to learn the names of these parts of the mouth limbs, but the teacher should thoroughly know them. They are explained in the author's *Briefer Zoology* (Henry Holt & Co.).

These gill-paddles come off with the gills, and are much as in Fig. 85.

So much for the legs and their gills. Now we will remove the leg like limbs in front; they can be easily detached with the point of a knife, and when removed laid upon the table in the order of Figs. 87–83; and finally the jaws (Fig. 82) can be removed. We will then examine the mouth parts, beginning with the jaws (Fig. 82). These are hard to remove, as they are held firmly in place by a strong muscle which spreads out on the top of the shield. They are very stout and broad at the end. Unlike our own jaws, they work from side to side, not up and down. They are like a pair of millstones, and crush bones and shells. To the upper side is attached a three-jointed feeler, called

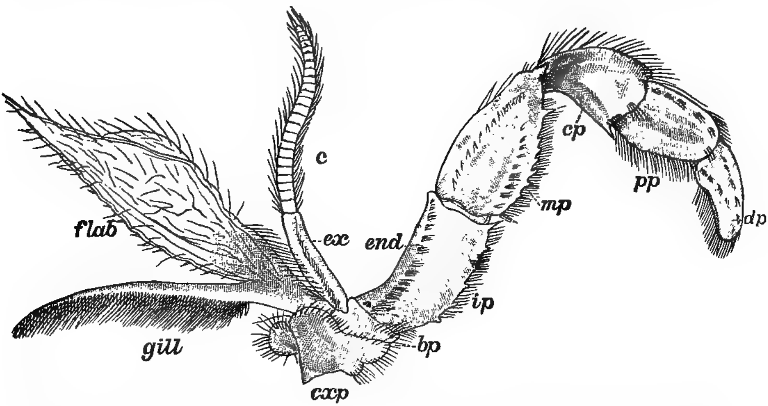

FIG. 87.—Third maxillipede. *end*, inner, and *ex*, outer, division, with the gill, and *flab*, the gill-paddle.

"palpus;" it is fringed with delicate hairs, which may possibly have the sense of taste.

Next to the jaws, and hugging them closely, are two small white deeply lobed appendages. These are the accessory jaws, called "maxillæ" (Fig. 83, 84). They act like our tongue to arrange the food and keep it in place to be crushed by the jaws. They have attached to the base a gill-paddle (*flab*) which in the second pair is very large and fan-shaped.

Between the second pair of accessory jaws and the great claws are three pairs of curious appendages, half jaws and half legs; they are the "foot-jaws," and are hence called "maxillipedes." (Fig. 85–87). Like the legs they bear gills, while the gill-paddles, especially in the first and last pair, are very large. The first pair is divided into three divisions, besides the gill and its paddle, while the two succeeding pairs have but two, and the inner one of these (Fig. 87, *end*) is very large and resembles one of the legs; the other divisions are two- or many-jointed and act as feelers.

Now, if we count all the appendages we shall see that there are in all nineteen pairs, as follows:

Head.

1st	Segment.	First pair of antennæ.
2d	"	Second pair of antennæ.
3d	"	Jaws (mandibles).
4th	"	First pair of accessory jaws (maxillæ).
5th	"	Second pair of accessory jaws (maxillæ).
6th	"	First pair of foot-jaws (maxillipedes).
7th	"	Second pair of foot-jaws (maxillipedes).
8th	"	Third pair of foot-jaws (maxillipedes).
		Mid-body or Chest. (Thorax.)
9th	"	First pair of chest-legs.
10th	"	Second pair of chest-legs.
11th	"	Third pair of chest-legs.
12th	"	Fourth pair of chest-legs.
13th	"	Fifth pair of chest-legs.
		Hind Body. (Abdomen.)
14th	"	First pair of abdominal legs.
15th	"	Second pair of abdominal legs.
16th	"	Third pair of abdominal legs.
17th	"	Fourth pair of abdominal legs.
18th	"	Fifth pair of abdominal legs.
19th	"	Sixth pair of abdominal legs.

Now, as a rule,—and this applies to several thousand species of the class of Crustaceans,—there is but one pair of limbs to a segment. Hence in the head, where it is impossible to count the segments, as they are incomplete, there are eight segments, one to each pair of appendages; and in the mid-body (or thorax), which is covered by the shield, which really is a part of the head, there are five segments, one for each pair of feet; and, finally, there are in the hind body (or abdomen) six segments which bear legs, besides a seventh rudimentary one, so that we have twenty segments in a lobster's body. These segments are collected into three regions, thus:

Head..............................	8	segments.
Mid-body..........................	5	"
Hind body.........................	7	"
	—	
	20	body segments.

There are over a thousand species of shrimps, prawns, crayfish and their allies, which agree with the lobster in the most important respects; hence this animal is an example or type of Crustaceans in general.

Now, how does the lobster see and hear? Its eyes are not, like ours, single and separate, but each eye is composed of hundreds, nay, thousands, of simple eyes. Fig. 81, *S*, represents four of these simple eyes, which are united

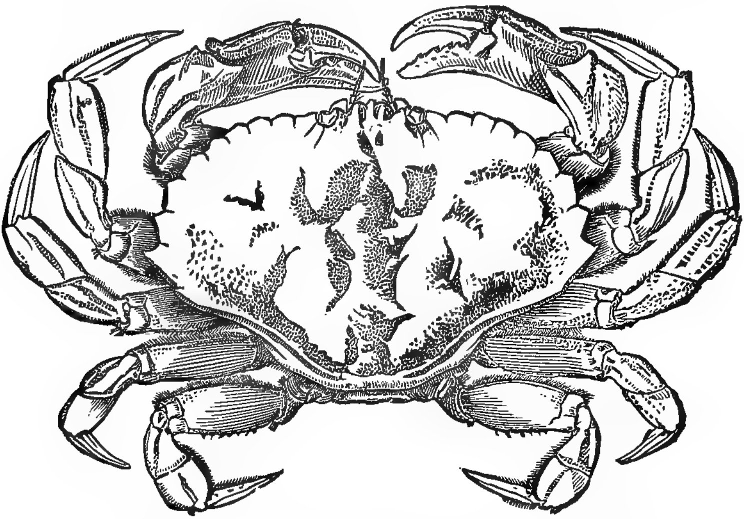

FIG. 89.—Common Shore-crab, *Cancer irroratus.* (Natural size.)

like a bundle of rods, to form a composite eye. With its eyes mounted on two long stalks, there is little doubt but that the lobster sees well enough to answer its own needs. It also hears well. The lobster's ears are seated in the base of the smaller or first antennæ; they may be detected by a clear, oval space on the upper side. On laying this open, a large capsule will be discovered; inside of this capsule is a projecting ridge covered with fine hairs, each of which contains a minute branch of the auditory nerve. The sac is filled with water, in which are suspended grains of sand which find their way into the capsule. A wave of sound disturbs the grains of sand, the vibrations affect the sensitive hairs, and thus the impression of a sound is telegraphed along the main auditory nerve to the brain.

The fine hairs fringing the mouth-parts and legs are organs of touch. The seat of the sense of smell in the Crustacea is not yet known, but it must be well developed, as nearly all Crustacea are in part scavengers, living on decaying matter as well as live fish, for the lobster is an expert fisherman, catching cunners, etc. We see, then, how complicated is the body of a lobster; it is an exceedingly active creature, its brain and nervous system are correspond-

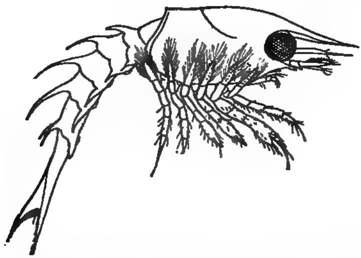

FIG. 88.—Freshly hatched Lobster. (Magnified.)

ingly complex, and its mental traits of no mean order. The creature is a great advance beyond a worm. Crabs also have the power of finding their way back to their original habitat when carried off even for several miles.

The lobster spawns from March till November. The eggs are attached in bunches to the swimming feet of the hind body. The young (Fig. 88) are hatched with much of the form of the adult, not passing through a series of singular changes, called a metamorphosis, as do most shrimps and crabs. They swim near the surface until about one inch long, afterwards remaining at or near the bottom.

The lobster, after having nearly grown up, probably moults but once, during midsummer. When about to moult, or cast its skin, the shield splits from its hind edge as far as the base of the beak, where it is too solid to separate. The lobster then draws its body out of the rent. The claw—at this time soft, fleshy, and very watery—is drawn out through the first joint, part of which disappears at this time, so as to make room for the passage of the flesh of the big claw. In moulting, the stomach, with the solid teeth, is cast off with the old crust or skin.

Having looked with some care at the lobster, we can glance more hastily at some of its allies. Its nearer relations are the crabs, and of these there are many kinds. In crabs the hind body is very small and folded to the under side of the chest. The common shore-crab (Fig. 89) lives under stones, where it may be found at low-water mark. When the tide comes in it may be seen running sideways in a comical fashion over the bottom.

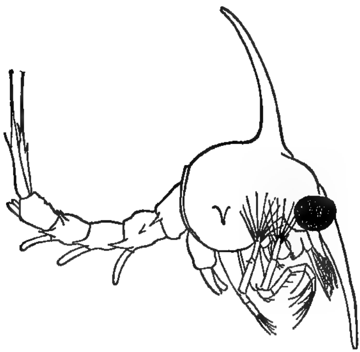

Fig. 90.—Young, or Zoëa, of *Cancer irroratus.* (Highly magnified.)

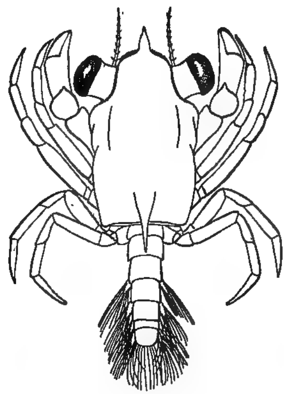

Fig. 91.—Megalops, or older stage, of Fig. 90. (Magnified.)

If we compare the crab with the lobster we see a great advance; the crab's head and mid-body are much better developed, while its hind body is small and folded to the under side of the chest. There is a transfer of parts headwards, a great step onwards and upwards.

A curious creature is the hermit-crab (Fig. 92). Selecting an empty shell, it thrusts its soft hind body into it, and

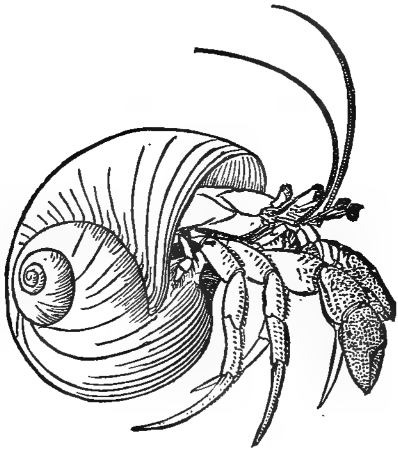

FIG. 92.—Common Hermit-crab. (Natural size.)

uses it as a protection—like Diogenes, carrying its house about with it. Small hermit-crabs are abundant in little shells in tidal pools along our coast. They may be put into saucers filled with water and their movements watched.

Less nearly related to the lobster are the "beach-fleas," the little active, hopping creatures one finds everywhere un-

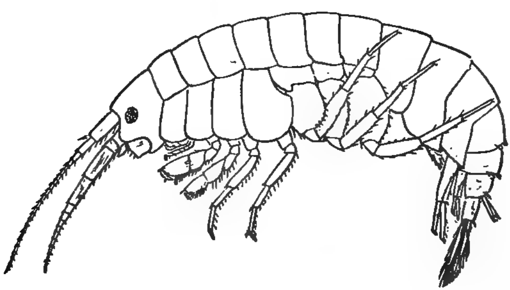

FIG. 93.—*Gammarus*, from fresh water. (Much enlarged.)

der sea-weed on the sea-shore. Similar forms (Fig. 93) are common among weeds in fresh-water ponds.

Crustaceans also occur everywhere under leaves and stones in damp places; these are the "sowbugs." Some of them, when disturbed, roll into a ball like a pill, hence they are called "pill-bugs." Lastly, we come to the most distant relations of the lobster.

The barnacles would, at first glance, hardly be regarded as Crustacea at all, so much modified is the body, owing to their fixed, parasitic mode of life. The barnacle is (Fig. 94) a shell-like animal, the shell composed of several pieces, with a conical movable lid, having an opening through which several pairs of long, many-jointed, hairy legs are thrust, thus creating a current which sets in towards the mouth. The common barnacle abounds on every rocky shore from extreme high-water mark to deep water, and the student can, by putting a group of them in sea-water, observe the opening and shutting of the valves and the movements of the slender hairy legs.

FIG. 94.—A Barnacle, *Balanus*. (Natural size.)

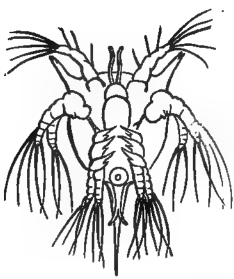

FIG. 95.—Young of *Balanus*. (Much enlarged.)

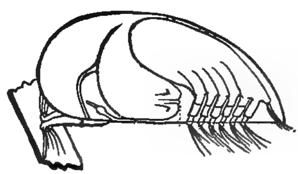

FIG. 96.—Pupa of a goose-barnacle, *Lepas*. (Much enlarged.)

The metamorphosis of the barnacle is remarkable. After leaving the egg, it swims about as a minute creature, represented by Fig. 95, with three pairs of legs which end in bristles. Finally, the larva attaches itself by its antennæ to some rock, and now a strange transformation follows. The body and legs (the number of legs having meanwhile increased) are inclosed by two sets of valves, so that the animal appears as if bivalved (Fig. 96), and at last the barnacle-shape is attained.

We thus see that the lobster is but one of a host of animals, all of which *have the soft parts of the body protected by a crust, which is jointed or segmented, while their appendages are also jointed; they breathe by gills attached to the outside of the body, and possess two pairs of antennæ.*

ORDERS OF CRUSTACEA.

1. Feet leaf-like..............*Branchiopoda:* Brine Shrimp, etc.
2. Limbs free; some parasitic..*Entomostraca:* Cyclops, Fish-lice.
3. Body fixed, protected by a shell of several pieces....*Cirripedia:* Barnacles.
4. Thoracic feet leaf-like; thorax covered by a carapace.*Phyllocarida:* Nebalia.
5. No carapace; eyes sessile...*Tetradecapoda:* Pill-bug, Beach-fleas.
6. Body partly covered with a large carapace...........*Thoracostraca:* Shrimps, Crabs.

Class *Podostomata.*—This group, represented by the king-crab (*Limulus*) and the trilobites, is in many respects intermediate between the Crustacea and Arachnida. Taking Limulus, the only form now existing, as an example, there are no antennæ or true jaws, but the mouth is surrounded by six pairs of legs, with spines at the base. There are attached to the abdomen six pairs of broad swimming feet, the last five pairs with gills. The brain supplies nerves to the eyes alone, there being a pair of large compound and a pair of small simple eyes. Our common king- or horseshoe-crab is *Limulus polyphemus.**

In the extinct order *Trilobita* the body is divided lengthwise into three lobes, and consists of distinct segments, in some kinds very numerous, while the legs are jointed, bearing gills. (See essay by Walcott on trilobites.)

* See essays by Milne-Edwards, Packard, Kingsley, Lankester, etc.

CHAPTER XI.

SCORPIONS AND SPIDERS.

If we examine a spider we shall see that its body is divided into two regions; i.e., a head-thorax (cephalothorax); and hind-body, or abdomen. The head, bearing the simple eyes and jaws, is closely united to the thorax, which bears four pairs of legs. There are no antennæ,* but behind them the poison-fangs (Fig. 96*a*, 3); and behind these is a pair of maxillæ with palpi (7) which in part supply the place of antennæ. The head-thorax of the spider bears usually eight simple eyes, and only two pairs of jointed appendages, while to the thorax are attached four pairs of legs, each ending in two claws. These claws are comb-like beneath (6), and around their bases are stiff hairs, enabling the spider to seize the thread and run with ease over its web. How is the web made? If we closely examine the under side of the hind-body we may detect the spinnerets (1*e*). There are three pairs of short jointed appendages, with minute 2-jointed tubes (5), out of which passes a clear sticky fluid, which becomes a very fine silken strand when forced out so as to come in contact with the air. Each strand unites to form the thread with which the web is made. Unlike any animals we have yet examined, spiders and their allies breathe by internal air-tubes, the air passing in through openings in the skin called spiracles. In the scorpion four pairs of these spiracles are easily seen; the spider has but a single pair. Most spiders also have a pair of book-lungs near the base of the hind-body; in the trap-door spiders there are two pairs. Scorpions chiefly differ from spiders in having the maxillæ ending in a forceps, while the long slender jointed hind-body ends in a poison-sting. (See Emerton's Structure and Habits of Spiders, 1883.)

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* They have been found to temporarily exist in the embryo.

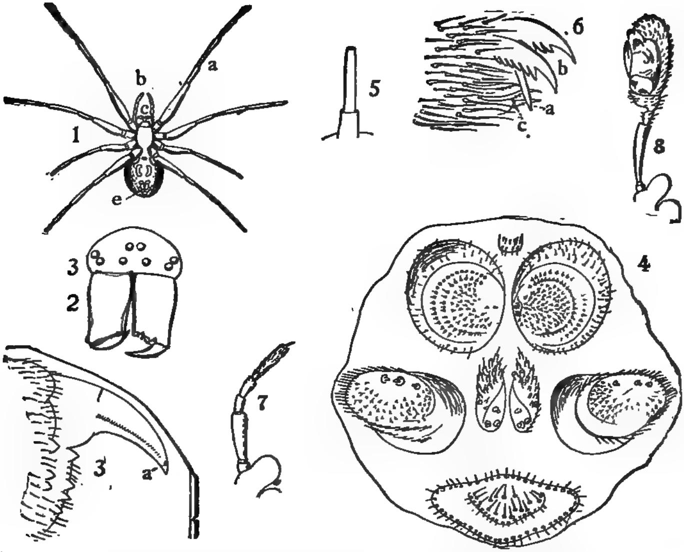

FIG. 96*a*.—1. The common garden spider (*Epeira*): *a*, leg; *b*, maxillary palpus; *c*, poison-jaws; *e*, spinnerets. 2. Front view of head with the eight simple eyes and the poison-jaws. 3. End of a jaw: *a*, outlet of the poison-canal. 7. Palpus of female; 8, of male spider. 6. Spines and claws at end of a leg. 4. Spinnerets, highly magnified. 5. A single silk-tube.—After Emerton.

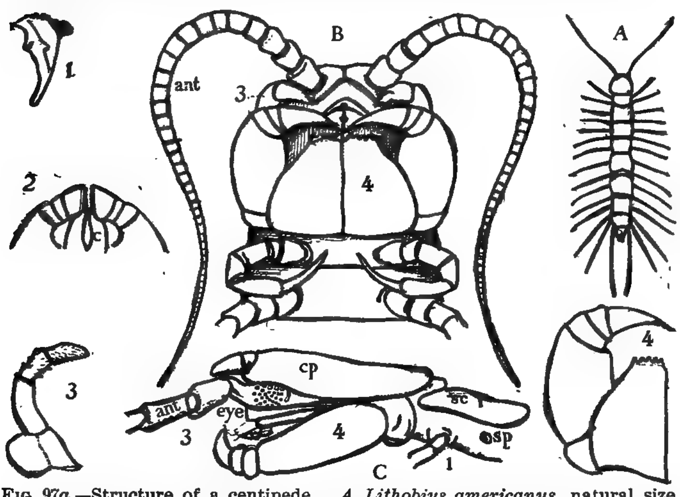

FIG. 97*a*.—Structure of a centipede. *A*, *Lithobius americanus*, natural size. *B*, under side of head and first two body-segments and legs, enlarged: *ant*, antenna; 1. jaws; 2. first accessory jaw; *c*, lingua; 3, second accessory jaw and palpus; 4, poison-jaw. (Kingsley del.) *C*. side view of head (after Newport): *ep*, epicranium; *l*, frontal plate; *sc*, scute; *p*, first leg; *sp*, spiracle.

(*To face page* 90.)

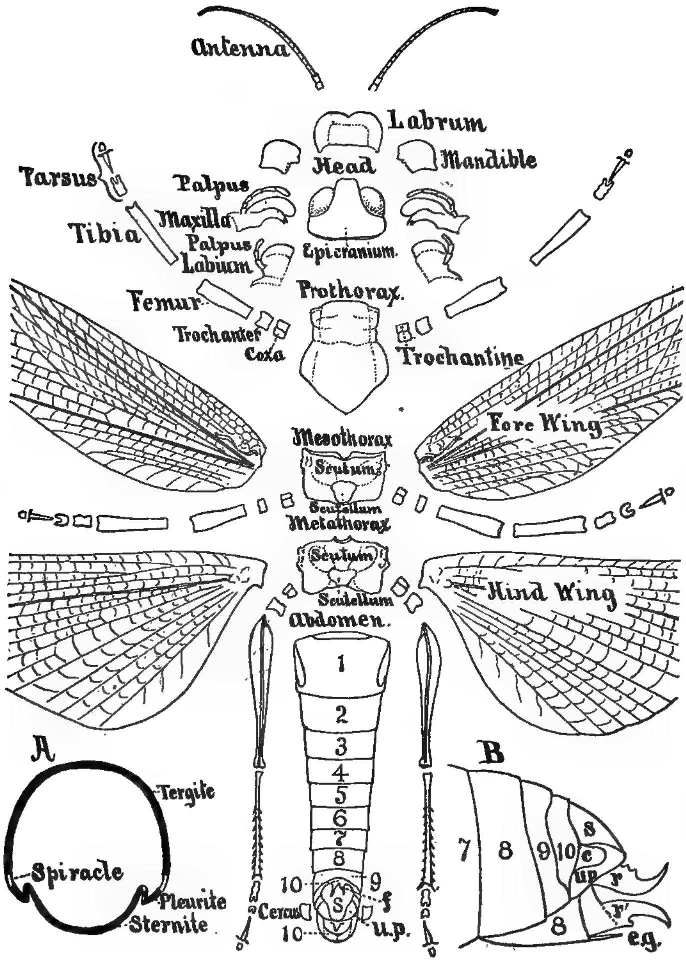

FIG. 97.—External anatomy of *Caloptenus spretus*, the head and thorax disjointed.

(*To face page* 91.)

CHAPTER XII.

MILLEPEDES AND CENTIPEDES.*

THE millepedes and centipedes are examples of the class *Myriopoda,* so called from the numerous feet they possess. If we examine a common millepede, called *Julus,* which may be found under sticks and dead leaves in damp places, its body will be seen to consist of a head with short antennæ succeeded by a large number of cylindrical segments, each bearing two pairs of feet, and not grouped into a thoracic and abdominal region. It will be seen that besides the antennæ there are but two pairs of mouth-appendages, the first pair being jaws, the second forming the under lip; while the feet are inserted close together, and the eyes are compound. When disturbed or at rest the body is coiled.

We may then compare with the millepede a centipede. Its body is seen to be flattened both above and below, the feet arising from the sides of the body. On examining the head, besides the antennæ, the large curved poison-jaws are the most noticeable appendages; these are perforated at the end, while in the base is a large poison-gland. The small Lithobius is poisonous to insects, but the bite of the centipede, particularly the large tropical species, is more deadly than the sting of the scorpion. Between the antennæ and poison-jaws are three pairs of jaws (Fig. 97*a*, 1, 2, 3), quite unlike those of insects. The eyes of centipedes are usually simple, but arranged in a group on each side of the head. When hatched the young Julus has a short body, with but three pairs of legs; hence before reaching maturity it undergoes a metamorphosis. On the other hand, the centipede when hatched has nearly the same number of segments as the adult. The Myriopoda breathe by air-tubes, which open externally through spiracles (*C, sp*).

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* See Wood's Myriopoda of North America. 1865.

CHAPTER XIII.

LOCUSTS AND GRASSHOPPERS.

THERE is no better way in beginning the study of insects than to catch a common locust or grasshopper, and to carefully examine its head, wings, legs, and other parts. By studying one insect with care the pupil can obtain a good idea of the nature of all other insects.*

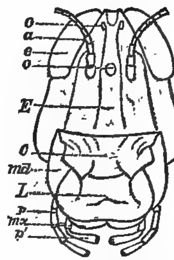

FIG. 99.—Front view of the head of *C. spretus*. *E*, epicranium; *C*, clypeus; *L*, labrum; *o o*, ocelli; *e*, eye; *a*, antenna; *md*, mandible; *mx*, portion of maxilla uncovered by the labrum; *p*, maxillary palpus; *p'*, labial palpus.

It will be seen that, as in the lobster, there are a head and hind body and upper and under side; and that if divided in halves, each side would exactly repeat the other. The body is more distinctly divided into three parts than in the lobster, since the head is more distinct from the chest or thorax. The body appears as if twice cut into; hence the name insect, from *insectum*, which is the Latin for "cut into," or insected.

As in the lobster, the outer wall or skin forms a hard

* Anybody can catch a grasshopper; after it is caught it may be killed without its suffering any pain, by throwing it into a bottle containing cotton saturated with ether. It may when dead be taken out of the collecting-bottle and dried. It is most convenient to pin it. This may be done by thrusting a slender insect-pin through the collar. For class use, it is better to preserve a lot of grasshoppers in alcohol; before using them they can be soaked in water to take out the alcoholic odor, and can then be easily handled, and the wings unfolded or the mouth parts and legs moved without their breaking off. In examining insects it is well to be provided with a hand-lens or microscope.

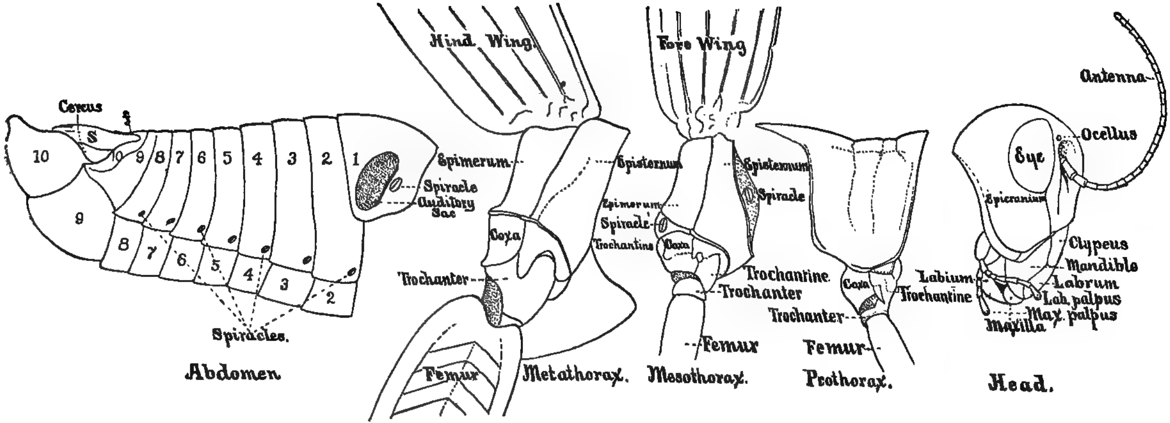

FIG. 98.—Locust, *Caloptenus*, side-view, with the thorax separate from the head and abdomen, and divided into its three segments.

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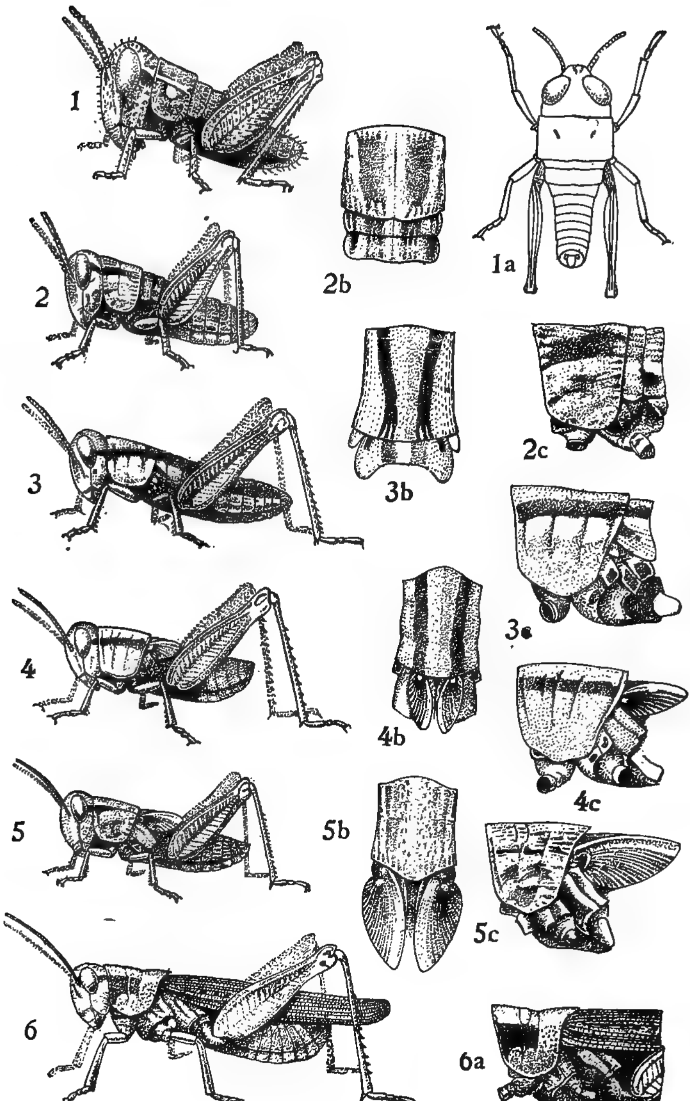

FIG. 98*a*.—Metamorphosis of the Locust. 1, 2, Larva; 3-5, pupa; 6, imago.

(*To face page* 93.)

crust, which however is more or less flexible, but strong enough (as seen in a beetle) to protect the soft parts within from injury, and yet so light that the insect can hop, run about, or fly, and not be impeded by its armor.

We will begin our examination with the hind body, which consists of ten rings, the tenth being imperfect. It will be seen that the first nine rings are quite circular and well formed. At the end of the hind body is the ovipositor.

It will be seen that the legs are six in number, and that they are attached to the chest or mid body in pairs, one to each segment. It will be easy to separate the head from the first segment of the mid-body or thorax, because it forms a large collar. If it be thus separated, the legs will come off with it. This will leave the rest of the mid-body composed of two segments, each bearing below a pair of legs, and above a pair of wings.

The chest or thorax, therefore, as seen in Fig. 97, consists of three segments, called the "prothorax," "mesothorax," and "metathorax," or fore, middle, and hind thoracic rings (see also Fig. 98). They each bear a pair of legs, and the two hinder each a pair of wings. The upper portion of the middle and hind segments, owing to the presence of wings and the necessity of freedom of movement to the muscles of flight, are divided or differentiated into two pieces, the "scutum" and "scutellum" * (Fig. 97), the former being the larger, extending across the back, and the scutellum a smaller, central, shield-like piece.

It will be seen, also, that the side of each segment of the thorax is divided into distinct pieces, so as to give freedom of motion to the muscles of the legs and wings which are contained within the chest.

The legs are each divided into a hip-joint (femur); a shank or tibia, and a tarsus, or foot, with two toe-joints, ending in a pair of claws. The thigh-joints, especially of the last pair, are much larger than the others, as the locust is a vigorous leaper, hopping many times its own height. The shanks are long and slender and armed with two rows of spines. How the legs are attached to the chest may be seen by observing the specimen with the aid of the enlarged sketch (Figs. 98, 100, and 101).

The two pairs of wings are quite unlike; the front pair, when the locust is not flying, rests directly upon the hinder pair, but during flight

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* There are in some insects, as in many *Lepidoptera* and *Hymenoptera* and the *Neuroptera*, four tergal pieces, i.e., *præscutum, scutum, scutellum*, and *postscutellum*, the first and fourth pieces being usually very small, and often imperfect.

is held in front. They are long and narrow, with a number of raised ridges called veins, a few larger ones extending along the wing, and the smaller ones across.

The hind wings are broad and thin, so as to be transparent, and are veined like a leaf. They are folded up like a fan, and, when spread out, the locust can sail all day in the air, borne along by the wind. Most locusts fly but a short distance, but the migratory locust of Eastern countries and the Rocky-Mountain locust of the Far West have longer wings, and can thus fly farther.

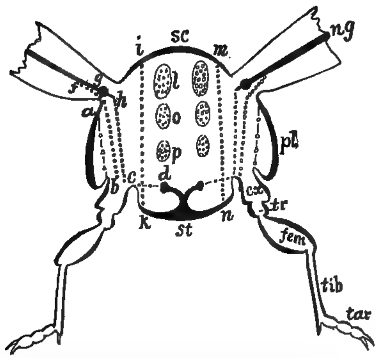

Fig. 100.—Cross-section through the thorax of a butterfly. *a b*, muscles for raising, *c d*, for drawing downward and inward, the legs; *d*, entothorax arising from the sternum, *k*, *st*; *ng*, wing-vein; *g*, fulcrum, or turning-point; *c h*, muscles for lowering, *b f*, for raising, the wing; *i k* and *m n*, muscles for lowering, *l o p*, for raising, the dorsal plates.

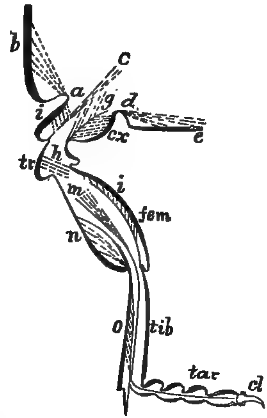

Fig. 101.—Diagram of muscles of an insect's leg. Besides the muscles at the insertion of the limb for raising and lowering it, in the trochanter (*tr*) is a muscle for rotating the leg; *i*, for stretching the tibia (*tib*); *n*, flexor of tibia; *o*, flexor of the tarsus; *m*, retractor of the tarsus and claws (*cl*).

Now we are ready to look at the head. First, as to the eyes. There are two kinds: a pair of large compound eyes, one on each side of the head. In front are three little shining points (Fig. 99, *o*), which are the simple eyes. They are rather hard to see without a lens, especially the upper ones, which are partly overhung by a ridge; they are arranged in a triangle, the third one forming the apex of the triangle, and situated between the antennæ, as seen in Fig. 99, *o*. The feelers are called antennæ, from their fancied resemblance to the antenna or yard of a Roman vessel. They are long and slender, and composed of about twenty joints, the number varying in different kinds of locusts and grasshoppers. Below the antennæ in front is the "clypeus," or visor (Fig. 99, *C*), and to the clypeus is attached a loose flap called the upper lip (*labrum*), which may be readily moved up and down.

How these grasshoppers take their food is not commonly understood; but a little close observation of the parts of the mouth will teach us. They consist of a pair of true jaws called "mandibles;" and of a pair of accessory jaws called maxillæ, and of the under lip or labium.

The jaws are black, horny, and toothed along the free or cutting edge. They work laterally, and are well adapted for cutting off bits of leaves and stalks of grass, passing through the leaf somewhat like a circular saw. One can easily watch the process.

But the food must be tasted and arranged in favorable positions and held between the jaws. In doing this the maxillæ are of service. If a maxilla is removed and examined with the microscope. we shall see that it is divided into three parts, an inner, middle, and outer division. The inner is like a slender jaw, with sharp, teeth-like hooks; these serve to hold the food while it is being cut or ground to pieces by the millstone-like jaws. The middle division is somewhat spoon-shaped; its special use is not well known. The outer division is a feeler (*palpus*), and consists of five joints. The sense of taste, and perhaps smell, probably exist in the feelers of some insects.

The under lip forms the lower side of the mouth, and is a movable flap, which supports another pair of tasters or feelers, which are, however, only three-jointed. We thus see that the mouth-parts of the insect are fewer in number and simpler in form than those of the lobster.

Now, one may like to know how insects hear and where the ears are situated. Strangely enough, they are not in the head or near it, but in locusts they are placed on the first ring of the hind body, where they form a sac, as is to be seen in Fig. 98. One can easily find the two auditory sacs by lifting up the wings and looking for them at the base of the hind body. In the green grasshoppers and crickets the ears are situated in the fore-legs.

Having ears to hear, locusts, grasshoppers, and crickets are also very musical. One may sometimes see the red-legged locust standing on the ground and rubbing one leg against the folded wing, and a shrill chirruping noise may be heard. The noise is made by a row of dull spines on the inside of the femur, forming a rude file which rasps the wing. Certain grasshoppers, as the katydid and the crickets, have on the under side of the uppermost of the fore-wings a sort of file which rubs over a resonant surface, like a drum's head. The file may be likened to the bow, and the drum-like space to the body of the violin. Thus, most grasshoppers are fiddlers, and during the summer, both by day and night, the air resounds with the music of these primitive violinists. This noise may add to our pleasure or become tedious and disagreeable. This makes little difference, for insect music is all-important. It is the cricket's love-call,

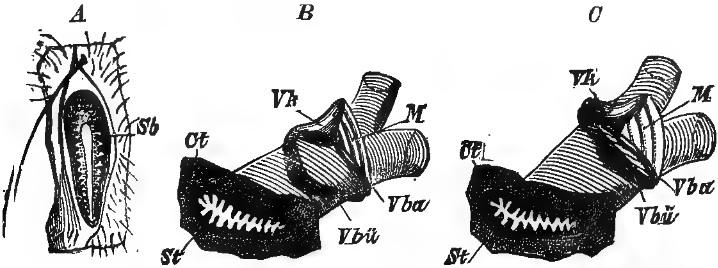

FIG. 102.—*A*, thoracic stigma of the house-fly: *Sb*, valve which closes the opening. *B*, *C*, diagrammatic figures of the internal apparatus which closes the trachea, in the stag beetle: *B*, the trachea open; in *C*, closed; *St*, the stigma, with its grated lips; *Ct*, cuticula of the body-walls; *Vk*, closing-pouch; *Vbü*, closing-bow; *Vba*, closing-band; *M*, occlusor muscle.—From Judeich and Nitsche, after Landois.

and were crickets, etc., deaf and dumb, we are safe in saying the breed would soon run out.

We have seen that the lobster breathes by gills on the outside of the body. With insects all this is changed. They do not, however, draw in the air through their mouth, but inhale it through minute openings on the side of the chest and hind body. There are in the locust ten pairs of these holes or "spiracles;" two pairs on the thorax, and the remainder on the sides of the abdomen. They are hard to find at first, but may be detected with the aid of Fig. 98, where they are distinctly pointed out. The air enters these holes, and is carried all over the body by air-tubes, which are fine chitinous tubes, kept open by a series of short elastic spiral thickenings, the tubes being enveloped by the tracheal hypodermis.

In collecting grasshoppers one often finds the young which are without wings, and others with wings just beginning to grow out. It will be seen, then, that the young grasshopper differs only from the old ones by having no wings. There is no great change, such as marks the life-

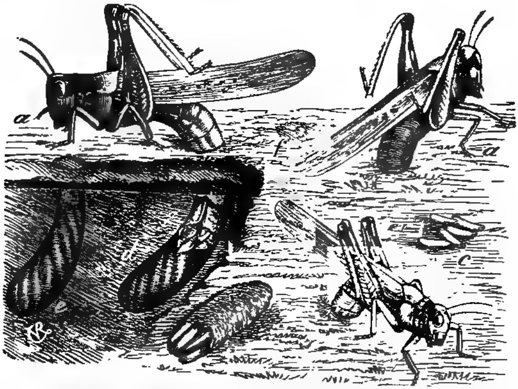

Fig. 103.—Rocky-Mountain locust laying its eggs (*c*) one by one, forming an oval mass (*e*). (All natural size.)—After Riley.

history of a butterfly. Perhaps it is by reason of their incomplete metamorphosis, the general uniformity of their habits, and their living on vegetable food, that Orthoptera are not numerous in species compared with the beetles and higher orders.

The locusts and grasshoppers lay their eggs in packets in the ground (Fig. 103). With its ovipositor, which is made up of three pairs of spines, the two outer pairs very large and stout, the locust thrusts its hind body deep into the earth and deposits its eggs one after another.

Fig. 104.—Leaf-insect (*Phyllium*). (Half natural size.)

Many dangers attend the life of these insects. To overcome or to avoid them, many kinds, as certain katydids, the leaf-insects (Fig. 104), and stick-insects, mimic leaves and sticks, so that birds are deceived by them.

Locusts are also attacked by parasites: little red mites stick to their bodies; hair-worms, and especially the maggot of the flesh-fly, infest them, and thus thousands of them are swept away. All this is of use, however, for were it not for the kindly aid thus rendered in nature, the earth would be each year overrun with locusts.

Fig. 98*a* illustrates the incomplete metamorphosis of the locust: 1, side view, and 1*a*, dorsal view, represent the freshly hatched larva; 2, the larva after its first moult; 2*b*, the three thoracic segments seen from above, there being no rudiments of wings; 3, 4, and 5 represent the three pupal stages; the rudimentary wings becoming larger at each moult, until, after the fourth moult, the wings attain their full size, as at 6 and 6*a*, when the insect is fully grown.

Besides the common black cricket, the green tree-cricket is very common. The males alone make the loud shrill noise so constantly heard late in summer; while the females bore into the branches of vines and shrubs for the purpose of laying their eggs.

In the cockroach the body is much flattened, so that it can hide by day in cracks or under stones.

To the *Orthoptera* also belong the Mantis and the "Stick-bug," which is wingless, and mimics sticks and stems of leaves.

The Orthoptera are so called because in the grasshoppers and locusts the fore wings are more or less narrow and straight.

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CHAPTER XIV.

NET-VEINED INSECTS WITH AN INCOMPLETE METAMORPHOSIS.*

SEVERAL orders of insects belong here, which agree in having net-veined wings and an incomplete metamorphosis.

The White Ants, etc.—The workers are wingless, somewhat resembling ants, and like them burrowing in wood, but they are white, while the males and females have long narrow wings which lie flat on the back. The insects of this order are called *Platyptera,* since their wings when at rest are laid flat on the back of the body.

The May Flies.—These insects are short-lived in the final winged state, living but a day or so. Some of the species belong to the genus Ephemera. In their winged state they take no food, their mouth-parts being rudimentary; their hind wings are small or wanting, while the hind-body ends in three long filaments. The order is called *Plectoptera* (Greek, *plectos,* a net, and *pteron,* wing).

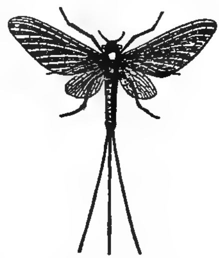

FIG. 104*a*.—May Fly. (Natural size.)

The Dragon Flies.—These insects represent an order called *Odonata.* Their larvæ and pupæ are aquatic. Their hind wings are as large as the fore pair and finely net-veined.

The Thrips.—It forms a connecting link between the net-veined insects and the bugs. The jaws are bristle-like, situated within the maxillæ, and there are two pairs of short palpi. The wings are narrow and fringed, hence the name of the order to which Thrips belongs, i.e. *Thysanoptera* (Greek, *thusanos,* fringe; *pteron,* wing).

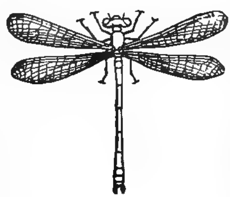

FIG. 104*b*.—Agrion, a dragon-fly. (Natural size.)

FIG. 104*c*.—Thrips. (Much enlarged.)

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* LITERATURE.—Hagen's Synopsis of N. A. Neuroptera.

CHAPTER XV.

THE BUGS, OR SUCKING INSECTS.

WE now come to insects which gain their livelihood by piercing and sucking the sap of plants or the blood of other insects; and the change in the jaws by which a sucking beak is formed is very curious.

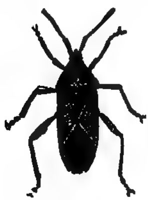

FIG. 106.—Squash-bug.

One can obtain an excellent idea of what a bug is by dissecting a common squash-bug (Fig. 105). With a lens and a needle mounted in a handle, the student can, after a few trials, dissect the head from the body, examine the beak, the wings; separate the thorax into its separate segments, dissect the hind body or abdomen from the thorax, and study these parts with the aid of Fig. 105, always remembering to compare each part with its corresponding part in the grasshopper. It will be seen that the bug has, besides a pair of compound eyes, two simple eyes behind; and that it takes its food by suction, plunging its long slender beak into the stems of plants or into the flesh of its victim. This beak is the distinctive mark of the bugs, which thus differ from other insects in

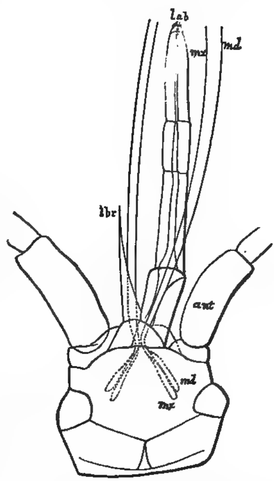

FIG. 107.—Head of bed-bug, showing the structure of the beak. *lab*, the four-jointed labium, which contains the bristle-like mandibles (*md*) and maxillæ (*mx*), whose bases are shown by the dotted lines in the head; *lbr*, labrum; *ant*, antenna.

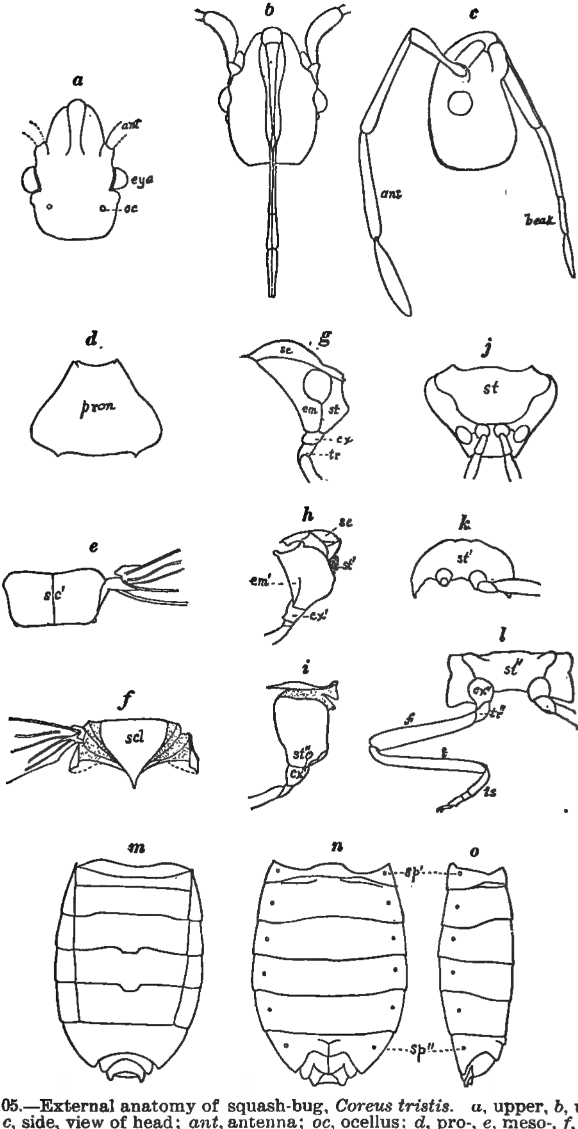

Fig. 105.—External anatomy of squash-bug, *Coreus tristis.* *a*, upper, *b*, under, and *c*, side, view of head; *ant*, antenna; *oc*, ocellus; *d*, pro-, *e*, meso-, *f*, meta-notum; *sc'*, meso-scutum; *scl*, meso scutellum; *g*, pro-, *h*, meso-, *i*, meta-pleurum; *st*, pro-, *st'*, meso-, *st''*, meta-sternum; *epis*. *epis'*, *epis''*, episternum of pro-, meso-, and meta-thorax; *em*, *em'*, *em''*, epimerum of pro-, meso-, and meta-thorax; *j*. *k*. *l*, under side of the pro-, meso-, and meta-thorax; *cx''*, coxa; *tr''*, trochanter; *f*, femur; *t*, tibia; *ts*. tarsus; *m*, dorsal, *n*, ventral, *o*, side, view of abdomen; *sp'*, *sp''*, six pairs of spiracles. (*To face page* 100.)

their manner of taking their food. It is formed of the long, slender needle-like mandibles and maxillæ which are united so as to form a hollow sucking-tube. The tube thus formed is ensheathed by the underlip (*labium*) which is long, hollow, and composed of four joints. Above, the sucking-tube is protected by the labrum (Figs. 107 and 108, *lbr*). There are estimated to be nearly 5000 species of bugs in North America, but all have a beak; and through their different kinds of food and habits there is a chance for the individuals of each species to get a living.

The bugs also differ from other insects, and somewhat

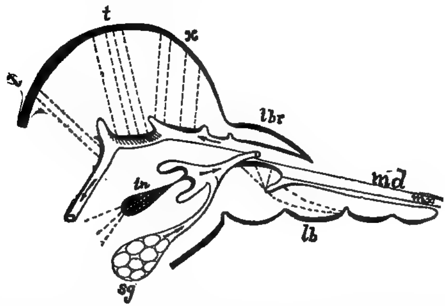

FIG. 108.—Longitudinal section of a bug's head. *lbr*, labrum; *lb*, labium; *md*, mandible; *mx*, maxilla; *sg*, salivary gland (the arrows pointing outward show the course of the salivary duct into the mouth; the inward-pointing arrows indicate the throat and the direction taken by the food to the stomach); *l t x*, muscles which elevate the roof of the mouth.

anticipate the beetles, in the fore-wings, which are thickened at the base so as to protect the thin under pair. Since the basal half of the fore-wings is thus thickened, the bugs are called *Hemiptera*, from *hemi*, half; and *pteron*, wing.

Like the grasshopper, the bugs have an incomplete metamorphosis. Fig. 109 represents the transformations of the chinch-bug, the young having no wings. After reaching the stage *e*, the wing appears as in the stages *f* and *g*. This bug does immense harm to farmers by sucking the sap of wheat and corn.

The Cicada and its allies, with the Aphidæ or plant-lice, have clear fore-wings, but otherwise do not essentially dif-

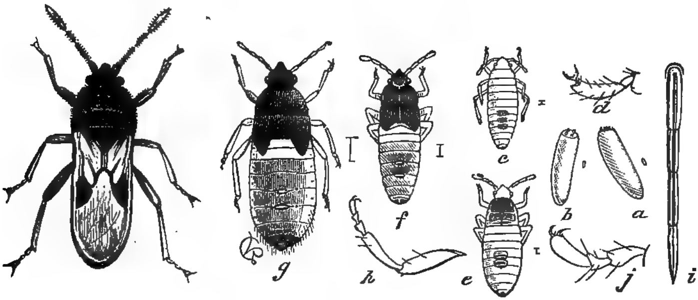

FIG. 109.—Chinch-bug. *a*, *b*, egg; *c*, *e*, larva; *f*, *g*, pupa.

fer from the true bugs. The seventeen-year Cicada (Fig. 110) lays its eggs in holes in oak twigs (Fig. 110, *d*) by means

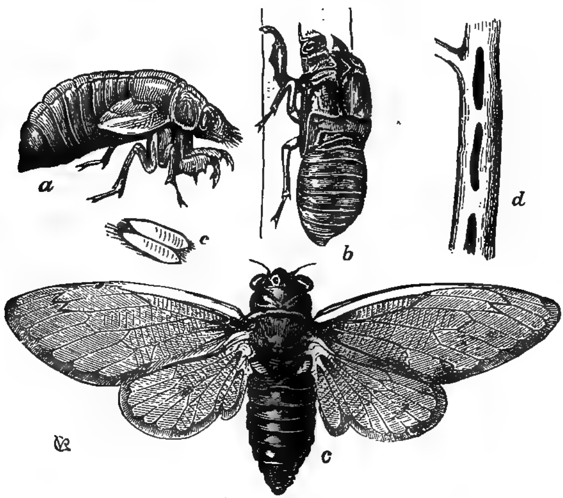

FIG. 110.—17-year Cicada. *c*, eggs; *a*, *b*, pupa.

of a stout saw or ovipositor in the end of its body, while the males alone have under their wings, at the base of the abdomen, a musical apparatus, like a pair of kettle-drums, by which the shrilling noise is produced. While the lives of most insects span not a year, or two at the most, the seventeen-year Cicada lives over sixteen years as a larva. It is possible that it owes its long life to the fact that it lives anchored by its beak to the rootlets of trees deep in the earth, beyond the reach of its enemies and the severity of the frost; hence every seventeen years it appears locally in great numbers in the warmer parts of our country.

The Aphides or plant-lice, on the other hand, prosper by reason of their wonderful fertility, the young being brought forth alive. There are as many as nine or ten generations;

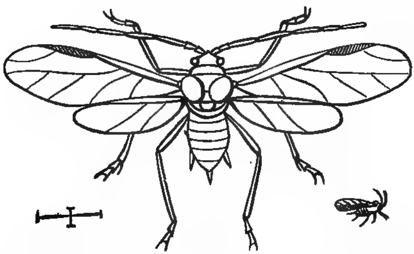

FIG. 111.—Apple Aphis. (Natural size and enlarged.)

a single Aphis becoming the parent in one summer of millions of children and grandchildren. Though they are devoured in enormous numbers by other insects and by birds, still hosts are left to prey on our fruit-trees, succulent vegetables, and household plants. Thus, these weak, defenceless creatures owe their success in life to their unusual powers of reproduction, the young budding forth within the parent, as the polyp sends forth bud after bud which eventually become jelly-fish. The last brood of Aphides lays eggs and then dies.

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CHAPTER XVI.

THE NET-VEINED INSECTS WITH A COMPLETE META-MORPHOSIS.*

WE now come to insects with a complete metamorphosis, the larva being more or less worm-like.

The Lace-winged Flies.—Insects of the order *Neuroptera* (Greek, nerve-wings) have free jaws adapted for biting; the tongue (ligula) is entire, large, broad, and rounded, while the prothorax is large and square. Examples of the order are Corydalus, the lace-winged fly (*Chrysopa*), and the ant-lion. The young of the lace-winged fly has great sickle-shaped jaws, and feeds on Aphides.

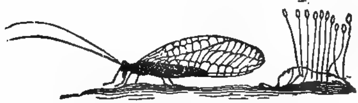

FIG. 111*a*.—Chrysopa and its eggs placed on stalks. (Natural size.)

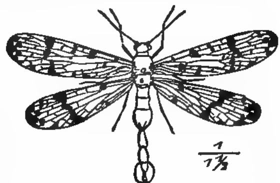

FIG. 111*b*.—Panorpa or Scorpion Fly.

The Scorpion Flies.—These insects represent the order *Mecoptera.* Their wings are narrow and long, hence the name of the order (Greek, *mecos,* length). They are net-veined insects, but differ from the *Neuroptera* in having larvæ like caterpillars; while the head of the adult is elongated and beaked, with minute jaws at the end of the snout.

The Caddis Flies.—These constitute the order *Trichoptera* (Greek, *thrix, trichos,* hair; the wings being quite hairy). The caddis flies closely resemble the smaller moths; as in moths the jaws are absent or obsolete, but well developed in the larva, which is called a case-worm, since it lives in water, in a tube or case which it constructs from grains of sand or bits of leaves.

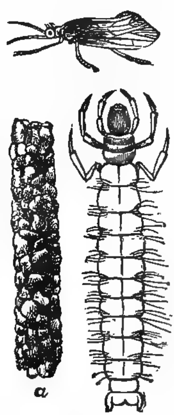

FIG. 111*c*.—Caddis Fly and Case-worm. *a*, its case (enlarged).

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* LITERATURE.—Hagen's Synopsis of N. A. Neuroptera.

CHAPTER XVII.

THE BEETLES, OR SHEATH-WINGED INSECTS.

All beetles are called *Coleoptera,* the word meaning sheath-winged. Fig. 112 represents a beetle in the act of

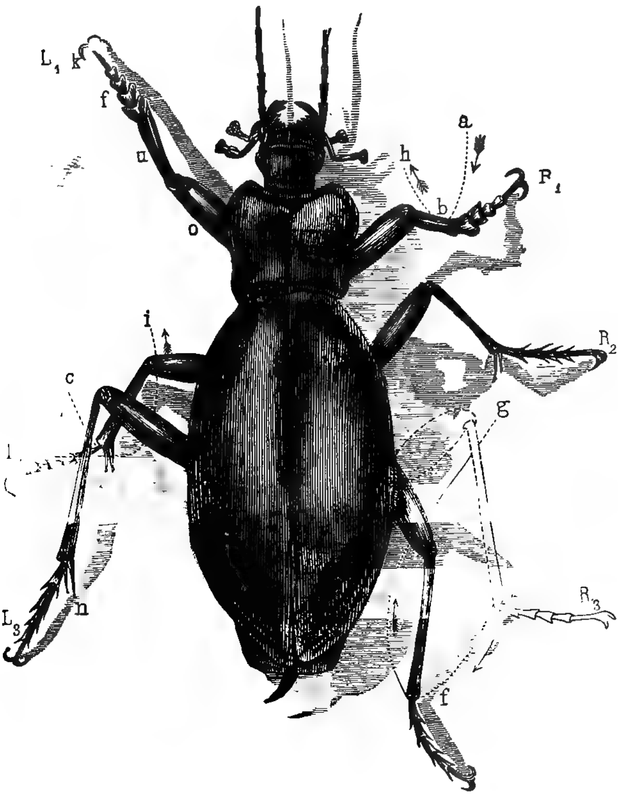

Fig. 112.—A Carabus beetle in the act of walking or running. Three legs (L_1, R_2, L_3) are directed forward, while the others (R_1, L_2, R_3), which are directed backward toward the tail, have ended their activity. *a b*, *c d*, and *e f* are curves described by the end of the tibiæ and passing back to the end of the body; *b h*, *d i*, and *f g* are curves described by the same legs during the passive change of position.

walking, and it would be worth while to watch a live beetle when in motion. It will be seen that, like all other insects, it raises each leg alternately with its fellow. Watch also the movements of the antennæ and mouth-feelers (palpi), how they feel and survey the ground over which the beetle passes. While the head is distinct from the thorax, the latter is divided into two distinct parts. The prothorax is separated from the rest of the thorax, and forms a solid shield, while the two wing-bearing segments are closely united, and are concealed by the wing-covers, when the beetle is not on the wing.

Beetles differ from the grasshoppers and all other insects in the fore-wings, which are thick and solid, and serve as sheaths to protect the body: hence their name, *elytra*, given to the fore-wings (Fig. 114, *d*, *m*). The hind-wings do all the work during flight, and at rest they are folded out of sight under the fore-wings or elytra. The different parts of the beetle may be examined with the aid of Fig. 114.

FIG. 113.—Maxilla and 4-jointed maxillary palpus of May-beetle (Enlarged.)

The antennæ of beetles are of various shapes and functions. If the jaws and other parts of the mouth be dissected out, and for this purpose a large ground-beetle or tiger-beetle is best, they will be found to closely resemble those of the locust. The legs are the same, but there are usually five joints to the feet, though there are many beetles with but two toe-joints.

A young beetle is called a "grub." If we place a common "white grub" (Fig. 115) by the side of a May-beetle, we shall see how unlike the child is to the parent, and how great is the change from the grub to the beetle. The series of changes or transformations is called a *metamorphosis*.

The "white worm" or grub, as everybody knows who has dug in a garden, is turned up with the spade early in the spring. It is as thick as one's little finger; soft and fleshy, with a dark honey-yellow head, while the rest of the body

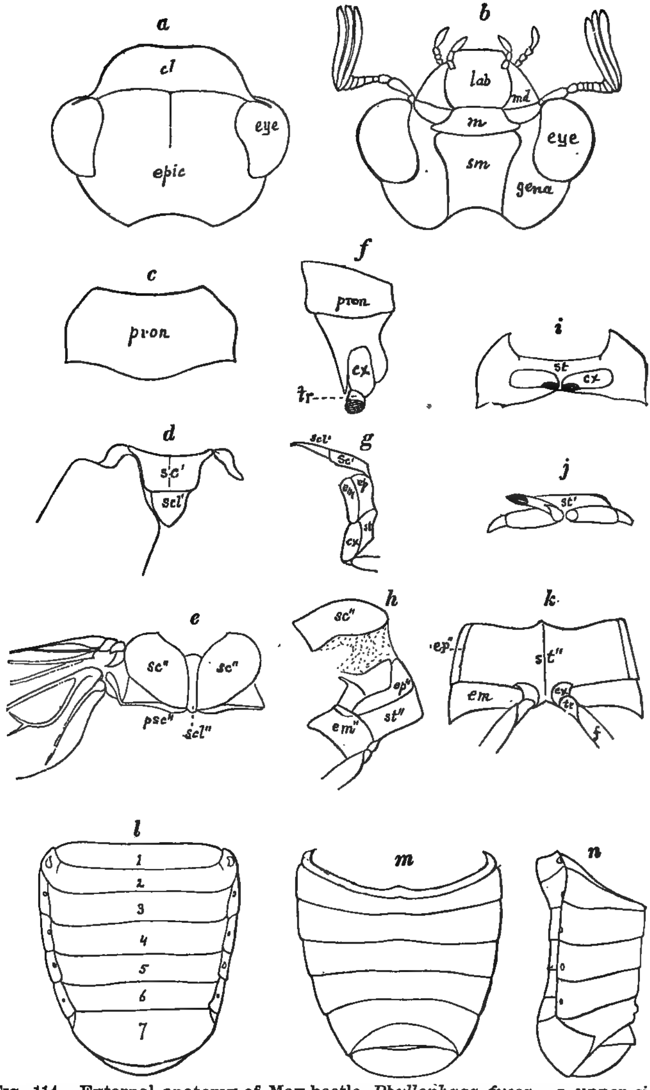

FIG. 114.—External anatomy of May-beetle, *Phyllophaga fusca*. *a*, upper side of head; *epic*, epicranium; *cl*, clypeus; *b*, under side; *m*, mentum; *sm*, submentum; *lab*, labium; *md*, mandible; *c*, pronotum; *d*, mesonotum; *e*, metanotum; *f*, pro-, *g*, meso-, *h*, meta-pleurum; *i*, pro-, *j*, meso-, *k*, meta-pleurum; *l*, dorsal, *m*, ventral, *n*, side, view of abdomen; 1–7, seven basal abdominal segments; *psc''*, post-scutellum; other letters as in Fig. 105. (*To face page* 106.)

is white; but the six legs are horny. It is so fat and unwieldy that it lies curled up on its side, a picture of helpless obesity. It is very destructive to the roots of grass and vegetables, but towards the first of May it stops feeding and makes a rude chamber or cell in the earth. Here it turns into a chrysalis or pupa (Fig. 115, 1), and now it looks like a pale, sleeping or mummy-like beetle, with small wings and legs folded against the body. By the end of May the beetle casts aside the pupa skin, makes its way up out

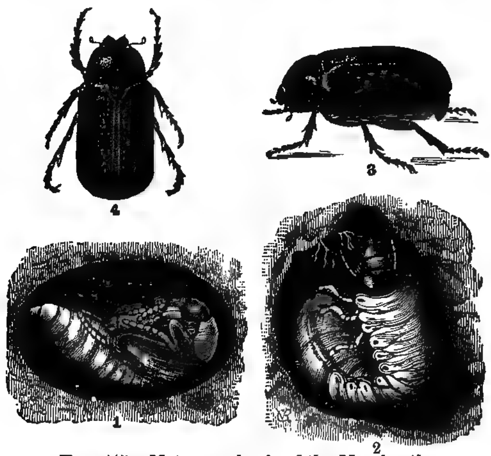

FIG. 115.—Metamorphosis of the May-beetle.

of the earth, and flies about during the early part of summer.

In describing a single beetle, we have noted the distinguishing marks of almost the whole order; although there are known to be over 80,000 species now living in different parts of the world. The great army of beetles is not a very motley body, but rather like a well-uniformed and well-drilled army-corps.

Protected from harm by their thick shell-like skin and their thick wing-covers, and living, as grubs, chrysalids, and beetles, quite different lives, it would be hard to exterminate them. Myriad as are their forms, every species has slightly different habits and surroundings from its allies, and thus fills a niche in the insect-world which it alone can occupy. And it is this wonderful power of adaptation to changes in circumstances, as well as their solid skins and complete metamorphosis, which has enabled the great beetle order of over 80,000 kinds to become so abundant and prominent a group. They are preyed upon at different times of life by different enemies. Worms, parasitic mites, and birds and beasts constantly make war upon them, but these enemies only reduce their numbers to healthy limits; so that, after all the inroads made upon them, there are still food enough and room enough for each kind to exist in its own beetle-fashion in its own little beetle-world.

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CHAPTER XVIII.

THE HOUSE FLY AND OTHER TWO-WINGED INSECTS.

The body of the fly differs in a good many points from that of a grasshopper or beetle. In the first place, there are but two wings; hence the flies are called two-winged or *Diptera*, from two Greek words signifying two wings.

Now, closely inspecting the house-fly, we see that the head is distinct from the thorax, and the latter from the hind body. The three divisions are seen to be very well marked.

Turning to the head (Fig. 116) we see that the compound eyes are very large and full. The antennæ are short

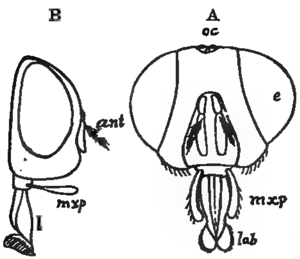

Fig. 116.—*A*, front, and *B*, side, view of head of house-fly. *oc*, simple, *e*, compound, eye; *ant*. antenna; *mxp*, maxillary palpi; *l*, tongue; *lab*, labellum. (Magnified.)

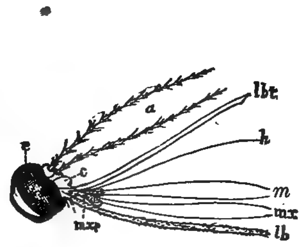

Fig. 117.—Head and mouth parts of mosquito. *e*, eye; *a*, antennæ; *lbr*, labrum; *h*, hypopharynx; *m*, mandibles; *mx*, maxillæ; *mxp*, maxillary palpus; *lb*, labium; *c*, clypeus. (Magnified.)

and two-jointed, and at rest fall down into a cavity in the face; they bear at their base two feathery bristles.

Instead of jaws and well-formed accessory jaws and an under-lip like those of the mosquito (Fig. 117), these parts are transformed into a sort of tongue for lapping liquid food (Fig. 118). The under-lip is changed into a great fleshy proboscis (Fig. 118 *A, B*), which is bent under the head when not in use. The structure of the tongue is very curious. When the fly settles upon a lump of sugar or other sweet object, or even upon the back of our hand

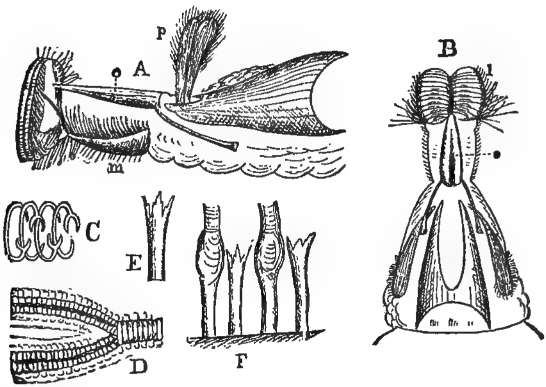

FIG. 118.—Proboscis of the house-fly. *A*, right side view; *B*, view of the same from above; *C*, semi-tubes of its false tracheæ; *E*, a tooth; *F*, arrangement of teeth between roots of false tracheæ. In *A* and *B*, *l*, labellum; *o*, operculum; *p*, palps; *f*, fulcrum; *m*, mentum. (Magnified.)—After Macloskie.

when covered with perspiration, it unbends its proboscis, extends it, and the broad knob-like end divides into two flat, muscular leaves (*B l*), which thus form a broad sucker-

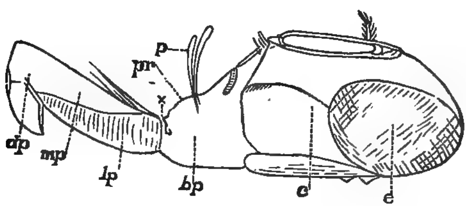

FIG. 119.—Head and proboscis of the blow-fly. *e*, eye; *c*, cranium; *bp*, basiproboscis; *p*, maxillary palpus; *pr*, chitinous ridges uniting with the rudimentary maxilla; *lp*, lower labial plate; *mp*, medi-, *dp*, disti-proboscis.

like surface, with which the fly laps up liquid sweets, or any matter which seems good to the fly's mind.

The two flaps at the end of the proboscis are supported upon a framework of strong but delicate rods which act as a set of springs to open and shut the broad flaps. The inside of this broad, fleshy expansion is rough, like a rasp, and, as Newport states, "is easily employed by the insect in scraping or tearing delicate surfaces. It is by means of this curious structure that the busy house-fly occasions

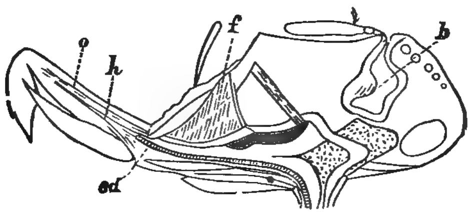

FIG. 120.—Section through the head of the blow-fly. *b*, cranial bladder; *f*, fulcrum; *h*, hypopharynx; *sd*, salivary duct leading into the throat; *o*, maxilla.

much mischief to the covers of our books, by scraping off the albuminous polish, and leaving tracings of its depredations in the soiled and spotted appearance which it occasions on them." The head of the blow-fly may also be examined with the aid of Figs. 119–122.

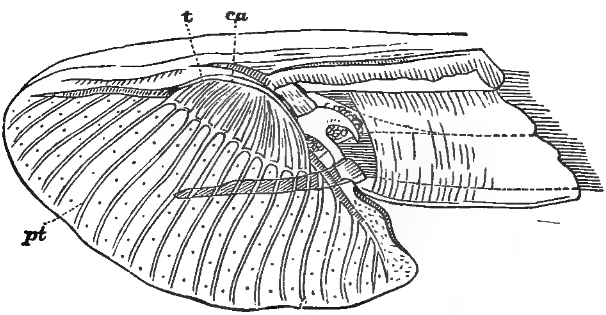

FIG. 121.—Side-view of the labellum. *ca*, chitinous arch supporting the false tracheæ (*pt*).

The thorax is somewhat rounded, and though composed of three rings, yet these are so consolidated that it is at first hard to identify them. The prothorax is rudimentary, the thorax consisting almost wholly of the middle ring (mesothorax). The latter forms the greater part of the thorax. It consists of three large upper pieces, the *præscutum, scutum,* and the triangular or shield-shaped *scutellum* (Fig.

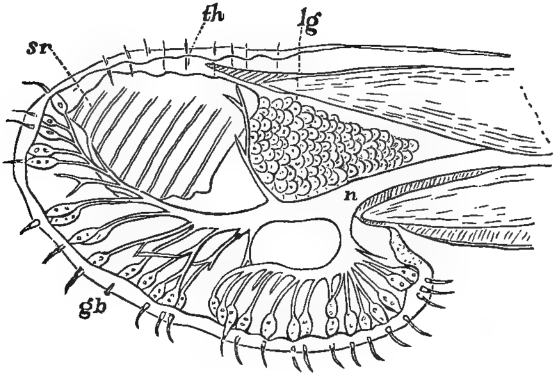

FIG. 122.—Nerves of the tongue. *lg*, labellar glands; *th*, tactile hairs; *gb*, gland-bristles; *n*, nerve —Figs. 119–122 after Kraepelin.

123, *sct'*). To the side of this segment are attached the two wings. The third ring (metathorax) is but partly

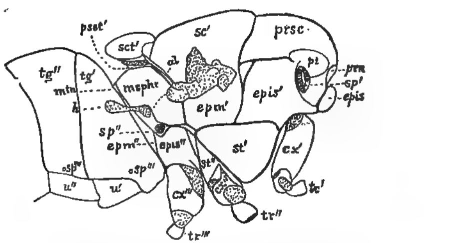

FIG. 123.—Thorax of the house-fly. *prn*, pronotum; *prsc*, præscutum; *sc'*, mesoscutum; *sct'*, mesoscutellum; *psct'*, postscutellum; *al*, insertion of alula, extending to the insertion of the wings, which have been removed; *msphr*, mesophragma; *h*, balancer (halter); *pt*, patagia; *mtn*, metanotum; *epis*, *epis'*, *epis''*, episternum of pro-, meso- and meta-thorax; *epm'*, *epm''*, meso- and meta-epimerum; *st'*, *st''*, meso- and meta-sternum; *cx'*, *cx''*, *cx'''*, coxæ; *tr'*, *tr''*, *tr'''*, trochanters of the three pairs of legs; *sp'*, *sp''*, *sp'''*, *sp''''*, *sp'''''*, first to fifth spiracles; *tg'*, *ty''*, tergites of first and second abdominal segments; *u'*, *u''*, urites.

formed, and cannot be seen from above. It supports the balancers (Fig. 123, *h*), which are in reality the hind wings, much changed in form and use. There are also broad scales, under the base of the true wings, called the winglets (alulæ). The fly's wing is broad, thin, and transparent, and strengthened especially along the front edge by slender, hollow rods called veins. There are five principal veins, some of which are branched, and they are in some cases connected by a few cross-veins. The wings move with great swiftness. The house-fly, when held captive, moves its wings 330 times a second, and the tip of the wing describes a figure 8 in the air.

The hum of the fly is its voice. There are three differ-

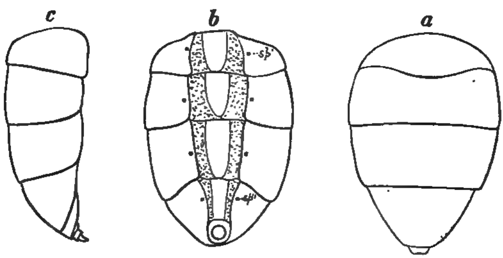

FIG. 124.—Hind body or abdomen of house-fly. *a*, **dorsal,** *b*, **ventral,** *c*, **side, view;** *sp'*, *sp''*, **the four pairs of spiracles. (Magnified.)**

ent tones in the fly's hum. While flying the tone is relatively low; when the wings are held so as to prevent their vibrating, the tone is higher, and a higher one still when the fly is held so as to prevent all motion of the external parts. The latter tone is the true voice of the fly, and is produced by the spiracles or breathing-holes of the thorax. Thus, the humming sound is not produced by the motions of the wings alone. The hind body (Fig. 124) is broad and somewhat conical in shape, and there are seen to be only four segments when observed from above or below; but in the living fly three more may be detected, which can be thrust out of the body like the joints of a telescope, and form a sort of egg-layer (ovipositor). Flies have no sting, though certain kinds can bite and stab with their mouth-parts.

The legs are long and slender, and composed of the same number of joints as in the beetle. Like the body, they are covered with fine but stiff bristles. There are five toe-joints, the last one with two claws. Between the claws is a cushion divided into two lobes or divisions, and armed with hairs, which are tubular, and secrete a sticky fluid, which aids the fly in walking upside-down on glass windows or the ceiling of a room.

We may here relate our experience in rearing house-flies. They are attracted to horse-manure, in which the young live in great numbers. On placing a fly in a glass bottle,

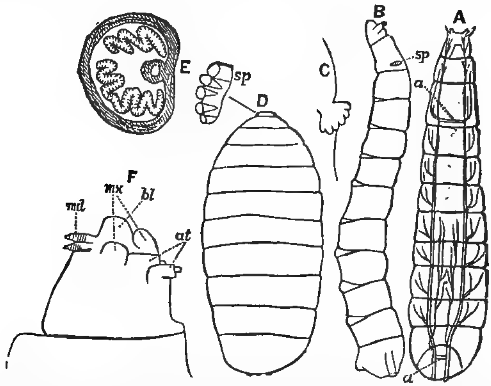

FIG 125.—The early stages of the common house-fly. *A*, dorsal and side view of the larva; *a*, air-tubes; *sp*, spiracle. *C*, the spiracle enlarged. *F*, head of the same larva, enlarged; *bl*, labrum (?); *md*, mandibles; *mx*, maxillæ; *at*, antennæ. *E*, a terminal spiracle much enlarged. *D*, puparium; *sp*, spiracle. (All the figures much enlarged.)

she laid, between 6 P.M., August 12th, and 8 o'clock the next morning, 120 eggs, depositing them in stacks or piles.

The egg is long and slender, cylindrical, and .04 to .05 of an inch long and about one fourth as thick. In twenty-four hours after they are laid the larva or maggot hatches, and is as represented in Fig. 125, *A*. It is footless, a smooth round white worm, with the merest rudiments of mouth-parts, as seen at *F*. In a day it grows too big for its skin, which bursts and peels off; this is again repeated a day later. The maggot thus sheds its skin twice, and consequently there are three larval stages; the third stage lasts three or four days.

When about to transform into a pupa or chrysalis, the body contracts into a barrel-shaped form, as seen in Fig. 125, *D*; its skin turns brown and hard, forming a case (called *puparium*) within which the larva changes to a chrysalis. Remaining in this stage for about a week (five to seven days), the fly is formed, and, pushing off one end of its pupa-case, walks nervously about, until its soft, baggy wings become dry, when it takes to flight. It thus lives a fortnight before acquiring wings, and may live a few weeks, perhaps until frost; and in a few cases may pass the winter within the house, and appear out of doors in the spring.

There are probably 10,000 species of the order of Diptera in the United States alone, but to a large proportion of them the preceding description will apply. Hence, by studying thoroughly one fly, we can obtain a good idea of the general structure of all.

In the flies, whose mouth-parts vary astonishingly in structure, so that some are piercers and biters and others suckers and lappers, there is also a great variety of larval forms, different modes of metamorphosis, and consequently great powers of adaptation to different stations in life. A few species live in the sea, many in fresh water, and many, as the Tachina, are parasites in the bodies of caterpillars and other insects. There is everywhere a wonderful harmony between the different kinds and their surroundings, and thus the order is rich in species and individuals.

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CHAPTER XIX.

THE BUTTERFLY AND OTHER SCALY-WINGED INSECTS

We will select for study one of our largest and most common butterflies, the yellow and black swallow-tail (*Papilio Turnus*, Fig. 126). It may be found flying about lilacs, etc., from the first of June until midsummer.

We shall see in this, as in most butterflies, how large the wings are in proportion to the body, and that they are so thickly covered with microscopic scales as to be opaque, while the body is also covered with fine slender scales like hairs. We shall see, also, that the form of the body is more or less spindle-shaped, well adapted for flying rapidly through the air. The head is small, not wider than the mid-body, and the hind body is narrower than the mid-body, and tapers to a rounded point.

Now, looking at the head, which in front and above is thickly covered with hairs, we notice the large compound eyes, and from between them arise the antennæ. These are very slender, and end in a knob. There is in many butterflies a naked space on the under side of the knob, in which are minute pits, which are organs either of hearing or smell. There is but a single pair of mouth-feelers (palpi) in the butterflies, though two pairs exist in many moths. These are the palpi of the under-lip, which are held up in front of the face. Between them is the tongue, which is a long slender black tube, which at rest is coiled up like a watch-spring between the feelers. If one will watch a butterfly at a flower it may be seen unrolling and probing the bottom of the corolla.

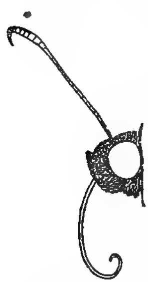

FIG. 127.—Side-view of head of a butterfly (*Eudamus Tityrus*), showing antenna and tongue.

The "tongue" is the only means by which the butterfly can obtain food. It sips or sucks up the nectar at the bottom

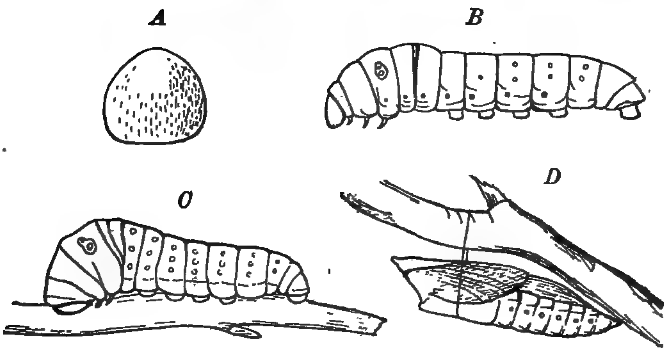

FIG. 126.—*Papilio Turnus*. *A*, egg (magnified); *B*, caterpillar; *C*, the same just before pupating; *D*, pupa or chrysalis. (Natural size.)

of flowers, or drinks water, imbibing it through this tube. It never uses its jaws; and, in fact, it cannot, because they are usually absent. Moreover, the butterfly needs little food; it only lives long enough to lay its eggs, when it dies.

How the tongue is formed and how it works is well worth knowing. It should be borne in mind that it is formed by

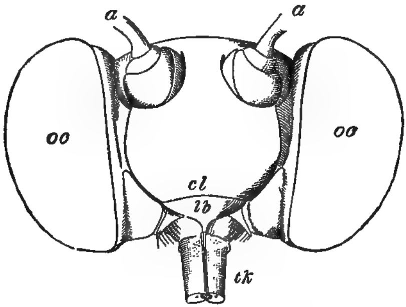

FIG. 128.—Front view of head of butterfly. *oc*, compound eyes; *a*, antennæ; *cl*, clypeus; *lb*, labium; *tk*, maxillæ or "tongue." (Magnified 10 times.)

the two accessory jaws (maxillæ), which unite to form a tube. By looking at our specimen after the scales have been rubbed off the head, which may be done by a stumpy hair-pencil, it will appear somewhat as in Fig. 128 of the

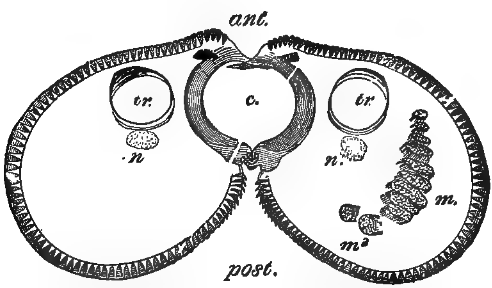

FIG. 129.—Section of butterfly's "tongue," the two maxillæ uniting to form the food-passage *c*; *tr*, trachea; *n*, nerves; *m*, muscles of one side. (Magnified 125 times.)

Archippus butterfly. This represents a front view of the head: *cl* is the front or visor, and *lb* indicates the upper lip; *tk* is the tongue, cut off to show the tube in the middle. An idea how it works can be seen by looking at

Fig. 129, which represents a cross-view of that of the Danais butterfly. The maxillæ in some moths, such as the great, green, tailed Luna moth, are short and separate, like a pair of blades. Now the tongue of the butterfly is formed by the union of these two blade-like maxillæ; and they are so closely united together as to form a hollow tube (*c*), through which the nectar is sucked, so that it passes into

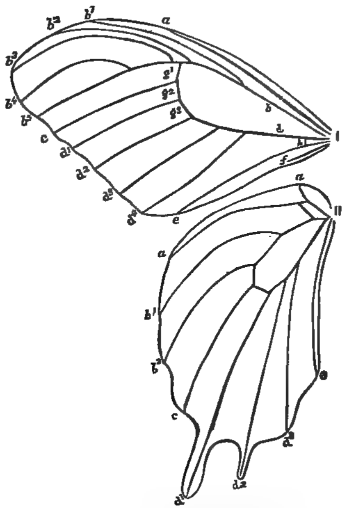

FIG. 130.—Fore and hind wings of a butterfly, showing the venation. *a*, costal vein; *b*, subcostal; b^1, b^2, b^3, b^4, b^5, the five subcostal veinlets; *c*, the independent vein (it is sometimes a branch of the subcostal and sometimes of the median vein); *d*, median vein; d^1, d^2, d^3, d^4, the four median veinlets; *e*, submedian vein; *f*, internal vein; *h*, interno-median veinlet, rarely found; *b* and *d* are situated in the "discal cell." Lettering the same in both wings.

the mouth. Each side of the tongue contains a nerve, muscles and an air-tube (*tr*).

The wings of butterflies are beautifully painted and ornamented. If, however, we examine the scales separately under the microscope, we shall see that they are colorless. The variety of color on the different spots and bands is due to the arrangement of the scales, i.e., to the interference of the rays of light passing through them.

In the butterfly, as in the house-fly, it will be seen that the front edge of the fore-wings is strengthened by two veins, one of which has three branches running parallel with the edge. As the weight or pressure of the air while making the stroke is borne chiefly by the front of the wing, it needs these rods to strengthen it.

The scales of a butterfly's wing are curious objects for study. They differ much in shape on different parts of the body. On the wing of the Cecropia moth the hairs of the body and base of the wing are seen to pass into broad scales represented in Fig. 131. They are attached to the wing

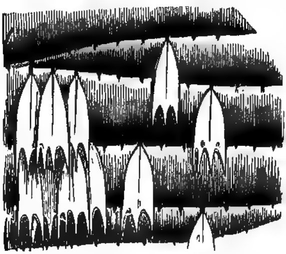

FIG. 131.—Arrangements of the scales on a moth's wing. (Magnified.)

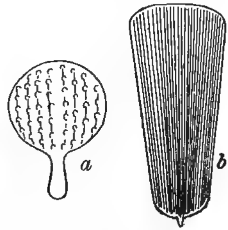

FIG. 132.—*a*, scent scales; *b*, ordinary scale of Lycæna butterfly. (Highly magnified.)

and laid partially over one another like the tiles on a roof, being inserted in irregular rows.

The legs are rather slender, and in general like those of the house-fly.

The hind body is composed of eight distinct segments, with rudiments of a ninth and tenth.

Nothing is more interesting or instructive to the beginner in entomology than to rear caterpillars, to see them change into chrysalids, and finally emerge as butterflies or moths. There are always plenty of caterpillars to be found, and many of them can be easily reared in either a tumbler or a roomy tin box, or in a well-appointed vivarium.

The caterpillar or larva of the Turnus butterfly may be found on the apple or birch and other trees. In July the butterfly lays a nearly round egg upon the leaf, and by the end of summer one may find the great green worm in the same place. The body is round, fat, and smooth; there are twelve segments behind the head. From the top of the segment next to the head is projected, when the caterpillar is disturbed, a singular V-shaped yellow organ, which sends out a disagreeable smell, and is thought to be repugnant to birds, ichneumon insects, etc. On each side of the third segment is a large eye-like spot, peculiar to this species. There are along the body nine pairs of spiracles, one on the segment next to the head, and eight pairs on the fourth to eleventh segments, or what correspond to the first eight abdominal segments of the butterfly, the latter having, however, but seven pairs of spiracles on the hind body.

The caterpillar's eyes are minute, simple eyelets, only useful, probably, in distinguishing day from night. This is useful information, considered from a caterpillar's standpoint, as most of them hide by day and feed by night. That caterpillars are very hearty eaters goes without saying. They perform prodigies of gastronomic skill. Did all the caterpillars which are born into the world survive the various ills and enemies they are heirs to, not a green thing would be left on the face of the earth. The locust's mission would be ended.

The jaws of the caterpillar are large, black horny affairs, easily discovered. They are toothed on the cutting edge, and thus pass through a leaf somewhat like a circular saw.

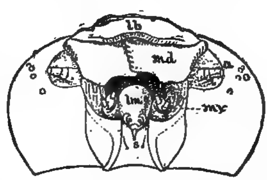

Fig. 133.—Head of caterpillar of Danais. *lb*, labrum; *md*, mandibles; *a*, antenna; *mx*, maxilla; *lm*, labium. (Magnified 10 times.)

The silk is spun through the tongue-like projection of the under lip (Fig. 133, *s*). It is secreted in two long sacs within the body. The thread is drawn out by the fore-feet. The legs on the hind body, sometimes called prop-legs, are fleshy, not jointed, and end in a crown of hooks which curve outward, enabling the caterpillar to firmly grasp the edge of the leaf or twig of its food-plant.

Most caterpillars are more or less hairy or spiny, rendering them, when especially so, disagreeable to birds; besides this, they are bright-colored, so that birds readily recognize them and waste no time over them, but search for the common green smooth-bodied ones, which are, however, so difficult of detection by the birds that plenty are left to become moths or butterflies. Certain caterpillars, as the currant-worm, though smooth-bodied, are brightly spotted; these, however, the birds find, have a disagreeable taste. The bright colors are thus danger-signals, warning off the birds.

We will now suppose that the caterpillar has got its growth, and is about to change to a chrysalis. When fully fed the caterpillar stops eating, and in a day or two throws off the caterpillar's skin and becomes a pupa or chrysalis. The latter word is derived from the Greek, meaning golden, in allusion to the golden spots which adorn the chrysalids of some butterflies. Our Turnus caterpillar, before *pupation*, as the act of becoming a pupa may be called, becomes thick, and the head is drawn in. It spins a loose open-work platform of silk on the under side of a leaf; its tail is firmly anchored in the mass of silk by certain hooks at the end, and meanwhile it throws around its body near the head a strong silken cord as a support. Our Turnus chrysalis is not bright-colored, but allied in color to a dry leaf or piece of wood, so as to be easily overlooked by birds. Here it remains through the winter until the end of the succeeding May or first of June, when the butterfly within, which has been growing rapidly during the preceding warm days, by its convulsive struggles bursts the pupal skin on the back, forcing the covering of the head and mouth-parts aside, and draws itself out of the rent. It stands on its feet for a few minutes, while its wings expand, and then takes flight and sails gracefully on its broad wings through the air.

While there is great uniformity in the shape of the body of butterflies and moths, their habits are, within narrow limits, quite diverse. Some fly by day, others at dusk, others by night. The great number of species, of which there are estimated to be 25,000, is undoubtedly due to the variety in the food-plants on which the caterpillars feed. Nearly every species of flowering plant affords room and board to one or more species of caterpillar. The oak nourishes in this country alone about 100 species; nearly 100 different kinds feed on evergreen trees, eating the buds and leaves, boring in the branches, and, in short, attacking the tree in a variety of ways, so that there is a place and abundance of food for each kind of caterpillar. In their chrysalis state they are comparatively safe from harm. Nature has thus favored the Lepidoptera above all other insects except the beetles and bees (Hymenoptera). From their number and variety, beauty of color, attractiveness of form, and ease with which they can be collected and their caterpillars reared, the butterflies and moths are the favorites of entomologists.

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CHAPTER XX.

THE BEE AND OTHER MEMBRANE-WINGED INSECTS.*

THE bee stands at the head of all the insects, as in its most important features it is superior to all, both in structure and in mental traits. We will select the honey-bee, as one is always sure of finding plenty of specimens. Those that we see in our gardens are the workers; the males, or drones, and the females, or queens, are rarely seen out of the hive.

In the first place, see how well-proportioned are the three

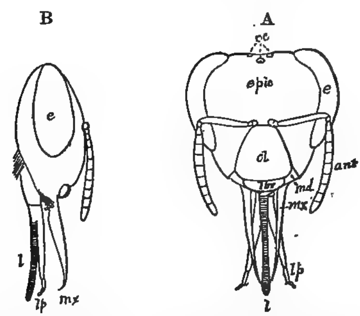

FIG. 134.—Head of a worker hive-bee. *A*, front, and *B*, side, view; *oc*, simple, *e*, compound, eyes; *epic*, epicranium; *cl*, clypeus; *lbr*, labrum; *md*, mandible; *mx*, maxilla; *l*, lingua or tongue; *lp*, labial palpi. (Magnified.)

regions of the body; the head is large in proportion to the thorax, which is nearly spherical; and the hind body, which has six visible segments, is short, conical, and attached by a slender waist to the chest.

Looking at the head, which is carried vertically, the compound eyes are seen to be very large, while the three

* See the works of Say, Saussure, McCook, F. Smith, Cresson, Howard, etc.

simple eyes (ocelli) are arranged in a triangle on the top of the head. The antennæ are slender, and elbowed or bent at the end of the long second joint. The large clypeus

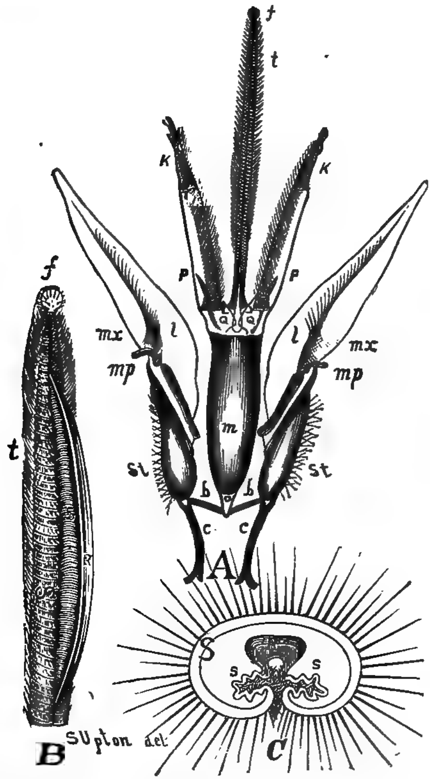

FIG. 135.—Mouth-parts of the honey-bee. *A*, *m*, mentum; *st*. stipes; *mx*, maxilla; *mp*, maxillary palpus; *l*, lacinia; *p*, paraglossa; *k*, labial palpus; *t*. ligula; *f*, "button" (mandibles not represented). *B*, ligula; *s*, sheath. *C*, section of *B*; *S*, *s*, tubular sack; *R*, rod. (Magnified.)

is succeeded in front by the short movable upper-lip (labrum).

The mouth-parts are rather complicated, and it is their complexity or high degree of specialization which for the most part gives the bee and others of its order their superior position over other insects.

The jaws are rather large, and cross each other in front, and are much as in beetles and grasshoppers, being adapted for biting. On the other hand, the accessory jaws, or maxillæ, are different from those of any other insects. They are long and slender, and with the under-lip bent under the head. They consist of three joints, the last forming a long flat blade. From the second joint arises a minute two-jointed feeler (palpus).

The under-lip is, however, the most peculiarly modified. As seen in Fig. 135, *A*, it consists of three parts; the two outer forming the feelers, and ending in three small joints, while the middle division is the so-called tongue; it is soft and fleshy; and, extending this into flowers, the bee gathers the nectar. The mouth-parts are thus a set of complicated tools,—the jaws for biting and for use as trowels in making its waxen cells, the sharp lancet-like maxillæ for piercing flowers, and the tongue a sort of writhing, hairy rod, for gathering the sweet liquid secreted at the bottom of flowers.

Altogether, we have nothing so complicated in the mouth-organs of any other group of insects; they present a peculiar specialization of structure, with a physiological division of labor quite unique.

The wings are seen to be clear and perfectly transparent, with no scales. They are formed of a clear membrane, hence the name of the order to which the bee belongs, i.e., *Hymenoptera*, or membrane-winged. The veins are few, irregular, inclosing a few cells. The hinder pair of wings are less than half as large as the front pair.

The legs are not very long, but very hairy, and the hinder ones have flattened shanks, while the first toe-joint is very broad and flat, with the inner surface covered with dense stiff hairs, upon which the pollen of flowers is stuck, or piled up, so as to form a yellow heap which is borne to the hive.

The sting, if examined by the microscope, is seen to be formed of three pairs of sharp narrow blades, of which the innermost pair are barbed at the end. The sting corresponds to the egg-layer or ovipositor of the grasshopper, or of the ichneumon-fly.

In their mouth-parts Hymenoptera are wonderfully specialized; they can bite, pierce, cut, suck, or lap. They are swift on the wing; their habits are related to their great range of station. Their metamorphosis is the most complete of all insects, the young wasps and bees being footless and fed by the parents. From all these and other causes the order has flourished to a wonderful degree.

Looking back and over the insect-world, we see what an astonishing variety of insect forms have lived, and still are living, on the earth and in the air. *And they all agree, as a rule, in having jointed bodies and jointed limbs, the segments arranged in three regions, most of them having wings, and most transforming from a larva to a pupa, and from a pupa to a perfect insect.*

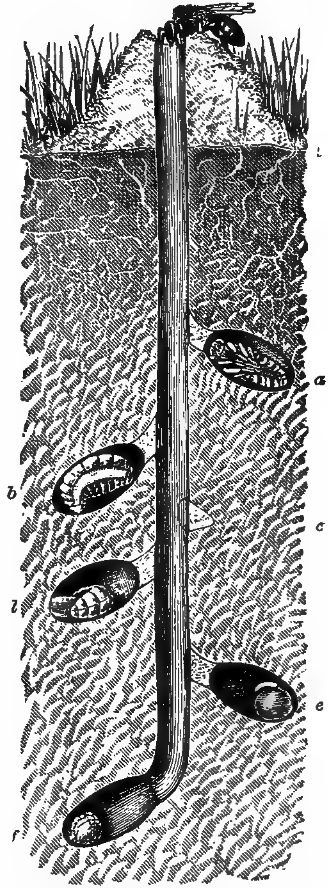

FIG. 136.—Nest of Andrena. *g*, level of ground; *a*, first-made cell, containing a pupa; *b l*, larvæ; *e*, pollen mass with an egg laid on it; *f*, pollen mass freshly deposited by the bee.

If we judge by numbers alone, the insects are the most successful group of animals; for there are perhaps 200,000 species of insects, and the jointed structure of body and limb admits of the greatest range in form, and allows of the greatest range of adaptation to the varied conditions of the earth, water, and air.

Undoubtedly the insects owe their supremacy in numbers to their having wings, not being confined to creeping, also to their undergoing a metamorphosis; while their brain is complex, corresponding to the intellectual activity of many species. (See Lubbock's Ants, Bees, and Wasps. 1882.)

Classes of Air-breathing Arthropods.

1. Body soft, caterpillar-like.............	*Malacopoda.*	Peripatus.
2. Body hard, many-jointed, with many pairs of feet........................	*Myriopoda.*	Millepedes.
3. Body in two regions; no wings; no antennæ; eight legs....................	*Arachnida.*	Spiders, etc.
4. Body in three regions; with wings; 6 legs..	*Insecta.*	Beetles, Bee.

Orders of Insects.*

1. Wingless, often leaping by a spring................. .	*Thysanura.*	Spring-tails, etc.
2. Fore wings minute, clytra-like; abdomen with a forceps	*Dermaptera.*	Earwig.
3. Wings net-veined; fore wings narrow; hind wings folded.	*Orthoptera.*	Locusts, Grasshoppers
4. Wings net-veined, flat on back	*Platyptera.*	White Ants.
5. Hind wings small.........	*Plectoptera.*	May Flies.
6. Four net-veined wings, mouth-parts adapted for biting; metamorphosis incomplete....................	*Odonata.*	Dragon Flies.
7. Mouth-parts forming a beak for sucking..............	*Hemiptera.*	Bugs.
8. Wings net-veined; metamorphosis complete..........	*Neuroptera.*	Lace-winged Fly, etc.
9. Fore wings sheathing the hinder ones...	*Coleoptera.*	Beetles.
10. One pair of wings.........	*Diptera.*	Flies.
11. Four wings and body scaled; maxillæ forming a proboscis............	*Lepidoptera.*	Butterflies and Moths.
12. Four clear wings; hinder pair small; a tongue.......	*Hymenoptera.*	Ants, Bees, Wasps, etc.

* There are in all sixteen orders of existing insects; for the definitions of those not mentioned here see the author's larger Zoology.

CHAPTER XXI.

ANIMALS WITH A BACKBONE.

IN order to understand how a backboned animal differs from any of the animals which we have thus far studied, we should carefully examine and dissect a fish.

We have seen that starfish, sea-urchins, lobsters, or insects have the body protected by a shell or crust, which protects the muscles and other soft parts within; but now we come to animals which have an internal bony support or skeleton. This consists, besides the skull and limb-bones, of a backbone, which is called the vertebral column, because it is composed of vertebræ.

Examining the fish, we see that the body is bilaterally symmetrical, i.e., each half repeats the other. There are two eyes, two internal ears, and two nasal openings. The body is protected by scales and is moved by fins. These are either arranged in pairs or are single. The fore pair are called "pectoral" fins, and are attached to the base of the skull. They correspond to the fore-limbs of a beast, or to our own arms; while the pair behind are called the "ventral" fins, and they correspond to, or are homologous with, the horse's hind legs or to our own legs. The single, or unpaired, fins are the "dorsal," "anal," and "caudal" fins (Fig. 137, *A*). The fins are supported by fin-rays, which are attached to the processes of the vertebral column, as indicated in Fig. 138, *h*, *g*, *k*.

In front of the base of each pectoral fin is the gill-opening; in order to look into it we have to lift up the gill-cover or *operculum*. Opening wide the gill-opening, and at the same time opening the mouth, we can see the four red gill-arches, supporting the gills. Now, opening the mouth wide, we see that the jaws are armed with numerous fine teeth, as are also the bony projections on the sides and roof of the mouth; the teeth are seen to be sharp, conical, and curved backwards, so that the jaws can retain a slippery fish in their grasp.

The shape and arrangement of the scales should also be noted, as well as the "lateral line" (Figs. 137, *ms*; 139, *L*).

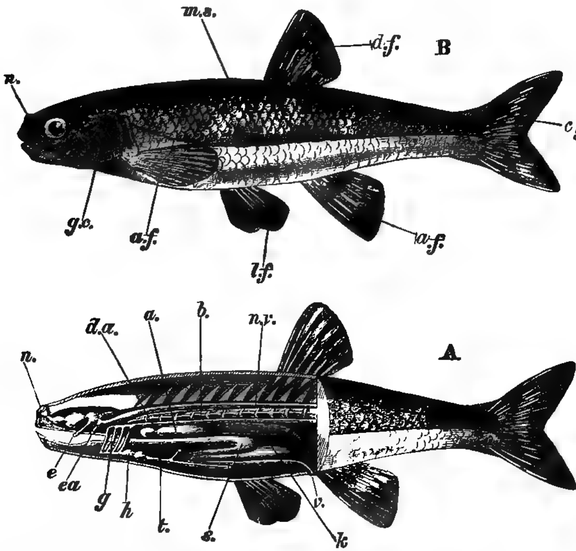

FIG. 137.—The minnow and its internal structure. A: *n*, nose; *gc*, gill-cover; *af*, pectoral or arm fin; *lf*, leg-fin or ventrals; *df*, dorsal fin; *af*, anal fin; *cf*, caudal fin; *ms*, mucous scales of the lateral line. B: *n*, nose-pit; *e*, eye-nerve; *ea*, ear-nerve leading from the brain; *g*, gills; *h*, heart; *t*, œsophagus; *s*, stomach; *k*, kidney; *v*, vent; *da*, dorsal artery; *a*, air-bladder; *b*, backbone; *nv*, nerve cord or spinal cord.

A well-prepared skeleton of a perch (Fig. 138) or cod should then be studied. The chief point of interest is the spinal or vertebral column, which consists of vertebræ.

From each vertebra arises a dorsal or spinous process (*g*), and a similar process below called the "hæmal spine" (*e*). These form the support of the dorsal, anal, and caudal fins. The spinal cord or nerve passes from the brain through the

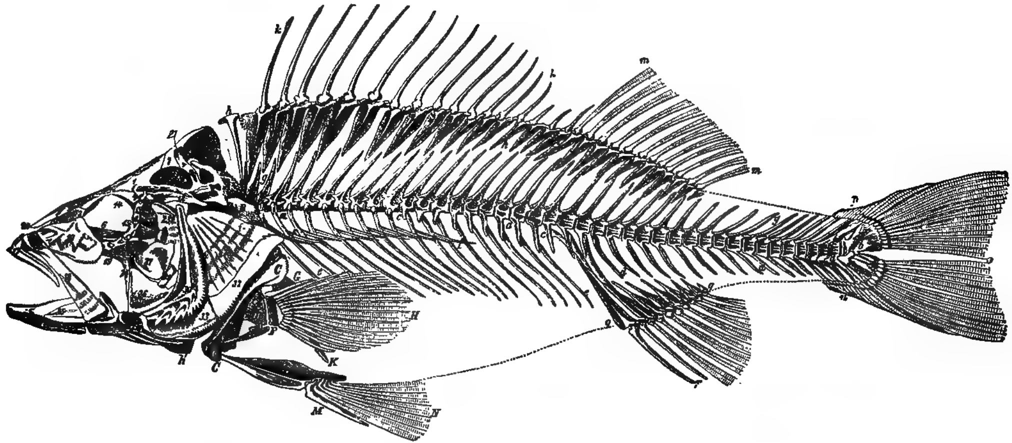

FIG. 138.—Skeleton of a perch.

1, frontal bone.
2, prefrontal.
3, ethmoid.
4, post-frontal.
6, parasphenoid.
7, prootic.
8, supraoccipital.
9, opisthotic.
10, exoccipital.
11, parietal.
12, pterotic.
13, squamosal.
14, alisphenoid.
15, infraorbitals.
17, premaxillary.
18, maxillary.
19, suborbitals.
20, nasal.
21, epiotic.
23, hyomandibular.
24, pterygoid.
25, mesopterygoid.
26, quadrate.
27, metapterygoid.
28, operculum.
30, preoperculum.
31, symplectic.
32, suboperculum.
33, interoperculum.
34, dentary.
35, articular.
36, angular.
A, post-temporal.
B. supraclavicula.
C, clavicula.
D, coracoid.
E, scapula.
F, basalia.
G, pectoral spine.
H. pectoral fin-rays.
I. *K*, post-clavicula.
L, pubic.
M, ventral spine.
N, ventral fin-rays.
a. vertebræ.
b, hypural bone.
c, transverse or hæmal processes.
d, hæmal processes of caudal region united to form an arch for the aorta.
e, ribs.
f. epipleural spines.
g, neural spines.
h, interneural spines.
k, dorsal spines.
m, fin-rays of second dorsal.
n, rudimentary caudal rays.
o, caudal rays.
q, interhæmal spines.
r, anal spines.
s, anal fin-rays.

arches of the spinous processes, the passage being called the "neural canal," and is thus preserved from injury by the strong arch-work over it. But the brain must be preserved from harm, and the jaws need a firm, bony support. Hence we have a skull formed of numerous more or less movable bones, in the upper and back part of which is the brain-cavity, communicating in front with the orbits or eye-cavity and the nasal cavity.

In front are the bones of the upper and lower jaws; behind are the four opercular bones; and below, at the base of the lower jaw, the tongue-bones, while the pectoral and

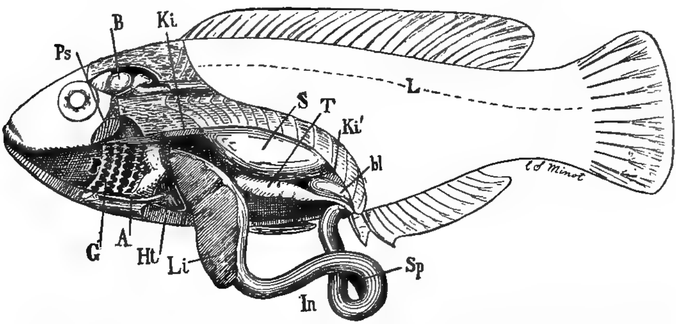

Fig. 139.—Anatomy of the Cunner, male. *L*, lateral line; *Ht*, heart; *G*. pharynx; *Ps*, pseudo-branchia; *Sp*, spleen; *S*, air-bladder; *Ki*, *Ki'*, kidney; *bl*, bladder; *T*, testis; *A*, aorta; *B*, brain; *In*, intestine; *Li*, liver; *G*, gills.

ventral fins are more or less connected by muscles and tendons to the base of the skull. The bones are small and exceedingly numerous, a number of small bones forming the skull and supporting the fins, so that we may in a single fish count upwards of five hundred separate bones.

To dissect a perch or cunner the side-wall of the mouth must be removed, then the gill-cover; study the arrangement of the gills. Next make an incision along the median ventral line from the level of the pectoral fins to just before the anus, and following the upper edge of the body-cavity upward and forward, cut away the body-wall, taking care not to injure the large swimming bladder above, nor the heart in front. Now open the pericardial cavity, which lies immediately behind and below the gills (see Fig. 139, *Ht*). Cut away the muscular masses around the back of the head; expose the cavity of the brain, and remove the loose cellular tissue around the brain. If the gills of one side are cut away and the intestine drawn out, the dissection will appear very much as in Fig. 139.

The cavity of the mouth widens rapidly, forming behind the branchial chamber or pharynx (*G*), whence we can pass a probe outward through any of the gill-slits. There is a single row of sharp-pointed teeth in front on both the under and upper jaws; in the pharynx above and below there are rounded teeth. At the side of the pharynx are the four gill-slits and the four arches. The entrance of each slit is guarded in front and behind by a row of projecting tubercles

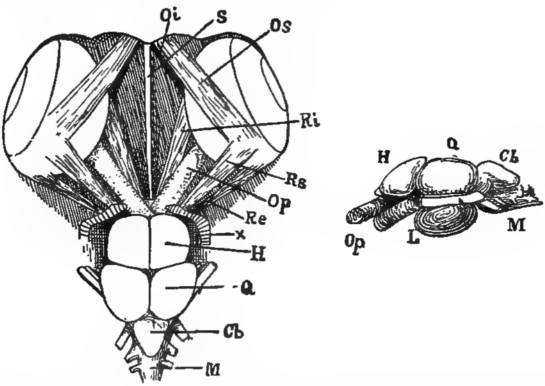

Fig. 140.—Anatomy of the brain of the Cunner, dorsal and side view. The olfactory lobes, the crura, and the thalami not represented.

appended to the arches. On the outside of each arch, except the fourth, is a double row of filaments, richly supplied with blood-vessels, which, shining through, give a brilliant red color to the gills; on the fourth arch there is but a single row. At the upper and posterior corner of the pharynx is the small opening of the short œsophagus. The branchial chamber has an upward extension on the sides of which lie the false gills (*Ps*), which are accessory respiratory organs not connected with the gills proper, and receiving their blood supply from distinct arteries.

The œsophagus dilates almost immediately to form the stomach (partly concealed in the figure by the liver, *Li*), which is hardly thicker than the intestine (*In*). This last is of nearly uniform size throughout; and after making three or four coils terminates at the anus, immediately in front of the urinary and genital apertures. The liver (*Li*) forms an elongated light-brown mass resting upon the stomach. The elongated gall-bladder lies between the liver and stomach, somewhat imbedded in the substance of the former. There is no pancreas, though it is present in some fishes. The spleen (*Sp*) lies between the stomach and intestine, in the mesentery; it is dark reddish-brown in color.

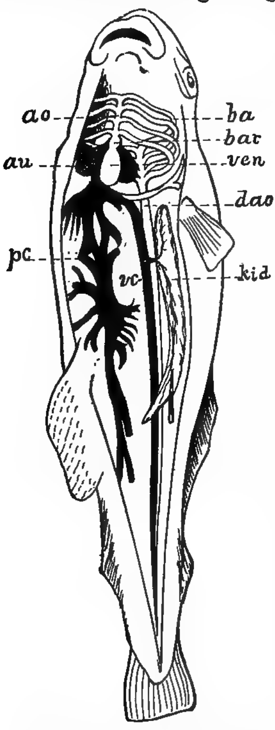

FIG. 141.—Circulation of the blood in a bony fish. *au*, auricle; *ven*, ventricle; *bar*, bulbus arteriosus; *ao*, aorta; *ba*, one of the four branchial arteries which carry the blood to the gills, and afterwards unite to form the descending aorta (*dao*); *pc*, portal circulation; *vc*, great descending vein (vena cava); *kid*, kidney.

The air-bladder (*S*) is a single large glistening sac, placed in the dorsal part of the body-cavity. The air-bladder normally contains only gases. It conceals most of the kidneys, which extend the whole length of the body-cavity on either side of the middle line, as two long, wide strips of a deep though dull red. They project beyond the air-bladder in front (*Ki*) and behind (*Ki'*).

The ovary is single, and varies greatly in size according to the season. In the male the sexual glands (testes) are double.

The heart (*Ht*) lies in the triangular pericardial cavity; it consists of two portions, the dark-colored venous chamber, or auricle, above, and the lighter-colored arterial chamber, below. The auricle receives from above two large veins, one from either side; these veins are called the Cuvierian ducts. Furthermore, a large vein, the sole representative of the *vena cava* of higher vertebrates, passes from the liver, near its anterior end, through the pericardium, and empties into the Cuvierian ducts near their common auricular orifice.

The brain should be exposed from above by carefully removing by a knife the skin and thin bones covering the brain-cavity. Beginning in front, we notice the minute olfactory lobes and the olfactory nerves proceeding to the nasal cavities. Behind the olfactory lobes lie in succession the cerebral hemispheres (*H*), optic lobes (*Q*), the single cerebellum (*Cb*), and, lastly, the medulla oblongata (*M*).

A general idea of the two body-cavities, the nervous and visceral, will be obtained by cutting the fish through transversely. The nervous cord is seen to lie above the vertebral column, the nervous canal being formed by the interarching spinous process. Below the vertebral column is the large cavity containing the heart, stomach, etc., while the rest of the section is occupied by muscles.

The noises produced by certain fishes are due to the action of the pneumatic duct or air-passage and swimming-bladder (Fig. 142, *S*, *S′*), though different kinds of noises are made accidentally or involuntarily by the lips or the bones of the mouth, as in the tench, carp, and a large number of other fishes. Over fifty species of fish are known to produce sounds of some sort. The swimming-bladders of

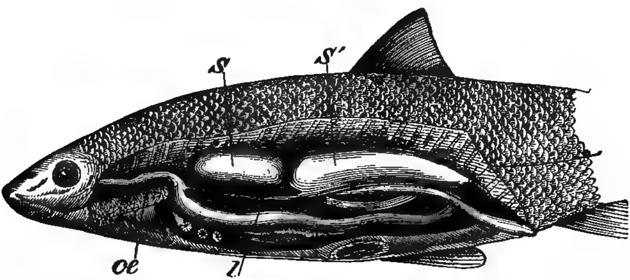

FIG. 142.—Swimming-bladder (*S*. anterior, *S′*, posterior, division) of the bleak; *œ*, œsophagus; *l*, air-passage of the air-bladder leading into the œsophagus.

Trigla and *Zeus* have a diaphragm and muscles for opening and closing it, by which a murmuring sound is made. The loudest sounds are made by the drum-fish. In some minnows, pouts, and eels the sound is made by forcing the air from the swimming-bladder into the œsophagus. In the sea-horse, the sounds are made by the vibrations of certain small voluntary muscles.

It should also be noticed that the organs of hearing in many musical fishes are said to be unusually well developed, hence these sounds are probably love-notes; and Abbot notices the fact that these fishes are dull-colored during the spawning season as well as at other times; while voiceless fishes, such as the perch, common sun-fish, chub, roach, etc., are highly colored while laying their eggs, and thus the sexes are mutually attracted, in the one case by music and in the other by bright colors. Finally, the sounds of fishes may be compared with those of reptiles, birds, and mammals, the air-bladder corresponding to the lungs of the higher Vertebrates, while the pneumatic duct is comparable with the windpipe of birds and mammals.

In swimming, the propelling motion is mainly exerted by the tail, the movements of which are somewhat like those of an oar in sculling. The spines of the tail-fin are movable, and are capable of being brought into such a position that the fin will meet with less resistance from the water while the tail is bent than straightened, and it is when being straightened that the fish is propelled. The movements of the pectoral and ventral fins are to steady the fish and to elevate and depress it, while the dorsal and anal fins steady the body and keep it upright, like a dorsal and ventral keel.

Having studied a fish, the student can now understand what a vertebrate is and perceive the great differences between vertebrates and the lower or invertebrate animals. And, before we go farther, we can, since everybody is familiar with the higher backboned animals, such as the frog, lizard, bird, or beast, pass in review the chief distinguishing marks of a vertebrate.

Vertebrates in general have bodies which are symmetrical, i.e., the two sides repeat each other; they have a brain-box or skull, containing the brain and the mouth and pharynx, with two eyes, two ears, and usually two nasal openings. To the trunk are attached two pairs of limbs; the arms in man corresponding to the fore-legs of the horse or dog.

Now, if we cut a fish in two, and closely examine the section, we shall notice that above the backbone is a little cavity containing the nervous cord, and below a much larger cavity containing the *viscera*, i.e., heart, liver, stomach, or

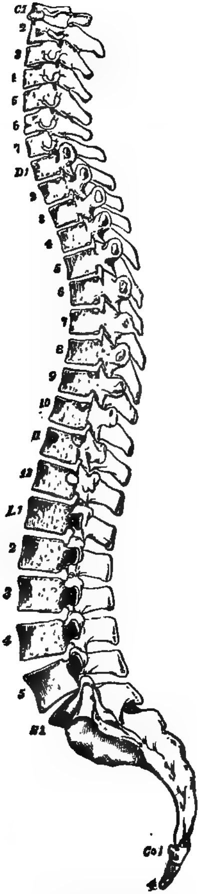

FIG. 143.—Side-view of the vertebral column or backbone of man.

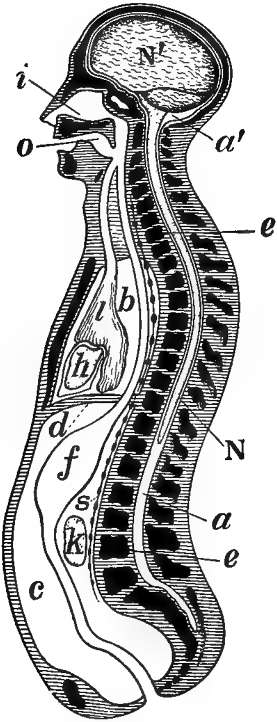

FIG. 144.—Diagrammatic longitudinal section of the human body. *a*, the neural tube, with its upper enlargement in the skull-cavity at *a'*; *N*, the spinal cord; *N'*, the brain; *e e*, vertebræ forming the solid partition between the dorsal and ventral cavities; *b*, the pleural, and *c*, the abdominal, divisions of the ventral cavity, separated from one another by the diaphragm, *d*; *i*, the nasal, and *o*, the mouth chamber, opening behind into the pharynx, from which one tube leads to the lungs, *l*, and another to the stomach, *f*; *h*, the heart; *k*, a kidney; *s*, the sympathetic nervous chain. From the stomach, *f*, the intestinal tube leads through the abdominal cavity to the posterior opening of the alimentary canal.

intestine. Thus there are two cavities,—the nervous one above, and the visceral one below, the backbone (Figs. 143, 144). In this respect the backboned animals differ from the backboneless or invertebrate animals, in which there is but one body-cavity, with the nervous system usually situated on the floor of this cavity.

Vertebrates have a true heart, with one, generally two, auricles, and one or two ventricles, and, besides arteries and veins, a system of capillary vessels, which are minute tubes connecting the ends of the smaller arteries with the smaller veins. There are no genuine capillaries in the lower animals exactly comparable with those of vertebrates.

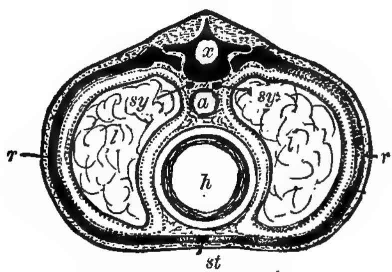

FIG. 145.—A diagrammatic section across the body in the chest region. *x*, the neural canal, which contains the spinal cord; the black mass surrounding it is a vertebra; *a*, the gullet, a part of the alimentary canal; *h*, the heart; *sy*, sympathetic nervous system; *l l*, lungs; the dotted lines around them are the pleuræ; *r r*, ribs; *st*, the breastbone.

The blood is red in all the vertebrates except the lancelet, and besides red, contains white corpuscles. While fishes and tadpoles breathe by gills, all land and amphibious vertebrates breathe the air directly by lungs connected by a windpipe (*trachea*) with the mouth. The nervous system consists of a brain and spinal cord. The brain consists of four pairs of lobes, i.e., the olfactory lobes, cerebral hemispheres, the optic thalami with the pineal gland, and the optic lobes; besides these lobes, which are arranged in pairs, there are two single parts of the brain, the cerebellum and the beginning of the spinal cord, called the *medulla oblongata*.

CHAPTER XXII.

THE SKULLESS VERTEBRATES.

As we have said, there is a great deal of difference between a backboned animal and a mollusc, a lobster, or an insect; and yet there are vertebrates without a backbone, and without even a skull or brain, and which look so much like worms or slugs as to have been mistaken for them. Such an animal is the lancelet (Fig. 146).

This animal (*Amphioxus lanceolatus*) lives in sand just below low-water mark, ranging on our coast from the mouth of Chesapeake Bay to Florida; it also occurs in other parts of the world.

From its worm-like form it was regarded as a worm by some authors, and even as a slug or shelless mollusc. The body is four or five centimetres (about 1½ inches) in length, slender, compressed, pointed at each end. The muscular segments are distinct to the naked eye. From the mouth to the vent is a deep ventral furrow, and a slight fin extends along the back around the tail, ending in front of the vent.

The mouth is oval, surrounded with a circle of ciliated tentacles. The mouth leads directly into a large broad pharynx or "branchial sac" (Fig. 146, *g*).

The walls of this sac are perforated by long ciliated slits. The water which enters the mouth passes out through these slits, where it oxygenates the blood, and enters the peribranchial cavity, thence passing out of the body through the abdominal pore (Fig. 146, *p*). The pharynx leads to the stomach (*f*), with which is connected the liver or cæcum. There is a pulsatile vessel or tubular heart, beginning at the free end of the liver, and extending along the under side of the pharynx. The blood-corpuscles are white and nucleated.

The vertebral column is represented by a flexible gristly rod called the "notocord," which extends to the end of the head far in front of the nervous cord, which lies over the notocord. The nervous cord is not divided into a true brain (though there are faint traces of one) and spinal cord, but sends off a few nerves to the periphery, with a nerve to the single minute eye-spot.

We see, then, that though the lancelet is at the bottom

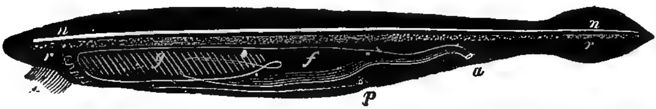

Fig. 146.—The lancelet. *a*, vent; *f*, stomach; *g*, pharynx; *n*, nervous cord; *p*, pore; *r*, notocord; *t*, tentacles around the mouth. (Enlarged twice.)

of the vertebrate scale, yet it has the most fundamental vertebrate marks, that of a rudimentary backbone, i.e., a notocord, with the nervous system placed above, and the other internal organs below.

But there is a group of animals which partly bridge over the gap between the lancelet and the worms.

These are the sea-squirts or ascidians (Fig. 147). One of them, called *Appendicularia*, is like a tadpole in general appearance, while the larvæ of most of them are tadpole-shaped, as in Fig. 148. In the infant ascidian the tail is supported by a gristly rod (*u*), extending into the chest, and corresponding to the notocord of the lancelet. Above it is the nervous cord (*n*), and in the head is an eye (*o'*) and an ear (*o*), while the mouth (*s*) opens into a pharynx, which in after-life has gill-slits. Towards adult life the ascidians (perhaps except Appendicularia) take a backward path in their development, and lose the startling vertebrate features of their youth. Like some precocious human children, they cease to fulfil the promise

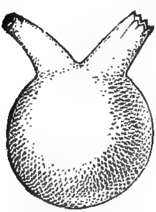

Fig. 147.—*Molgula.* An ascidian. (Natural size.)

of their youth, and go downward and backward, becoming scarcely higher than clams. But without doubt some favored forms, now lost to science, pressed onward and upward, held on to their tails, preserved their notocord, became active swimmers, dashed vigorously about after other

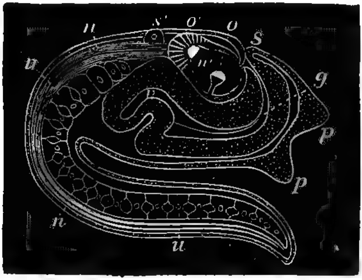

FIG. 148.—Diagram of an ascidian tadpole-like larva. *p*, suckers (?); *s*, incurrent, *s'*, excurrent, opening; *n*, nervous cord; *u*, notocord: *g*, respiratory sac; *n'*, sense-cavity containing the eye (*o'*) and the ear (*o*). (Magnified.)

minute animals, as the lancelet does, until, in their descendants, the notocord supported the entire body, and an incipient brain was formed, approaching that of the lancelet, imperfect as it is, and behold the backboned type of life was established!

In the Balanoglossus worm, with its gill-slits in its pharynx, and the central nervous system situated above a notocord, we have a sign-post among worm-like animals pointing out the way to the ascidians, the forerunners of the vertebrates.

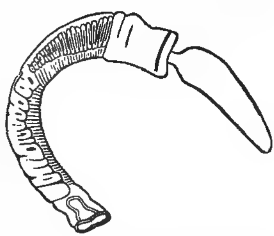

FIG. 149.—Young Balanoglossus.

In the highest molluscs, such as the cuttle-fish, we have anticipations of the vertebrates in the principal nerve-centres being gathered into the head and there forming a large brain, which is partially protected by pieces of gristle, forming a slight brain-case; their eyes, moreover, are nearly as perfect as those of a fish. But the cuttle was, so to speak, an abortive attempt to reach the vertebrate level. It was given to some lonely worm, whose very family name and form are now lost, to found a chain of being whose links are now slowly, and with much painstaking search on the part of naturalists, being picked up and brought to light.

Even after the lancelet came into being, the steps by which the genuine backboned family became recognized in animal society were painful, and only in a degree successful

Classes of Vertebrates.

1. Young with a nervous and dorsal cord	*Tunicata.*	Ascidians.
2. No skull or brain; blood white	*Leptocardii.*	Lancelet.
3. Notocord persistent; no jawbones; six to ten pairs of purse like gills	*Marsipobranchii.*	Lampreys.
4. Swimming by fins; with gills; a movable under jaw	*Pisces.*	Fishes. 1. Elasmobran 2. Ganoidei 3. Teleostei 4. Dipnoi
5. Amphibious; true limbs and lungs; skin smooth, no scales, no claws	*Batrachia.*	Amphibians. Frog, etc
6. Claws and scales present	*Reptilia.*	Snake, lizard.
7. Body covered with feathers; fore-limbs forming wings	*Aves.*	Birds.
8. Body covered with hair; suckling their young	*Mammalia.*	Beasts.

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CHAPTER XXIII.

THE PURSE-GILLED VERTEBRATES.

THE next step above the lancelet is the hag-fish. This creature was also once mistaken for a worm. It lives, covered with slime, in the mud deep in the sea, and often bores into the bodies of fishes, living parasitically in them. It is about a foot long, nearly round, with a small mouth. It has no backbone, only a gristly rod, or notocord, extending from head to tail; it has no bones in its body, no jaws, and only three conical rudimentary teeth within its mouth.

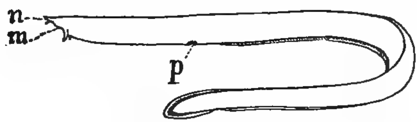

FIG. 150.—Hag-fish or Myxine. (¼ natural size.)

The small eyes are hidden beneath the skin. There is but a single opening from the nasal cavity into the mouth; and while in the true hag-fish there is but a single gill-opening on the under side of the body (*p*), in a second kind (*Bdellostoma*) there are seven gill-openings on each side. The creature has only a caudal fin, and its life and instincts are not above the level of those of the lower sea-worms. In its brain, however, which is much like that of fishes, the hag-fish shows a promise of better things. The brain is there, but the brain-power is almost dormant.

The lamprey is a step upwards, though but a slight improvement on the hag-fish. Its large circular mouth, by which it adheres to the body of fishes, is armed within with rows of conical, horny teeth; the eyes are well developed. Moreover, there is a dorsal fin. The brain is comparatively well developed, though of a low fish-like grade, and it is protected by a gristly brain-box, rudely anticipating a skull. The breathing-organs or gills are very peculiar, being purse-like cavities (whence the name of the class, *Marsipobranchii*), which in the lamprey are seven in number on

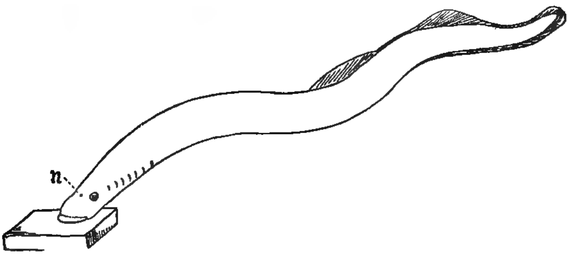

FIG. 151.—The Lamprey Eel. *n*, nostril. (½ natural size.)

each side of the pharynx, opening externally by small apertures; internally they connect with a long cavity lying under the œsophagus, and opening into the mouth.

The lamprey lives both in fresh and salt water. The eggs of the common lamprey, *Petromyzon marinus* (Linn.), are laid in early spring, the fish following the shad up the rivers, and spawning in fresh water, seeking the sea in autumn.

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CHAPTER XXIV.

THE SHARKS.

We now come to animals with a backbone, a movable lower jaw, a true skull, and with fins in pairs. Such back-boned creatures are the fishes. *All fishes agree in having either a gristly or bony skeleton, a lower jaw, and in swimming by means of fins.* The following is a view of the

Sub-Classes of Fishes.

1. Skeleton cartilaginous; 5–7 pairs of gill-openings.............*Elasmobranchii.* Sharks, Rays.
2. Skeleton cartilaginous or bony; scales often square, enamelled. *Ganoidei:* Sturgeon, Garpike.
3. Skeleton bony, of numerous separate bones; 4 pairs of gills...*Teleostei:* Cod, Cunner, Perch, etc.
4. With one lung or two lungs.....*Dipnoi:* Lung-fishes.

The sharks, though fish-like, are very different from ordinary bony fish. Their cartilaginous skeleton, includ-

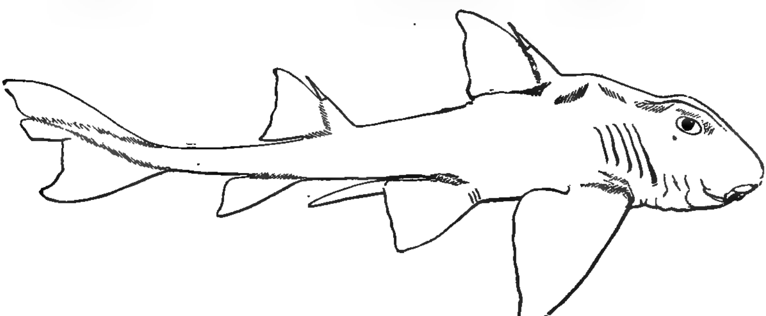

Fig. 152.—*Cestracion*, or Australian Shark.

ing the skull, is so soft that it can be cut with a knife, while the tail is one-sided, the vertebral column ending

Hetero-cercal

in the larger, upper lobe. They also have from five to seven gill-openings or slits, whereas the cod or perch has but one. The skin is either smooth, or with minute scales, forming *shagreen*. Both jaws are armed with numerous sharp, flattened teeth, arranged in rows and pointing backward, enabling them to seize and retain their prey.

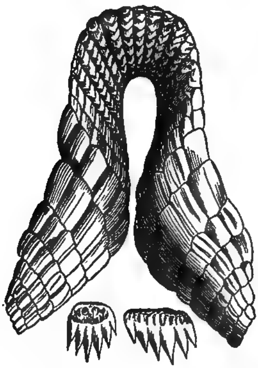

FIG. 153.—Teeth of the Cestracion.

With the appearance of sharks the world of life realized a new order of things. Never before had animals lived so well adapted for the destruction of the lower orders of animals, however well protected they were by solid shells and other means of protection. Sharks and skates are engines of destruction, being the terror of the seas. Their entire structure is such as to enable them to seize, crush, tear, swallow, and rapidly digest large fishes, shell-fish, star-fish, sea-urchins, or other marine animals. Moreover their own forms are gigantic, soft, not protected by scales or armor, as they have few enemies. Hence they do not need a high degree of intelligence, nor special means of defence or protection, though from their activity, having large, powerful fins, the circulatory system is highly developed, the heart being more complicated than in bony fishes. The

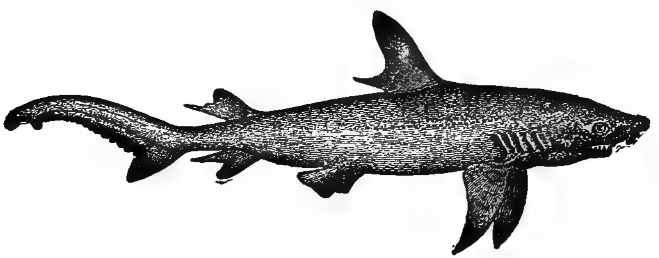

FIG. 154.—*Carcharias*.

sharks owe their prosperity in life to their great size, great vitality, and to the abundance of weaker animal life of all descriptions which they can find in all situations; and when their food at the bottom gives out, they rise to the surface and chase schools of herring, mackerel, etc. Their home is the sea, which has undergone little change since the time when the first shark lived.

The eggs of sharks and rays are very large compared with those of bony fishes. The Cestracion (Fig. 152) is an old-fashioned form, which inhabits the Australian seas. It should be noticed that its mouth is placed well forwards, near the end of the head, and the teeth are rounded, while in the genus *Carcharias* (Fig. 154) it is much larger and placed further back under the head, the teeth being sharp, flattened, and conical. Nearly all the sharks are bottom feeders, grubbing up the shell-fish as well as flounders and other fish which remain at the bottom; when they rise near the surface and chase the surface-swimming fish, or try to seize a man overboard, they have to turn upon their backs in order to grasp their victim.

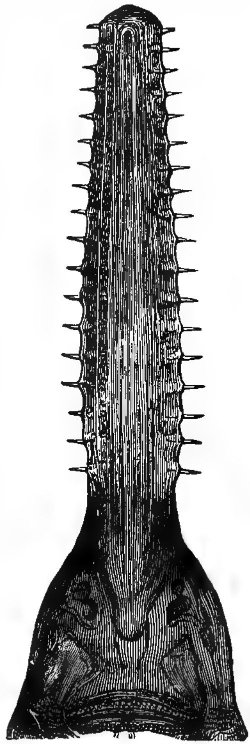

FIG. 155.—Beak of Saw fish seen from below, showing its mouth, nostrils, and lateral teeth.

Of the rays and skates, the sawfish (*Pristis antiquorum*) is most like the sharks. Its snout is prolonged into a long, flat, bony blade, armed on each side with large teeth (Fig. 155). The common sawfish inhabits the Mediterranean Sea and the Gulf of Mexico; it is viviparous.

The genuine skates or rays have the body broad, flat, and rhomboidal, owing to the great development of the pectoral fins. They swim close to the bottom, feeding upon shell-fish, crabs, etc., crushing them with their powerful flattened teeth. The smallest and most common skate of our north-eastern Atlantic coast is *Raja erinacea.* It is one half of a metre (twenty inches) in length, and the males are smaller than the females. The largest species is the barndoor skate, *Raja lævis,* which is over a metre (forty-two inches) long.

The sharks have from the earliest geological ages (the Silurian) remained the masters of the sea; even now there are species as big as whales, the great basking shark being from thirty to forty feet in length, and the Rhinodon over fifty. They need little protection beyond spines, as in the sting ray and the dog-fish, etc., the exception being the torpedo, a slothful ray which lies half buried in the sand, and with its electrical battery strikes dumb any intruder.

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CHAPTER XXV.

THE MAILED FISHES.

ABOUT the time that sharks appeared, and perhaps sooner, a very singular group of fishes were ushered into existence, whose vertebral column and skull were gristly, so that their fossil remains consist only of scales, plates, and teeth. These were the forerunners of the modern square-scaled fishes or *Ganoids*, of which our sturgeon and garpike are examples.

The term ganoid was applied to these fishes from the form of the scales, which in most of the species are angular, square, or rhomboidal, and covered with enamel, as seen in the common garpike. In others, however, as in the *Amia*

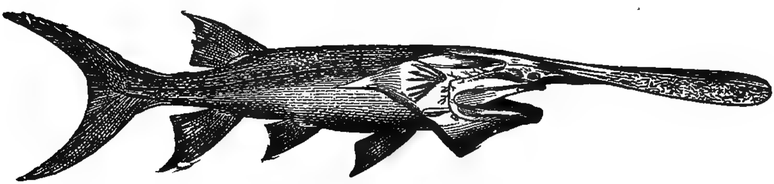

FIG. 157.—Spoon-bill Fish.

and Dipnoans, the scales are rounded or *cycloid*. The sturgeons (Fig. 156) have the snout long and pointed, with the mouth situated far under the head, and toothless; while the body is protected by a few very large scales. *Acipenser sturio* is the common sea-sturgeon of our coast, ascending rivers. It is sometimes eight to ten feet in length.

The singular spoon-bill (*Polyodon folium*, Fig. 157) is five feet long; it is smooth-skinned, and has a snout one third as long as the body, and spatulate, with thin edges. It has a very wide mouth with minute teeth, and lives on

FIG. 156.—European Sturgeon. 1, 8, shoulder-arch; 6, gill-arches; *a*, upper, *b*, lower, spinous processes; *c*, dorsal fin; *c'*, processes supporting the fin; *e*, heterocercal caudal fin; *f*, anal fin; *g*, ventral, *h*, pectoral, fin.

small crustaceans. It abounds in the Mississippi and its larger tributaries.

Geologists tell us that these strange, old-fashioned, plated fish were sometimes of colossal size. They lived in the sea, but probably in the shoaler parts near the shore. They swarmed in the retired bays, estuaries, and rivers of the coal period. But the type began to wane and die out; many of them had small mouths situated far back under the head; they could not resist the attacks of the sharks when they ventured into deep water, and the changes of the old coast lines were so great and sudden that their homes underwent similar changes, so that they could not maintain a footing. When we look at the sturgeon, one of the descendants of these plated fishes, we see that the mouth is very small, and only adapted for eating worms and snails; it lives, to be sure, a part of the year in the sea among the sharks, but then it goes up our large rivers in the spring to spawn, and the young grow up there comparatively out of danger, as they feed at the bottom and are protected by the great bony plates which cover the more exposed part of their bodies.

The other living representative of the old-time plated fish is the garpike, and a very different fish indeed it is from the great, harmless, peaceable sturgeon.

It has a very large mouth, armed with large, conical, sharp teeth, and the body is encased in an enamelled coat of mail; the skeleton, including the skull, is bony, so as to show some resemblance to the skeleton of the perch. Gars are the terror of the Mississippi River and its branches, as they destroy all the smaller fish. The largest species is the alligator gar (*Lepidosteus spatula*), which is sometimes nearly three yards (three metres) in length, sometimes weighing several hundred pounds. So hard is its armor that a blow with an axe cannot penetrate its back, the only vulnerable point being its throat or the back of its head. It inhabits the lower Mississippi and the stagnant bayous and sluggish streams entering it. The spawn

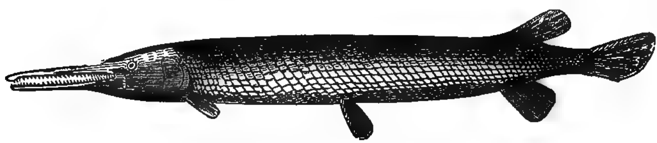

FIG. 158.—Garpike.

resembles that of the toad, forming long ropes several inches in diameter, which are hung on old snags or roots. The eggs are laid in December and January; the young, appearing in the spring, become fourteen inches long late in August.

The garpikes from some cause became confined to bodies of fresh water only in North America, in Cuba and in that part of the United States drained by the Mississippi Valley, and to the great lakes. And we see why they are such terrible engines of destruction among the smaller, weaker fry: they have the heads and teeth of alligators, their ferocity and cunning, and in their watery element they are more formidable than sharks. Were it not that their young can be eaten by other fish, they would exterminate all other fish-life about them. Thus we see that the Ganoid fishes have in places survived by reason of their vigor, ferocity, big jaws and teeth, as well as their thick, close-set, enamelled scales.

While one branch of the ichthyic tree of life ended in the garpike, a twig from this branch is represented by the mud-fish.

The mud-fish of Western and Southern waters (*Amia calva*) is a connecting link between the Ganoids and common or bony fishes. It bears a general resemblance to and is about the size of a small bass. Its tail is less uneven or "heterocercal" than that of the garpike, and thus it comes nearer to the bony fishes. Its spinal column and skull are also bony, and it indeed differs but in details from the bony fishes.

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CHAPTER XXVI.

THE BONY FISHES.

In the age succeeding the coal period, the Ganoids became small and scarce, and mostly confined to rivers and estuaries, and soon the sea began to swarm with a new type of fish-life, until at the present time there are in our museums nearly 10,000 species of new-fashioned bony fishes. Our herring, menhaden, shad, mackerel, cod, etc., which traverse the ocean in vast swarms, are modern creations. Not only do the bony fishes stock the ocean, but they enliven our rivers, lakes, and ponds with myriad scaly forms. What is there in this modern type of fish which has made it so triumphant in life's struggle? The fact is apparent, but the causes obscure, and naturalists are just beginning to discover them.

One reason is their immense fertility. Thus the cod deposits each year from eight to nine millions of eggs, and the hake and haddock are probably only less prolific. While most of the eggs and young fishes are snapped up by other fish, many come to maturity—at least enough to stock the ocean. And so on with other kinds of fish.

Another reason is the adaptation of bony fish to every variety of station in salt, brackish, or fresh water, and to the different localities within these limits. Some are surface-feeders, others remain at the bottom; there is a great variation in the organs of digestion, in the shape of the swimming-bladder, when it is present, but especially in the shape and position of the fins. While no two kinds of fish swim in exactly the same manner, the power of swimming has been wrought out most thoroughly in the bony fishes, in which Nature has exhausted every refinement and variety of movement in the art of swimming. Tadpoles and frogs, turtles and alligators, ducks and loons, dogs and horses, can, after a fashion, get through the water; but how clumsy and grotesque are the movements of the most elegant swimmers among the vertebrates with legs compared with the movements of a fish in its natural element! The student should watch the movements of goldfish in a jar; or, better, of larger fish in an aquarium.

While in human life address, delicacy of perception, and tact are important elements of success in making one's way in the world, the same holds good even with bony fish.

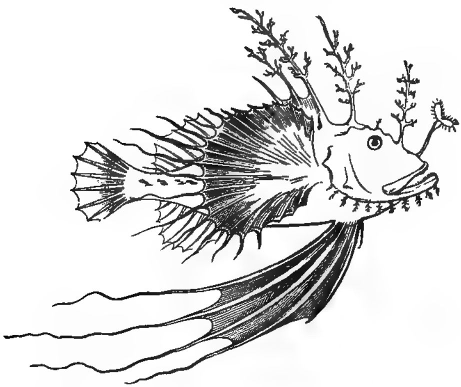

FIG. 159.—Young Angler-fish.

The cod's under jaw has a long barbel, or organ of touch. In swimming over the bottom, or in grubbing in the mud and sand, it may with this be better able to detect the star-fish, snail, or crab partly hidden beneath it. Many fishes, especially bottom-feeders, as the pout, etc., as well as the carps, especially the barbel, are provided with barbels. The angler-fish, which buries itself in the mud and sand, with its mouth partly open, has along the back a row of slender tactile filaments, which stand up above the surface. Small fry swim along, touch the danger-signals thus hung out, stupidly disregard them, and the great jaws, like a concealed spring-trap, snap together, and the victims are engulfed by the dozen.

But still more useful to the fish in finding their way through the water, and perhaps of use in avoiding their enemies, is the row of touch-organs forming the "lateral line" (Fig. 139, *L*), which extends from the head to the tail. It is a very delicate apparatus peculiar to fishes and Batrachians. It is sensitive to the faintest movement of the water, enables the fish to notice the slightest displacements of water, giving it continual information as to the state of things about it, which its eyes or ears do not afford. This line is governed by the lateral nerve. Among the various experiments made by a French physiologist, De Sède, to ascertain the use of the lateral line, a barbel was blinded, and, by way of extra precaution, its barbels were cut off; afterwards its lateral nerve was cut. As long as the fish, even though deprived of its eyes and barbels, retained the lateral nerve it guided itself easily; but as soon as this nerve was severed it remained persistently motionless. In another experiment a perch, blinded and deprived of its lateral line on one side only, was placed in an aquarium divided into numerous compartments; it contrived to keep the unmutilated side turned towards any obstacle.

The bony fishes have also shown great adaptability to different and changing surroundings. Of the cod family, the cod lives in deep water, about "banks" or gravelly shoals, or about rocks, while the hake prefers muddy bottoms; the pollock lives in shoaler water nearer shore; on the other hand, the herring and mackerel swim in schools near the surface, devouring the surface-feeding crustacea, while the members of the flounder family are adapted for swimming close to the bottom, burrowing in the mud after the shellfish peculiar to such ground. The members of the salmon family have adapted themselves both to the sea and to fresh water; the salmon- and sea-trout live in the sea in winter, but ascend rivers to spawn; then there are land-locked salmon-trout, lake-trout, and brook-trout. There are sea-bass and lake-bass. In our ponds are perch, bass, pickerel, and trout, and these have their separate stations; the voracious bass spawning at the edge of the water, and there bringing up its shoals of young, driving off all other fish, while the lake-trout lie at the bottom. In extreme cases the flying-fish uses its pectoral fins as wings to aid it in leaping over the waves when pursued by larger fish; while the *Anabas*, or walking-fish of India, actually leaves its ponds and travels in companies over the land from one pond to another.

By an economical arrangement fishes often use the same spawning-grounds, but at different seasons; the trout and perch spawn in the winter in the shallows of rivers or ponds, while the sunfish or bream and horned pout use the same ground in summer. The eggs of the cod rise to the surface of the ocean and there float out of harm's way, and in our bays and harbors the eggs of the cunner are found at the surface, with the young in different stages of growth.

There are pelagic fishes, which are never seen in sight of land, while in the abysses of the ocean are strange forms which have become specially adapted for life at great depths.

Most of these, living in perpetual darkness, are phosphorescent, lighting up the deep around them so that they may perceive one another, and perhaps detect their food.

We will now pass in review some of the typical bony fishes.

Orders of Bony Fishes.

Order 1. Body long; ventral fins either abdominal or wanting... *Opisthomi.* Notacanthus.
Order 2. Body long, snake-like; no ventral fins................ *Apodes.* Eel.
Order 3. Five pairs of gills; mouth enormous; no fins.............. *Lyomeri.* Eurypharynx.
Order 4. Body broad; lips with barbels... .... *Nematognathi.* Catfish, Pouts.
Order 5. Body more or less oblong (in African rivers)........ *Scyphophori.* Mormyrus.

Order 6. Body usually compressed; all the bones and fins well developed................	*Teleocephali.*	Salmon, Perch, Cod.
Order 7. Head and mouth very large; pectoral fins supported by slender bones...............	*Pediculati.*	Lophius, Angler.
Order 8. Gills tufted; body long and slender....................	*Lophobranchii.*	Sea-horse.
Order 9. Bones of upper and lower jaw united; often rounded and spiny..........................	*Plectognathi.*	Tetrodon, Sunfish.

The Eels—The common eel (*Anguilla acutirostris*, Fig. 160) occurs on both sides of the Atlantic, on the North American coast as far south as Cape Hatteras, and in inland

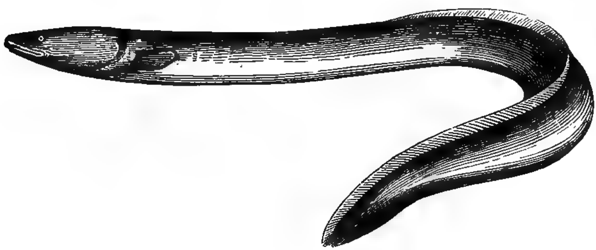

FIG. 160.—Common Eel, *Anguilla acutirostris.*

rivers and lakes. The males are extremely rare, only four having been found in this country. It is probable that the eel descends rivers in October and November, spawning in the autumn and early winter at the mouths of rivers, and in harbors and estuaries in shallow water. By the end of the spring the young eels are two or three inches long, and then ascend rivers and streams. They grow about an inch a month, and the females do not spawn at least before the second year, i.e., when about twenty inches long. Mr. Mather estimates that the ovary of an eel weighing six pounds when in spawn contains upwards of 9,000,000 eggs.

The Pelican Fish.—A very strange fish of unknown affinities, but supposed to be a degraded eel, is the *Eurypharynx* (Fig. 161) dredged in the Mediterranean Sea. It is .427 metre (18 inches) long, with an enormous mouth; it is without fins, and it differs from all other bony fishes in

FIG. 161.—*Eurypharynx pelecanoides.*

having six pairs of internal branchial slits, and consequently five pairs of gills. A similar form lives off New York at great depths.

The Pouts and Catfish.—The horned pout (*Amiurus*

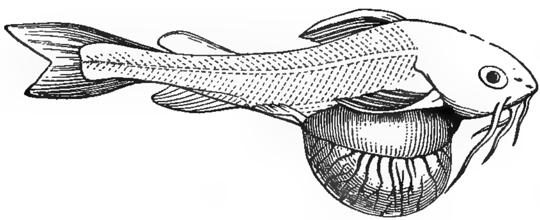

FIG. 162.—Young Arius, with its yolk-sac, probably taken from the mouth of its male parent.

atrarius) lays its eggs in holes in gravel during midsummer. The Great-Lake catfish is sometimes a yard in length.

In certain Siluroid fish in tropical seas, as *Arius* (Fig. 162), the eggs are carried by the males in their mouth, from five to twenty being thus borne about until the young hatch.

They are probably caught up after exclusion and fertilization. Some of these eggs are half an inch in diameter.

In Aspredo (Fig. 163) the eggs are attached to the outside of the body by slender stalks.

The Order of Teleocephali (cod, perch, trout, etc.) comprises most of the bony fishes; and they are, on the whole, the most perfectly developed of all fishes.

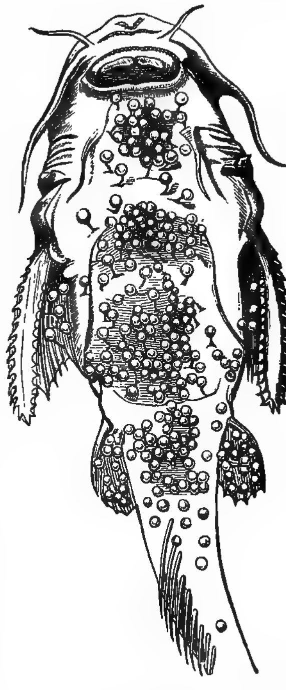

Fig. 163.—*Aspredo*, a Siluroid fish, with little sacs filled with eggs attached by slender stalks.

Beginning with the lower kinds, we have the electrical eel (*Gymnotus electricus* Linn.) of South America, which is two metres in length, and is characterized by its greatly-developed electrical batteries. These are four in number, situated two on each side of the body, and together form nearly the whole lower half of the trunk. The plates of the cells are vertical instead of horizontal, as in the torpedo, while the entire batteries or cells are horizontal, instead of vertical, as in the electrical ray. The nerves sent to the batteries of the eel are supplied by the ventral branches of about two hundred pairs of spinal nerves.

Succeeding these fish are the herrings, represented by the common English herring, *Clupea harengus*, which inhabits both sides of the North Atlantic, extending on the American side from the Polar regions to Cape Cod; the alewife (*Pomolobus pseudoharengus*), which ranges from Newfoundland to Florida; the shad (*Alosa sapidissima*), which has the same geographical distribution as the alewife; and the menhaden or pogy (*Brevoortia tyrannus*), which extends from the coast of Maine to Cape Hatteras. These, with the cod, hake, haddock, salmon, and a few other species, comprise our most valuable marine food-fishes. The fisheries of the United States yield about $43,000,000 annually, whilst those of Great Britain amount in value to about $8,000,000, and those of Norway to about $14,000,000.

The herring (Fig. 164) is a deep-water fish which visits the coast in spring in immense schools, in which the females are three times as numerous as the males, to spawn, selecting shoal water from three to four fathoms deep in bays,

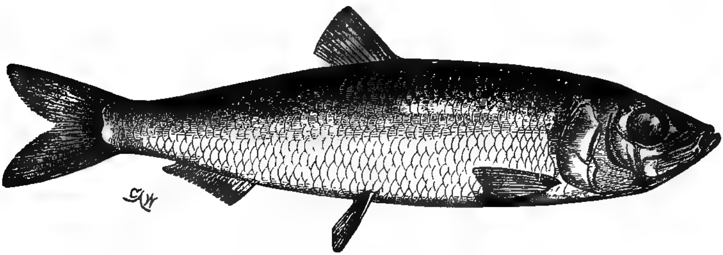

FIG. 164.—The Herring, *Clupea harengus*. (One third natural size.)

where the eggs hatch. At this season, and early in the summer, hundreds of millions are caught, especially on the Canadian, Newfoundland, and Labrador coasts. The English whitebait is the young of the herring. The herring is caught in deep nets with meshes large enough to capture individuals of ordinary size, the nets having a finer mesh than those used for the mackerel-fishery.

The alewife and shad are said to be *anadromous*, from their habit early in spring of visiting the coast and ascending rivers in vast numbers to spawn. The eggs are of moderate size; the ovaries are said to contain about 25,000, and at times as many as 100,000 or 150,000, eggs. They are discharged near the surface, sinking slowly to the bottom. The shad eats little or nothing in fresh water, being then engaged in spawning. In the sea they live on small shrimps. The menhaden is now put up as a substitute for sardines, and is of great value as fish-bait, especially in the mackerel-fishery, and for its oil.

The family *Salmonidæ* comprises the salmon, trout, and whitefish, with a number of species and varieties. The

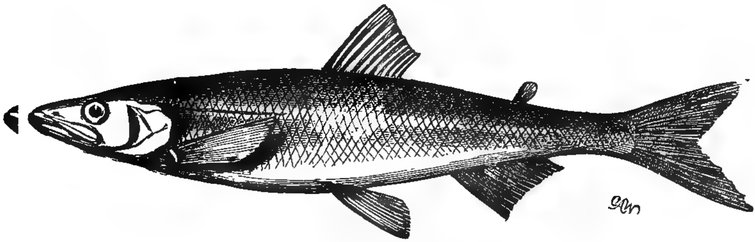

Fig. 165.—The Smelt, *Osmerus mordax.* **(One half natural size.)**

eastern salmon (*Salmo salar*) sometimes weighs eighty pounds. It is common to Europe as well as Northeastern America. In the autumn the salmon ascends rivers to spawn, penetrating as near the source as possible. The eggs are very large, exceeding a pea in size, and are laid in

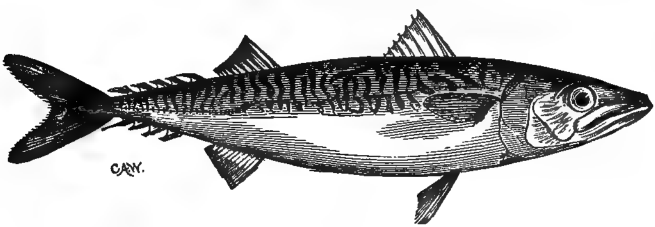

Fig. 166.—The Mackerel, *Scomber scrombrus.* **(One quarter natural size.)**

shallow holes made in the gravel of streams. The extreme young is banded and called a *parr;* when about a year old, and of a bright silvery color, before descending the rivers to the sea, it is called a *smolt;* after its return from the sea into fresh water it goes by the name of *grilse;* and finally, after returning a econd time from the sea, it assumes its name of salmon. The trout (*Salmo fontinalis*) also breeds in the autumn and early winter; it is not migratory, living permanently in streams and ponds.

An allied family embraces the smelt (Fig. 165).

One of the most valuable food-fishes is the mackerel (*Scomber scombrus*, Fig. 166), whose range is from Greenland to Cape Hatteras. It remains in deep water during the late autumn and winter, approaching the coast in May and June for the purpose of spawning, its annual appearance being very regular. The number of eggs deposited in one season by each female is said to be from five to six hundred thousand. After spawning they move northward, following the coast until they are checked by the coolness of the water, when they return, and in November seek the deep water again. When spawning they do not take the hook; they are then lean; but at the time of their departure from the coast they are fat and plump. The eggs of the mackerel, as well as of the cod, are so light as to rise to the surface, where they develop. Allied to the mackerel, though of great size, are the horse-mackerel and the sword-fish, whose upper jaw is greatly prolonged.

The singular *Anabas* of the East Indies is the representative of a small group of fishes called *Labyrinthici* or labyrinth-fishes, in allusion to a cavity on the upper side of the branchial cavity on the first gill-arches, containing a labyrinthine organ, which consists of thin plates, developed from the upper pharyngeal bones, enabling the fish to live for a long time out of water. *Anabas scandens*, of the fresh waters of India, will travel over dry land from one pond to another, and is even said to climb trees by means of the spines in its fins.

Near the head of the order stands the cunner (*Tautogolabrus adspersus*), whose anatomy is represented by Figs. 139, 140. Passing over the tautog, the voracious wolf-fish (*Anarrhichas*), the blennies (*Blennidæ*), in which the body is long and narrow, and viviparous eel-pout (*Zoarces*), the cottoids or sculpins, and a number of allied forms, we come to the hake (*Merlucius bilinearis*), the haddock (*Melanogrammus æglefinus*, Fig. 167) and cod (*Gadus morrhua*, Fig. 168), all of which extend northwards from Cape Hatteras, the cod abounding on both sides of the Atlantic, being a circumpolar fish. The cod does not, as formerly supposed, migrate along the coast, but seeks the cool temperature to which it is adapted by gradually passing in the early summer from shallow to deep water, and returning as the season grows colder. It visits the shallow water of Massachusetts Bay to spawn about the first of November, and towards the last of the month deposits its eggs. About eight or nine millions of eggs are annually deposited by

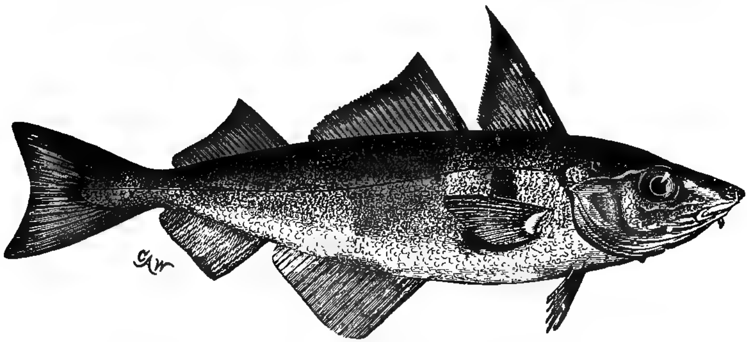

FIG. 167.—The Haddock, *Melanogrammus æglefinus.*

each female. The eggs laid by the cod rise to the surface of the water, on which they float. The young fish hatch on the New England coast in twenty days after they are extruded.

The cod is the most important of all the food-fishes, whether we consider the number taken or the amount of capital involved in the cod-fishery. It abounds most on the Grand Banks of Newfoundland. The breeding habits of the haddock, hake, and pollock are probably like those of the cod.

At the head of the *Teleocephali* stand the flounders, halibut, and soles, which are an extremely modified type of the order. In these fishes the body is very unsymmetrical, the fish virtually swimming on one side, the eyes being on the upper side of the head. The upper side is colored dark, due, as in other fishes, to pigment-cells; the lower side is colorless, the pigment-cells being undeveloped. When first hatched the body of the flounder is symmetrical, and in form is somewhat cylindrical, like the young of other fishes, swimming vertically as they do, and with pigment-cells on the under side of the body. The flounder is not born with the eyes on the same side of the head, but one eye gradually passes from the blind to the colored side; the transfer of the eye from the blind side to the colored side occurs

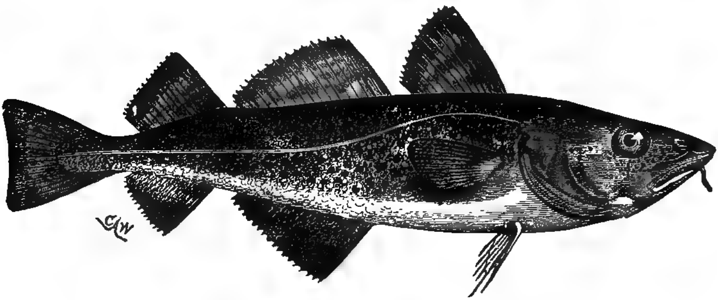

FIG. 168.—The Codfish, *Gadus morrhua*.

very early in life, while all the facial bones of the skull are still cartilaginous, long before they become hard and ossified, i.e., when the flounder (*Plagusia*) is twenty-five millimetres (one inch) long. Young flounders, when less than two inches in length, are remarkably active compared with the adults, darting rapidly through the water after their food, which consists principally of larval, surface-swimming crustaceans, etc. The common flounder from Nova Scotia to Cape Hatteras is *Pseudopleuronectes Americanus*.

The Anglers.—The type of the order *Pediculati* is the goose-fish. The name was given to the group from the long slender bones supporting the pectoral fins. The gill-openings are small and placed in the axils of the pectoral fins. *Lophius piscatorius*, the goose-fish or angler (Fig. 169) has an enormous mouth, and swallows fishes nearly as large as itself. Its eggs are laid in broad, ribbon-like, thin, gelatinous masses, two metres long and half a metre wide, which float on the surface of the ocean.

The Tufted-gilled Fish, or Lophobranchiates.—The male of the pipe-fish (*Syngnathus peckianus*) receives from the female the eggs, and carries them in a small pouch under his tail, which is grooved beneath. The sea-horse (*Hippocampus Hudsonius*, Fig. 170) lives off-shore from Cape Cod

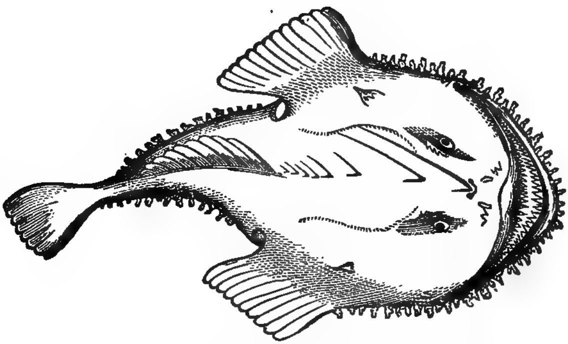

Fig. 169.—Goose-fish. (One tenth natural size.)

to Cape Hatteras. The male has a pouch situated on the breast. By simple mechanical pressure of its tail, or by rubbing against some fixed object, as a shell, it forces the fry, to the number of about a thousand, out of its brood-pouch, the young at this time measuring about twelve millimetres (5–6 lines) in length.

The Trunk- and Sun-fish.—The order *Plectognathi*, represented by a few singular forms, such as the trunk-fish, file-fish, puffers, and sun-fish, is characterized by the union of the bones of the upper and especially the lower jaws. The ventral fins are usually absent, and the skin is often spiny. They are inhabitants of warm waters. The trunk-fish or box-fish, *Lactophrys trigonus*, is a West-Indian fish; one specimen has appeared at Holmes's Hole, Mass. The porcupine-fish (*Chilichthys turgidus*) and smooth puffer (*Tetrodon lævigatus*) and the spring box-fish (*Chilomycterus geometricus*) range from Cape Cod to Florida. The sun-fish (*Mola rotunda*) is, like the others of the order, a surface-swimmer. It is sometimes a metre or more in length, weighing five hundred pounds or more.

Thus it seems that while the sharks have prospered from

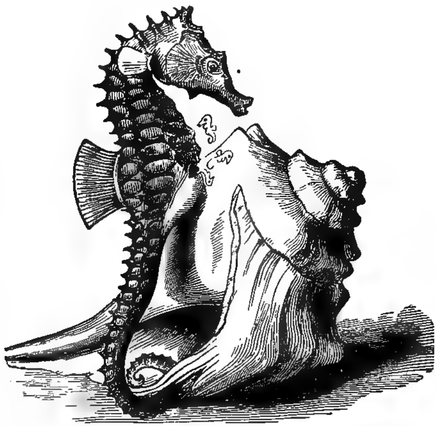

FIG. 170.—Sea-horse, male, with the young issuing from the brood-pouch.

the earliest times, i.e., since the appearance of any vertebrate life, their great size and ferocity mainly accounting for their success, after all, when we consider the number of species and individuals, the bony fishes have greatly outrun them in life's race, and conquered by virtue of their more highly wrought structure, their greater and more varied activity in swimming, their fertility and power of adaptation to every part of the watery world. For lack of these qualities, especially of adaptation, the ganoid type became wellnigh extinct.

CHAPTER XXVII.

THE LUNG-FISH.

EARLY in geological history the continents were much smaller than now, but as soon as they began to attain their present shape and size, when they were covered with forests, and were diversified by mountain ranges, inland seas, and great rivers, a new type of vertebrate life appeared—land animals with limbs and lungs. But their appearance was not altogether sudden.

They were preceded by a group of singular fishes. They form perhaps an order of Ganoids, called *Dipnoi* or lung-fishes. They are so called from the fact that, often living in pools and streams liable to dry up, they breathe air directly, having true lungs, like those of frogs, as well as gills. From the nature of their brain and their three-chambered heart, that of other fishes being two-chambered, the Dipnoans are quite different from all other fishes; while, on the other hand, the notocord is persistent, there being no bony spinal column, and the skull is cartilaginous.

The body of the Dipnoans is somewhat eel-shaped, though not very long in proportion to its thickness, and is covered with round scales. The pectoral and ventral fins are long, narrow, and pointed, and the imperfect vertebral column extends to the end of the caudal fin, which ends in a point, not being two-lobed, as in other fishes.

The Australian lung-fish (Fig. 171) has but a single lung. It attains a length of six feet. It can breathe by either gills or lungs alone. Ordinarily it uses its gills, but when the fish is compelled to live during droughts in thick muddy water charged with gases which are the product of decomposing organic matter, it is obliged to use its lungs.

It lives on the dead leaves of aquatic grasses, etc. The local English name is "flat-head," the native name being "barramundi."

The African lung-fish (Fig. 172) has two lungs. It lives on leaves in the White Nile, the Niger, and Gambia rivers, where it buries itself in the mud a foot deep. A similar

FIG. 171.—*Ceratodus*, or Australian Lung-fish. (The tail in nature ends in a point.)

lung-fish (*Lepidosiren*) lives in the rivers of Brazil. These three lung-fish, with their amphibious habits, whose allies began to exist in Devonian times, long before the coal period, unmistakably point to the appearance of a new and higher type of vertebrate life,—the Amphibians, or Sala-

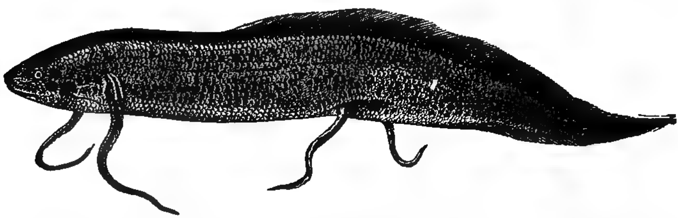

FIG. 172.—*Protopterus annectens*, a Lung-fish of Africa. (One third natural size.)

manders, etc. If their limbs were stronger, jointed, and divided into toes like those of a frog's, they would be able to walk and live on land. The transition from a swimming to a walking air-breathing animal is a remarkable one; yet we should bear in mind that at first the tadpole is without limbs and breathes by gills.

LITERATURE.—*Hyrtl:* Lepidosiren paradoxa. Prag, 1845.—*Günther:* Description of Ceratodus. Phil. Trans., 1871.

CHAPTER XXVIII.

THE SALAMANDER, FROG, AND OTHER AMPHIBIANS.

A SALAMANDER is rather a puzzle to many persons, who call the land species "lizards," and the newts "fish-with-legs." And so the latter are; for in most respects, save their legs, the newts are only a slight step higher than a fish.

The red-backed salamander is not uncommon throughout the Northern States in damp places under leaves; and southward the yellow spotted salamander is as common as any. The student should have a specimen before him and draw an outline of it. It will be seen that the body is fish-like, with a long tail, the newt having a caudal fin. There are two pairs of legs ending in toes, four toes on the fore legs, and five toes behind; the toes are smooth and rounded, without claws. The head is broad and flattened; the mouth large, the teeth small. The skin is smooth and slimy, and close inspection shows that there is a lateral line, much as in fishes. When the salamander walks or runs, it simply pushes itself along on its belly over the ground by means of its weak feet, though frogs and toads can walk, leap, and climb.

We see, then, that the salamander or newt mainly differs from fishes in having limbs. This, however, is a great step upwards. Let us look at the structure of limbs in general.

The limbs each consist of a single long bone, succeeded by two long bones, which support two transverse rows of short wrist- or ankle-bones, and five series of long finger- or toe-bones called *phalanges*. For example, in the fore limb of most vertebrates, as in the arm of man, to the shoulder-girdle is articulated the *humerus;* this is succeeded by the *ulna* and *radius;* these by the wrist-bones or carpals and metacarpals, and the finger-bones or *phalanges*, the single row of phalanges forming the digit (finger or toe). To the pelvis are attached the hind limbs, consisting each of a *femur* or thigh, which is succeeded by the *tibia* and *fibula* (shank-bones), these being followed by the tarsal and metatarsal bones (ankle-bones), and by the phalanges, or bones forming the toes.

On examining the internal anatomy of the salamander, the most striking difference from fishes is the presence of a pair of lungs. These are long sacks, which somewhat resemble the air-bladder of a fish; and, indeed, the lung is the "homologue" or representative of a fish's air-bladder. It will be remembered that the Australian lung-fish has but a single lung, while the African lung-fish has two, which connect by an air-passage with the throat. Some bony fishes

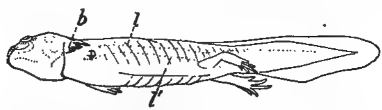

FIG. 176.—Salamander, showing the double row of lateral sense-organs (*l l'*); the dots on the head being organs of the same kind. *b*, gills.

have air-bladders divided into chambers, and thus we see that the lungs of amphibians and higher land vertebrates have their beginnings in the air-bladder of fishes. Tadpoles and salamanders also resemble fishes in having similar lateral sense-organs (Fig. 176).

If now we compare a salamander's skeleton (Fig. 179) with that of a fish (Fig. 138), we shall see some notable differences; besides the limbs, great changes have taken place in the shoulder and pelvic arches to which the legs are attached; the bones composing these are more as in the lizards and higher vertebrates, while there is a breastbone or *sternum*. Moreover, the skull is broad and flat, composed of few bones, among which may be distinguished the outer or investing bones of the skull, so well developed in the higher vertebrates; these are the parietal, frontal, nasal bones, the vomer, etc.; still, important parts of the skull remain cartilaginous as in fishes. Another distinguishing mark is that the skull is connected with the vertebral column by two condyles, these being bony, rounded projections which fit into corresponding sockets in the first neck-vertebra. In having two condyles, Amphibians differ from lizards and birds, and resemble mammals. Another new feature is the presence of short, rudimentary ribs. Eyelids are often present, no fishes having them. Thus, as a rule, *Amphibians are characterized by having true legs, toes, and lungs; the toes without claws, the skin smooth, without visible scales; the skull has few investing bones, but with two condyles; external gills are often present; there is a sternum and ribs; the heart is three-chambered, and most of the species undergo a metamorphosis.*

Orders of Batrachia (Amphibians).

1. Body long, eel-like, with gills; no hind legs.................... *Trachystomata.* Siren.
2. Body flat, with gills; four legs.....*Proteida.* Mud-puppy.
3. No gills in adult life.............. *Urodela.* Salamanders.
4. Body snake-like; no feet, no tail....*Gymnophiona.* Blind Snake.
5. Extinct; body partially scaly... ...*Stegocephala.* Labyrinthodonts.
6. Tailless, with four legs, long toes; great leapers; young with tails..*Anura.* Toads, Frogs.

The Sirens.—These singular creatures are eel-like in their form and movements, with gills on the sides of the head. They have no hind legs, and the small, weak fore legs are three- or four-toed. The great siren (*Siren lacertina*) is two or three feet in length, and is four-toed. It lives in swamps and bayous in the Southern States, especially in rice lands. Its food is supposed to be earth-worms, insects, etc.

The Mud-puppy.—The *Proteida* are flat-bodied, with bushy thick gills, of a beautiful deep red beneath, with gill-openings, while the jaws are armed with small conical teeth.

The *Proteus* of Austrian caves is blind, having no use for eyes, as it lives in total darkness; it has three toes in the fore feet and two in the hinder pair. Our American Protean is four-toed on all the feet. The mud-puppy or Menobranchus (*Necturus lateralis*) is a large, broad, flat-bodied, fish-like creature. It is brown, mottled with darker spots; it has small eyes, and is from eight inches to two feet in length. It inhabits the Mississippi Valley, and is common in the lakes of Central New York, where it is caught with the hook and line. It is easily kept in confinement, eating bits of meat.

The Salamanders and Newts.—The tailed Amphibians rarely have gills when mature, these organs being larval or transitory. The body is still long and fish-like, the tail sometimes with a caudal fin, as in the newts, but usually rounded, while the four legs are always present. One or

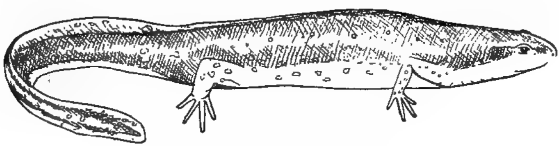

FIG. 177.—Spotted Newt.

two of the salamanders living away from water bring forth their young alive; but, as a rule, salamanders lay eggs in the water. The eggs of the spotted newt are laid singly on the leaves of floating plants. The common red-backed salamander (*Plethodon erythronotum*) lays its eggs in summer in packets under damp stones, leaves, etc.; the young are born with gills.

FIG. 178.—Young Newt. (Natural size.)

The lowest form of this order is the aquatic Congo-snake, or *Amphiuma means*, in which the body is large, very long, round, and slender, with small rudimentary two-toed limbs; there are no gills, though spiracles or gill-openings survive. It lives in swamps and sluggish streams of the Southern States.

A step higher is the *Menopoma*, which is still aquatic, with persistent gills, but the body and feet are as in the true salamanders. The *Menopoma Alleghaniense* (Fig. 179), called the hellbender, or big water-lizard, is about half a metre (1½–2 feet) in length, and inhabits the Mississippi Valley.

We now come to the true salamanders, whose body is still

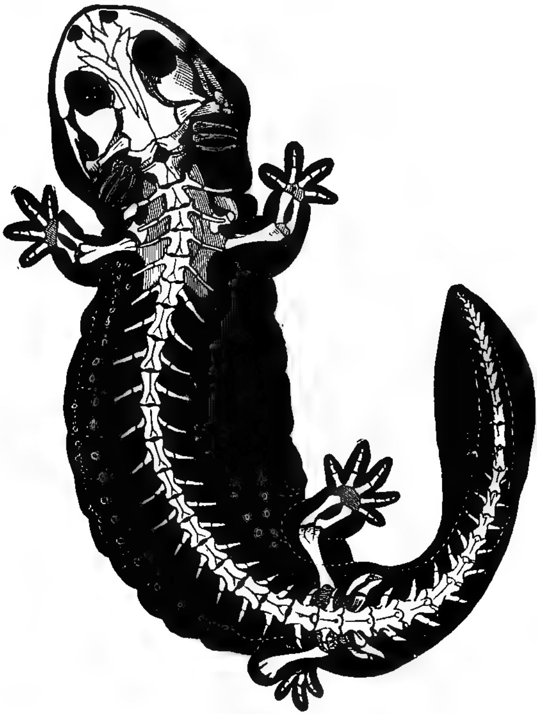

FIG. 179.—Skeleton of the hellbender (*Menopoma*).

tailed, with larger eyes; there are no spiracles; they breathe mainly by their lungs, but in part by their skin.

The genius *Amblystoma* comprises our largest salamanders; they are terrestrial when adult, living in damp places and feeding on insects. The larvæ retain their gills to a period when they are as large or even larger than the parent. The most interesting of all the salamanders is the *Amblystoma mavortium,* whose larva is called the *Axolotl* (Fig. 180). This larva is larger than the adult, which lives on land, sometimes being about a third of a metre (12 inches) in length, the adult being twenty centimetres (8 inches) long.

The axolotl, or siredon, abounds in the lakes of the Rocky Mountain plateau from Montana to Mexico, from an altitude of 4000 to 8000 or 9000 feet. Late in the summer the siredons at Como Lake, Wyoming, where we have observed them, transform in large numbers into the adult stage, leaving the water and hiding under sticks, etc., on

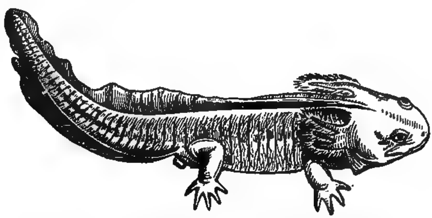

FIG. 180.—Siredon or larval Salamander.

land. Still larger numbers remain in the lake and breed there.

The change from the larva to the adult consists in the absorption of the gills, which disappear in about four days; meanwhile the tail-fins begin to be absorbed, the costal grooves become marked, the head grows smaller, the eyes larger, more protuberant, and the third day after the gills begin to be absorbed the creature becomes dark, spotted, and very active and restless, leaving the water.

Experiments show that the legs and tail of the axolotl, as of other larval salamanders, may be reproduced. The larva lays eggs as well as the adult salamander.

The Tritons, or water-newts, represented by our common, pretty spotted-newt (*Diemyctylus viridescens,* Fig. 177), is common in sluggish brooks; it lives on insects.

The Blind Snake.—Its body is snake-like, being long and cylindrical. We have seen that in the siren the two hind legs are wanting, and that in those which walk on all-fours the number of toes may vary. In the blind-snake

FIG. 181.—Head and tail end of blind-snake (*Cœcilia*).

there are no legs at all, and thus we have amphibians without legs, just as snakes are reptiles without legs. Though this creature is blind and limbless, and would appear to have a hard time in getting the means of living, yet by adopting the mode of life of an earthworm it thrives, and affords another of the instances, of which there are so many, of the harmony in nature between animals and their surroundings. The skin is smooth externally, with minute scales embedded in it. The eyes are minute, covered by the skin (Fig. 181). The species inhabit the tropics of South and Central America, Java, Ceylon, and live like earthworms in holes in the damp earth, feeding on insect larvæ. They are large, growing several feet in length. *Cœcilia compressicauda* of Surinam is viviparous, the young being born in water and possessing external leaf-shaped gills.

FIG. 182.—Young of *Cœcilia*, with the gills, and head of the same after the gills have been absorbed.

Toads and frogs.—These are the tailless Batrachians. Frogs either live in or by the edge of pools and brooks, and when attacked on land they can by vigorous leaps escape to a place of safety. Unlike other amphibians, they are powerful leapers, the legs being muscular, and their toes very long. They can also run and climb. The lower jaw is usually toothless. In the toad there are no teeth in either jaw ; it swallows its food whole. The lower eyelid can be drawn over the eye and the nostrils can be covered by membranes, while the ears are covered externally by a large tympanic membrane. In the toad the skin, especially near the ear, is rough and warty, containing glands, which pour out an acrid, milky secretion, which may be distasteful to

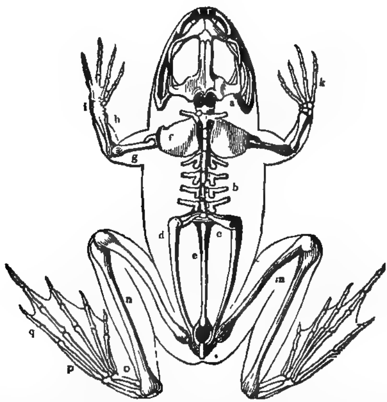

FIG. 183.—Skeleton of a frog. *a*, skull; *b*, vertebræ: *c*, sacrum, and *e*, its continuation (urostyle); *f*, suprascapula; *g*. humerus; *h*, fore-arm bones; *i*, wrist-bones (carpals and metacarpals); *d*, ilium; *m*, thigh (femur); *n*, leg-bone (ulna); *o*, elongated first pair of ankle-bones (tarsals); *p*, *q*, foot-bones or phalanges.

birds, and is an irritant poison when applied to the eye-lids.

While most frogs are greedily devoured by herons and other large wading-birds, as well as ducks, geese, and snakes, and while such species are only preserved from extinction by their nocturnal habits and their protective resemblance to the herbage and leaves of trees, there is a little bright red and blue frog in Nicaragua which hops about in bright daylight. It owes its life to its bad taste, for ducks and fowl will on this account not eat it.

The toad is nocturnal, hopping about when the birds are asleep, and is exceedingly useful in destroying noxious insects. The salamanders, toads, and frogs hibernate buried in the mud at the bottom of ponds.

Male toads and frogs are musical, the females being comparatively silent; the vocal organs of the male are more developed than in the females, and in the European edible frog large sacs for producing a greater volume of sound swell out on each side of the head of the males.

The toad (*Bufo lentiginosus*) is exceedingly useful as a destroyer of noxious insects. It is harmless. In the Northern States toads begin to make their peculiar low trilling notes from the middle to the 20th of April; from the latter date until the first of June they lay their eggs in

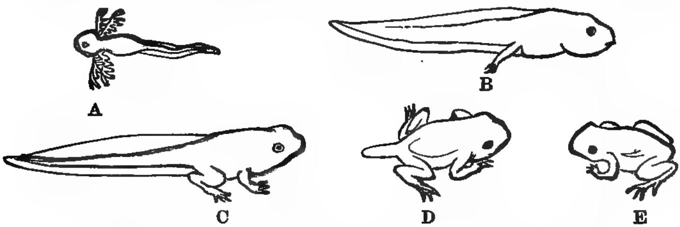

FIG. 184.—Different stages in the Metamorphosis of the Toad.

long double strings, and the tadpoles are usually hatched in about ten days after the eggs are laid.

The toads and frogs after hatching pass through a wonderful series of changes before reaching maturity. Fig. 184 represents the external changes of the toad from the time it is hatched until the form of the adult is attained. The tadpoles of our American toad are smaller and blacker in all stages of growth than those of the frog. The tadpole is at first without any limbs (Fig. 184, *A*), and with two pairs of gills; soon the hinder pair bud out. After this stage (*B*) is reached the body begins to diminish in size. Then the fore-legs grow out (*C*); and finally, as at *D*, the tail is mostly absorbed, and at *E* we see the little toad which hops about on the bank.

In the spade-footed toad (Figs. 185, 186) the feet are provided with a horny, spade-like process, which aids the

FIG. 185.—Spade-foot Toad (*Scaphiopus*). (Natural size.)

creature in digging, as this species is usually subterranean in its habits, rarely appearing above ground, except in spring to lay its eggs.

Of the true frogs (*Rana*) there are numerous species; of these, the largest is the bull-frog, which makes a deep, hoarse, grunting noise. Smaller and more common species are the pickerel-frog and the marsh-frog. The frogs lay their eggs in roundish masses in ponds and pools from April to June, according to the latitude.

FIG. 186.—*A*. inside of adult left foot of spade-foot toad. (Natural size.) *B*. left foot of young spade at earlier stage of growth.

Miss Hinckley has described the habits of the larger tree-toad (*Hyla versicolor*, Fig. 187). The eggs are attached from early May till July, singly and in small

Metamorphosis of the Tree-toad.

groups, in grass which grows up and rests on the water. The tadpoles hatch in two days. In a week after the tadpoles appear the gills are absorbed. Meanwhile the tadpoles hang by their "holders," or suckers on the lips, to the leaves, as seen in the engraving. When about three weeks old the hind legs begin to bud out in front of the base of the tail. During the eighth week they take little food; the four legs grow out, the tail disappears, the mouth becomes adapted for seizing and eating insects, and they leave the water. This tree-toad depends for safety on its power of changing its color from green to gray; it hides among leaves, or in crevices in the bark of trees, when it becomes like an excrescence on the bark of the tree.

We have noted the metamorphoses of the jelly-fish, the starfish, the butterfly, and that of the frog or toad is no less remarkable. The tadpole is, so to speak, an entirely different animal from the adult. It is even lower in the scale than a fish; it has neither fins nor legs; like a young shark, it breathes by external gills. The mouth is very small (Fig. 188, *A*), with no tongue and the horny toothless jaws only enable it to nibble decaying leaves, etc. The digestive canal is remarkably long and coiled in a close spiral, while in the carnivorous adult it is much shorter, with few turns. The vertebræ of the tadpole are biconcave, as in fishes, afterwards becoming converted into cup-and-ball joints.

We thus see that during the changes from the tadpole to the frog or toad the body is, so to speak, made over anew, both within and without, and that the creature, as tadpole and frog, leads two lives,—one fish-like in the water, feeding on decaying vegetable and animal matter; the other as an active, leaping, tailless, air-breathing creature, feeding on smaller animals.

Reviewing the essential characters of the fishes and amphibians, we see that they have many in common, and that they should be associated together; while, as we shall see farther on, the reptiles and birds are intimately allied.

The frogs and toads, though at the head of existing amphibians, being the most unlike the others, are by no means the most perfectly developed examples of the class. They are examples of a special development of the limbs; the blind worm, on the other hand, is an example of a backward development, losing its limbs and becoming blind and worm-like; and then we have the Siren without hind legs, and Proteids with but two toes on the hinder feet.

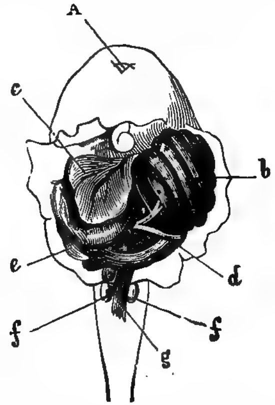

FIG. 188.—Mouth and digestive canal of a Tadpole. *A*, mouth; *b*, intestine coiled on itself; *c*, liver; *d*, hepatic duct; *e*, pancreas; *f*, rudimentary hind legs; *g*, rectum.

Without doubt the most perfectly developed Amphibia were certain forms which flourished during and immediately after the Coal period, and which more than any living amphibians anticipated the lizards and alligators. They were either small or colossal in size, some as big as whales, being thirty feet in length. They, in most cases, had well-developed legs and toes and long tails, while the body was partly protected by large

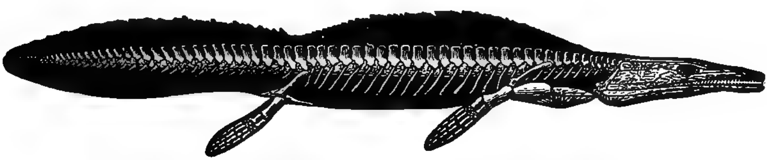

FIG. 189.—Archegosaurus. Restored. (About four feet long.)

breastplates, with smaller scales on the under and hinder parts of the body. The teeth were more complex than in any existing amphibians, the enamel being folded in a labyrinthine manner; hence the name, Labyrinthodonts, applied to them. From restorations of certain forms they must have been more like lizards than any others of the class. On the other hand, some were remarkably like certain ganoid fishes, having gills and paddles, and adapted for an aquatic life (Fig. 189).

Thus the Amphibia connect in a degree the fishes and reptiles, and show that these three classes arose like the branches of a tree, from one and the same trunk.

The salamanders, toads, and frogs are common in all countries, temperate and tropical, and though those now existing are but the dwarfed or modified representatives of former ages, they occupy a place in nature which neither fishes, on the one hand, nor reptiles, on the other, can fill.

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CHAPTER XXIX.

THE LIZARDS, SNAKES, AND OTHER REPTILES.

We will select as an example of the reptiles our common lizard, which lives in pine woods as far north as Pennsylvania. Its scientific name is *Sceleporus undulatus*. If we compare a lizard with a salamander, we notice that the general shape of the body is the same, but that the lizard differs in the body being covered with scales, and the toes ending in claws. The number of toes on each leg is usually five. The eyes are protected by an upper and lower eyelid, and there is a nictitating membrane at the inner angle of the eyes, so that, as in birds, lizards, which are creatures of the bright sunlight, can withstand the direct rays of the sun. While in the lizard the nostrils are not well marked, they are so in the turtle and alligator. For the first time we meet with true lips. Though the lizard runs swiftly, darting up and down trees, yet it slides along on its belly, pushing itself forward by its legs, not lifting its body above the surface over which it moves.

When we compare the skeleton of a lizard with a salamander's, there are important differences; the vertebræ are usually hollow in front and rounded behind, and the skull is much more like that of a bird than a salamander; and, as in birds, it is connected with the spinal column by one condyle. The lungs are long and sack-like, but connect with the back of the mouth by a long windpipe, as in birds. The brain is also better developed than that of any amphibian, and the heart and circulation are adapted to the more active habits of the lizard.

The lizard, like birds, lays a few very large eggs, and thus we see that the lizard, on the whole, is much more like a bird than a salamander. The lizard lives a more active life than the salamander, and we shall see that certain forms now extinct fairly rivalled the birds in power of flight. Reptiles are vastly more numerous in species than amphibians, and play a more important part in the animal economy.

As a general rule, then, *the lizard and other reptiles are air-breathers, with scaly bodies, their limbs ending in claws; their ribs well developed, their eyes with two lids, their nose with nostrils; the circulation of the blood is incompletely double, and the eggs are large. They do not pass through a metamorphosis.*

ORDERS OF LIVING REPTILES.

1. Body long, slender, cylindrical, limbless.................. *Ophidia.* Snakes.
2. Body with a long tail; usually two pairs of limbs................ *Lacertilia.* Lizards.
3. Body inclosed in a thick shell.... *Chelonia.* Turtles.
4. Lizard-like; vertebræ hollow at each end..................... *Rhynchocephalia.* Sphenodon.
5. Body thick scaled; teeth in sockets. *Crocodilia.* Crocodiles.

The Lizards.—Let us now look at lizards more in general, and afterwards we can learn in how many ways the various kinds are adapted to different modes of life. Most lizards have cylindrical bodies, usually covered with small overlapping scales, with a long, slender tail, and generally two pairs of feet, the toes long and slender, and ending in claws. They run with great rapidity, and are active, agile creatures, adorned with bright metallic colors, in some cases green or brown, simulating the tints of the vegetation or soil on which they live; some are capable of changing their color at will, as the chameleon and Anolis; this is due to the fact that the pigment- or color-cells are under the influence of the creature's will.

In many lizards (*Lacerta, Iguana,* and the Geckos) the middle of each caudal vertebra has a thin cartilaginous partition, and it is at this point that the tails of these lizards break off so easily when seized. In such cases the tail is renewed, but is more stumpy.

Both jaws are provided with teeth, while some have them developed on the bones of the mouth. Most lizards prey on insects; some live on plants. The eyelids are well developed except in the Geckos, in which, as in the snakes, there is a transparent sack filled with fluid over the cornea or ball of the eyes. The tongue is free and long, sometimes forked; in the iguana it ends in a horny point.

Lizards lay their eggs in the sand or soil. The iguana,

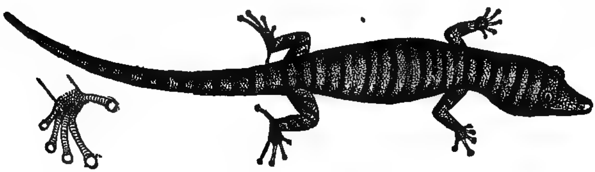

FIG. 190.—West Indian *Gecko*.

or great lizard of the West Indies, deposits hers in the hollows of trees. Certain kinds are viviparous.

Our most common lizard in the Middle and Southern States is *Sceleporus undulatus;* it is about six inches long, gray, with dark wavy bands, and may be seen in sunny glades running up the trunks of trees.

It is evident that this lizard is protected by its resemblance, when at rest, to the bark of the pine. The iguanas are very large, being nearly three feet in length, but rather sluggish lizards, with a dorsal row of high, thin spines. They are said to be excellent eating.

The "horned toads" (*Phrynosoma*, Fig. 191) are characteristic of the dry Western plains; the body is broad, flattened, and spiny. Their color is like that of the soil they inhabit; hence, protected by their color and their strong spines, they are probably not often snapped up by birds. Like all other lizards, the horned toad can withstand a long fast; they will in captivity eat insects and take milk.

The chameleons have the five toes arranged in two opposable groups adapted for grasping the twigs of trees;

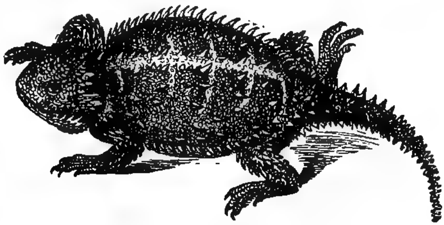

FIG. 191.—Horned Toad.

their eyes have a movable circular lid; they have remarkably long tongues (Fig. 192), which can be darted out five or six inches at insects, which adhere to the sticky swollen extremity while the body of the chameleon is perfectly immovable. Chameleons can change their color at will; as

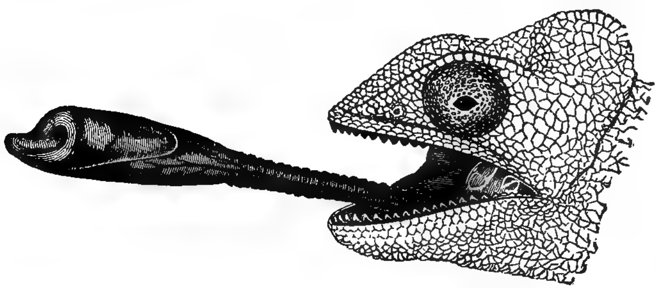

FIG. 192.—Tongue of Chameleon. (Natural size.)

can the *Anolis* (Fig. 193) of Florida, which is a long smooth-bodied lizard, having the power of changing its color from a bright pea-green to a deep bronze-brown.

We have seen that among amphibians the blind snake is entirely limbless, and so among lizards there are several limbless forms, among them the glass-snake (*Ophisaurus*) and the *Amphisbæna*. These are very sudden transitions from the swift, agile lizard; but nature does not make a leap, and in the two-footed lizards, *Pseudopus*, with its fore legs wanting, and in *Chirotes* and *Pygopus*, in which the hind feet are wanting, we have connecting links between the ordinary lizard and the Amphisbæna (Fig. 194). This

FIG. 193.—West Indian *Anolis*.

singular creature, which lives in ant-hills, is thus the result of adaptation. Its tail is nearly as broad as its head; and since the creature runs backwards as well as forwards, it is popularly supposed to be two-headed. It feeds on ants and other insects.

The Snakes.—It would be difficult for the untrained observer to distinguish between the glass-snake and the ordinary snake. Indeed, there are snakes with rudimentary legs, such as the boas, as well as lizards without limbs. Thus, the snakes are really lizards without legs, for there are no very important marks to distinguish one order from the other, except that snakes in general are without limbs

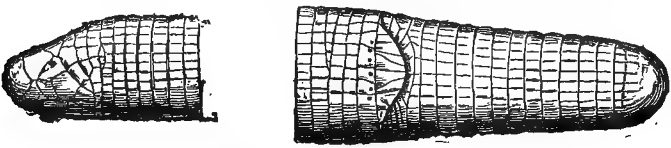

FIG. 194.—Head and tail of *Amphisbœna.* (Natural size.)

and eyelids, and the scales on the head are arranged differently from those of lizards; and the jawbones are movable, so that a snake can open its mouth very wide and swallow a large animal.

Indeed, the lizards are ancient forms and the snakes are much more recent in their appearance, and everything goes to show that the snake-form is the result of adaptation to their peculiar mode of life. At all events, snakes are very common. There are many species; we have 130 species in the United States; and all contrive, in spite of their want of legs, to gain a living and to play a part in the world of animated existence which no other creatures can assume. Thus, while most snakes run on the ground, others live almost entirely on trees and shrubs, and still others exclusively in the sea.

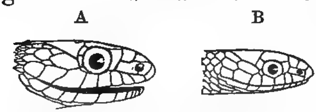

FIG. 195.—*A*, head of Striped Adder. (Natural size.) *B*, head of Green Snake.

The skeleton and internal organs are curiously modified in accordance with the shape of the body and its needs.

Notwithstanding the fact that snakes have no legs, they can creep, glide, grasp, suspend themselves, erect themselves, leap, dart, bound, swim, and dive. The peculiar gliding motion of snakes is due to the lateral bends of the vertebral column, while the ribs can be moved back and forth; moreover, the large scales on the under side of the body are successively advanced, the hinder edges of the scales resting on the ground and acting as supports; resting on these, which are attached to one another and to the ends

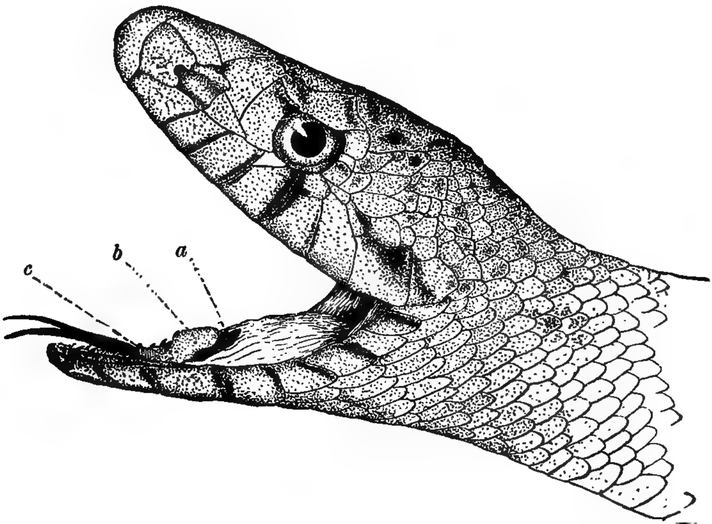

FIG. 196.—Mouth of the Bull-snake (*Pityophis sayi*). *a*, tongue-sheath; *b*, epiglottis; *c*, rima glottidis or opening of the windpipe. (Natural size.)–Shufeldt.

of the ribs, the body is then drawn or pushed rapidly forward.

Snakes can swallow animals much thicker than their own bodies, because the bones of their skull and throat separate so that the mouth and throat can be greatly extended. Thus, a boa can swallow a calf whole, or a common striped snake can swallow a toad or bullfrog. The bones of the mouth are also armed with teeth pointing backwards, to prevent the prey from slipping out of the mouth. Snakes occasionally are known to hiss, the noise being caused by the passage of the breath from the lungs through the windpipe. In the bull-snake, the loud, hoarse hiss is due to the presence of an unusually large epiglottis (Figs. 196, 197 *b*). The fixed, stony gaze of snakes is due to the fact that the eye is covered by a thin stationary capsule, the true lids not being present.

The proverb "deaf as an adder" is not founded on fact, as snakes, like all reptiles, have internal ears. Their sense of hearing may be dull; but certain snakes, as the cobra de capello, are attracted by music.

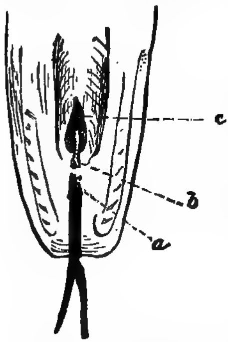

FIG. 197.—Mouth of Bull-snake, seen from above; letters as in Fig. 196.—Shufeldt.

Most snakes resemble in color the ground or soil they frequent; some being, as the rattlesnake of the Western plains, of the color of the soil in which they burrow. The little green snake is of the color of the grass through which it glides; others are dull gray or dusky, harmonizing with the color of the trunks of trees on which they rest. The poisonous coral-snake (*Elaps*) of the forests of the Southern States is, however, gayly and conspicuously colored; indeed, it can afford to be brightly colored, as no birds dare to attack it.

The poisonous snakes may always be recognized by their broad, flattened heads, and usually short, thick bodies.

The poison-gland of the rattlesnake (Fig. 198, *a*) is a modified salivary gland. The two fangs are modifications of maxillary teeth, each of which has been, so to speak, pressed flat, with the edges bent towards each other, and soldered together, so as to form a hollow cylinder open at both ends, the poison-duct leading into the basal opening. When the fangs strike into the flesh, the muscles closing the jaws press upon the poison-gland, forcing the poison into the wound. The poison-fangs are largest in the most deadly species, as the viper (*Vipera*), the puff-adder (*Clotho*), the rattlesnake, and fer-de-lance (*Trigonocephalus*), but are small in the asps or hooded snakes (*Naja*). The bite of the rattlesnake is intensely painful; it is best cured by sucking, freely lancing, and by cauterizing the wound, and drinking large quantities (at least a pint) of whiskey or brandy, sufficient ordinarily to produce insensibility. Deaths from the bite of rattlesnakes are not common, while in India it is estimated that several thousand persons annually die from the bite of the cobra—20,000 dying each year from the bites of snakes and the attacks of wild beasts. The "rattle" of the rattlesnake is a horny appendage

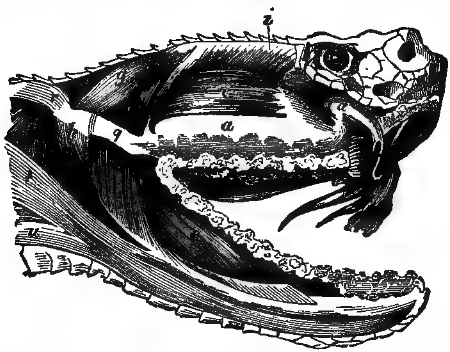

FIG. 198.—Head of the Rattlesnake. *a a*, poison-gland and its excretory duct; *e*, anterior temporal muscle; *f*, posterior temporal muscle; *g*, digastricus; *h*, external pterygoid muscle; *i*, middle temporal muscle; *q*, articulo-maxillary ligament which joins the aponeurotic capsule of the poison-gland; *r*. the cervical angular muscle; *t*, vertebro-mandibular muscle; *u*, costo-mandibular muscle.

formed of button-like compartments; the sound made by the rattle, which has been compared by some to the stridulation of a Carolina locust or of the Cicada, is an alarm-note, warning the intruder; the rattle is sprung before the snake strikes.

The poisonous snakes stand lowest in the series; they are succeeded by the striped snake, milk-adder, and by the boas, which attain a length of five metres; while the anaconda grows eight metres long.

The Turtles.—Retracing our steps in the path ending in the snakes, we return to the point where were reptiles with four limbs, and follow another path leading to the turtles. And in these creatures we have very singular, highly-modified forms, specially adapted to a life of unusual security. Nature has been kind to the turtles; she has given them a strong shell, into which the head and legs may be withdrawn, so that they can get all the food they want, and yet not become food for other animals. She has endowed them with wonderful vitality and long life, adapting them for life on the land, in rivers and lakes, and in the high seas. If the turtle is slow, it is sure; it does not push itself along

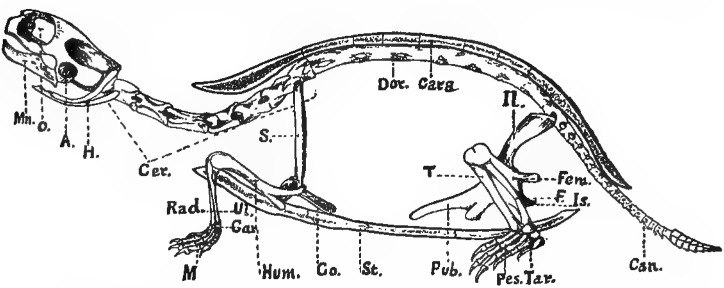

FIG. 199.—Skeleton of the common Spotted Turtle. *Mn*, mandible; *O*, orbit of eye; *A*, ear-opening; *H*, hyoid bone; *Cer*, cervical vertebræ; *Dor*, dorsal vertebræ consolidated with the carapace, *Cara*; *Cau*, caudal vertebræ; *S*, scapula; *Co*, coracoid; *St*, sternum; *Hum*, humerus; *Rad*, radius; *Ul*, ulna; *Car*, carpal bones; *M*, metacarpals; *Il*, ilium; *Pub*, pubic bone; *Is*, ischium; *Fem*, femur; *T*, tibia; *F*, fibula; *Tar*, tarsus; *Pes*, foot.

on its belly, like an ordinary lizard, but its legs are so perfectly formed that it can walk, lifting its body above the ground; its senses are acute, so that it can perceive coming danger and withdraw into its shell, or, if near or in the water, dive to the bottom out of harm's way.

No one is at a loss to recognize a turtle at sight; all have a shell, and the toothless jaws are protected, as in birds, by horny sheaths.

The skeleton of the turtle should be carefully examined. It will be seen that the shell consists of an upper bony shield and a lower shield, which is joined to the upper by lateral arches; the upper shell, or carapace, then, is partly due to the outgrowth of the spinous processes and ribs of the thoracic vertebræ, to which are soldered broad, thin, bony plates. Above these are usually thin horny epidermal or skin-plates, forming the tortoise-shell of commerce. The ventral shield or plastron consists of two rows of bony plates covered by skin-plates.

Turtles are invariably toothless, but the absence of teeth is made up by sharp-cutting horny plates, so that most turtles can bite savagely. On the whole, however, turtles require but little food, and take long fasts.

Moreover, they breathe very slowly; they have to, as the chest cannot heave when the air is drawn in, since it is solidly fastened to the carapace. In breathing the air is gently drawn in through the nostrils, and then very slowly passes out again. There is thus a harmony between their slow movements and slow respiration; while the heart is not highly developed, compared with a crocodile's. There are about forty species of turtles in America north of Mexico. The lower forms of turtles are the marine species. Such is the great sea-turtle (*Sphargis coriacea*) of the Atlantic and Mediterranean, which is the largest of all existing turtles, and is sometimes eight feet long, weighing from eight hundred to twelve hundred pounds. The green turtle of the West Indies weighs from two hundred to three hundred pounds, and is used for making delicious soups and steaks, being caught at night when laying its eggs on sandy shores. The sea-turtles have large, flat, broad flippers or fin-like limbs, while in the pond- and river-turtles the feet are webbed and the toes distinct.

The turtles lay their eggs in sand on the shores of ponds and rivers. In the Middle and New England States nearly all the turtles lay their eggs on or about June 10th, the eggs being hatched late in the summer. Turtles do not lay eggs until from eleven to thirteen years old.

The land-tortoises, as probably all turtles, are long-lived, and often reach a great age. White, in his "Natural History of Selborne," relates that one was kept in a village till it was supposed to be one hundred years old.

When we see how few turtles are devoured by other animals because of their thick shell, and also take into account their vitality and the length of time it requires for them to arrive at maturity, the cause of their great longevity is explained.

The Crocodiles.—In the crocodile, gavial, and alligator, we return again to a lizard-like form. They present a decided step in advance of other reptiles, the heart approaching that of birds, in having the ventricle completely divided by a partition into two chambers; the venous and arterial blood mingling outside of the heart, not in it, as in the foregoing orders. The brain is also more like that of birds.

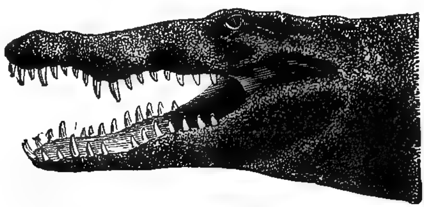

FIG. 200.—Head of the Florida Crocodile.

The nostrils are capable of closing, so that crocodiles and alligators draw their prey under the water and hold it there until it is drowned; but they are obliged to drag it ashore in order to devour it. The skin is covered with large bony, epidermal scales. The conical teeth are lodged in sockets in the jaws. The feet are partly webbed. The crocodiles and gavials lay from twenty to thirty cylindrical eggs in the sand on river-banks. The crocodiles are distributed throughout the tropics, even Australia; the gavials are mostly confined to India and Malaysia, and also Australia.

It is among certain fossil reptiles that we find links connecting the reptiles and birds, and thus the highest, best-developed reptiles are not those now in existence, but those which flourished long ago, and whose tracks have, in some cases, been preserved in the New Red Sandstone of the Connecticut Valley. Many of these forms were colossal, standing from fifteen to twenty-five feet in height. They walked on their hind legs, making a three-toed track, and holding their short, small fore legs off the ground. In peculiarities of the skeleton they approached very nearly the lower aquatic birds.

Another extinct reptile, the Pterodactyl, came near the birds by another line of approach. It was a flying reptile, the fore leg not used in walking, but with a long, slender little finger, and a broad membrane connecting the fore and hind legs. The skull was small and bird-like in shape, the jaws very long, and in certain kinds toothless.

Such forms as these, and many others, were once the rulers of the sea and land, as well as of the air; and they gave the name of the Age of Reptiles to one of the most striking periods in the earth's history—that immediately succeeding the Coal period. As the reptilian dynasty, after a long and successful reign, began to die out, there appeared the birds and beasts, whose supremacy it was reserved for man himself to witness.

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CHAPTER XXX.

THE BIRDS.

Any bird selected at random, so much alike are they all, will serve as an example of the class. We will suppose the student to have before him a dove; by studying this he can readily grasp the characters which distinguish birds from all other animals.

The graceful, pleasing lines of the bird's body; its clothing of feathers; the toothless jaws encased with horn to form the bill, and the remarkable change of the fore-limbs into wings—these are the marks which separate the birds from other vertebrates. Besides this, they are warm-blooded, and their bones are compact, and in most cases

Fig. 201.—Various curves of the wing of a bird at different points in its length.

hollow, thus combining lightness with strength; hence birds are the most active and volatile creatures among all the backboned animals. The vertebral column is so adapted that birds can fly in any direction, particularly upwards; and it is the strength and flexibility of its spinal column that enable the lark to rise and shoot high into the air. Birds can turn their heads around and look directly back, as seen in the owls: this is owing to the unusually free articulation of the first neck-vertebra to the skull; thus, the bird can reach every part of its body with its bill.

The most striking difference from other animals is in those features which adapt the bird to a life in the air, viz., in the modification of the fore-limb so as to support a broad expanse of feathers. Another peculiarity in the skeleton connected with the power of flight is the very large breastbone, with its keel (Fig. 202, *h*), which is very high and thin, serving for the attachment of the large muscles of flight. Thus, in all respects we see a complete adaptation of the

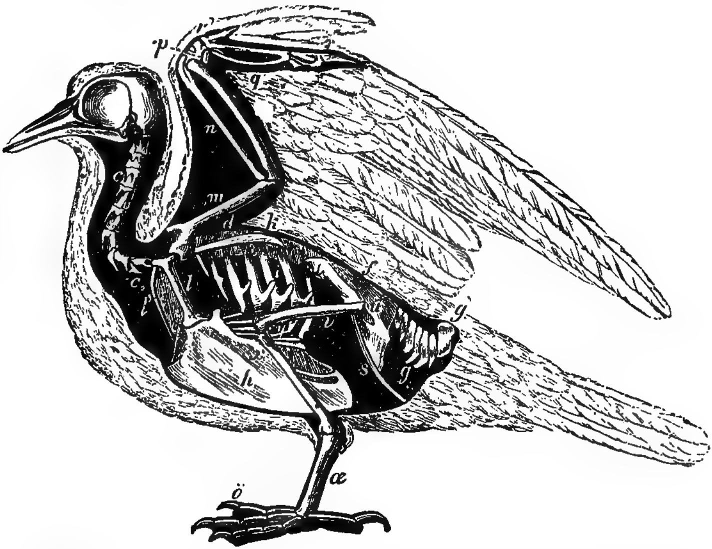

Fig. 202.—Skeleton and outline of the Dove. *c*, cervical vertebræ; *d*, dorsal vertebræ; *f*, lumbar vertebræ; *g'*. coccyx; *h*, breastbone, sternum; *i*. ribs; *k*, shoulder-blade, scapula; *l*. corocoid; *l'*, wish-bone, clavicles; *m*, humerus; *r*, ulna; *n*, radius; *q*, carpus; *r*. metacarpals and three digits; *s*. pubic bone; *u*, pelvis; *t*. ilium; *v*, femur; *x*, tibia; *æ*, tarso-metatarsus; *ö*, digits.

bird's body to its life in the air. The wings are attached exactly at the highest part of the thorax, and hence when the outstretched wings act upon the air as a fulcrum all the weight of the body is placed below this surface of suspension. The flight of birds has been studied by Marey, who states that "from the manner in which the feathers of its wing lie upon each other, it is evident that the resistance of the air can only act from below upwards, for in the opposite direction the air would force for itself an easy passage by bending the long barbs of the feathers, which

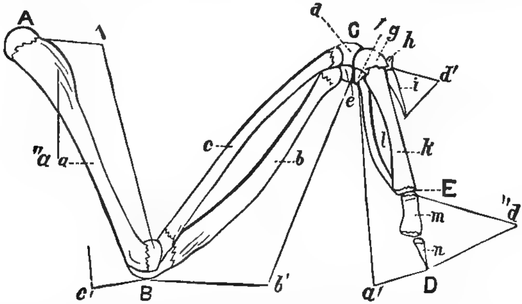

FIG. 203 — Right wing-bones of a young chicken. *A*, shoulder; *B*, elbow; *C*, wrist or carpus; *D*, tip of third finger; *a*, humerus; *b*, ulna; *c*, radius; *d*, scapholunar bone; *e*, cuneiform bone; *f*, *g*, epiphyses of metacarpal bones, *l*, *k*, respectively; *h*, metacarpal and its digit *i*.

would no longer sustain each other." The wing acts on the air like a wedge or an inclined plane, "in order to produce a reaction against this resistance which impels the body of the bird upward and forward."

FIG. 204. — Wing-bones of Penguin.

The wings are moved by the two pectoral muscles, one of which is much larger than the other, and lowers the wings, causing it to make the downward strokes, while the wings are raised by the smaller pectoral muscle. A long sharp wing like that of the swallow or tern is best adapted for continued flight, while a short, rounded wing is least so.

Certain birds have the power of soaring, i.e., of moving in the air on motionless wings, no muscular power being apparently used to overcome the bird's weight or the resistance of the air. While crows, hawks, and gulls can soar, yet they flap their wings at intervals; but "frigate-birds live in the air night and day for a week at a time without touching a roost. Their congeners, the buzzards, spend the day in the same style." The various cranes common to the coast of Florida often spend hours resting in the air; while the gannet is an admirable soaring bird, though with a heavy body and relatively small expanse of wings.*

In the hind legs of most birds the metatarsal bones are grown together and consolidated with the rudimentary tarsus into one bone, called the *tarso-metatarsus* (Fig. 205, *c*, *c*). In the embryo bird, however (Fig. 205, *A*), the tarsus is represented by two short bones, while the metatarsal bones are separate. This early separation of the metatarsal bones is retained in the fully-grown penguin (Fig. 206). In being thus consolidated the fully-grown bird's ankle is best adapted to support the toes, the bird's body being adapted both for flight and walking or running.

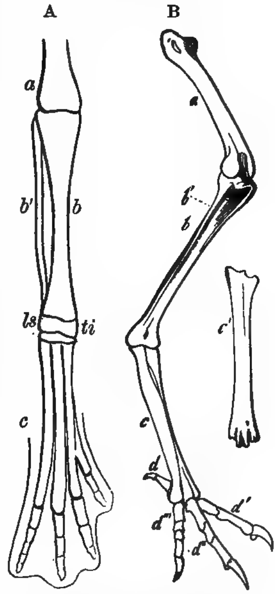

FIG. 205.—*A*, bones of the foot of an embryo bird. *ls*, upper, *ti*, lower, pieces of the tarsus. *B*, leg of the Buzzard (*Buteo vulgaris*). *a*, femur; *b*, tibia; *b'*, fibula; *c*, tarso-metatarsus; *c'*, the same piece isolated, and seen from in front; *d*, *d'*, *d''*, *d'''*, the four digits or toes.

The tarsus (properly *tarso-metatarsus*) may be covered with feathers, as in the owl, or with scales. When covered with a network of numerous scales, the tarsus is said to be *reticulate;* when they are united in front to form a series of square scales, the tarsus is *scutellate,* and "booted" when they form two or sometimes a single plate covering the entire tarsus.

There are never more than four toes in birds, the fifth toe corresponding to our little toe, not being present. In the ostrich the two toes represent the third and fourth; in birds with three toes, the first and last toes are wanting.

* I. Lancaster, in the *American Naturalist*, xix. 1885.

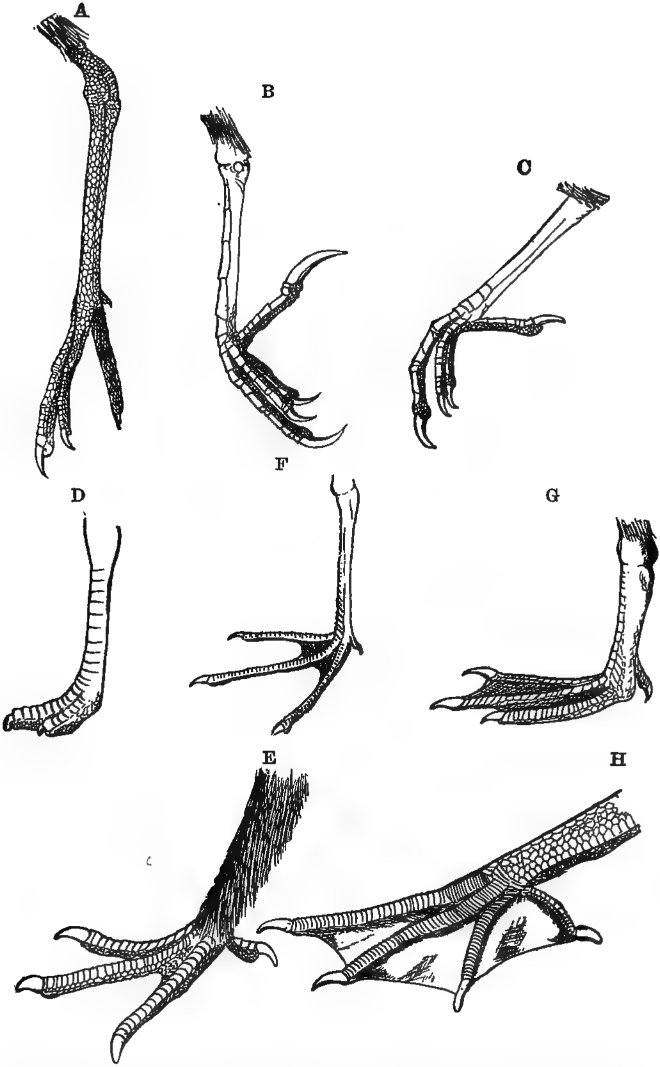

FIG. 207.—Types of birds' feet. *A*, reticulate tarsus of black-bellied plover; *B*, scutellate tarsus of meadow-lark; *C*, booted tarsus of robin; *D*, cursorial foot of ostrich; *E*, rasorial foot of prairie-chicken; *F*, semi-palmated foot of peep; *G*, totipalmate foot of wood-duck; *H*, of cormorant.

There are three general types of feet in birds, viz., the running, walking, or wading; the swimming, and the perching;

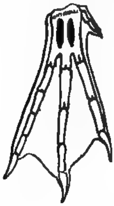

FIG. 206.—Tarso-metatarsus of the Penguin.

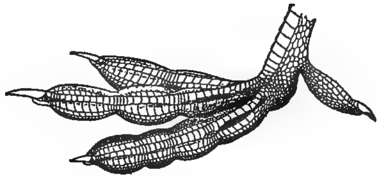

FIG. 208.—Lobate foot of the Coot. (One-half natural size.

and under these heads are many varieties (Figs. 207, 208).

In the toes of the perching birds the muscles and their tendons are so arranged that they automatically maintain while the bird is asleep a grasping position on the perch by means of the bird's own weight.

The most striking external feature of birds is the presence of feathers; no reptile, on the one hand, or mammal, on the other, is clothed with feathers. The ordinary feathers are called *pennæ,* or contour feathers, as they determine by their arrangement the outline of the body. They are, like hairs, developed in sacs in the skin; the quill is hollow, partly imbedded in the skin; this merges into the shaft, leaving the outgrowths on each side called *barbs,* which send off secondary processes called *barbules.* The barbules and hooklets (barbicels, Fig. 209) are commonly serrated, and end in little hooks by which the barbules interlock (Fig. 209). Down is formed of feathers with soft, free barbs called plumules.

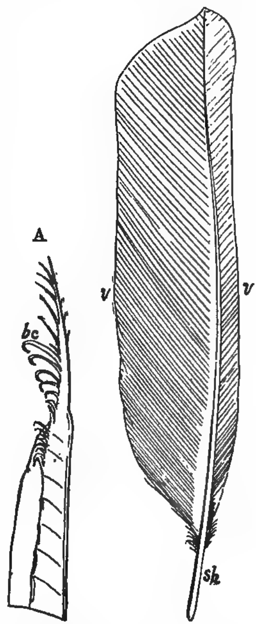

FIG. 209.—Feather. *sh,* shaft; *v,* vanes; *A,* barbule, with (*bc*) the barbicels.

The differences between the feathers, especially of the wings and back, aid us in discriminating the different kinds of birds. The student should have a dead or stuffed bird before him, and, with the aid of Fig. 210, learn the names of the different kinds of feathers, as well as the other terms

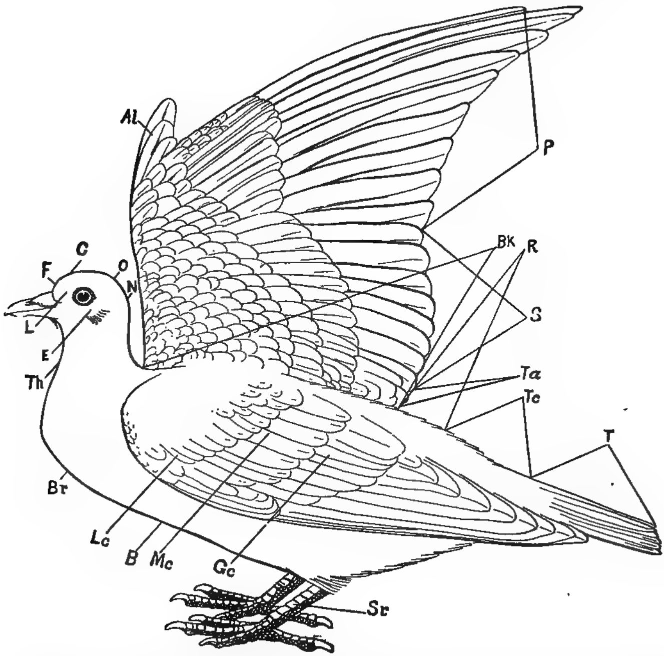

FIG. 210.—Topography of the Dove. *Al*, alula; *B*, belly: *Bk*, back; *Br*, breast; *C* crown; *E*, ear; *F*, forehead; *L*, lore; *Gc*, greater coverts; *Lc*, lesser coverts; *Mc*, middle coverts; *N*, nape; *O*, occiput; *P*, primaries; *S*, secondaries; *R*, rump; *Sr*, scutellate and reticulate tarsus; *T*, tail; *Ta*, tertiaries; *Tc*, tail coverts; *Th*, throat.

used in descriptive ornithology. Of the wing-feathers, the *primaries* (or primary remiges) are attached along the lower edge of the wing from the tip to the carpal joint; the *secondaries* extend from the carpal joint to the elbow-joint. There are usually ten primaries, and a greater number of secondaries (from six to forty). All the remiges are covered at their base by smaller feathers called coverts, the three growing on the upper arm or humerus being called *tertiaries.*

The large tail- or quill-feathers are called *rectrices,* because they act together as a rudder in flight. There are usually twelve of them which are attached to the last tail-vertebra, and they can be moved up and down, singly or together, or spread out like a fan. Their bases are covered by the tail-coverts.

Over the tail-bone (*coccyx*), which ends in a single bone, called the "ploughshare," which very early in life consists of several tail-vertebræ, are usually sebaceous glands, which secrete an oil, used by the bird in oiling and dressing or "preening" its feathers. In some birds, as the cock and turkey, the head and neck are ornamented with naked folds of the skin called "combs" and "wattles."

At the close of the breeding season birds moult their feathers; but some birds moult twice and thrice. The quill-feathers are usually shed in pairs, but in the ducks they are shed at once, so that these birds do not at this time go on the wing, while the males put off the highly-colored plumage of the days of their courtship, and assume for several weeks a dull attire. In the ptarmigan both sexes not only moult after the breeding season is over into a gray suit, and then don a white winter suit, but also wear a third dress in the spring. In the northern hemisphere the males of many birds put on in spring bright, gay colors. Other parts are also shed; for example, the thin, horny crests on the beak of the white pelican after the breeding season, are shed like the horns from the head of deer. Even the whole covering of the beak and other horny parts, like those about the eyes of the puffins and dwarf-auks, may also be regularly shed, while the claws of ptarmigans are regularly cast off.

The power of remaining a long time in mid-air is increased by the large air-cells, which are pockets filled with air from the lungs. There are nine of these air-sacs—three near the clavicle, four in the thorax, and two in the abdomen; they connect with the ends of some of the air-tubes, and also with the hollows of the bones, so that the bird's body is lightened and buoyed up by air.

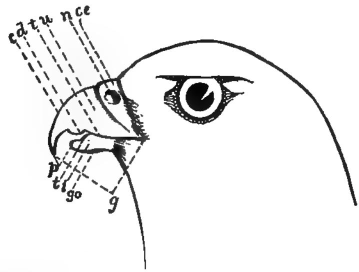

FIG. 211.—Head of a bird. *ce*, cere; *n*, nostril; *u*, upper mandible; *t*, tomia; *d*, tooth; *e*, culmen; *p*, tips of mandibles; *i*, under mandible; *go*, gonys; *g*, gape.

Another feature in which birds differ is in the shape of the bill (Figs. 212, 213, 214). The jaws are toothless and

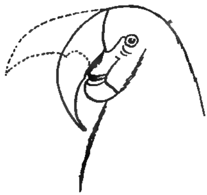

FIG. 212.—Cockatoo's Beak, the dotted line showing the position of the upper bill when raised.

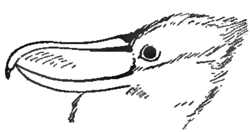

FIG. 213.—Beak of the Shoe-bill, *Balæniceps rex*. Africa.

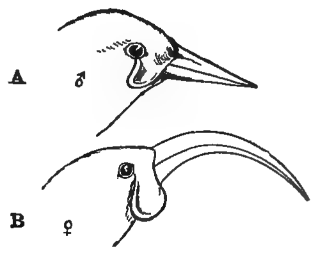

FIG. 214.—*Heteralocha acutirostris*. From New Zealand. *A*, male; *B*, female, with its remarkably long, curved beak, enabling it to search for insects in rotted trees.

encased in horn, and the form of the bill is closely related to the kind of food and the manner in which it is taken. The bill in its simplest form is pointed and conical; the lower edge of the bill extending from the angle of the chin to the tip is called the *gonys*, the crest of the upper jaw the *culmen*, and the region between the eye and the base of the beak (which in the birds of prey is covered by the *cere*) is called the *lore*. (Fig. 211.)

While the beaks of most birds are slender or stout and conical, as in the loon, those of the ducks and geese are broad and lamellate, adapted for sifting shells and worms from soft mud; those of the curlew, snipe, woodcock, and avoset, as well as the humming-bird, are remarkably long and slender, sometimes upcurved, and adapted for boring into the mud and turning over small stones for worms. The hen's beak is for picking up seeds, while the eagle's is for tearing the flesh of its prey, and the sparrow's (or conirostral) beak is adapted for separating seeds from their husks or for opening buds. More extreme examples are the auk's bill, by which it can peck out a tunnel in hard soil or even soft rock, or the flamingo's, whose under jaw forms a cover for the upper while drinking (Fig. 215), or the voracious pelican's, whose enormous bill and naked, distensible throat enables it to scoop up and swallow a shoal of fish at a time.

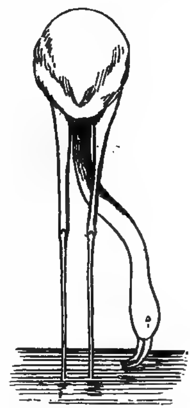

Fig. 215.—Flamingo.

Since the food, whether small fish, shells, or seeds, is swallowed whole by the bird, it must be crushed and comminuted before it can be digested; hence the hinder end of the stomach is enlarged and forms a gizzard. The walls of the gizzard are, in the seed-eating birds, such as the hen, very thick and muscular; and on the inner surfaces are two solid, horny plates, which act like an upper and nether millstone to crush hard seeds. In the fowls, pigeons, and parrots the throat dilates on one side into a round crop in which the food is softened before it passes on to the gizzard to be finally crushed.

The senses of sight, smell, and hearing are acute in birds, particularly that of sight. Birds have three eyelids, besides an upper and lower lid, a membrane which can be drawn over the eye, and is called the "nictitating membrane." This covers the whole front of the eyeball like a curtain. With this it is said the eagle can look directly at the sun. The eyes of owls, hawks, and eagles are provided with a ring of bony plates occupying the front of the sclerotic. By means of this ring the eye can adjust itself like a telescope so as to take in both near and distant objects. The penguin also is endowed with this apparatus, which enables it to adjust its eye to see both above and under the water.

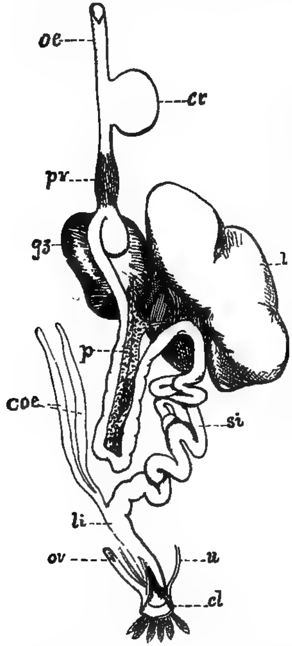

FIG. 216.—Digestive canal of a seed-eating bird. *œ*, œsophagus; *cr*, crop; *pv*, proventriculus; *gz*, gizzard; *l*, liver; *p*, pancreas; *cœ*, cæcum; *si*, small intestine; *li*, large intestine; *ov*, oviduct; *u*, ureter; *cl*, cloaca.

Though birds (except the night-birds, especially the owls) have no external ear, they can hear well; otherwise what would be the use of their powers of song?

The eggs of birds are, with the exception of those of lizards, enormous in proportion to those of other vertebrate animals. The largest egg known is that of the *Æpyornis*, an extinct bird of Madagascar, which is about a third of a metre (13½ inches) in length. Birds lay but few eggs, and the young of those which build nests are, when hatched, blind, naked, unable to walk, and are fed by the parent birds. In the fowls, such as the hen and partridge, as well as the ducks and other swimming birds, the young, on breaking from the shell, walk or swim nearly as well as the old birds and pick up their own food.

As a rule, male birds are larger and have brighter colors, with larger and more showy combs and wattles, than the females, as seen in the domestic cock and hen; and the ornamentation is largely confined to the head and the tail, as seen especially in male humming-birds. Sometimes, however, both sexes are equally ornamented, and in rare cases the female is more highly colored than the male; she is sometimes also larger, as in most birds of prey. There is little doubt that the bright colors of male birds render them more conspicuous and to be more readily chosen by the females as mates; for in birds, as in higher animals, the female may show a preference for or antipathy against certain males. Indeed, as Darwin remarks, whenever the sexes of birds differ in beauty, in the power of singing, or in producing what he calls "instrumental music," it is almost invariably the male which excels the female.

The songs of birds are doubtless in part love-notes, though birds also sing for pleasure. The notes of birds express their emotions of joy or alarm, and in some cases at least the calls of birds seem to convey intelligence of the discovery of food to their young or their mates.* They have an ear for music; some species, as the mocking-bird, will imitate the notes of other birds. The songs of birds

* "It is necessary in a philosophical spirit to regard every sound made by a bird under the all-powerful influence of love or lust as a 'song.' It seems impossible to draw any but an arbitrary line between the deep booming of the emeu, the harsh cry of the guillemot (which when proceeding from a hundred or a thousand throats strikes the distant ear in a confused murmur like the roar of a tumultuous crowd), the plaintive wail of the plover, the melodious whistle of the widgeon, the 'cock's shrill clarion,' the scream of the eagle, the hoot of the owl, the solemn chime of the bell-bird, the whip-cracking of the manakin, the chaffinch's joyous burst, or the hoarse croak of the raven, on the one hand, and the bleating of the snipe or the drumming of the ruffed grouse on the other."—A. Newton.

can be set to music. Mr. X. Clark has published* the songs of a number of our birds. The singular antics, dances, mid-air evolutions, struts, and posturings of different birds are without doubt the visible signs of emotions which in other birds find vent in vocal music.

The nesting habits of birds are varied. Many birds, as the gulls, auks, etc., drop their eggs on bare ground or rocks; as extremes in the series are the elaborate nests of the tailor-bird, and the hanging nests of the Baltimore oriole, while the woodpecker excavates holes in dead trees. As a rule, birds build their nests concealed from sight; in tropical forests they hang them, in some cases, out of reach of predatory monkeys and reptiles. Birds may change their nesting habits sufficiently to prove that they have enough reasoning powers to meet the exigencies of their life. Parasitic birds, like the cow-bird, lay their eggs by stealth in the nests of other birds. "Some of the swifts secrete from their salivary glands a fluid which rapidly hardens, as it dries, on exposure to the air, into a substance resembling isinglass, and thus furnish the 'edible bird's-nests' that are the delight of Chinese epicures. In the architecture of nearly all the Passerine birds, too, some salivary secretion seems to play an important part. By its aid they are enabled to moisten and bend the otherwise refractory twigs and straws and glue them to their places. Spider's webs also are employed with great advantage for the purpose

FIG 217.—Nest of the Tailor-bird.

* *American Naturalist*, vol. xiii. p. 21.

last mentioned, but perhaps chiefly to attach fragments of moss and lichen so as to render the whole structure less obvious to the eye of the spoiler. The tailor-bird deliberately spins a thread of cotton and therewith stitches together the edges of a pair of leaves to make a receptacle for its nest (Fig. 217). . . . In South America we have a family of birds (*Furnariidæ*) which construct on the branching roots of the mangrove globular ovens, so to speak, of mud, wherein the eggs are laid and the young hatched. . . . The females of the hornbills, and perhaps of the hoopoes, submit to incarceration during this interesting period, the males immuring them by a barrier of mud, leaving only a small window to admit air and food, which latter is assiduously brought to the prisoners." (Newton.)

The duties of incubation are, as a rule, performed by the female, but in most Passerine birds and certain species of other groups, the males divide the work with the females.

It is in their nesting habits and care for their young that birds greatly surpass fishes and reptiles, and in intelligence they are allied rather to the beasts. In our ascent of the scale of life we have met with no evidences of such high intelligence, unless we except the social white ants, ants, wasps, and bees. The brains of birds, therefore, as we would expect, are of a much higher type than those of reptiles, for the cerebral hemispheres are greatly increased in size, while the cerebellum is transversely furrowed, and is so large as to cover the entire medulla.

While there are probably from 7000 to 8000 species of living birds, they are mostly of small size, 5000 species not being larger than a sparrow. And yet each species differs slightly in station or habit from its allies, and thus there are room and food for all.

Of the whole number of birds known, 878 distinct species or well-marked geographical races inhabit North America north of Mexico and including Greenland. The geographical distribution of birds is somewhat complicated by their migrations. While the larger number of species are tropical, arctic birds are abundant, though most of them are aquatic. In the United States there are three centres of distribution: (1) the Atlantic States and Mississippi Valley; (2) the Rocky Mountain plateau, and (3) the Pacific coast.

Nearly all the birds which breed in the central and northern portions of the United States migrate southwards in the autumn, and spend the winter in the warmer Southern States or in Central America or the West Indies. The causes of this regular annual migration are probably due to the changes of the season, and to the want of food in the winter-time, and also to the breeding habits of birds. Tropical birds which breed at home do not migrate to other climes; but some Brazilian species migrate southwards into Buenos Ayres; it is those birds which live far north which have what is called the "migratory instinct." Birds migrate by night as well as by day; and the young return the following spring to their birthplace.

In North America, the birds of the Western plains and of the Rocky Mountains as well as of the Pacific coast are sedentary, or migrate but a short distance. It is the Eastern birds which migrate regularly. These pass southwards into Mexico and Guatemala, and reach South America. Thus, the extent of the migration varies greatly, some species only going a few degrees north and south, while others migrate annually from Arctic America to the tropics, and every gradation occurs between these extremes. Among those which migrate farthest are the species of warblers (*Dendrœca*), and the fly-catching warblers (*Mniotiltidæ*), many of which breed on the shores of Hudson's Bay, and spend the winter in Mexico or the West Indies. More species of birds breed in Canada than in the warm Southern States. Birds have been known to extend their range of migrations; the rice-bird or bobolink continually widens its range as rice and wheat are more extensively cultivated. This bird winters in Cuba and other West Indian islands, and probably also in Mexico. In April it enters the Southern States and passes northward, till in June it reaches Canada and extends west to the Saskatchewan River, in 54° north latitude.

Says Baird: "While birds proceed generally in the spring to the very spot of birth, and by a definite route, their return in autumn is not necessarily in the same line. Many birds are familiar visitors in abundance in certain localities in either spring or autumn, and are not known there in the other season." He thinks that in very many instances birds proceed northward along the valley of the

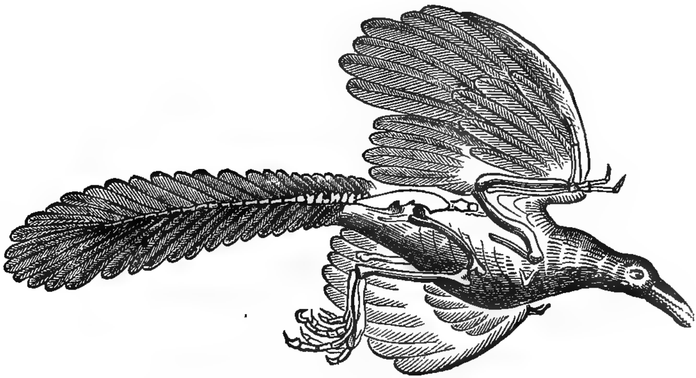

Fig. 218.—Restoration of *Archæopteryx macrura*. After Owen.

Mississippi, to return along the coast of the Atlantic. In general, also, the northward vernal movement is performed much more rapidly, and with fewer stops by the way, than the autumnal. "Birds generally make their appearance in given localities with wonderful regularity in the spring—the *Sylvicolidæ* especially; a difference of a few days in successive years attracting the notice of the careful observer: this difference is generally influenced by the season. The time of autumnal return is, perhaps, less definite."

The class of birds, so far as regards the living species, is very distinct from any other group of vertebrates, but there is an extinct form, the *Archæopteryx* (Fig. 218), which is a connecting link between the birds and reptiles, not only in the shape of certain bones, but from its having teeth and a long vertebrated tail. After this strange form, half reptile and half bird, had passed away,

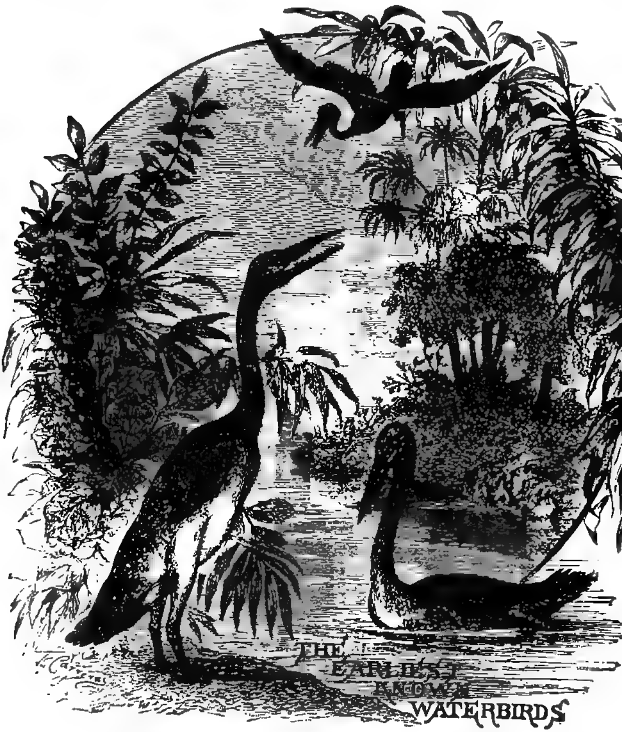

Fig. 219.—Birds with teeth. Below, two Hesperornis; above is an Ichthyornis.

it was succeeded by birds with teeth. Of these, the most notable was the wingless diving-bird, called *Hesperornis*, and a gull-like swiftly-flying bird, with teeth implanted in sockets, the *Ichthyornis* (Fig. 219). The former was probably the forerunner of the birds with a keelless breastbone, and the latter of the flying birds, such as gulls, etc., i.e., the carinate birds.

The Birds with a Keelless Breastbone.—The kiwi-kiwi, the moa, cassowary, and ostrich differ from other birds in the smooth, unkeeled sternum and the short tail; the wings are rudimentary and the legs strong, these birds (ex-

FIG. 220.—Moa, *Palapteryx*, with three Kiwi-kiwi birds.

cept *Apteryx*) being runners, and either of large or (as in the extinct forms) of colossal size.

The simplest form is the "kiwi-kiwi," or *Apteryx* of New Zealand (Fig. 220), of which there are three or four species. It is of the size of a hen, with a long slender beak, the nostrils situated at the end of the upper jaw, while the body is covered with long hairy feathers. The female lays only a single large egg, which weighs one quarter as much as the bird itself, in a hole in the ground. It is a night bird, hiding by day under trees.

The giant, ostrich-like, extinct birds of New Zealand, called *moa*, and represented by several species (Fig. 220), were supposed to have been contemporaries of the Maoris, or natives of New Zealand. While a fourth toe is present in the *Apteryx*, the moa-bird has only three toes.

FIG. 221. — Rudimentary wing of the Emeu.

The largest of the moas, *Dinornis giganteus*, stood nearly three metres (9½ feet) in height, the tibia or shin-bone alone measuring nearly a metre (2 feet 10 inches) in length.

Allied to the moa was a still larger, but not higher, bird, the *Æpyornis maximus* of Madagascar, supposed by some to be the roc of the Arabian Nights' Tales. Of this elephantine bird, its legs being remarkably thick and clumsy, remains of the skull, some vertebræ, and a tibia 64 cent. long, have been found. The single egg discovered is of the capacity of one hundred and fifty hen's eggs.

Here also belong the three-toed cassowaries of the East Indies, and the emeu of Australia; both of these birds are about 2 metres (5–7 feet) high. The South American ostrich (*Rhea Americana*, Fig. 222), with three toes to each foot, is a smaller bird, standing 1.3 metres high, running in small herds on the pampas. The two-toed ostrich (*Strutho camelus*), of the deserts of Africa and Arabia, now reared for the feathers of its wings and tail, so valuable as articles of commerce, is the largest bird now living, being 2–2.7 metres (6–8 feet) high. It can outrun a horse, and lives in flocks. It lays about thirty large white eggs in a nest in the sand; they are covered in the daytime by the hen or left exposed to the sun, while at night the male sits over and guards them. In Cape Colony ostrich-culture has become an important business; in 1865 there were only eighty individuals on the ostrich farms; in 1875 there were

32,247 ostriches, either free or in parks where Lucerne grass is cultivated as food for these useful birds. They are also reared in California. The South American ostrich is in Patagonia hunted for its feathers. Its food consists of seeds, grass, insects, etc., and the herdsmen say that

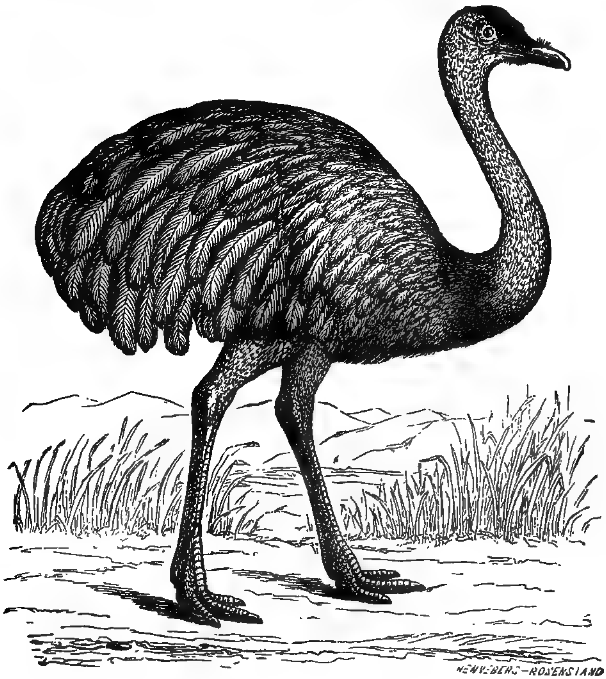

Fig. 222.—South American Ostrich.

they also eat snakes. The nest is a mere shallow hole scratched in the ground; twenty, thirty, or more eggs are found together, but it appears that these are not all laid by one bird: several females lay their eggs together, and take turns in sitting on them.

Birds with a Keeled Breastbone.—All other living birds are characterized by the keeled breastbone or sternum; the wings, as a rule, being well developed. The lowest of the keeled birds are penguins and other water-birds, while the highest are the singing-birds.

Orders of Carinate Birds.

1. Wings small and short; diving-birds..... *Pygopodes.* Penguin.
2. Wings long, pointed; rapid fliers; anterior toes webbed..... *Longipennes.* Gull.
3. Feet wholly webbed, including the inner toe..... *Stegopodes.* Pelican.
4. Bill lamellate, i.e., both mandibles with teeth-like projections..... *Lamellirostres.* Duck.
5. Wading-birds; the leg long and naked above the heel; bill usually long and slender..... *Grallatores.* Crane.
6. Land birds; four toes, three in front, one behind; tibiæ often spurred..... *Gallinæ.* Hen.
7. Toes like the foregoing; the bill horny and convex at tip..... *Columbæ.* Dove.
8. Bill cered, hooked, and large; feet large, not yoke-toed..... *Raptores.* Eagle.
9. Feet yoke-toed; bill stout, and strongly hooked..... *Psittaci.* Parrot.
10. Toes often in pairs, two in front and two behind; wings with ten primaries..... *Picariæ.* Woodpecker.
11. Perching and singing birds; feet adapted for grasping; hind toe opposed to the others..... *Passeres.* Robin.

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CHAPTER XXXI.

THE CAT AS A TYPE OF THE MAMMALS.

THE highest and last step in the scale of backboned life is the class represented by the duck-bill, the opossum, the cat, and man. In this group hair takes the place of feathers as a covering for the body. They all originate, like the lower animals, from eggs, but the latter are retained within the body of the parent, and the young continue to grow until old enough to be born and fed with milk.

Let us now examine more carefully than we have perhaps ever done before the common cat, which will serve as an example of this class; and much can be learned by examining even a living cat.

We see that, as in reptiles and birds, the cat's body is divided into a head, neck, trunk, tail, and four limbs. Its body is closely covered by skin, which is quite loose between the trunk and the elbow, as well as the knee. The skin is clothed with soft glossy fur, each hair of which grows out of a little wart situated at the bottom of a pit in the skin. A hair consists of a root buried in the skin, and the shaft; the substance consists of the pith and rind, outside of which are thin overlapping scales. In the cat the edges of these microscopic scales are smooth, but in the hairs of the sheep the edges of the scales project, so as to form a toothed envelope. Such rough hairs stick together, forming a felt or wool. We have white and black cats, as well as Maltese, tortoise-shell, and gray cats. This difference of color is due to the coloring matter deposited just within the layer of scales. We also see that pussy's hairs are directed backwards on the trunk, so that we can stroke her soft fur from the head to the tail, but on her limbs the hairs usually point downwards. We notice some long hairs inside of the ears, and a few over each eye, but there are no true eyelashes or eyebrows. The whiskers consist of about a dozen very large stiff hairs on each side of the upper lip; these extend out beyond the body and are very sensitive, so that the cat can feel her way through narrow places. A cat is very dependent upon her whiskers for a knowledge of what is near her. Every part of the body, however, is not covered with hairs; they would be useless on the end of the nose, on the lips, and the foot-pads, which are naked. How useful the hair really is to a mammal is proved by the fact that all, with rare exceptions, are hairy.

The cat's eyes are large and rather wide apart, and placed

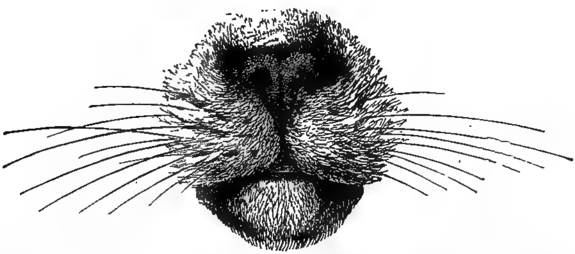

Fig. 223.—Cat's muzzle, with "whiskers" and naked skin about the nostrils.

in roomy orbits; besides the upper and lower lid, there is, as in the birds, a nictitating membrane which rises from the inner angle of the eye, and can be drawn over the eyeball. The red portion lining the eyelids and corners of the eye is called the *conjunctiva*; over the ball of the eye it is transparent and colorless. The "pupil" is the central part of the eye; it is surrounded by the "iris," which varies much in color and can contract in the light, or expand in darkness. In a bright light the iris closes so as to leave only a narrow vertical chink. We thus see how perfectly the cat's eye is adapted to its habits of night prowling.

In none of the backboned animals previously mentioned is there a well-formed outer ear; but that of the cat is large and full, with its deep hollow directed forwards and outwards.

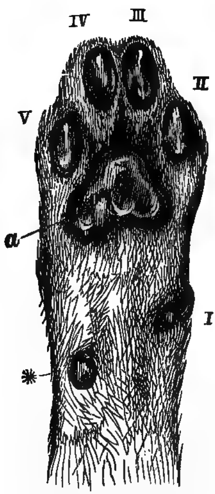

FIG. 224.—Under-surface of cat's fore-paw. I, II, III, IV, V, the five toes, I being the pollex; *a*, trilobed pad which lies beneath the distal ends of the metacarpal bones; *, pad beneath the pisiform bone of the wrist.

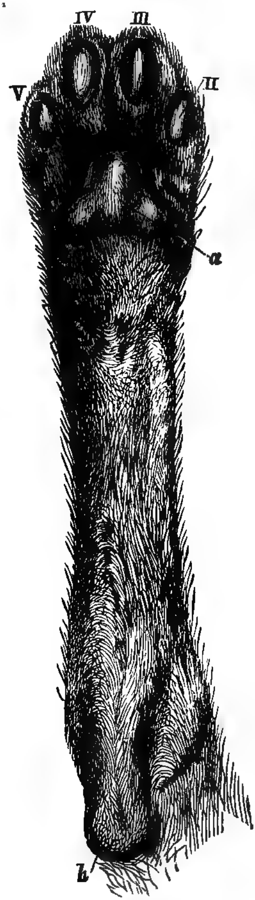

FIG. 225.—Under-surface of hind-paw. II, III, IV, V, the respective four digits. *a*, pad beneath the metatarsal bones; *h*, heel.

Now observe the limbs (Figs. 224, 225). The front pair is shorter than the hind legs, and each limb consists of an upper arm, a fore arm, and a paw, with five short toes. The hind limbs each consist of a thigh, a leg, and a foot with but four toes. The elbow and knee are close to the trunk. It is so with the dog. The legs of the ox and horse do not project from the body above the knee or elbow; those of the monkeys project two thirds of their length, while the limbs of man are wholly free from the trunk.

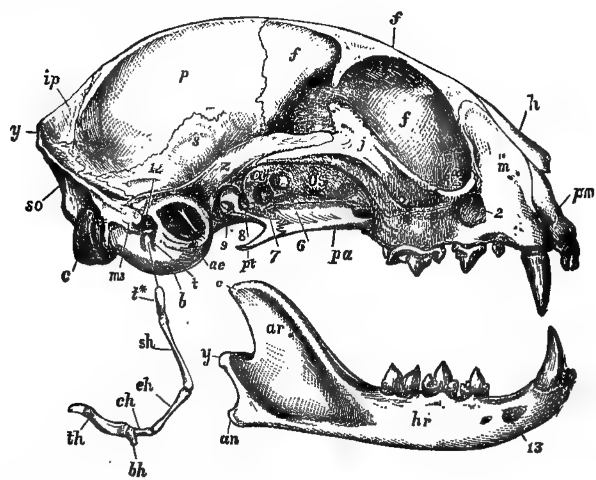

FIG. 226.—Side-view of the cat's skull, the lower jaw and hyoid bone (*th*, *t**) being detached. *a*, alisphenoid bone; *ae*, external auditory canal; *ar*, ascending ramus; *b*, auditory bulla; *c*, occipital condyle; *f*, frontal; *ip*, interparietal; *j*, malar or jugal; *la*, lachrymal; *m*, maxilla; *ms*, mastoid process; *n*, nasal; *os*, orbito-sphenoid; *p*, parietal; *pa*, palatine; *pt*, pterygoid; *pm*, premaxilla; *s*, squamosal; *so*, supraoccipital; *z*, zygoma; 2, infraorbital foramen; 6, optic foramen.

Opening the mouth, we see that it is lined with a soft, delicate wet skin called *mucous membrane*, while the jaws contain teeth. A full-grown cat has thirty teeth, or fifteen on each side of the head, but two more in the upper than in the lower jaw.

We have seen that in reptiles the teeth are conical and much alike, but in the cat and other mammals there is a great difference in the teeth of different parts of the jaw.

Looking at the teeth in one side of a jaw (Fig. 226) we see that there are four kinds, i.e., the front teeth or *incisors*, the large flesh teeth or *canines*, the front molars or *premolars*, and the back teeth or *molars;* the premolars and molars have two roots or fangs, and the upper largest molar has three fangs. It will be seen that the incisors are adapted to cut into the flesh; the canines serve to retain the prey in the mouth, while the premolars and molars

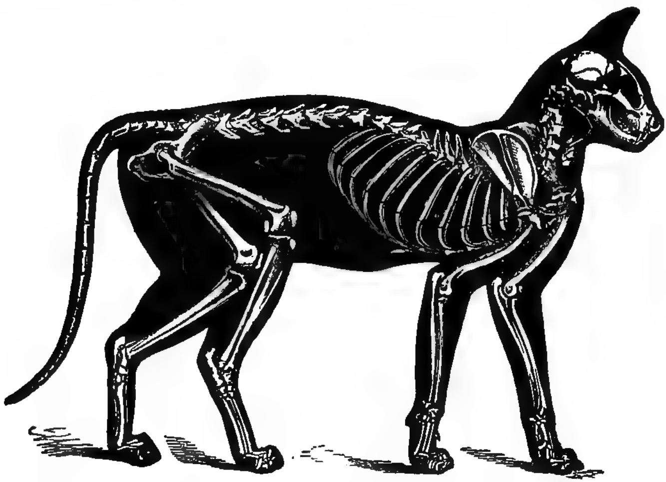

Fig. 227.—Skeleton of European Wildcat.

with their sharp *cusps*, like the teeth of a saw, serve to cut the food which is swallowed in large pieces.

The skeleton of the cat (Fig. 227) differs in two important respects from that of reptiles and birds. The skull has two occipital condyles instead of one, and the lower jaw is directly connected with the skull. It will also be seen that the brain-cavity is much larger in proportion to the rest of the skull than in birds; the brain itself, particularly the hemispheres (Fig. 230), being very much larger, the latter forming the bulk of the brain.

Other differences between birds and cats (and all other mammals) are the presence in the cat of a circular muscle called the "diaphragm" (Fig. 228, *di*), which divides the body-cavity into two compartments, the thoracic cavity and the abdominal cavity; in the former lie the heart and lungs, and in the latter the stomach and intestines. In the bird the aorta, or great artery given off by the heart, turns to

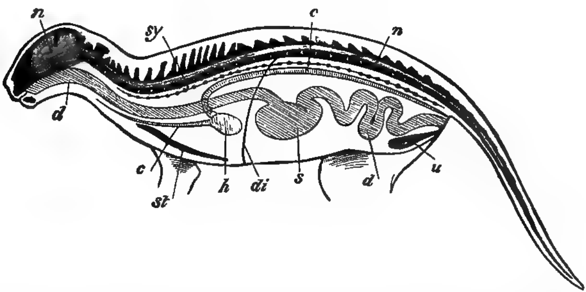

FIG. 228.—*n*, brain and spinal marrow contained within the skull and backbone, which are deep black; *st*, breastbone; *d d*, alimentary canal; *s*, stomach; *h*, heart; *c c*, great blood-vessels; *u*, bladder; *sy*, chain of sympathetic ganglia; *di*, diaphragm.

the right, but in the cat to the left. And then there are many other differences, in most of which the cat shows its superiority both to the reptile and to the bird.

Fig. 229 illustrates the general anatomy of the cat; the skin and right half of the body-wall having been removed. The body-cavity is divided into an anterior and posterior division by a transverse arched partition, the diaphragm (*D*), composed of a thicker peripheral muscular portion and a thinner central tendinous part. Through the latter pass the great blood-vessels and the œsophagus. The anterior chamber is the thorax or pleural cavity, and contains the respiratory organs and heart. To show these, the right lung has been removed. The heart (*Ht*) was inclosed in the thin walled pericardial sac, which has been cut away. The great systemic veins enter from behind—i.e., dorsally; from below the *vena cava inferior* (*V*), passing up through the diaphragm and uniting opposite the heart with the large *vena cava superior*, from above, the two emptying into the right auricle. The œsophagus (*Oe*) overlies the trachea (*Tr*). The aorta arises from the heart, and, curving upward and backward, runs to the *left* of both trachea and œsophagus, as indicated by the dotted lines, and con-

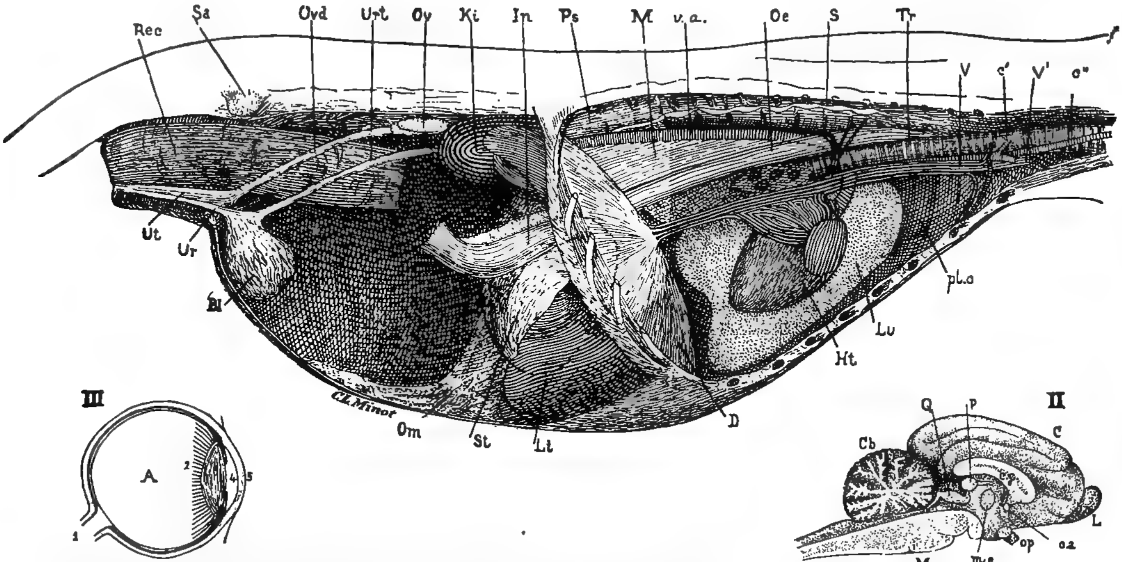

Fig. 229.—Anatomy of the cat. *D*, diaphragm; *Ht*, heart; *Lu*, lung; *pl. c*, pleural cavity; *V*, vena cava superior; *V'*, vena jugularis; *c'*, branch of the external, *c''*, branch of the internal, carotid; *Tr*, trachea; *S*, sympathetic ganglia; *Oe*, œsophagus; *v. a*, vena azygos; *M*, mediastinum; *Ps*, psoas muscle; *In*, intestine; *Ki*, kidney; *Ov*, ovary; *Urt*, ureter; *Ovd*, oviduct; *Sa*, sacrum; *Rec*, rectum; *Ut*, uterus; *Ur*, urethra; *Bl*, bladder; *Om*, omentum; *St*, stomach; *Li*, liver.

Fig. 229 II.—Median longitudinal section of the brain. *M*, medulla oblongata; *Cb*. cerebellum; *Q*, corpora quadrigemina; *p*, pineal gland; *C*, cerebrum or hemisphere; *L*, olfactory lobe; *c. a*, anterior commissure; *op*, optic nerve; *m. c*, middle commissure; *c. c*, corpus callosum.

Fig. 229 III.—Median vertical section of the eye, diagrammatic. 1, optic nerve; *A*, posterior chamber, containing the vitreous humor; 2, corpus ciliare; 3, lens, partly covered in front by the pigmented iris; 4, anterior chamber, containing the aqueous humor; 5, cornea. The walls of the chamber *A* consist of three layers, represented by three lines, the outer, the sclerotic; the middle, the choroid; the inner, the retina. (Drawn by C. S. Minot.)

tinues its backward course (*Ao*) just in front of the vertebral column into the abdomen. The trachea gives off a bronchus to each lung (*Lu*). The lungs are sacculated elastic organs, with no main central cavity. They are separated dorsally by a thin median vertical membrane (*M*), the *mediastinum*, the equivalent of the mesentery in the abdomen. Lying on the side of the vertebral column can be seen part of one of the two chains of sympathetic nervous ganglia (*S*).

The abdominal cavity contains the principal reproductive, excretory, and digestive organs. The œsophagus terminates in the stomach almost immediately below the diaphragm. The stomach (*St*) occupies a transverse position, its larger (*cardiac*) end, which receives the œsophagus, lying on the left, the smaller (*pyloric*) end on the right. The pylorus is furnished with a sphincter muscle, a ring of fibres, which can completely close the orifice by their contraction. The stomach is followed by the long, coiled small intestine (*In*). The posterior portion of the intestine is somewhat dilated, and is called the *colon*, which passes into the wide terminal rectum (*R*). The whole abdominal portion of the intestinal canal is suspended from the median dorsal line by a thin membrane, the mesentery, which forms several folds, the most striking of which is the *omentum* or grand epiploon (*Om*). This fold, when *in situ*, hangs down from the stomach like an apron, covering over the intestines ventrally. Upon opening the walls of the abdomen, it is the first structure met with. It usually contains a great deal of fat. Its principal function is supposed to be to prevent the loss of heat. The omentum is present in all mammals, but is least developed in Cetaceans, being most prominent in Carnivora and Ruminants. Connected with the intestine are two glands, the liver (*Li*) and pancreas (*Pan*). The liver is large and lies directly underneath the diaphragm. One part of it has been cut across and left *in situ* to show the oblong gall-bladder (*G*). The pancreas is very much elongated, and lies upon the upper part of the intestine, the so-called *duodenum*. The spleen (*Sp*) is closely connected with the stomach, and is of an elongated shape.

The kidneys (*K*) are large and oval, and lie on either side of the vertebral column; the aorta passes between them, giving off a renal branch to each gland. A delicate *ureter* passes from each kidney obliquely across the rectum to the large flask-shaped bladder (*B*). A *urethra*, not shown in the figure, arises from the bladder posteriorly and opens immediately below the anus.

The ovary (*Ov*) is small and is placed near the open end of the oviduct or *Fallopian tube*, which can be seen in the figure extending alongside the rectum above the bladder (Minot).

The cat, more truly than birds, lives by its wits. She does not expend her intelligence in building an elaborate nest for her kittens, but in a variety of ways she has to provide for their safety and maintenance. Hence she has a large, well-developed brain (Figs. 230, 231), one adapted for designing and cunning; for it is by address, swiftness in forming plans, and shrewdness that the cat approaches and seizes its prey and avoids its enemies. Thus, the cat has a mind, and its mental traits, besides being instinctive, are in a rudimentary way rational. It has sufficient reasoning power to meet occasional emergencies in its life. In granting the cat a mind and reasoning powers of some sort, there is still a world-wide difference between a cat's mind and the human mind, for man differs from all the animals beneath him in being able to speak his thoughts, whereas a cat can only mew when hungry, angry, or alarmed. But in giving due credit to our own intelligence we need not underestimate, as is often done, that of the dumb animals.

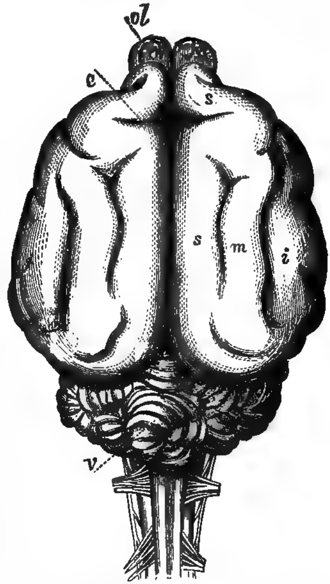

FIG. 230.—Cat's brain seen from above, showing the deep longitudinal fissure dividing the two hemispheres and the cerebellum behind them. *c*, crucial furrow; *s*, superior, *m*, middle, *i*, inferior, external gyrus; *v*, vermiform process of cerebellum; *ol*, olfactory lobe.

Moreover, a cat's mind is a different thing from a cow's or a horse's mind, because the habits, needs, and structure of the cat are so different from those of the patient, dull, ruminating, cloven-footed cow, or the nervous, swift horse.

The cat springs and jumps; it has, therefore, no need of a true collar-bone, as the fore-limbs must move freely on the trunk. Moreover, the cat catches a mouse or bird by striking at it with its outstretched claws. Hence, the

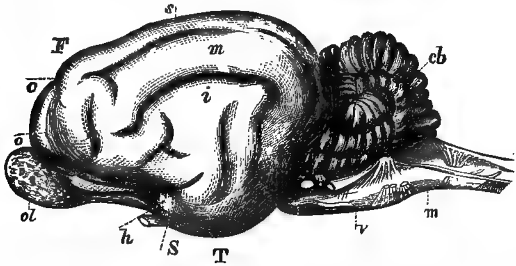

FIG 231.—Side-view of cat's brain. *F*, frontal lobe; *T*, temporal lobe; *ol*, olfactory lobe; *m*, medulla oblongata; *cb*, cerebellum; *v*, pons Varolii; *S*, sylvian fissure.

shoulder-joint is very free, allowing the fore-leg to be rotated in all directions. Fig. 232 shows the shape of the claws, and how they are extended and retracted. When the elastic ligament passing from above the root of the claw downward and backward to the end of the second phalanx is contracted, the claw is withdrawn; but when the ligament is relaxed, and the long flexor tendon on the under side of the toe is, with its muscle, contracted, the claw springs out. The cat is a flesh-eater, and its powerful jaws, armed with sharp, knife-like teeth, moved by powerful chewing muscles, enable it to tear apart the body of its prey and swallow its flesh piecemeal.

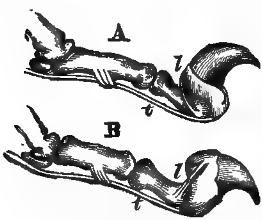

FIG. 232.—Claws of the cat or tiger. *A*, claw held back by the strong ligament *l*; *B*, claw pulled forward by the tendon *t* being drawn back so that *l* is stretched out.

But the cat is neither the highest nor lowest type of mammalian life. It does not stand alone, but is only a single link in the chain of mammalian life. And in order to fully understand what a mammal is, we must glance at the leading types or examples of the class.

We shall see that the different groups vary greatly in form and in their adaptation to different modes of life. Confined to the earth, they are subjected to far greater perils than birds, and hence, though birds and mammals appear at the same epoch in geological history, the mammals have never perhaps got on so well as regards numbers as the birds, since only 2100 species are known, and in the United States there are about three species of birds to one of mammals, there being only 310 species of the latter group. But with mammals it is quality and not quantity.

They have had to depend more on their intelligence than other animals for their success in life; they have had to adopt, so to speak, many different professions to keep life in their bodies. Hence there are moles, which burrow out of sight after worms and insects; rats, mice, and squirrels, which live by gnawing; bats, which fly in the air out of harm's way; the whales and seals, which have taken to the sea; the elephant, whose dependence is his trunk, tusks, and colossal size; the horse and deer, which rely on their legs to carry them out of danger; and the carnivorous kinds, which live by stealthiness, cunning, boldness, and agility; while the monkeys and apes lead an arboreal life. The founders of the different orders have all, in the course of time, by striking out into different paths in life, won success each in its way, until we have, as the crowning results, man, a being of mind and reason, his fore-limbs converted into arms ministering to his thoughts. Man also has a spiritual nature, which, in the best examples of his race, dominates the animal nature he has in common with the creatures below him.

While the cat protects itself from its enemies by its agility, its sharp teeth and claws, many mammals, especially those that chew the cud, as the deer, ox, rhinoceros, etc., are armed with horns. There are two kinds of horns —those with a bony core surrounded with a horny case of skin, as in the deer; while in others, as the antelopes, sheep, goats, and oxen, the horns are hollow. In most horned mammals the horns are not shed; in the deer they drop off every year; in the prong-horned antelope the horns are also shed yearly.

The males of such animals as are provided with tusks or horns need them for self-defence in their frequent contests with one another; at the same time, these are organs of defence by which the males protect their family, flock, or herd. On the other hand, in the female rhinoceros, some antelopes, the reindeer, as opposed to the other deer, some sheep and goats, etc., the horns are nearly as well developed as in the males. The modes of attack are various: the ram charges and butts with the base of his horns, the domestic bull gores and tosses any troublesome enemy, while the Italian buffalo "is said never to use his horns; he gives a tremendous blow with his convex forehead, and then tramples on his fallen enemy with his knees." Darwin also says that male quadrupeds with tusks use them in a variety of ways: thus, the boar "strikes laterally and upward, the musk-deer with serious effect downward," while the walrus can strike either upward, downward, or sideways with equal dexterity.

The male cat is a little larger than the female, and in most mammals the males are usually larger when there is any difference in size; this is seen in the eared seals, in the ox, Indian buffalo, and the American bison, as well as the lion. The mane of the latter adds to its appearance of greater weight and bulk, and Darwin says that the lion's mane "forms a good defence against the one danger to which he is liable—namely, the attacks of rival lions." As regards distinctions in color, male ruminants are most liable to exhibit them. In the Derbyan eland the body is redder, the neck much blacker, and the white band separating these colors broader than in the females. In the Cape eland the male is slightly darker than the female. In the Indian black-buck the male is very dark, almost black, while the female is fawn-colored: male antelopes are blacker than the female. The Banteng bull is almost black, while the cow is of a bright dun. Among the lemurs the male of

Lemur macaco is coal-black, while the female is reddish yellow. The sexes of monkeys differ much in coloration. Certain male seals, bats, rats, and squirrels have brighter colors than in the opposite sex. On the other hand, the female Rhesus monkey is adorned with a brilliant red naked ring around the tail; this is wanting in the male, which, however, is larger, with larger canines, more bushy whiskers and eyebrows; and Darwin states that in monkeys the males usually differ from the females in "the development of the beard, whiskers, and mane."

When the cat mews or caterwauls the sound is caused by the air rushing out of the lungs through the upper part of the windpipe, which is called the larynx. The larynx is formed by a modification of the uppermost ring of the windpipe, called the *cricoid* cartilage, to the anterior and dorsal edges of which two *arytenoid* cartilages are attached, while a V-shaped *thyroid* cartilage, open behind, is attached to its side. The *vocal cords,* which are modified folds of the mucous membrane lining the windpipe, are stretched between the arytenoid and thyroid cartilages, the slit between them being called the *glottis,* which is covered by the *epiglottis.* Thus, in the cat the organs of voice are situated almost solely at the upper end of the trachea or windpipe. In the voiceless whales the vocal cords are not developed. The male gorilla, which has an exceedingly loud voice, as well as the adult male orang and the gibbon, is provided with a laryngeal sac. In the howling monkey of Brazil, the hyoid apparatus and larynx are remarkably modified, the body of the former being changed into a large bony drum or air-sac communicating with the larynx. The vocal organs are a third larger in the males than in the females. "The males begin the dreadful concert, in which the females, with their less powerful voices, sometimes join, and which is often continued during many hours" (Darwin). They apparently howl, as birds sing, for the simple pleasure of the thing. Apparently, the most musical mammal, man excepted, is a gibbon, which can sing "a complete and correct octave of musical notes."

While the cat gives out no disagreeable odors, there are others of its class which are mutually attracted or are individually protected from the attacks of other species by odors. The scent-bags or odoriferous glands, secreting a fluid differing in consistency in different animals, are situated near the base of the tail, as in the skunk, pole-cat, musk-deer, civet-cat, and allies, or they may be developed in the side of the face, as in the male elephant, as well as in sheep and goats. The odor is either of musk or some form of it. The sense of smell must be very delicate, a $\frac{1}{13,000,000}$ part of musk being perceptible, says Mivart, when mixed with common air. The shrew-mice, by reason of their odoriferous glands, are disliked and consequently not hunted by birds. Universal deference is paid to the skunk; few dogs, and only those which are either inexperienced or peculiarly gifted, attacking them.

The cat renews her fur by shedding the hair gradually, the color remaining the same throughout the year. But there are a few mammals which have a summer and a winter dress. The American hare, ermine, least weasel, and long-tailed weasel, soon after the fall of snow in the beginning of winter, assume their winter dress, the ends of the hairs first turning white.

Sub-Classes of Mammals.

1. With long toothless jaws like a bird's bill.................................*Ornithodelphia.* Duck-bill.
2. With a pouch for holding the young..*Marsupialia.* Opossum.
3. With a placenta; brain in most cases with convolutions.................*Monodelphia.* Rat, Cat, etc.

CHAPTER XXXII.

THE REPTILIAN MAMMALS.

BEFORE we come to the true mammals, we should notice two very singular forms which in some important respects are intermediate between the reptiles and birds and the higher mammals. These are the duck-bill and spiny anteater. Besides peculiarities in the breastbone and other parts, one of the most obvious distinctions in these animals is the long, toothless jaws (there are eight horny teeth in

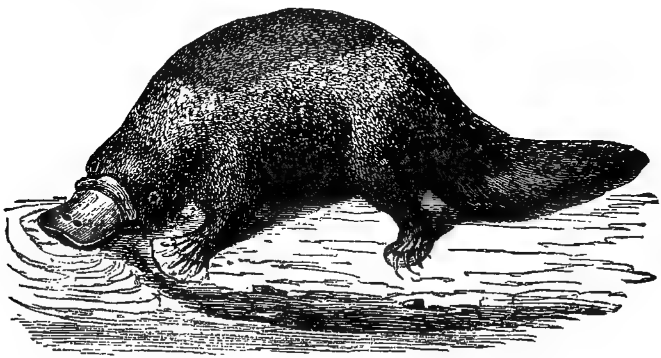

FIG. 233.—Duck-bill. Australia. (One-fourth natural size.)

the duck-bill), which are long and narrow in the *Echidna*, or broad and flat in the duck-bill (*Ornithorhynchus paradoxus*), where it is covered by a leathery integument; the external ear is wanting; in these respects they resemble reptiles and birds.

In the aquatic duck-bill (Fig. 233) the feet are webbed, with claws of moderate size. It is covered with a soft fur, and is about half a metre (17–22 inches) long. Its habits

FIG. 234.—Spiny Ant-eater (*Echidna hystrix.*) (One-third natural size.)

are like those of a muskrat, frequenting rivers and pools in Australia and Van Diemen's Land, sleeping and breeding in holes extending from under the water up above its level into the banks, and with an outlet on shore. It lives on mollusks, worms, and water-insects.

The spiny ant-eater (Fig. 234) inhabits Australia and New Guinea. In this animal the tongue is long and slender, like that of the ant-eater, while the body is armed with quills like those of a porcupine, as well as hairs. The claws are very large and strong, adapted for tearing open ant-hills in order to devour the ants.

Not only do these singular quadrupeds in their structure resemble the reptiles, but, unlike other mammals, whose eggs are of microscopic size, and which are born into the world in a shape much like their parents, they lay eggs as large as those of some reptiles, and the young are born in a very rudimentary condition. Hence, we see that the lowliest mammals are connecting links between the reptiles and birds, on the one hand, and their more highly organized brethren, of which we shall next speak.

LITERATURE.—Caldwell's Embryology of Monotremata and Mar supialia. Phil. Trans. Roy. Soc., London, 1887.

CHAPTER XXXIII.

THE MARSUPIALS OR POUCHED MAMMALS.

ALTHOUGH the spiny ant-eater has a brood-pouch, the true pouched mammals are represented by the opossum (Fig. 235), kangaroo (Fig. 236), and a number of other kinds, all of which, except the opossum, live in Australia. The pouch is supported by two long slender bones (Fig. 235, *M*) attached to the front edge of the

FIG. 235.—Opossum, and side-view of pelvis, with the marsupial bone, *M*.

pelvis, and projecting forwards. In the opossum, the kangaroo, and probably most marsupials, the young, which are very rudimentary and small when born, live in the pouch attached to the nipple, which fills the mouth. "To this it remains attached for a considerable period, the milk being forced down its throat by the contraction of the cremaster muscle. The danger of suffocation is avoided by the elongated and conical form of the upper extremity of the larynx, which is embraced by

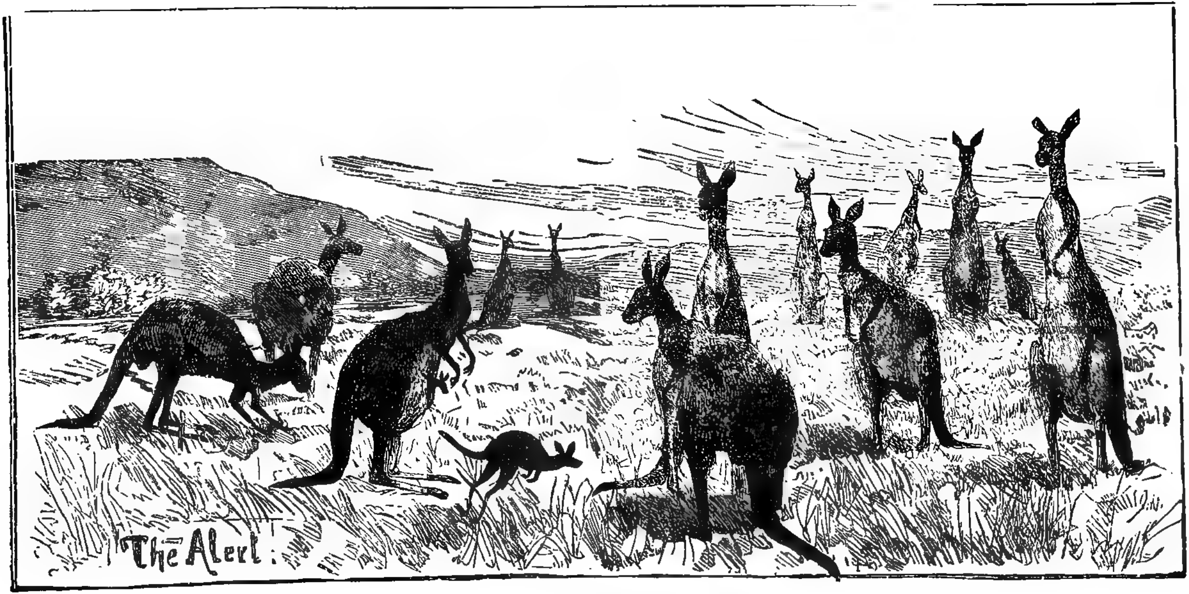

Fig. 236.—Herd of Kangaroos.

the soft palate, as in the *Cetacea*, and thus respiration goes on freely, while the milk passes, on each side of the laryngeal cone, into the œsophagus" (Huxley).

Long after the young are weaned, and when they are partly grown, they run into the pouch upon the approach of danger, or enter it when tired, and, there safely ensconced, present a comical sight, peeping out to see if the danger is past.

The opossums inhabit North and South America. They have a long, nearly naked, scaly tail, and they walk, like bears, on the sole of the whole foot. The species range in size from being a little larger than a mouse to the size of a cat, and they live on birds and their eggs, reptiles and insects. The Virginian opossum (*Didelphys Virginiana*) (Fig. 233) lives for the most part in trees.

There are squirrel-like flying marsupials (*Petaurus*), marsupial rats, marsupial bears, and marsupial ant-eaters (*Myrmecobius*), but the most characteristic Australian animals are the different kinds of kangaroo (Fig. 236).

The largest species, *Macropus giganteus*, is 1.8 metres, or nearly six feet, long, being as large as a sheep and sometimes weighing 140 pounds. Like other kangaroos, it goes in herds, and moves by a succession of long leaps, clearing obstacles seven or eight feet high.

All marsupials are stupid, low in intelligence, and, in those which eat flesh, of vicious temper. With the exception of the opossums, all are confined to Australia, New Zealand, and New Guinea.

All the pouched mammals, both the spiny ant-eater and opossum, with their allies, are very old-fashioned animals, and the earliest mammals which appeared on the earth's surface were more nearly related to them than to any higher beasts. But the primitive kinds were inferior in the size and shape of the brain and in intelligence to those now living; they mostly perished to make way for the more improved types, which we are next to consider.

CHAPTER XXXIV.

THE DOCILE MAMMALS.

WE may call the third sub-class docile or teachable mammals, because they comprise the domestic animals, such as the sheep, ox, pig, elephant, dog, cat, and monkey, all of which have a high grade of intelligence, while their brains are larger, and more complicated, the nearer they approach man.

They are also called *placental mammals*, because the young at birth are of considerable size and nearly perfect in development, being nourished until born by means of a highly vascular mass or thick membrane (*placenta*) supplied with arteries and veins, developed originally from the *allantois*, which is a temporary embryonic membrane.

The different groups of placental mammals are wonderfully adapted to different modes of life, so that though nearly all live on the ground, they have such different habits, such varied modes of obtaining their livelihood that there is room for all. We shall see that though all live on milk when young, yet when able to earn their own living they are very dependent upon the structure of their teeth and limbs. If we pick up a tooth we may know whether it belonged to a grass-eating creature, like an ox, or a flesh-eater, like a lion or cat, so intimate is the relation between the structure and uses to which the different organs are put, all being controlled by a brain and system of nerves so much more perfect than any we have hitherto studied.

ORDERS OF PLACENTAL MAMMALS.

1. No incisor teeth; sometimes entirely toothless .... *Bruta*. Sloth.
2. Rodents: with large incisor teeth...... *Glires*. Rat.
3. Fore-limbs often adapted for burrowing; teeth sharp; feeding on insects.. *Insectivora*. Moles.

4. Fore-limbs long, webbed, and adapted for flying	*Chiroptera.*	Bats.
5. Cetaceans; body fish-like in shape; no hind limbs	*Cetacea.*	Whales.
6. Body fish-like in shape; teeth like those of ruminants	*Sirenia.*	Manatee.
7. Snout prolonged into a proboscis	*Proboscidea.*	Elephants.
8. Long curved incisor teeth; feet with pads; toes hoofed	*Hyracoidea.*	Hyrax.
9. Toes hoofed	*Ungulata.*	Horse, Ox.
10. Teeth pointed for tearing flesh; claws large	*Carnivora.*	Dog, Cat.
11. Nails usually present; walking on all-fours; or using fore legs as hands, or erect and walking on the hind legs	*Primates.*	Monkey, Ape, Man.

The Toothless Brutes.—The most remarkable examples of adaptation to very different modes of life occur in this group. Look at the sloth (Fig. 237). On the ground it is the most helpless of brutes. Its great claws and small feet render it absolutely helpless, but in the tops of trees it is an excellent climber. Its front teeth are wanting, and the back teeth become sharp with use, like chisels, with which to crush boughs and leaves of trees. In disposition the sloth is very sluggish, since its food is near at hand, while it is protected from its enemies by living in the tops of tall forest trees in Brazil. Its fur is so near in hue to the moss which grows on the branches that it is difficult for the hunter, whether a man or a panther, to perceive it.

FIG. 237—Ai, or Three-toed Sloth, in its natural attitude.

Quite different in all respects are the ant-eaters. Though they live on animal food, yet they have no teeth; but as a compensation, the jaws are remarkably long, while the tongue is of great length, slender and extensible. Thus provided, the ant-eater burrows into ant-holes, thrusts its tongue among the swarming ants, which stick in multitudes to the viscid, writhing rod, and are withdrawn into the mouth. But how will the ants be crushed so as to be readily digested? Nature has made up for the loss of teeth in the ant-eater by providing it with a sort of gizzard, like that of birds, between whose walls the ants are crushed to a jelly. The great ant-eater is seven feet long, and when attacked by a panther or jaguar is, with its powerful claws, sometimes more than a match for its assailants.

Very curious creatures are the pangolins and armadillos.

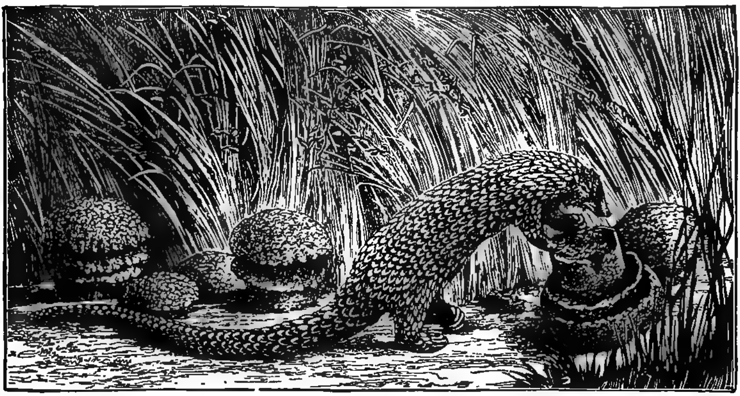

FIG. 238.—African Pangolin (*Manis longicaudata*) robbing white-ant nests.

They are mail-clad insect-eaters, whose bodies, and even their heads and tails, are covered with large, solid overlapping scales. They have back teeth, but, as in the sloth, they do not have a second set. Though the armadillos live on the plains of South America, where panthers and jaguars are frequent, they escape their assaults by rolling themselves into a round ball, leaving no place open to attack.

According to Herbert Smith, the armadillos in Southern Brazil burrow in the grass of the plains, and the smaller species tear open the high conical nests of the white ants. "These nests are almost as hard as brick; the bones and muscles of the fore feet in the armadillos are specially modified so as to secure great strength for digging, and the

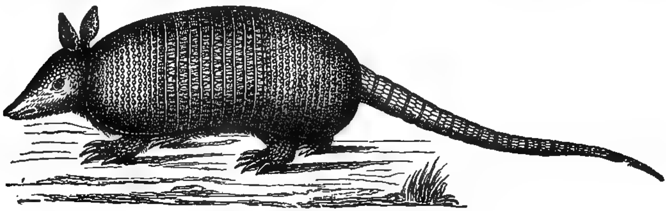

FIG. 239.—Nine-banded Armadillo.

large claws are used like miniature picks in boring into the tough clay."

The Gnawers.—Weak in bodily strength and usually diminutive in size, with brains inferior in capacity to those of higher mammals, the gnawers or rodents, early choosing, so to speak, the trade of carpenters and builders, have increased and multiplied until their order is more widespread and more numerous in species than any other order of mammals. They live in every variety of station, burrowing in the earth, making their homes in streams and ponds, or taking up their abode in trees. Dissimilar as their stations are, they all agree in having the same kind of teeth, and in getting their food in much the same manner.

They differ from animals of other orders in the large incisor teeth and in the absence of canine teeth (Fig. 240). Their feet are adapted for walking, climbing, or burrowing, the claws being long and curved. A peculiarity in the incisors is that they grow out as fast as they are worn down; this is due to the fact that the pulp is persistent; the enamel in front causes them to wear away behind so that they are chisel-shaped. The species are prolific, live mostly on vegetable food, and are of small size; the musk-rat, beaver, and capybara being the largest members of the order.

With rare exceptions, rodents feed on the stalks, roots, and leaves of plants, as well as seeds and fruit. The hares are very prolific, and would multiply to an enormous extent were they not held in check by hawks and beasts of prey. In Australia, where there are no larger animals to prey upon them, the rabbits introduced there from England have increased so as to threaten the sheep-raising industry of that country, the rabbits cropping the herbage and leaving none for the sheep. In one colony, in 1882, 2,000,000 sheep died of starvation from this cause. Nearly all the rodents, such as mice, rats, gophers, squirrels, as well as beavers, build nests, and in this respect they are not unlike birds. While the hare and rabbit are the least intelligent,

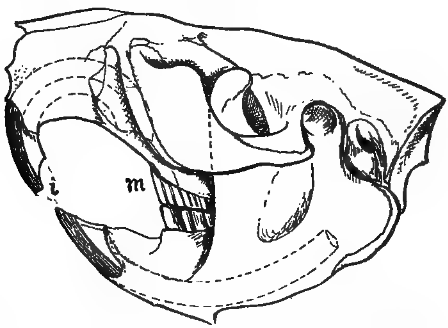

FIG. 240.—Skull of the Beaver. *i*, incisor teeth; *m*, molars.

building no place of refuge, the beaver evinces a high degree of intelligence in its architectural habits.

Beavers build a dam in a running stream so as to create an artificial pond as a refuge when attacked, as well as a subaquatic entrance to their lodges and to their burrows in the banks of the streams they inhabit. Beaver dams are built at first by a single pair or family, and are added to from year to year, and afterwards maintained for centuries by constant repairs. They are built of sticks and mud, and usually curve up stream, with a sloping water-face. Beavers lay up stores of wood for winter use in the autumn; they can gnaw through trees eighteen inches in diameter; they work mostly at night. They often construct artificial canals for the transportation of the sticks of wood to their lodges. This, in the opinion of Mr. Morgan, "is the highest act of intelligence performed by beavers." When ponds do not reach hard-wood trees or ground in which they can burrow for safety, they build canals with dams, and so excavate them that they will hold the surface drainage. Morgan describes one canal about 161 metres (523 feet) long which "served to bring the occupants of the pond into easy connection, by water, with the trees that supplied them with food, as well as to relieve them from the tedious, and perhaps impossible, task of moving their cuttings five hundred feet over uneven ground, unassisted by any descent." Beavers, in swimming, use their

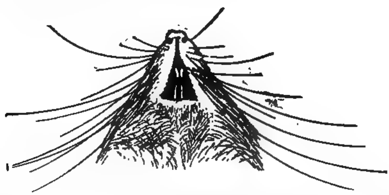

FIG. 241.—Head of common mouse, showing the incisor teeth.

tail as a scull, and, the hind feet being webbed, the propelling power while swimming is very great. They carry small stones and earth with their paws, holding them under the throat, and walking on their hind feet. They use the tail in moving stones, working it under so as to "give it a throw forward." Beavers are very social, working together and storing up wood in common. "A beaver family consists of a male and female, and their offspring of the first and second years, or, more properly, under two years old. The females bring forth their young from two to five at a time, in the month of May, and nurse them for a few weeks, after which the latter take to bank." They attain their full growth at two years and six months, and live from twelve to fifteen years.

The largest of all existing rodents is the capybara of South America, which looks like a pig. This is succeeded by the slow, ugly porcupine, which either lives in trees or burrows in the earth; it eats the bark and leaves of pine, larch, spruce, and other trees, and the buds of the willow. The quills fall out at the slightest touch, and, lodged in the skin of a dog or wolf, are said in some cases to make their way into the body until they cause death. The more intelligent, active forms are the beaver, musk-rat, the rats and mice, squirrels, and, lastly, the marmots. The two domestic rats, namely, the brown or Norway rat (*Mus decumanus*), and the black rat (*Mus rattus*), and the common house mouse (*Mus musculus*), are cosmopolitan animals. The musk-rat or musquash (*Fiber zibethicus*) has the hind feet partly webbed, so that it swims and dives well. It ranges from Florida to Arctic America. Northward it has three litters in the course of the summer, and from three to seven at a litter. It feeds on the roots and tender shoots of rushes and of the sweet flag, as well as mussels. In the autumn, before the shallow lakes and swamps freeze over, it builds its low conical house of mud, the base high enough to raise the interior above the level of the water; the entrance being under water. When the ice forms the musk-rat makes breathing-holes through it, and protects them from the frost by a covering of mud. In the summer it makes long burrows in the banks of streams, with a dry nest at the end.

Of the squirrels, the chipmunk (*Tamias Asiaticus*) inhabits Northwestern America; it is striped with five black and four white stripes on the back. It is an active and industrious little creature, with its cheek-pouches full of seeds. During the winter it lives in a burrow, with several openings made at the base of a tree. The chickaree or common red squirrel (*Sciurus Hudsonius*) may be seen in the dead of winter in pleasant weather; it burrows under trees; it feeds chiefly on nuts and seeds, and in the fur countries subsists chiefly on the seeds and young buds of the spruce. In New England it eats the seeds in pine cones, letting the scales fall to the ground under its seat on a lofty pine bough. In the winter its collects the cones of spruce and pine, and carries them to the entrance of its burrow, where it picks out the seeds beneath the snow. It also makes hoards of seeds, etc., on the approach of winter.

The gray squirrel (*Sciurus Carolinensis*) makes a rude nest of leaves in trees, where its young may be found in April and May. It feeds on nuts and acorns, and is active during the winter.

The woodchuck (*Arctomys monax*) is a mischievous creature, destructive to gardens and field crops, especially red clover. It is rather social, making burrows in the sides of hills which extend to a great distance, and end in various chambers, according to the number of inhabitants. The chambers are lined with dry grass or leaves, and here

FIG. 242—Jumping-mouse (*Zapus Hudsonius*).

they pass the winter in a torpid state, previously closing the entrance. There are six young to a litter.

The common pocket-gopher (*Geomys bursarius*) burrows in sandy soil and feeds on acorns, nuts, roots, and grass, which it carries to its burrows in its enormous hanging cheek-pouches, which, when full, have an oblong form and nearly touch the ground.

The jumping-mouse (Fig. 242) has remarkably long hind legs and short fore legs. This creature, like the bear and bats, hibernates in the winter months; it enters the ground before the frosts set in, and makes a burrow from five to seven feet in depth, usually in sandy soil. At the end of this burrow it constructs a nest of dried grass, in which it lies curled up in an unconscious state. Peculiar to the Western plains is the prairie-dog (*Cynomys ludovi-*

cianus; see Frontispiece, on the right side); it is semi-social, and takes in perforce as boarders the owl and rattlesnake, which devour its young.

The Moles and other Insect-eaters.—The miners among mammals are the moles (Fig. 244). They are rarely seen, not leaving their tunnels except at night. How admirably their bodies are adapted to a subterranean life, and for rapid progress under the surface of the soil, is seen in their sharp nose and their strong, spade-like fore feet. The fore legs are short, thick, and muscular, the bones (Fig. 243) very stout and solid. Moreover, they shun the light, for if they

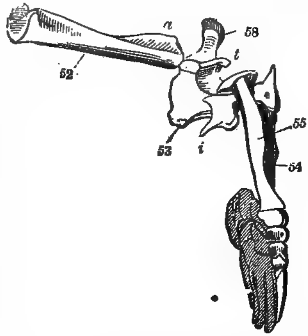

FIG. 243.—Bones of fore leg of a Mole. 52, the cubital scapula; 53, humerus; 54, ulna; 55, radius.

FIG. 244.—Common Mole, *Scalops aquaticus* Linn. (Natural size.)

appeared above the surface of the ground they would be snapped up by owls, hawks, or cats. Hence their eyes are very small and mostly hidden under the fur, while the ears are small and concealed by the hair.

FIG. 245.—Common Shrew.

In the little shrews, the feet are more as in mice, and the tail is long (Fig. 245).

The Bats.—These flying creatures, living as they do a part of their time on the wing, are the very opposites of the moles, and their whole body shows a thorough adaptation to their needs. If the mole's fore-limbs are remarkably short and spade-like, those of the bats go to an opposite extreme, and are remarkably long and slender, especially the third, fourth, and fifth fingers. A thin, naked membrane connects the fore and hind limbs, forming two great wings. The shoulders are well braced by collar-bones, and even as in birds the breastbone is somewhat keeled for the insertion of the large pectoral muscles.

Bats are more common than generally supposed, and they owe their immunity from harm to their powers of rapid flight, and their twilight habits, while they live in caves and in hollow trees by day. Bats hibernate in the same situations, going into winter quarters in the autumn, and reappearing in the warm twilight of spring. Though the eyes are small, and the sight, so far as we know, deficient in keenness, they show wonderful skill in avoiding objects during their rapid flight. The ears are very large, and in the vampires the nose is adorned with sensitive, leaf-like growths of complicated form. Certain bats, but not the true vampires, are known to enter houses and to suck the blood of sleeping persons, who awake to find their feet covered with blood.

The largest bats are the fruit-bats or flying foxes (*Pteropus*) of the East Indies; one species of which expands one and a half metres (nearly five feet) from tip to tip of the wings. They assemble in large flocks in the Moluccas to eat fruit, hanging by day in thousands on the trees.

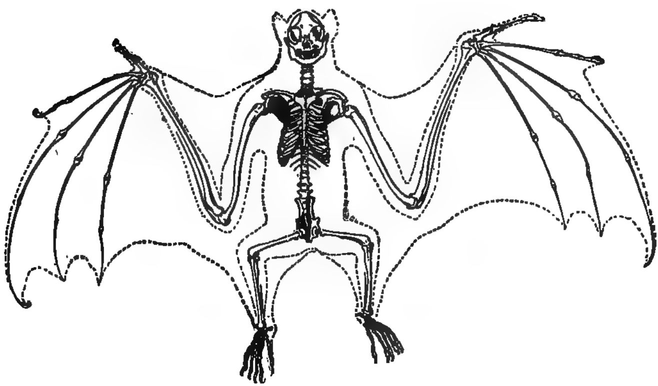

FIG. 246. Skeleton of a Fruit bat (*Pteropus*).

The Whales.—The transition from the bats to the whales is a startling one, and they are not nearly related. In whales, as in the remaining orders of mammals, the brain is larger, with convolutions on the cerebral hemispheres.

Here, again, we see how remarkably well adapted the body of the whale is to its needs. A whale is by no means a fish, but the body is fish-like in shape, being adapted for swimming and diving in the sea. Having no need of hind limbs, they are wanting, and the front limbs are modified in a singular way to serve as paddles (Fig. 247). Moreover, the tail is fluked horizontally to enable it to dive to enormous depths.

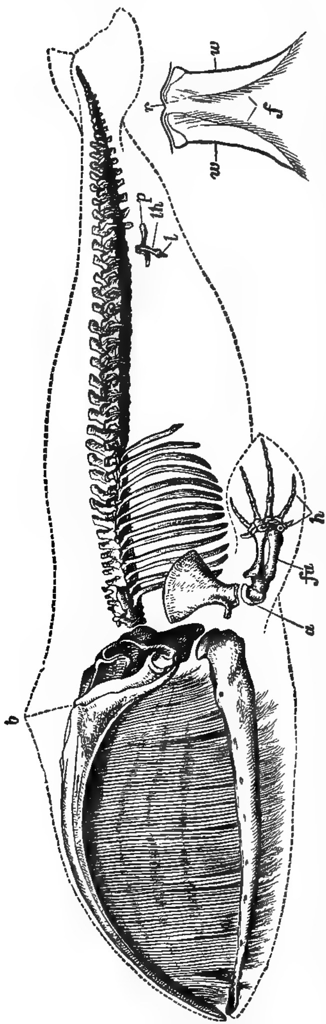

FIG. 247.—Skeleton of a Whalebone Whale (*Mysticete*). *b*, blow-hole; *a*, upper arm (the shoulder-blade above); *fa*, fore-arm; *h*, hand; *p*, *th*, *l*, small remains of pelvis or hip-bone, thigh, and leg. The small figure on the right represents a section of the mouth with the whalebone. *r*, roof of the mouth; *w*, *w*, plates of whalebone; *f*, whalebone fringe.

The external nostrils are either single or double, and are situated on the top of the head; they are modified to form the spiracles or "blow-holes;" certain folds of the skin prevent the water from entering the air-passages. The vapor blown from the holes does not consist of water, but of the mucus from the nostrils, and the moisture in the breath. The blow-holes vary in form in different kinds of whales. The "spout" of the sperm whale issues in a single short stream from the extreme end of the snout, and curls over in front of the head; that of the fin-back whale forms a single column of vapor about ten feet high; the right, humpback and sulphur-bottom whales each "blow" in a double stream, which is directed backward towards the tail.

Whales are rarely over fifty feet long; the sperm-whale has been known to reach a little over twenty-three metres (76 feet) in length. The largest of all whales, as of all existing animals, is the fin-back (Fig. 248) or rorqual (*Balænoptera boops*), which sometimes measures thirty-four metres in length. The smallest Cetacea are the porpoises.

In the whalebone whales (Fig. 247) the teeth, present in the embryo, become reabsorbed into the gums before birth

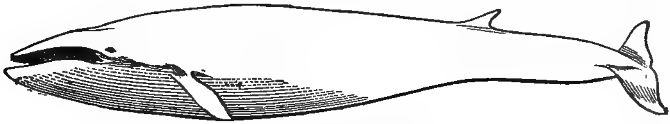

FIG. 248.—Fin-whale.

and are replaced by plates of whalebone, three hundred of which may be present on each side of the mouth. The inner edges of these plates have projecting fibres, forming a rude strainer; these whales feed on small pelagic jelly-fish, mollusks, and crustacea, by taking in a mouthful of water, and then pressing the tongue against the roof of the mouth, expelling the water through the openings between the plates, the fibres acting as a strainer. Three thousand five

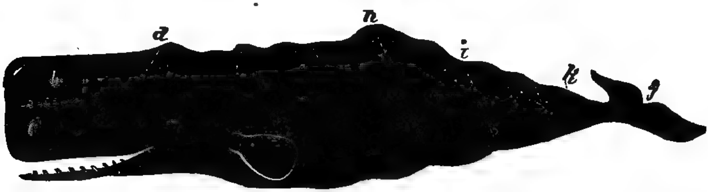

FIG. 249.—Outline of the Cachelot, showing how the blubber is removed. *b*, the situation of the "case;" *c*, the junk; *d*, the bunch of the neck; *h*, the hump; *i*, the ridge; *k*, the small; *f*, the tail or flukes; between the oblique dotted lines are the spiral strips or blanket pieces.

hundred pounds of whalebone have been obtained from a single bow-head or Greenland whale (*Balæna mysticetus*).

The cachelot or sperm-whale (*Physeter macrocephalus*, Fig. 248) has an enormous head, and is without the power of smell. In the upper jaw are cavities filled with a fatty fluid called *spermaceti*, used in the manufacture of candles, ointments, and cosmetics, such as cold cream. A large sperm-whale will yield 2500 kilograms of this substance. Another valuable substance is *ambergris*, a morbid product, the result of injury to the intestine by the beaks of cuttle-fishes, upon which animals the toothed whales largely prey.

But the chief use of whales is the oil extracted from the fat enveloping the body, called "blubber" by whalers. The most valuable of the whales is the Greenland whale, as it contains the most oil, individuals having been known to yield nearly three hundred barrels.

The Sea-cows.—The manatee or sea-cow represents the order of Sirenians; it is whale-like in form, but the teeth and skull are quite unlike those of whales, while the manatee is herbivorous, the crowns of the teeth being flattened and ridged as in the ox.

The Elephants.—The elephants are distinguished by their colossal size, their tusks, and the large air-cells in the skull. Another remarkable feature, from which the group takes its name, is the trunk or proboscis, a long, thick, fleshy, flexible snout, growing from the front edge of the nasal bones. The trunk ends in a finger-like, highly sensitive point, below which are situated the nostrils. In the elephants the upper incisor teeth are enormously developed, forming the tusks so characteristic of these animals, while there are none in the lower jaw. There are no canine teeth, while the few molars are large and transversely ridged.

In the nature of the limbs, especially from the fact that elephants walk on their toes, a relation to the hoofed beasts is indicated. They are usually five-toed, but the toes are represented externally only by the five broad, shallow hoofs, the foot being supported by thick, broad pads. The legs are almost wholly free from the body. The skin is naked in the existing elephants, but the extinct mammoth was covered sparsely with long hairs. Elephants live in herds, browsing on the leaves of trees and herbs. They are rarely over nine feet in height. The Asiatic elephant has a concave forehead and small ears, while the African species has a full, rounded forehead and large ears, with four hoofs on the fore feet and three on the hind feet, the Asiatic elephant having one more hoof on each foot.

The Hoofed Mammals.—The larger proportion of mammals belong to this interesting order, which comprises nearly all those species of mammals useful to man, such as the ox, camel, pig, deer, and horse. They are, in general, characterized by walking on their toes, each toe being at the end encased in a horny hoof; not more than four toes are completely developed on a foot. The collar-bone is absent. The brain still remains small compared with the bulk of the skull.

The Ungulates have been divided by Owen into two sub-orders, according to the odd number of toes (*Perissodactyla*) or even number (*Artiodactyla*). In the odd-toed Ungulates (Perissodactyles) there may be three toes on each foot, as in the rhinoceros, or one, as in the horse; while in the even-toed Ungulates (Artiodactyles) there may be four toes (*Hippopotamus*), or two, as in the giraffe, or two functional and two rudimental, as in the ox and deer, i.e., most ruminants.

It will be seen that the character of prime importance in these mammals is the limbs, and particularly the feet. Walking on their hoofs, which are modified claws, they can neither climb, nor dig, rarely using them as weapons of offence or defence. The hoofed beasts are swift on their feet, and perhaps as swift as any is the race-horse, which runs on a single toe in each foot. The horse is among the most specialized of all backboned animals, i.e., its feet are most specially modified, unless we except the limbs of birds.

The hoofed mammals browse on leaves or grass, and their teeth, both in position and shape, are well adapted for biting and chewing their food. They have no more teeth than they need. In the sheep, deer, and ox, which grasp a bunch of grass with their tongue pressed against the roof of the mouth and then give it a tug, pulling up a mouthful at a time, there is no need of incisors in the upper jaw;

hence they do not grow out. In the horse, which nibbles the grass, sharp chisel-like incisors are needed both in the upper and lower jaw. Moreover, feeding only on grass or leaves, the flesh or canine teeth are not needed, and they are absent; but the molars are square and flat-topped for crushing their food. In all important respects, then, the hoofed animals are perfectly adapted to their surroundings. Being weak and unprotected, they go in herds, and, as in horses, asses, oxen, or buffaloes, they have self-appointed leaders. Horses, deer, and oxen are timid, nervous creatures, and a single bear, panther or lion, will put a herd of them to flight. Hence it is necessary that there should be a great number of individuals, and so it has come to pass that the type of hoofed mammals has been very successful in point of numbers, the order being only less numerous in species than the rodents, and perhaps greatly exceeding them in numbers of individuals. And so have resulted the great herds of horses and sheep, and the droves of cattle necessary to doing that work in the world which it was destined for man to undertake. We could do without rats, mice, and other rodent vermin; but what could we do without beasts of burden, and hoofed beasts to afford us beef, pork, and mutton?

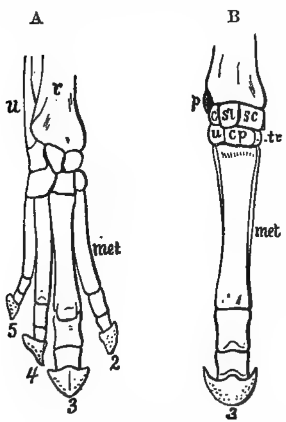

FIG. 250.—A, fore foot of Tapir; B, of Horse. *u*, ulna; *r*, radius; *p*, pisiform bone; *c*, centrale; *sl*, semi-lunar; *sc*, scaphoid; *u*, unciform; *cp*, capitatum; *tr*, trapezoid; *met*, metacarpus; 2, 3, 4, 5, 2d, 3d, 4th, and 5th digits.

Hoofed Mammals with Odd Toes.—To this group belong the tapir, rhinoceros, and horse. Of these the most interesting, from a scientific point of view, are the tapir and the horse. Put them side by side, and how unlike they are! The tapir is short-legged, uncouth, and clumsy in figure, its snout almost proboscis-like, and the feet end in front in four toes and behind in three, and these toes end in hoofs which spread out; a useful feature, since the tapirs, when alarmed, take refuge in swamps and streams.

On the other hand, the horse has a graceful form, all its lines indicating capacity for great speed, particularly as regards the feet. Here, so to speak, everything has been sacrificed to a single object, i.e., speed. To this end the first, second, fourth, and fifth toes have been abandoned,

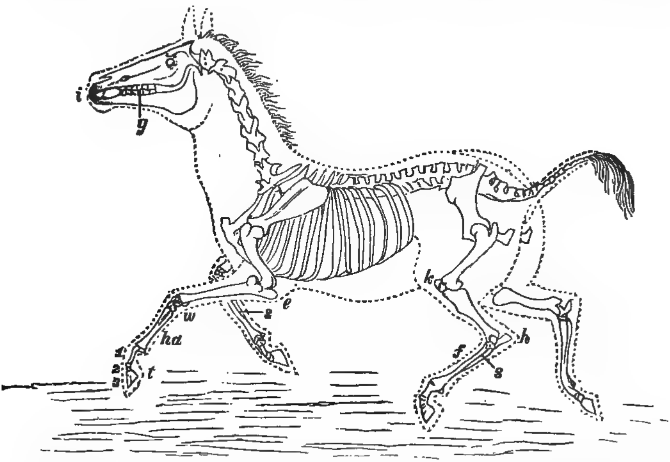

Fig. 251.—Skeleton of Wild Ass. *i*, incisor teeth; *g*, grinding teeth, with the gap between the two sets, as in all large grass-feeders; *k*, knee; *h*, heel; *f*, foot; 1, 2, 3, three joints of the middle toe; *s*, splint, or remains of one of the two lost toes; *e*, elbow; *w*, wrist; *ha*, hand-bone.

and the leg is supported on the third toe alone, that corresponding to our middle finger. Where else shall we find among the mammals such a special adaptation of structure to the needs of the creature? On the other hand, the tapir is what naturalists call a "generalized" form; all the parts of the body being equally developed, just as among mankind we have jacks-of-all trades, while as examples of specialized types are the geniuses who, as poets, artists, or philosophers, do one thing remarkably well.

The horse was preceded in geological history by a long series of creatures which fill up more or less completely the gap between it and the tapir. In the Tertiary deposits of the Western plains have been found over twenty species, forming a series from an animal about the size of a fox, with four toes and the rudiments of a fifth on the fore limbs, and three toes behind, up to horse-like forms of the size of a sheep, until in the uppermost beds we have the Hipparion, with three usable toes, which was about as large as a donkey; finally, the horse was preceded by a near ally with but a single toe, the two others reduced to "splint" bones, those of the modern horse representing the two usable toes of his Tertiary three-toed predecessor. We thus see that the modern one-toed horse, so well adapted for use by man, affords a marked example of that process of intelligent, beneficent selection of favored, useful types which has gone on from early geological times.

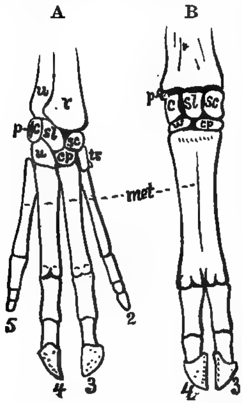

FIG. 252.—A, fore foot of Pig. B, Ox. Lettering as in Fig. 249.

The Even-toed Hoofed Mammals.—These are the pig, hippopotamus, and those cloven-footed beasts which chew the cud. The pig and hippopotamus are not remote allies, the latter having been considered as "intermediate between an overgrown hog and a high-fed bull without horns and with cropped ears." But while the pig is cloven-footed and clothed with bristles, the hippopotamus has four toes and the thick skin is naked.

The Ruminants.—While these cloven-footed beasts (Fig. 255), comprising the deer, sheep, ox, and camel, are, as regards their feet and teeth, adapted for a grazing life, the adaptation is rendered still more perfect by the nature of the digestive organs.

The stomach (Fig. 253) is divided into at least three, usually four, compartments, i.e., the paunch, the *reticulum* or honeycomb, so named from the polygonal cells on its interior, the *psalterium* or manyplies, and lastly the rennet or true stomach. When a sheep, cow, or any other ruminant feeds, it thrusts out its long tongue, seizes a bunch of grass, and bites it off by pressing the incisors of the lower jaw against the toothless gum of the opposing part of the upper jaw; the mouthful of grass is then swallowed, mixed with much saliva. When its appetite is satisfied it seeks a re-

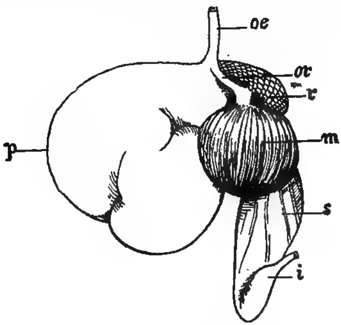

FIG. 253.—Stomach of a Calf. *œ*, œsophagus; *or*, œsophageal groove; *p*, paunch or rumen; *r*, reticulum; *m*, manyplies; *s*, abomasum or rennet stomach; *i*, intestine.

tired spot away from its carnivorous enemies, if not a domesticated animal, and, after lying down, suddenly regurgitates a ball of grass, the cud,* which it slowly grinds up between its molar teeth into a pulp. The cropped grass passes into the honeycomb and paunch; the manyplies serves as a strainer for the pulp, which in the fourth stomach is digested by the gastric juice.

The prong-horn antelope (*Antilocapra Americana*, Fig. 254) so characteristic of the Western plains, like the true

* The regurgitation of the cud is probably due to a sudden and simultaneous contraction of the diaphragm and of the abdominal muscles, which compresses the contents of the rumen and reticulum, and drives the sodden fodder against the cardiac aperture of the stomach, which opens and the cud is propelled into the mouth.—HUXLEY.

deer, drops its horns in the autumn, though they are hollow when shed, and with a persistent core, as in the ox and goat. The antelope crops grass, not, like the deer, eating leaves of trees and shrubs. It is the fleetest animal on the plains, though short-winded and not capable of running a great distance.

In its horns, hollow when cast off, and in the presence of

FIG. 254.—The Prong-horn Antelope.

a gall-bladder, which is absent in the deer family, the prong-horn antelope connects the deer family with the ox family (*Bovidæ*), which is represented by the sheep, goat, antelope, gazelle, and ox.

The domestic sheep (*Ovis aries*) is not a natural species, but an association of races whose specific origin is obscure. Some authors regard the turf sheep of the Stone Age of Europe as the ancestor of the domestic sheep, since forms like it are now living in the Shetland Islands and in Wales. It was of small size, with slender legs, and erect, short horns. This sheep was supplanted by a form with large, curved horns, the modern domestic sheep.

We now come to the bison and ox. The American bison (*Bison Americanus*) is now nearly exterminated, being mainly restricted to two small herds on the Western plains. It is closely allied to the European bison (*Bison Europæus*), the "aurochs," now preserved in the forests of Poland, and living wild in Caucasus. *Bos primigenius*,

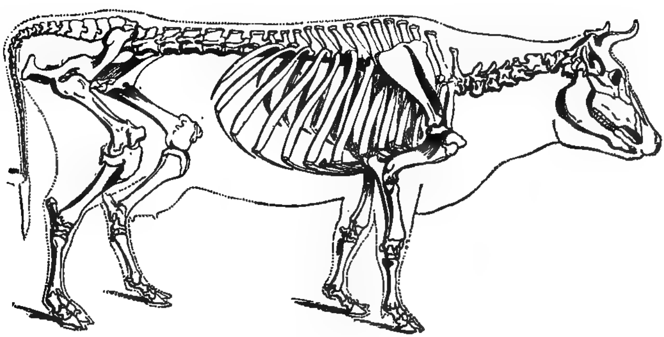

FIG. 255.—Skeleton of the Cow.

which in the time of Cæsar lived in Germany and England, bearing the name "urus," is the "ur" of the Nibelungen Song. From it have descended the half-wild cattle in certain English parks, also certain large domestic races, such as the Holstein and Friesland breeds. From another fossil species (*Bos longifrons*) arose the so-called brown cattle of Switzerland, and the "runts" of the Scottish Highlands. Still other domestic races are traced back to another fossil Quaternary species, *Bos frontosus*. Our present races of domestic cattle, therefore, do not represent a genuine species, but a number of races which have descended from several fossil species; the name *Bos taurus* is simply, then, a conventional name.

The ox is succeeded by the giraffe (Fig. 256), with its long neck, which renders it the tallest of all quadrupeds.

The last family of hoofed mammals, the *Camelidæ*, comprises the camels of the Old World, and the llama and vicuña of South America. In the camels the upper lateral incisors are present; the stomach is less distinctly divided into four chambers; the third stomach, as such, is wanting, though the second stomach has deep cells, the so-called "water-cells," which, according to Huxley, "serve to strain off from the contents of the paunch, and to retain in store, a considerable quantity of water;" thus the camel is popularly said to store up a supply of water in its stomach for its march over deserts. The toes have very large, thick pads, while the hoofs are reduced to nail-like proportions. In the camel the foot-pad is common to all the toes, but in the llama (*Auchenia*) of the Eastern Andes each toe has a distinct pad, besides the claw. The llama in a wild state keeps together in herds; from early times it has been also domesticated and used as a beast of burden, and for its wool, chiefly in Peru and Chili. It is rather larger than a sheep, with the form of a camel. The huanaco is probably the wild form of the domesticated llama (*Auchenia lama*), while the vicuña is perhaps the wild form of the alpaca (*Auchenia pacos*).

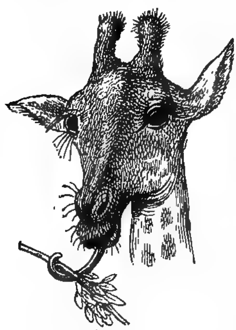

FIG. 256.—Head of Giraffe.

The Flesh-eating Mammals.—The change from a grazing, cud-chewing, meek, timid, hoofed beast to a clawed, sharp-toothed, ferocious, flesh-eating creature, like a lion or cat, is a marked one. And here the adaptation of structure to the needs and habits of the animal is no less remarkable than in the orders which we have already considered. The lion's or cat's skull (Fig. 257) is massive, the canine teeth very large, and the feet have large retractile claws.

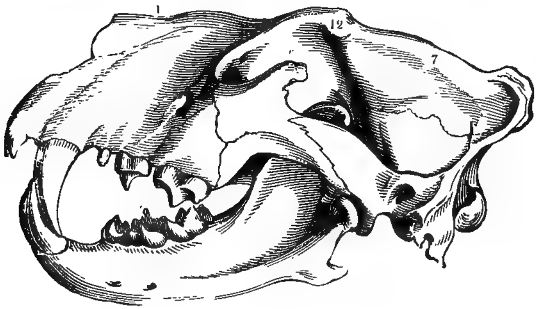

FIG. 257.—Skull of the Lion.

But before we describe the genuine Carnivora, we must draw attention to the seals (Fig. 258) and their allies, which are admirably adapted to an aquatic life. Their limbs are modified into "flippers" for use in swimming,

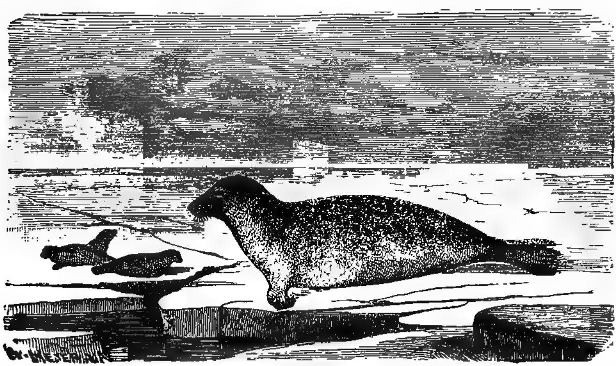

FIG. 258.—Rough Seal (*Phoca hispida*).

the toes being webbed; the hinder pair extended backwards, so that it is impossible for them to walk. They live for the most part in the sea on fish, occasionally shuffling out of the water and lying on the rocks by the shore.

In the walrus (Fig. 259) the upper canine teeth form tusks by which the creature can climb upon cakes of ice, or dig for clams, its principal food, in the deep mud of bays.

While the Carnivora are destructive and often injurious to the domestic animals, they are economically valuable, especially the marten family, for their fur.

The true or land Carnivora begin with the bears and end with the lion and other cats. The bears are the least specialized of the order, as they walk on the sole of the en-

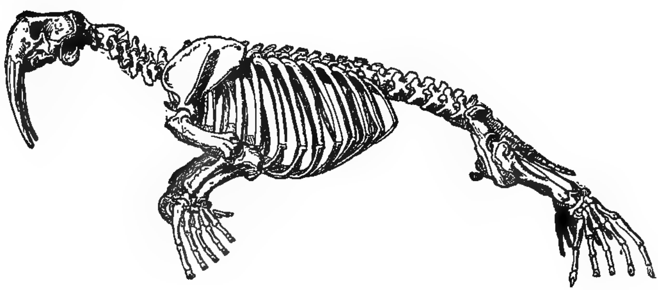

Fig. 259.—Skeleton of the Walrus.

tire foot, whence the term "plantigrade" applied to them; whereas the cats, the more agile of the flesh-eaters, walk on their toes.

The bears have a thick, clumsy body, with a rudimentary tail, and the molar teeth are broad and tuberculated, so that they can live indifferently on fish, insects, or berries. Our North American species are the polar bear (*Ursus maritimus*) and *Ursus arctos*, with its varieties of brown, cinnamon, and grizzly bears; and the true black bear (*Ursus Americanus*). The black bear weighs from two to four hundred pounds, is common in the wooded or mountainous parts of the country, and is destructive to sheep, lambs, and calves. It will rarely attack man, unless wounded, or in defence of its young. When the weather is severe and the snow is deep it makes a den in a hollow tree, cave, or under the root of a tree, and there hibernates. It has young but once in three years.

The bears are succeeded by the marten family (*Mustelidæ*), or the otter, skunk, badger, wolverene, weasel, mink, ermine, etc., all of which are valuable for their furs.

The skunk (*Mephitis mephitica*), says Merriam, who thinks this malodorous creature has been too much abused, "is pre-eminently an insect-eater;" he "destroys more beetles, grasshoppers, and the like than all our other mammals together, and, in addition to these, devours vast numbers of mice." Skunks hibernate only during the severest portion of the winter. They are very prolific, bringing forth six to ten young at a birth; these young, with their parents, remaining in one hole for the ensuing year.

The dog family (*Canidæ*) is represented by the fox, wolf, and dog. The gray fox (*Urocyon Virginianus*), the common red fox (*Vulpes vulgaris*), with its varieties, the cross, silver, and black fox, as well as the wolf (*Canis lupus*), are valuable for their furs. The common red fox is more frequent even in thickly settled portions of the Eastern States than is usually supposed.

The wolf is one of the most cowardly and yet wary, crafty, and sagacious of our wild beasts, and, when game is abundant, wantonly destructive and wasteful. It makes its lair in rocky caverns, under the roots of fallen trees, and in hollow logs. The young are born in April and May, from six to ten pups constituting a litter. The wolf is mostly gray northward, becoming "southward more and more blackish and reddish, till in Florida black wolves predominate and in Texas red ones."

The prairie-wolf or coyote (*Canis latrans*) is characteristic of the Western plains and Pacific coast. The Indian dogs breed with the coyote, and the offspring is fertile. This fact appears to support the theory that the Indian dog, Mexican dog, and the spitz dog are descendants of the prairie-wolf. The Eskimo and Newfoundland dogs are probably descendants of the gray wolf. On the other hand, fourteen kinds of dogs can be distinguished in the Roman and Greek records; of these five are principal types or species, five others climatic varieties, the remainder being either breeds artificially produced, or hybrids. As regards the Egyptian dogs, seven kinds may be distinguished, besides the jackal, three of them being distinct species.

The *Viverra* and *Genetta* or civet cats, and the hyænas, lead to the cat family, which stands at the head of the Carnivora. The lion, jaguar (Fig. 260), panther, leopard,

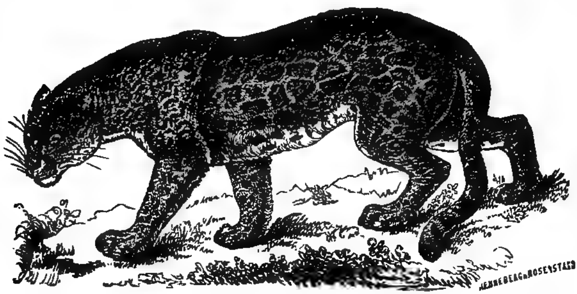

FIG. 260.—Jaguar, South America.

and tiger belong to the genus *Felis*. *Felis concolor*, the cougar, panther, or puma, ranges over both American continents. A very large panther may weigh about 200 pounds, and stand about 2½ feet high at the shoulders, and be 1–1.3 metres in length. It is very gaunt, but not so thin as it looks. It is not so fierce as supposed, not attacking man unless wounded and cornered.

The domestic cat (*Felis domestica*) was first domesticated in Egypt, the Greeks and Romans not possessing it; the cat and common marten were in use as domesticated animals at the same date in Italy, nine hundred years before the crusades. It appears that the domestic cat of the Greeks and Romans was a species of marten.

Of the lynxes there are two species in North America, *Lynx rufus*, the American wildcat, and the Canada lynx, *Lynx Canadensis*, or *loup cervier*, the latter being much the larger species. The Canada lynx preys upon the northern hare and other small mammals, as well as the ruffed grouse and spruce partridge, and has been known to devour pigs, lambs, and young fawns.

The Monkeys, Apes, and Man.—The last and highest order of mammals contains a series beginning with creatures resembling squirrels and bats, i.e., the lemurs, and ending with the monkeys, apes, and man. In all the *Primates*, the legs are exserted, being almost or quite free from the trunk, with the great toe of the hind foot usually enlarged and opposable to the others; nails, except in the marmosets, replace claws.

The brain is larger than in any other mammals, and while the hemispheres of the brain may in the lower forms be quite smooth, in the apes they nearly, and in man they completely, overlap the cerebellum, and the surfaces are deeply and abundantly furrowed. The collar-bones (clavicles) are well developed, adapting the fore limbs for climbing. The set of teeth is completed with four chisel-shaped small incisors, forming a closed series.

As a rule the monkeys and apes live in trees, and the complete adaptation of their bodies to a climbing life is seen in the shape of the hands and feet. The hinder feet in the monkeys and apes are very like hands, being adapted for climbing and grasping (Fig. 265), but in man the foot is plantigrade. The teeth are adapted to a mixed diet of flesh and vegetables, but the monkeys and apes feed exclusively on fruits, nuts, etc.

The *Primates* are divided into two sub-orders, i.e., the *Prosimiæ* and *Anthropoidea*. The former group embraces the lemurs, which vary in size from that of a rabbit to a large monkey. They are covered, the face as well as the rest of the body, with a dense fur; walk on all-fours, usually have long tails, though the lori is tailless, while the fore limbs are shorter than the hind limbs. The skull is small, flattened, and narrow in front; the brain-cavity small in proportion to the rest of the skull. The cerebral hemispheres are small and flattened, the frontal lobes narrow and pointed, and behind they only slightly cover the cerebellum.

Allied to the true lemurs is a very puzzling creature, the

FIG. 261.—Galago. From Lütken's Zoology.

aye-aye or *Chiromys*, of Madagascar, whose dentition differs from that of all other *Primates*, and resembles that of the Rodents; the thumb also is not truly opposable, and all the hind digits, except the great toes, have claw-like nails. The *Galago*, of West Africa (Fig. 261), somewhat recalls the *Insectivora*, while "in the more active and flexible-bodied lemurs, the trunk-vertebræ resemble in proportions, connections, and direction of neural spines those of the agile *Carnivora*" (Owen).

The genuine *Primates* or sub-order *Anthropoidea* are, in brief, characterized by the large, convoluted cerebral hemispheres. The ears are rounded, with a distinct lobule, and the two mammæ are pectoral. These *Anthropoidea* are divided into two subdivisions, the first comprising the monkeys and apes, and the second, man. In the first group (*Simiæ*) the body is prone, the animal walking on all-fours, only the orang and gorilla walking partly erect; the great toe is rather short, thumb-like, and opposable to the fingers, while the body is very hairy.

Fig. 262.—Head of *Cebus vellerosus*.

Fig. 263—Head of *Semnopithecus cornutus*.

The apes live in trees, only occasionally walking on the ground; their posture is semi-erect; they are tailless; the fore legs are much longer than the hind legs, and used as arms, the radius being capable of complete pronation and supination. In the form of their skull, of their brain with its convolutions, and in the teeth, there is a still nearer approach to man.

There are four typical forms or genera of apes, i.e., the gibbon (*Hylobates*); the orang (*Mimetes pithecus*), the chimpanzee (*Mimetes niger*), and the gorilla. The gibbons are nearest to the monkeys; they are little less than a metre (3 feet) in height, and are very slender, with very long arms, so that they are rapid, agile climbers, also running over the ground with ease and rapidity; when standing erect the fingers touch the ground; only the thumbs and great toes have true nails, in all the higher apes the nails of all the digits being flattened; the spinal column is nearly straight; they have fourteen pairs of ribs.

The orang (Fig. 264) dwells in Sumatra and Borneo, be-

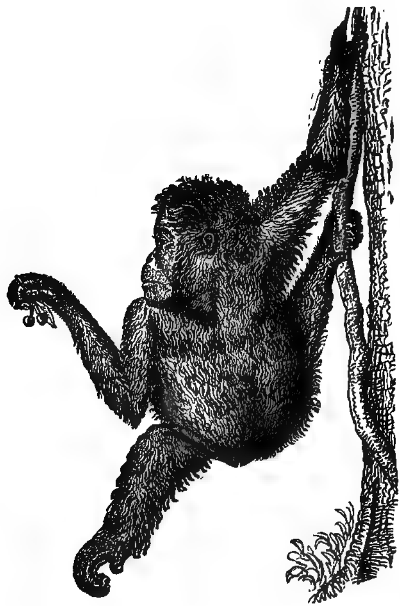

FIG. 264.—Orang-outang or Mias.

ing confined to those two islands; it is 4 feet 6 inches tall; it has twelve pairs of ribs, the same number as in man; the arms are very long, stretching 7 feet 9 inches, and reaching the ground, so that in walking the creature rests on its knuckles, swinging the body through its long arms as if walking on crutches; its posture is only partially erect. The forehead is less strongly marked than in the other apes, showing better the shape of the skull.

The chimpanzee (Fig. 265) and gorilla are confined to the west coast of Africa. The chimpanzee (*Mimetes niger*) inhabits the coast from Sierra Leone to Congo. It is about

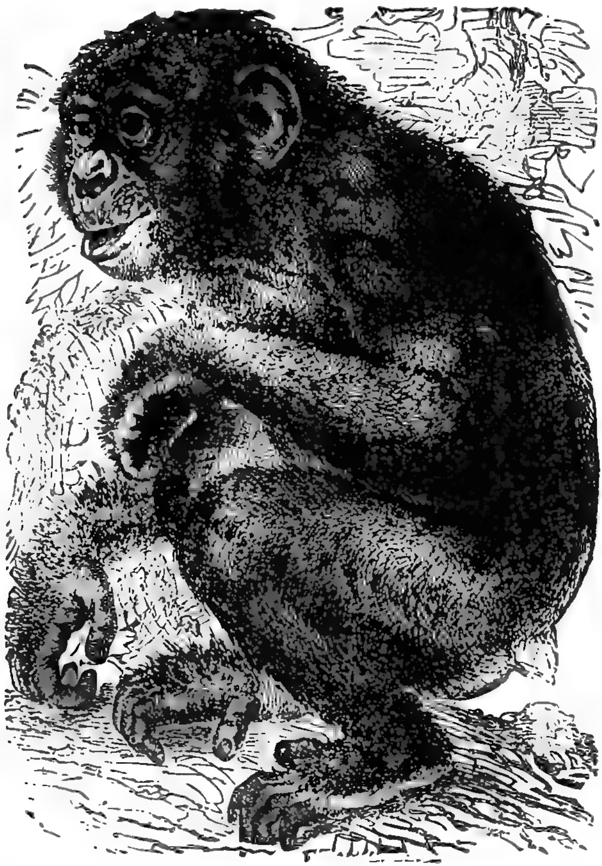

Fig. 265.—Young Chimpanzee.

1 metre (five feet) in height. It can stand or run erect, but it usually leans forward, resting on its knuckles; the arms span about half as much again as the creature's

height. Both the chimpanzee and gorilla have fourteen pairs of ribs. The chimpanzee lives on fruit, is an active climber, and nests in trees, changing its rude quarters according to circumstances.

The gorilla (Fig. 266), like the chimpanzee, goes in bands, but the company is smaller, and led by a single adult male. It makes similar nests, which, however, in the case of both apes, afford no shelter, and are only occupied at night. The gorilla sometimes reaches the height of about $1\frac{2}{3}$ metres ($5\frac{1}{2}$ feet) and weighs about 200 pounds. Its ordinary attitude is like that of the chimpanzee; there is a web between the first joints of all the fingers and three of the toes, and both hands and feet are broader, while the body is much more robust than in the other apes, being very broad across the shoulders. The span of the arms is to the height as three to two, or a little over eight feet. The skull is thick, and the strength and ferocity of the creature are evinced by the thick supraorbital ridges and the high sagittal and lambdoidal crests on the top of the skull; the face is wide and long, the nose broad and flat, the lips and chin prominent. The gorilla walks like the chimpanzee, though it stoops less. It is very ferocious and bold, never running when approached or attacked by man. It lives on a range of mountains in the interior of Guinea, its habitat, so far as known, extending from a little north of the Gaboon River to the Congo.

"Thus, to recapitulate, while the gibbons are most remote from man, the orangs approach him nearest in the number of the ribs, the form of the cerebral hemispheres, and other less obvious characters; the chimpanzee is nearest related to him in the form of the skull, the teeth, and the proportions of the arms, while the gorilla resembles him more in the proportions of the leg to the body, of the foot to the hand, in the size of the heel, the curvature of the spine, the form of the pelvis, and the absolute capacity of the skull." (Huxley.) Anatomists have differed and do differ as to whether the chimpanzee or the gorilla is nearest to man.

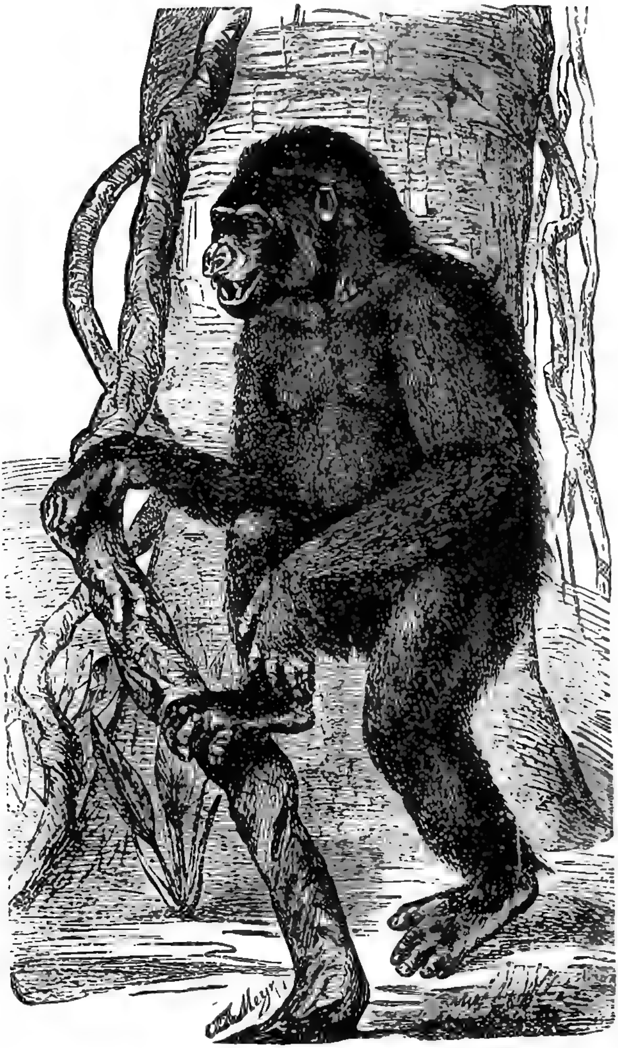

FIG. 286.—Aged Male Gorilla.

Man is widely separated from the monkeys and apes in being endowed with well-developed reasoning and moral powers, in having the faculty of speech, and in possessing a religious nature, being able to apprehend the existence of a Creator, the Author of Nature. But zoologically the absolute differences from the monkeys and apes are so slight as to lead naturalists to rank man in the same order as those creatures.

The absolute differences between man and the apes are these: his brain is at least double the size of that of the highest ape, the gorilla, while the difference between the skulls of the gorilla and man is very great.

In man the skull overhangs the orbits; in the gorilla the forehead is hollowed out. The hinder portion of the brain is also much more developed in man than in the apes, and in the hinder part of the hemispheres the convolutions are more numerous than in the chimpanzee, this part in monkeys in most cases losing its convolutions. Man stands erect; his arms span a distance equal to his height; the spinal column has four curves; the skin of the hands and feet of man is highly sensitive compared with that of the apes.

Naturalists are now agreed that there is but one species of man. Blumenbach, from the shape of the skull and the color of the skin, divided mankind into three varieties,—the white or Caucasian, the brown or Mongolian, and the black or Ethiopian; considering the American variety as connecting the Caucasian and Mongolian, and the Malayan as intermediate between the Caucasian and Ethiopian. Cuvier also believed that there were three primary races of men,—the white or Caucasian, the yellow or Mongolian, and the black or Ethiopian race; and this grouping is still regarded by some of the best authorities as perhaps the simplest and best.

This ends our survey of the animal kingdom. We have seen that, on the whole, it comprises a series of forms ranging from the microscopic, simple monad to man. We have seen a gradual increase in the number of organs and in the diversity of their uses, and have also observed the adaptation of certain organs to special purposes fitting different beings for special stations in life. We have seen that there is a balance of power between the vegetable-feeding animals and those which prey upon them, and that there is a harmony in nature between animals and their surroundings. Throughout our studies we have seen that in the higher animals, especially the vertebrate forms, the brain has increased in size and complexity, accompanied on the whole by an increase in intelligence, until it reaches its highest development in man, who is fitted to become the historian of creation, and by observation and reflection on external nature to rise to the conception of a God of nature, by whose infinite and all-pervading intelligence all things, material and immaterial, have been created by processes which man can in a measure trace. The study of animated nature, then, is glorious in its results, while disciplining and developing man's intellectual and moral powers.

Literature of Mammals.

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GLOSSARY.

AB-DO'MEN. In mammals the part of the trunk below or behind the thorax; in insects the third region of the body, or hind body.

AB-ER'RANT. Departing from the regular or normal type.

AB-O'RAL. Opposite the oral or mouth region.

A-BRAN'CHI-ATE (Gr. *α*, without; *bragchia*, gills). Without branchiæ or gills.

A-CU'MI-NATE. Ending in a prolonged point.

AL-VE'O-LUS. A cavity forming the socket in the jaws of vertebrates for the teeth.

AM-BU-LA'CRUM (Lat. from *ambulare*, to walk, a garden-walk). The perforated space or area in the shell of the sea-urchin or the arm of a star-fish, through which the foot-tubes or ambulacral feet are protruded.

A-ME-TA'BO-LIC (Gr. *α*, without; *metabole*, change). Referring to insects and other animals which do not undergo a metamorphosis.

A-MOR'PHOUS (Gr. *α*, without; *morphe*, form). Without a definite figure; shapeless; especially applicable to sponges.

AM-PHI-CŒ'LOUS (Gr. *amphi*; *koilos*, hollow). Applied to vertebræ which are doubly concave, or hollow at both ends.

A-NAL'O-GY (Gr. *analogia*, proportion). The relation between organs which differ in structure, but have a similar function; as the wings of insects and birds.

A-NAS-TO-MO'SING. Inosculating or running into each other like veins.

AN-CHY-LO'SIS. The growing together of two bones so as to prevent motion between them.

AN'NU-LATE. When a leg or antenna is surrounded by narrow rings of a different color.

A'PLA-CEN-TAL. Referring to those mammals in which the embryos are destitute of a placenta.

A'PO DOUS. Footless.

AP'TE-ROUS (Gr. *α*, without; *pteron*, wing). Destitute of wings.

A-QUI'FE-ROUS (Lat. *aqua*, water; *fero*, I carry). Applied to the water-carrying or water-vascular system of the sponges, etc.

A-RACH'NI-DA (Gr. *arachne*, a spider). The class of Arthropods, embracing the spiders, scorpions, and mites.

A'RE-O-LATE. Furnished with small areas; like a network.

A-RIS'TATE. Furnished with a hair.

AR-THRO'PO-DA (Gr. *α*, without; *arthros*, a joint; *pous, podos*, foot). Those Articulata with jointed feet.

AR-TI-CU-LA'TA (Lat. *articulus*, diminutive of *artus*, a joint). Cuvier's subkingdom of worms, crustacea, and insects.

AR-TI-O-DAC'TY-LA (Gr. *artios*, even; *daktulos*, finger or toe). Those Ungulates with an even number of toes, as the ox.

A-SEX'U-AL. Applied to animals, especially insects, in which the ovaries or reproductive organs are imperfectly developed; and which produce eggs or young by budding.

AU-RE'LI-A. Old term for the pupa of an insect.

AU'RI-CLE (Lat. *auricula*, a little ear). One of the cavities of the heart of mollusks and vertebrates.

AZ'Y-GOS (*α*, without; *zugon*, a yoke, a pair). An organ, such as a nerve or artery, situated in the middle line of a bilaterally symmetrical animal, which has therefore no fellow.

BÆ-NO'PO-DA (Gr. *baino*, to walk). The thoracic legs of insects.

BÆ'NO-SOME (Gr. *baino*, to walk; *soma*, body). The thorax of insects.

BI'FID. Divided into two parts; forked.

BLAS'TO-DERM (*blastos*, a bud or sprout; *derma*, skin). The first-formed layer of the germ-cells of the embryo.

BLAS'TO-PORE. The mouth of the gastrula.

BLAS'TO-SPHERE. The embryo when consisting of a single cell-layer. The same as the blastula.

BLAS'TŪ-LĂ. The embryo with but a single layer of cells.

BRAN'CHI-A. A gill or respiratory organ of aquatic animals.

BUC'CAL. Relating to the mouth cavity; or rarely to the cheeks.

BUL'LATE. Blistered.

CA-DU-CI-BRAN'CHI-ATE (Lat. *caducus*, falling off; Gr. *bragchia*, gills). Applied to those *Batrachia* in which the gills become absorbed before adult life.

CAL'CA-RA-TED. Armed with spurs.

CA'LYX. A little cup, often applied to the body of a Crinoid.

CAP'I-TATE. Ending in a head or knob.

CEN-TRUM. The body or central part of a vertebra.

CE-PHAL'IC. Relating to the cephalum or head.

CE-PHAL'O-MERE. A cephalic segment of an Arthropod.

CE-PHAL'O-SOME. The head of insects, Arachnida and Myriopoda.

CER-CO'PO-DA (Gr. *cercos*, tail; *pous, podos*, foot). The last pair of jointed abdominal appendages of insects; the "cerci."

CHE'LA. The terminal portion of a limb with a movable lateral part, like the claw of a crab; as in the chelate maxilla of the scorpion.

CHI-AS'MA (Gr. *chiasma*, a crossing). The commissure of the optic nerves in most vertebrates.

CHI'TIN (Gr. *chiton*, a tunic). The horny substance in the skin of insects, etc.

CHYLE (Gr. *chulos*, juice). The milky fluid resulting from the action of the digestive fluids on the food or chyme.

CHYME (Gr. *chumos*, juice). The acid, partly fluid or partly digested food, produced by the action of the gastric juice on the food.

CIL'I UM (pl. *cilia*). Microscopic filaments attached to cells, usually within the body, and moving usually rhythmically.

CIR'RUS. A slender process on the body of worms.

CLO'A-CA (Lat. a sewer). The common duct or passage at the end of the intestine into which the oviducts and urinary ducts open, as in reptiles, birds, and monotreme mammals.

CŒ'CAL. Ending blindly or in a cul-de-sac.

CŒ'CUM. A blind sac; usually applied to one or more appendages of the digestive canal.

CŒ-NEN'CHY-MA (Gr. *koinos*, common; *chumos*, chyme or juice). Applied in polyps to the coral mass containing the chymiferous or nutritive canals connecting the different polyps.

COL'LO-PHORE. The sucker-like organ extended from the under side of the abdomen of Podurans.

COM-MIS'SURE. The nerves connecting two ganglia.

CON-COL'O ROUS. Of the same color as another part.

CON'DYLE (Gr. *kondulos*, a knuckle). The articular surface of a bone, especially of the occiput.

COR'TI-CAL. Relating to the cortex or inner skin; external, as opposed to medullary.

COS'TAL (Lat. *costa*, a rib). Relating to the ribs.

CRIB'RI FORM (Lat. *cribrum*, a sieve; *forma*, form). With perforations like those of a sieve.

CROP. A partial dilatation of the gullet or œsophagus, the ingluvies; in many insects the fore stomach or proventriculus.

CU'TI-CLE. The outermost layer of the integument.

DE-CID'U-OUS. Relating to parts which fall off or are shed during life, as the gills of the frog, etc.

DEN'TATE. Furnished with teeth.

DERM'A-TOP-TE-RA (Gr. *derma*, skin; *pteron*, wing). The earwigs.

DEU-TOM'A-LÆ. The third pair of head appendages of Myriopoda.

DI-DEL'PHI-A (Gr. *dis*, two, or double; *delphus*, womb). The sub-class of Marsupials.

DIF-FER-EN-TI-A'TION. The specialization or setting apart of special organs for special work, as the specialization of the hand of man from the fore-foot of other mammals; also applied to the special development during embryonic life of parts adapted for peculiar or special functions.

DIG'IT. A finger or toe.

DI-MID'I-ATE. Half round.

DI-Œ'CI-OUS. (Gr. *dis*, two; *oikos*, house). With distinct sexes.

DIP'TE-RA (Gr. *dis*, two; *pteron*, wing). Two-winged flies; an order of insects.

DI-VER-TIC'U-LUM. An offshoot from a vessel or from the alimentary canal.

DUCT. A tube or passage usually leading from glands.

EC-DY'SIS (Gr. *ekdusis*, casting off). The process of casting the skin; moulting.

E-CHIN-O-DER'MA-TA (Gr. *echinos*, a hedgehog or urchin; hence applied to the sea-urchin; and *derma*, skin). The fourth sub-kingdom of animals.

E-LAS-MO-BRAN'CHI-I (Gr. *elasma*, a strap; *bragchia*, gill). The sharks and rays.

E-LA'TER. The spring or forked "tail" of Podurans.

E-LY'TRA (Gr. *elutron*, a sheath). The fore-wings of beetles, serving to cover or sheathe the hind wings.

EM'BRY-O. The germ or young animal before leaving the egg or body of the parent.

EN'-DO-BLAST. The primitive, embryonic endoderm.

EN'TE-RON (Gr. *enteron*). A general term applied to the digestive canal as a whole.

E-PHEM'E-RI-NA. The order of net-veined insects represented by Ephemera.

E'-PI-BLAST. The ectoderm in its embryo state. The ectoblast.

E-PIB'O-LE. Where the gastrula is formed by a spreading of a thin layer of epiblast cells over the much larger hypoblast cells.

E-PIS'TO-MA. That part of the face of flies situated between the front and the labrum.

E-QUI-LAT'E-RAL. Having the sides equal, as in Brachiopod shells.

E'QUI-VALVE. Applied to shells like the clams and most Lamellibranchs, which are composed of two equal pieces or valves.

EX-SER'TED. Protruded; opposed to enclosed.

EX-U'VI-UM. Cast-off skin.

FIS-SIP'A-ROUS (Lat. *fissus*, cleft; *pario*, to bring forth). Applied to a form of asexual generation where the parent splits into two parts, each part becoming a new individual.

FŒ'TUS. The embryo of a mammal.

GANG'LI-ON (Gr. *gagglion*, a swelling or lump). A centre of the nervous system, consisting of nerve-cells and fibres.

GEM-MIP'A-ROUS (*gemma*, bud; *pario*, to bring forth). Applied to a form of asexual generation where new individuals arise as buds from the body of the parent.

GLA'BROUS. Smooth; opposed to hairy; downy, villous.

GLAND. A cellular sac which secretes, *i.e.* separates, certain constituents of the blood. The liver is a gland secreting bile; the kidneys excrete urine.

GLAU'COUS. Bluish green or gray.

GON-OP'O-DA (Gr. *gone*, generation; *pous*, *podos*, foot). The modified first pair of abdominal appendages of the male lobster, shrimps, and crabs.

HÆ'MAL (Gr. *haima*, blood). Connected with the blood-vessels or heart.

HAL'LUX. The thumb or great toe.

HAL'TER-ES (Gr. *halteres*, poisers). Balancers: the rudimentary hind wings of Diptera.

HAUS'TEL-LATE. Furnished with a proboscis so as to take food by suction.

HE-MIP'TE-RA (Gr. *hemi*, half; *pteron*, wing). An order of insects with the fore-wings partly opaque, hence called hemelytra.

HER-MAPH'RO-DITE (Gr. *Hermes*, Mercury; *Aphrodite*, Venus). Any animal having the organs of both sexes, usually the ovary and testes, combined in the same individual.

HE-TE-RO-CER'CAL. Unevenly lobed, as in the tail of sharks and Ganoids, when the backbone is prolonged into the upper lobe.

HET-E-ROG'A-MY. = Parthenogenesis.

HEX-A'PO-DOUS. Provided with six feet.

HO-MO-CER'CAL. Even-lobed, as in the tails of bony fishes.

HO-MOL'O-GY (Gr. *homologia*, agreement). Implies identity in structure between organs which may have different uses; as the fin of a whale, and the foot of a dog, or a bird's wing. Homology implies blood-relationship, *i.e.*, a community of origin between parts which may have distinct uses.

HY'DA-TID. The bladder-worm, or the cystic stage of a tapeworm.

HY-MEN-OP'TE-RA (Gr. *humen*, hymen, or membrane; *pteron*, wing). An order of insects with two pairs of membranous wings.

HY'OID (Gr. Υ, *eidos*, resemblance). A bone in mammals resembling the Greek letter U; its form being different in other vertebrates: also called *os linguæ*, from its supporting the tongue.

HY'-PO-BLAST. The under or inner layer of the embryo. = ectoblast, and the endoderm of the adult.

IMÁ-GO. The final or fourth, winged and adult state of insects.

IN-E-QUI-LAT'E-RAL. Having the two ends unequal, as in the clam, quohog, and most Lamellibranch shells.

IN-E'QUI-VALVE. With one valve

differing in size or shape from the other, as in the oyster or Brachiopod shells.

IR'RO-RA-TED. Freckled; sprinkled with atoms.

LAMB-DOI'DAL. Referring to the lambdoidal or Λ-shaped suture, with the apex upward, in a mammal's skull.

LAM-EL-LI-BRAN'CHI-A-TA (Lat. *lamella*, a leaf or sheet; *branchia*, gill). A class of mollusks with large leaf-like gills.

LAR'VA (Lat. *larva*, a mask). The second stage of the insect, a caterpillar, grub, or maggot.

LUM'BAR (Lat. *lumbus*, a loin). Connected with the loins.

LU'MEN. The cavity of an organ.

MA-LI'PE-DES. The fourth and fifth pairs of head-appendages of chilopod Myriopods.

ME-DUL'LA (marrow). The spinal cord of vertebrates.

MEN'TUM (chin). The basal piece or sclerite of the labium or second maxillæ of insects. Submentum is the posterior division of the mentum.

MES-EN'TE-RON. The mid-gut or stomach.

MES'EN-TE-RY (Gr. *mesos*, intermediate; *enteron*, intestine). The membrane between the intestine and abdominal walls.

ME'-SO-BLAST. The primitive, embryonic mesoderm.

ME-TAG'E-NE-SIS. Alternation of generations.

ME'-TA-MERE. The same as somite or arthromere.

MON-Œ'CI-OUS (Gr. *monos*, single, *oikos*, house). With the sexual glands, etc., united in the same individual.

MY'-O-BLAST. The embryonic cells which become muscle cells.

MYR-I-OP'O-DA (Gr. *murios*, thousand; *pous, podos*, foot). The class of tracheates comprising the Millepedes and Centipedes.

NE-MAT'O-CYST (Gr. *nema*, a thread; *kustis*, a bladder). The nettling, stinging organs or thread-cells or lasso-cells of the jelly-fishes and polyps, etc.

NE-PHRID'I-A (Gr. *nephros*, kidney). The segmental organs of worms, etc.

NEU-ROP'TE-RA (Gr. *neuron*, nerve; *pteron*, wing). The order of net-veined insects with a complete metamorphosis.

NID-A-MEN'TAL. Referring to a nest, or egg-sac.

NO'TO-CORD (Gr. *noton*, back; *chorde*, a string), or *chorda dorsalis*. The primitive support of the body of vertebrate embryos, larval ascidians, and the backbone of the lancelet and lampreys.

OB'TEC-TED. Covered; concealed.

O'DO-NA-TA (Gr. *odous*, teeth) The dragon flies.

O-DON'TO-PHORE (Gr. *odous*, a tooth; *phero*, I carry). The so-called tongue or lingual ribbon of the higher mollusks.

Œ-SOPH'A-GUS (Gr. *oisos*, a reed ; *phagein*, to eat). The gullet.

ON-TOG'E-NY (Gr. *on*, *ontos*, being; *gens*, birth). The development from the egg, of an individual animal.

O-PER'CU-LUM (Lat. *operio*, to cover). In fishes one or more bones covering the gills ; in Gastropod mollusks a horny plate or solid limestone mass closing the orifice of shells.

O-PIS-THO-CŒ'LOUS (Gr. *opisthen*, behind ; *koilos*, hollow). Those vertebrates with bodies hollow behind and convex in front.

O'RAL. Related to the mouth.

OR-NI-THO-DEL'PH I-A (Gr. *ornis*, bird ; *delphus*, womb). The sub class of mammals and order *Monotremata*.

OR-THOP'TE-RA (Gr. *orthos*, straight ; *pteron*, wing). The order of insects with straight narrow fore-wings, as the grasshoppers.

OS-TRA'CO-DA (Gr. *ostracodes*, shelled). A group of shelled crustacea.

O'TO-LITHS (Gr. *ous*, ear ; *lithos*, stone). Small bones suspended in the internal ear of fishes, or concretions in the auditory sacs of invertebrates.

O-VIP'A-ROUS (Lat. *ovum*, an egg; *pario*, I bring forth). Applied to animals bringing forth eggs instead of living, active young.

O-VI-POS'I-TOR (Lat. *ovum*, an egg; *pono*, I place). An organ in insects homologous with the sting, by which eggs are deposited in solid substances.

O'VI-SAC. A sac or bag-like membrane attached to the parent, and containing eggs.

O-VO-VI-VIP'A-ROUS (Lat. *ovum*, an egg; *vivus*, alive; *pario*, I bring forth). Applied to such animals as retain their eggs in the body until they are hatched.

PÆ DO GEN'E-SIS. Parthenogenous development in larval insects.

PAL'LI-UM (Lat. a cloak). The mantle or body-wall of mollusks, which secretes the shell; adj. pallial.

PA-PIL'LA. A minute soft projection.

PA-REN'CHY-MA (Gr. *paregchuma*, from *para*, *en*, *chuo*, something poured in besides). Applied to the proper substance of viscera, excluding connective tissue, blood-vessels, and other accessory parts.

PAR-THE-NO GEN'E-SIS (Gr. *parthenos*, virgin; *genesis*, generation). Reproduction by direct growth of germs from the egg, without fertilization by male germs or spermatozoa, as in the aphis, gall-insects, fluke-worm, etc.

PEL'A-GIC. Living on the high seas, away from the coast; in mid-ocean.

PER'-I-SOME (Gr. *peri*, around; *soma*, body). In Crinoids the oral region of the cup or body.

PER-EN-NI-BRAN'CHI-A-TA (Lat. *perennis*, perennial; *branchia*, gill). Those Batrachia which retain their gills throughout life.

PER-IS-SO-DAC'TY-LA (Gr. *perissos*, uneven; *daktulos*, finger).

Those Ungulates with an uneven number of toes, as the horse.

Pe-ri-to-ne'um (Gr. *peri*, around; *teino*, I stretch). The membrane lining the abdominal walls and covering the enclosed viscera.

Per-i-vis'ce-ral (Gr. *peri*, around; Lat. *viscera*, the internal organs, especially of the abdominal cavity). The body-cavity containing the alimentary canal with its outgrowths.

Pha-ryn'ge-al. Relating to the pharynx.

Phy-log'e-ny (Gr. *phulon*, stem; *gene*, birth). The development by evolution of the members of a genus, family, order, class, or the animal kingdom as a whole.

Pi'ce-ous. Pitchy; the color of pitch; shining reddish black.

Pi'lose. Clothed with pile, or dense short down.

Plan'u-la. The two-layered embryo of Cœlenterates.

Pla-typ'te-ra (Gr. *platus*, flat; *pteron*). The order of insects represented by the white ants, Psocidæ and Perlidæ.

Plex'us (Lat. a knot). Applied to a knot-like mass of nerves or blood-vessels.

Pol-lex. The thumb or innermost digit of the hand or fore-foot.

Pol'y-pide or Pol'y-pite. The separate animals of a Hydrozoon.

Pre'o-ral. In front of the mouth.

Proc'ess. A projection; used chiefly in osteology.

Pro-cœ'lous (Gr. *pro*, front; *koilos*, hollow). Those vertebræ concave or hollow in front.

Proc-to-dæ'um. The primitive hind gut, or rectum.

Pro-tom'a-læ. The second pair of head-appendages in Myriopoda.

Pro'to-plasm (Gr. *protos*, first; *plasma*, from *plasso*, I mould). The albuminous, elementary matter forming cells and the body-substance of *Protozoa.*

Prox'i-mal (Lat. *proximus*, next). The fixed end of a limb, bone, or appendage; that nearest the body; opposed to *distal*, the farther end.

Pseu-do-po'di-a (Gr. *pseudes*, false; *podes*, feet). The temporary processes sent out from the bodies of *Protozoa.*

Pter-op'o-da (Gr. *pteron*, wing; *pous, podos*, foot). A class of pelagic mollusks.

Pu-bes'cent. Coated with very fine hairs.

Punc'tured. Marked with numerous small impressed dots.

Pu'pa (Lat. a doll). The third or usually quiescent, chrysalis stage of insects.

Py-lo'rus. The valve between the stomach and intestine.

Rat'i-tæ (Lat. *ratis*, a raft). A division of birds with a keel less, raft- or punt-like sternum.

Rhab'di-tes. The blade-like elements of the sting and ovipositor of insects.

Rhi-zo'po-da (Gr. *riza*, root; *pous, podos*, foot). The root-footed *Protozoa.*

Ro-TI'FE-RA (Lat. *rota*, a wheel; *fero*, I bear). A class of worms with a pair of ciliated vela which in motion resemble wheels.

SA-GIT'TAL. Referring to a line or plane parallel with the sagittal or median suture of the skull of higher vertebrates.

SAR'CODE (Gr. *sarx*, flesh; *odos*, way). Equivalent and earlier term for protoplasm.

SCA'BROUS. Rough like a file, with small raised dots.

SCLE'RITE. Any separate piece of an insect's integument.

SCUTE. Applied to the dorsal pieces in Myriopods.

SEP'TUM. A partition.

SO-MAT'IC. Relating to the body.

SOM'ITE. A segment of a segmented animal, such as a worm.

SE-TA'CE-OUS (Lat. *seta*, a bristle). Bristle-like.

SPI'RA-CLE (Lat. *spiro*, to breathe). The lateral breathing pores of insects.

STIG'MA-TA (Gr. *stigma*, a mark). A synonym of spiracle.

STO'LON (Lat. *stolo*, a shoot springing from the root of a plant). Applied to the root-like creeping growths of polyps and other Cœlenterates.

STO-MO-DÆ'UM. The primitive mouth and œsophagus of the embryo of worms and Arthropoda.

STREP-SIP'TE-RA (Gr. *strephis*, a twist; *pteron*, wing). A group of beetles, whose minute front wings appear as if twisted.

STRO'BI-LA (Gr. *strobilos*, a fir cone). The chain of zooids of a larval medusa; the chain of proglottides of a tape-worm.

SUC-TO'RI-AL. Adapted for sucking.

SU-PRA-OR'BI-TAL. Above the orbits.

SU'TURE. A seam or impressed line between the bones of the skull or parts of the crust of an Arthropod.

SYM'PHY-SIS (Gr. *sumphusis*, a growing together). The union of two bones.

TAC'TILE. Relating to the sense of touch.

TÆ-NID'I-UM. The band or chitinous fibre, forming the so-called "spiral thread" of the tracheæ of insects.

TEL'SON (Gr. *telson*, from *telos*, end). The rudimentary terminal segment of the abdomen of Arthropods.

TEN'E-RAL. A state of the Neuropterous imago after exclusion from the pupa, in which it has not fully completed its coloring, clothing, etc.

TEN-TAC'U-LUM (Lat. *tento*, I touch). A feeler or tentacle.

TER'GUM (Lat. back). The dorsal region of Arthropods.

TEST (Lat. *testa*, a shell). The thickened integument of *Tunicata*.

TES-TA'CE-OUS. Dull red; brick color.

THO'RAX (Gr. *thorax*, a breast-plate). The chest in vertebrates; the middle body in insects and some crustacea.

THY-SAN-U'RA (Gr. *thusanoi*,

fringes; *oura*, tail). The lowest order of insects.

TO-MEN-TOSE'. Covered with fine matted hairs.

TRA-BEC'U-LÆ (cranii), dim. of *trabs*, a beam. Applied to the longitudinal cartilaginous bars of the fore-part of the head of vertebrate embryos.

TRA'CHE-A (Gr. *tracheia*, the rough windpipe). The respiratory tube in vertebrates; the air-tube of tracheate insects.

TREM-A-TO'DA (Gr. *trema*, a pore or hole). An order of worms.

TRUN CA'TED. Cut squarely off; docked.

TU-BER-CU'LOSE. Covered with tubercles.

TUN-I-CA'TA (Lat. *tunica*, a cloak). The class of Chordata called Ascidians.

UM'BO (Lat. the boss of a shield). The beak of a Lamellibranchiate shell.

UN-GU-LA'TA (Lat. *ungula*, a hoof). The order of hoofed mammals.

U-RO-DE'LA (Gr. *oura*, tail; *delos*, visible). The tailed Batrachians.

U-RO-MERE' (Gr. *ouros*, tail; *meros*, a part). Any of the abdominal segments of an Arthropod.

U-ROP'O-DA (Gr. *ouros; pous, podos*, foot). Any of the abdominal feet of Arthropoda.

U-RO-SOME' (Gr. *ouros*, tail; *meros*, a part). The abdomen of Arthropods.

U-RO STERN'ITE. The sternal or under piece of the uromeres or abdominal segments of insects.

VAC-U-OLE' (Lat. *vacuus*, empty). The little cavities in the bodies of *Protozoa*.

VEIN. Applied to the ribs or "nervures" of the wings of insects; the branches of the veins are called *venules*.

VEN'TRAL. Applied to the under side of the abdomen, or of the body of invertebrates.

VEN'TRI CLE (Lat. *ventriculus*, diminutive of *venter*). One of the cavities of the heart or brain.

VER-RIC'U-LATE. With thick set tufts of parallel hairs.

VER-RU'COSE. Covered with wart-like prominences.

VER'TE-BRA (Lat. *verto*, I turn). One of the bones of the spinal column or backbone.

VER-TI-CIL'LATE. Placed in whirls.

VE-SI'CLE (Lat. *vesica*, a bladder). A little sac, bladder, or cyst.

VIS'CE-RA (Lat. *viscus*). The internal organs of the body.

VI-VIP'A-ROUS (Lat. *vivus*, alive; and *pario*, I bring forth). Applied to animals which bring forth their young alive.

ZO'ÖID (Gr. *zoön*, animal; *eidos*, form). The highly specialized organs of such animals as the Hydroids, and other compound forms which have a marked individuality, and which might be mistaken for genuine individuals.

ZO-O'PHYTE (Gr. *zoön*, animal; *phuton*, plant). Applied to the plant-like polyps, sertularians, and sponges.

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