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# PRINCIPLES

*OF*

# ECONOMIC ZOÖLOGY

BY


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# PREFACE

The authors have long felt the need of one book in the hands of the student which would give not only the salient facts of structural Zoölogy and the development of the various branches of animals, but also such facts of natural history—or the life and habits of animals—as to show the interrelations of structure, habit, and environment. For we believe that a knowledge of both structure and life-history is necessary before any suggestions or discoveries can be made concerning the principles which underlie and control all animal life, including that of man. For it is *principles and their application* for which we are searching.

This book is an attempt to supply this need. It is especially designed to accompany the "Field and Laboratory Guide" (Part I).

For the sake of the natural history many examples have been included. To reduce the size of the book it has been necessary to print this natural history in smaller type, but that in no way implies that it is of minor importance, and it is by far the most interesting portion of the subject. The scientific names need not, in all cases, be learned. They have been used because common names are so often misleading.

Much of the subject matter has been derived from our own observation and experience, but we have made use of material from all available sources and we have tried to give credit by continual reference to the authorities used. That a book of this character can never be original, everyone knows. The scope is too great for the observations of one lifetime.

We are aware that we have fallen far short of our ideal. But we believe the book will be of much service if followed as suggested and used in connection with Part I. "If a better system is thine, impart it frankly. If not, make use of mine."

THE AUTHORS.

KIRKSVILLE, MO.,
*August,* 1912.

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"There are more things in heaven and earth, Horatio,
Than are dreamt of in your philosophy."

SHAKESPEARE.

# PRINCIPLES OF
# ECONOMIC ZOÖLOGY

## BRANCH PROTOZOA

THE animals of this branch are one celled and microscopic, or very small. These cells may unite, but as the union is not organic, it is said to form a colony, and not an individual animal as is the case in the higher forms. A colony may consist of a few cells, as in Gonium, or of many cells, as in Volvox.

Since protozoans are so minute and their soft protoplasmic substance is so easily dried up, they are usually aquatic, but some forms are parasitic, while others, as *Amœ'ba terric'ola*, are terrestrial, but these live or remain active in moist places only. Protozoans are most abundant in salt water, or in stagnant pools of fresh water, and are found in almost all parts of the globe.

Since, by reason of their simplicity, protozoans are adapted for living where other animals could not exist, they are supposed to be the oldest or first animal life, and it is believed that they existed in the Archæan time.

**Numbers.**—There are many thousands of species of these protozoans, each species differing from all others in some detail, yet all agreeing in their unicellular simplicity. Only a few of the typical forms can be mentioned.

### CLASS I. RHIZOPODA

The lowest class, or *Rhīzŏp'oda*, is represented by the *Amœba* (Fig. 1). It is an irregular mass of colorless, semifluid, or jelly-like living protoplasm destitute of a cell wall. There is no distinct line between the clear outer homogeneous layer, or *ectoplasm*, and the inner granular substance, the *endoplasm*. Within the endoplasm is the *nucleus*, a small, round, denser mass.

Sometimes the *contractile vacuole*, a clear sphere of liquid and gas, appears, increases in size, then contracts, and disappears, and a new one is formed. This is supposed to aid in respiration

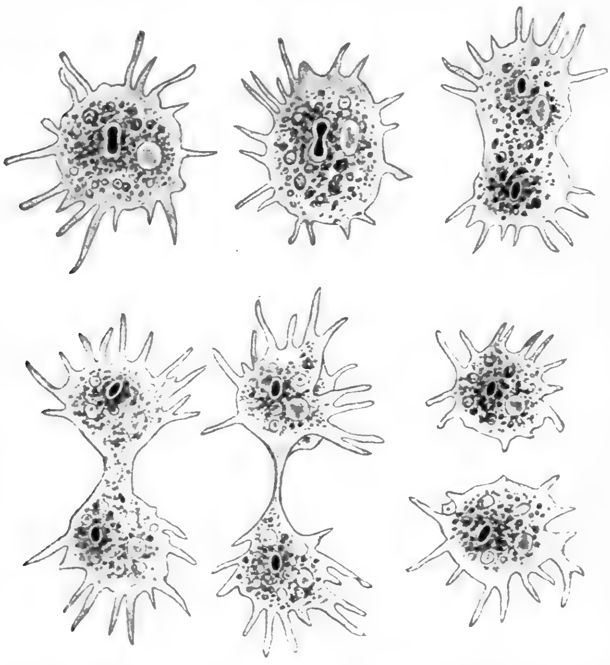


Fig. 1.—*Amœba polypodia* in six successive stages of division. The dark white-edged spot in the interior is the nucleus. (Schulze.)

and in carrying off the waste products formed by oxidation, such as carbon dioxid.

**Motion and Locomotion.**—Under the microscope the amœba may be identified by its movements. The body surface will be seen to protrude or rather flow out at one or several points, forming irregular lobes, called false feet, or *pseudopodia*, which may be contracted, or the whole body protoplasm may flow along after them, thus producing *locomotion* as well as constant change of form.

According to the experiments of Professor H. S. Jennings, particles attached to the ectoplasm move forward on the upper surface, disappear over the anterior edge, and, as the protoplasm flows along, appear again at the posterior end, to repeat the circuit, showing that this locomotion is a sort of "rolling process."

**Feeding.**—As the amœba flows or rolls along, if it comes in contact with a particle which is unfit for food, it passes by or over it, but if the particle is fit for food, it flows about and envelops it, and forms the so-called *food vacuole.* As this food vacuole moves along the endoplasm, the digestible part of the food disappears in digestion, while the indigestible portion is left behind as the protoplasmic body moves along.

**Multiplication** in the case of the *Amœba* is by binary division or fission and by sporulation. This becomes necessary, since the entire animal is but a single cell, and all the functions for the whole animal must be performed by this one cell. Hence, it must remain exceedingly small, so the nucleus, as well as the body substance, divides into two halves, and two individuals result.

**Encysting.**—Under unfavorable environment, such as drouth, the *Amœba* contracts into a tiny sphere, becomes encysted or encased in a horn-like membrane, and remains in a dormant condition until favorable environment returns to it, or it is transported by the wind or carried by other animals—in the dirt which has clung to them—to a favorable environment, where it bursts its cyst and resumes active life.

The **Radiola'ria** are marine Rhizopoda which have their pseudopodia arranged like rays. Many of these forms possess a silicious shell or skeleton, and myriads of these shells are found in rocks of various geologic ages. One type reproduces by swarm spores, the original nucleus dividing into hundreds of daughter-nuclei.

The **Foraminif'era** are Rhizopoda whose fresh-water forms have chitinous or silicious coverings, while the typical members, which are marine, have calcareous shells. When the animal dies the shell sinks to the bottom of the ocean. Such multitudes have existed that vast formations of chalk or limestone rock have been made by their shells. The stone of the Pyramids is said to be composed of fossil Foraminifera.

It is said that in the bodies of some Radiolaria are found unicellular Algæ, or microscopic plants, which furnish, even in this low stage of life, an example of *symbiosis, or the living together of different kinds of organisms for mutual benefit.*

## CLASS II. MASTIGOPHORA

The **Eugle'na** is a representative of the second class of Protozoans (*Mastigoph'ora*). It has a more fixed arrangement of parts than the *Amœba.* The cell is surrounded by a delicate membrane perforated at the blunt anterior end by a funnel-shaped mouth through which the food passes into the body substance. From the base of this mouth the protoplasm extends out in a long *flagellum* which, by its lashing, propels the body forward, and produces currents of water which bear food into the mouth. Back of the mouth is a tiny pigment spot beside a clear space which is sensitive to light.

## CLASS III. SPOROZOA

This class consists of parasitic protozoans. The **Gregari'na** is parasitic in the intestines, reproductive organs, or, rarely, in the body cavity of invertebrates, such as crayfish, insects, and worms. It absorbs liquid food from its host and has no mouth nor pseudopodia. One or two individuals become encysted and then break up into a number of minute portions called spores.

The **Hæmosporid'ia** are sporozoans which live in the blood-corpuscles of vertebrates. In man they are the germs which produce malaria. The malaria-producing protozoans spend part of their life in man and part in a certain genus of mosquito *Anoph'eles*). When this mosquito sucks the blood of a malarial patient the germs are taken into the stomach of the mosquito. "After fertilization the oösphere wanders into the intestinal wall of the mosquito, grows larger, encysts, and produces many sporoblasts, which in time form many sporozoites." These pass out with the saliva of the female *Anoph'eles* as it "bites" another person, and thus the germs of malaria are transferred to his blood, where, under proper conditions, they multiply rapidly, and fever results. It is evident that the bite of this mosquito does not cause malaria unless the mosquito is itself infected with the germs.

Yellow fever is believed to be caused by another sporozoan carried by a different genus of mosquito (*Stegomy'ia*).

## CLASS IV. INFUSORIA

The fourth class of protozoans is the *Infuso'ria*, of which the *Paramœcium*, or "slipper animalcule," is a type (Fig. 2). It is somewhat cylindric in form and is surrounded by a cuticle perforated with minute openings, through which the protoplasm projects in the form of short hair-like structures, called cilia, which are the organs of locomotion. On the ventral surface of the Paramœcium is a groove which runs backward and inward into a short tube or gullet. Both the tube and the gullet are lined with vibrating cilia which cause currents of water. These currents carry the food into the inner end of the gullet, where it is pushed by occasional constrictions into the soft endoplasm and carried about in its movements as a food vacuole. The undigested particles are cast out at a fixed point in the cell wall, but it is not permanently open, so it is not easily recognized. The Paramœcium is supplied with two coiled threads which may be used as *organs of fendese.* The Paramœcium has two nuclei, one, the macronucleus, supposed to be the seat of all vital functions, and the other, the micronucleus, which controls the reproduction. The Paramœcium reproduces by fission, both nuclei being divided, but conjugation also is manifested. In conjugation, two Paramœcia unite temporarily, exchange a portion of the micronuclei, and perform other processes; they then separate, and continue more actively the process of transverse division or fission.

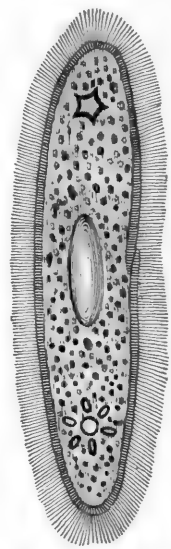


Fig. 2.—*Paramœcium aurelia.* In the center may be seen one of the nuclei, and at each end a contractile vacuole. (After Verworn.)

While these examples are only a few of the thousands of species and of the countless myriads of individuals of protozoans, yet, if carefully studied, they teach many things.

**Protoplasm.**—Living protoplasm is the active substance of all living organisms. All the forces or conditions which tend to

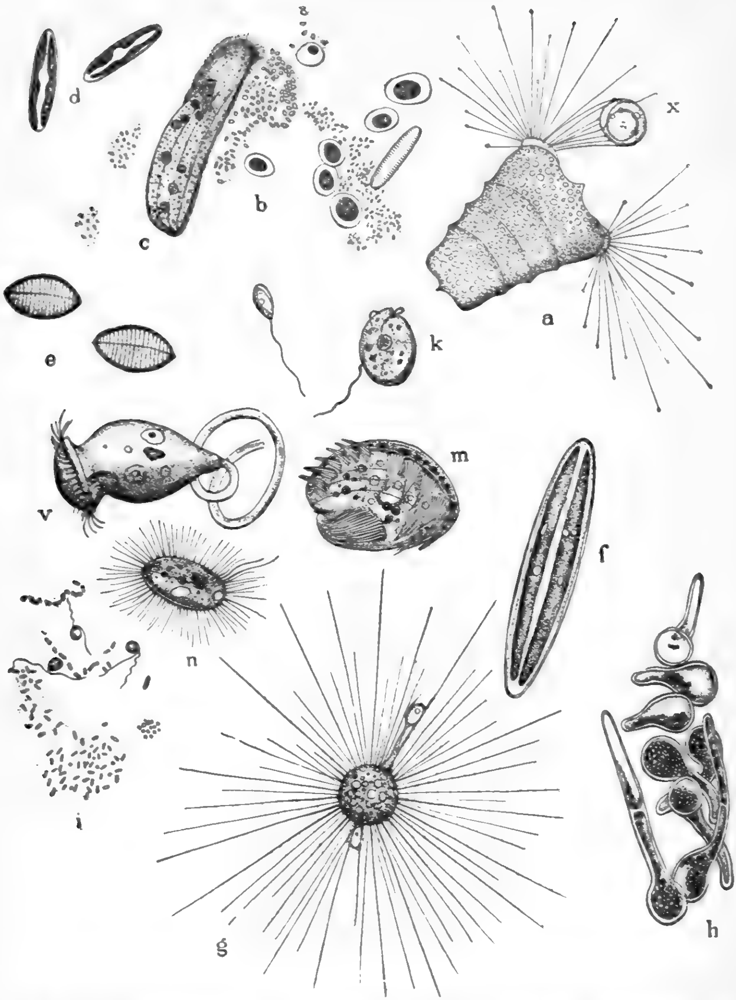



Fig. 3.—Organisms very abundantly found in common sea-water that has stood a few days in an open shallow dish: *a*, Acineta with embryo budding off; *b*, resting spores of *alga*, with bacteria; *c*, *Chilodon; d*, small *Navicula; e*, Cocconeis; *f*, larger species of *Navicula; g*, heliozoan, with two entrapped infusoria; *h*, germinating *alga* cells; *i*, small colony of bacteria in zoöglea stage with small flagellate infusoria near by; *k*, flagellate infusorian; *m*, infusorian *Mesodinium; n*, ciliate infusorian; *v*, Vorticella, with small portion of its stalk. (Bull. U. S. F. C., 1895.)

cause response or reaction in living protoplasm are called stimuli. The principal stimuli[1] may be classed as chemical stimuli, differences in temperature, light, contact, electricity, and gravity. Protozoans possess: (1) Irritability, that property of living protoplasm which gives it power to respond to stimuli; (2) automatism, the power of movement, or of changing the form.

**Locomotion.**—Protozoans move by means of pseudopodia, cilia, or flagella. Some forms, as the *Vorticel'la*, are fixed, and can move only by the contractility of their stalks or stems.

**Nutrition.**—The *food* of protozoans is composed of whatever minute organisms or fragments of organic matter they are able to obtain in the water. The parasitic forms, of course, simply absorb nutriment from the liquids of the host. The process of nutrition in the simplest protozoan consists in wrapping or, more correctly, flowing itself about the particle of food, absorbing the nutriment needed, and rejecting what it cannot use. Thus we see that it has the power of selective absorption, or *digestion.*

Circulation is brought about by simply changing the form of the body mass, thus changing the position of the absorbed nutriment in the one-celled body.

**Assimilation,** or the making of this absorbed material into its own body substance, next takes place, and, as a consequence, *growth.* The using up of assimilated material for heat or motion (energy), or *metabolism,* also takes place.

**Respiration,** or the taking in of oxygen and the giving off of carbonic acid gas and other wastes, is effected by the absorp-

[1] The reactions (orientation) of animals in response to these various stimuli are called *tropisms;* the response to chemical stimuli is called *chemotropism;* to heat, *thermotropism;* to light, *phototropism;* to contact, *thigmotropism;* to electricity, *electrotropism;* to gravity, *geotropism,* and so on. Loeb and others claim that the movements of the lower forms and many of those of the higher forms are purely physical and chemical reactions, just exactly as those known to us in the inorganic world. H. S. Jennings, who is another very careful investigator, asserts that his investigations show " that in these creatures their behavior is not, as a rule, on the tropism plan—a set, forced method of reacting to each particular agent —but takes place in a much more flexible, less directly, machine-like way by the method of trial and error. . . . This method leads upward, offering at every point opportunity for development, and showing even in the unicellular organisms what must be considered the beginnings of intelligence and of many other qualities found in higher animals."

tion of the one and the throwing off of the other through the surface.

**Excretion** takes place through the surface or through the contractile vacuole, there being a definite point at which the waste is ejected in the more advanced forms, such as the *Paramœcium* and the *Vorticella*.

**Multiplication.**—While these life processes are going on, the animal grows or increases in size. This size must necessarily be very limited, for only small animals could live in this primitive way; hence, when the protozoan has reached a sufficient size, it divides into two complete halves, each half containing its share of the original cell-nucleus, as well as of the cytoplasm or protoplasmic cell body. This cell division, or the multiplication of individuals, is called *fission*. After simple fission has taken place for many generations the fusion of two individuals, or *conjugation*, in which the nucleus of one individual is broken up and fused with that of the other, occurs. After this fusion, the process of fission continues, in which each new individual now contains a portion of the two parent nuclei which were fused in conjugation, instead of one parent nucleus as before conjugation. This surely contains a suggestion of sexual multiplication, though the conjugating cells may appear exactly alike. However, instances are given in which the individuals differ in size, the " males " being smaller and more mobile. Also we see, not exactly " alternation of generations," but, at any rate, alternation of *methods* of reproduction.

**Animal Mind.**[1]—Of the mental life of the protozoan little is known. If the rudiments of future complex animals is foreshadowed in the protozoan, why may we not recognize the fact that here, too, is found the *merest suggestion* of the mental life as well?

It has been abundantly demonstrated that protozoans possess *irritability* and *contractility*. It has been shown that they are sensitive to *touch* or *contact*, and, indeed, can discriminate between a hard substance and a softer substance suitable for food, as well as to recognize their kind by contact.

[1] Mind is here used in the biologic sense, and is the "sum total of all psychic changes, actions, and reactions."—Jordan and Kellogg's " Evolution and Animal Life," p. 448.

Weir, in his " Dawn of Reason," tells of observations with an *Actinoph'rys*, in which it was seen to discriminate between starch grains and uric-acid crystals.

Protozoans are also known to be responsive to heat and light. Weir also states as his opinion that all animals can distinguish day from night. The question remains as to whether or not this is ascertained by sight. However this may be, there can be absolutely no vision, because there is no mechanism for it.

**Importance of Protozoans.**—(1) They furnish, either directly or indirectly, food for all higher forms of life. (2) They are scavengers of decayed organic matter. (3) By their countless numbers throughout the ages, vast formations of chalk or limestone have been made. Myriads of them are still sinking to the bottom of the ocean as *Glŏbĭgeri'na* ooze or *Radiolarian* ooze. Since these animals are aquatic, geologists know that wherever these vast formations are found, there was once the sea. (4) Some of them are parasitic in the lower animals and in man, causing diseases which are ofttimes widespread and serious.

**Classification.**—(Adapted from Parker and Haswell):

| | *Class.* | *Examples.* |
|---|---|---|
| I. | Rhīzŏp'oda. | Amœ'ba, etc. |
| II. | Mastigŏph'ora. | Euglē'na, Vol'vox. |
| III. | Sporozō'a. | Grĕgarī'na, etc. |
| IV. | Infusō'ria. | Paramœ'cium and Vorticĕl'la. |

## BRANCH PORIFERA

ALL animals except the Protozoans are multicellular and are classed as Metazoa.

**Differentiation.**—In all we find, to a greater or less degree, *division of labor* among the cells, or the differentiation into tissues and organs for special functions.

**Reproduction.**—True sexual reproduction is the characteristic method among Metazoans.

**Porifera.**—These aquatic, many-celled animals were formerly considered as plants. Indeed, they look like seaweeds among the rocks at the bottom of the sea. Most of the sponges are marine, but there are a number of fresh-water forms.

Fresh-water sponges are widely distributed, and are attached to weeds or submerged objects along the margins of clear springs or ponds.

Sponges vary in color from a greenish hue to red, brown, or flesh color. All of the soft parts, as well as the skin or covering, is gone from the commercial sponges.

Their shape, as is seen in the sponges of commerce, is irregular even in the same species; it varies with the environment, in order that the sponges may adapt themselves to the surface to which they are attached or the depth and currents of the water. Their size varies from a fraction of an inch to two or three feet in diameter.

**Structure.**—The body of the Porifera consists of many cells arranged in two layers, an inner, or *endoderm*, and an outer, or *ectoderm*. There is a middle undifferentiated layer (*mesoglea*). The simplest sponge is cylindric or vase shaped (Fig. 4), while others, more complicated, consist of a system of branching tubes. At the free end of each is a small opening, the *osculum*, or *exhalant* orifice, while the walls of the cylinder are perforated by exceedingly minute *inhalant* pores. The ectoderm consists of flattened cells, which are also found to extend for a short distance inside the osculum, while the rest of the tube is lined with a single layer of peculiarly shaped columnar cells, each possessing a flagellum.

The **skeleton** is developed in the middle layer and may consist of silicious or of calcareous spicules of a great variety of form, sometimes they are anchor shaped, and again others are club shaped, spear shaped, or cruciform. The so-called glass sponges sometimes have beautiful silicious skeletons. In other cases the skeleton consists simply of fine, flexible, interwoven fibers of tough, horny spongin. It is the skeleton, denuded of the flesh, or *sarcode*, that covers it in life, which forms the commercial sponge. A few sponges have no skeletons.

Fig. 4.—A simple sponge (*Calcolynthus primigenius*) with part of outer wall cut away. (After Häckel.)

**Nutrition.**—There are no organs of digestion, circulation, or respiration in the sponge. The food consists of microscopic plants or animals, or of minute particles of organic matter floating in the water. The food-laden water enters through the inhalant pores and is carried by the movement of the flagella through the canals or paragastric cavities. The food as well as oxygen is taken up by the cells lining the canals and by the ameboid cells. The waste is carried out by the outgoing currents of water, which empty through the osculum, or, if the sponge is complex, the oscula.

**Locomotion.**—At first the larval sponge is free swimming, by means of cilia. It soon becomes fixed to some stone or other object or animal, and assumes the fixed ways of its ancestors.

**Multiplication.**—(1) Asexual, by external budding and the consequent formation of a united colony, or by internal gemmules; (2) sexual, thus insuring the perpetuation of the species. Sponges are *hermaphroditic*, that is, both the male elements (sperm cells) and the female elements or eggs (ova) are contained in the same individual (Fig. 5). It is from the union of a sperm cell with an ovum that the new individual sponge is developed. The sperm cells and the ova rarely mature at the same time in the same individual. Hence, the ova in the canals of one sponge are fertilized by the spermatozoa of another sponge, which are carried to them by the afferent currents of water in the canals, thus insuring cross-fertilization. The eggs are retained in the canals until the blastula stage of their

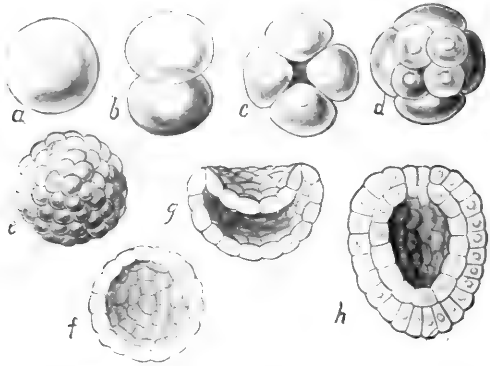



Fig. 5.—First stages in embryonic development of the pond snail (*Lymnæus*): *a*, Egg cell; *b*, first cleavage; *c*, second cleavage; *d*, third cleavage; *e*, after numerous cleavages (Morula); *f*, blastula (in section); *g*, gastrula just forming (in section); *h*, gastrula completed (in section). (After Rabl.) This may be taken as a type of the earliest development of all many celled animals (*Metazoa*). (From Jordan and Kellogg, " Animal Life," D. Appleton and Co., Publishers.)

development is reached, then they are set free and pass out at the exhalant opening or osculum. The fresh-water sponges (*spongilla*) bear small, seed-like bodies called gemmules toward the approach of winter. The parent sponge dies, the gemmules remain dormant until the next spring, when the rising temperature calls them to renewed life. They grow into mature spongilla, bear other gemmules, and thus the life-history of their race is repeated.

**Animal Mind.**—Sponges have no well-marked nerve-cells, though the simplest elements of both nerve and muscle have been described as belonging to them. It is evident that the sponge possesses *irritability* and *contractility.* It has the instincts of self-preservation and of the perpetuation of its species. No one can correctly interpret the psychologic phenomena of any animal until he has passed through the same psychic phenomena as that animal, and then become a man with the memory of these experiences and what they signified to that animal. Since we cannot do that, we must be content to *infer the significance* of certain biologic phenomena from comparison with our own experiences.

**Environment.**—As has been said, sponges are greatly influenced as to their shape by the objects to which they are attached and by the depth and currents of the water. They are much more nearly uniform in deeper waters. The plastic sponge well illustrates the influence of gravity (*geotropism*) upon an animal. It also shows *rheotropism.*[1]

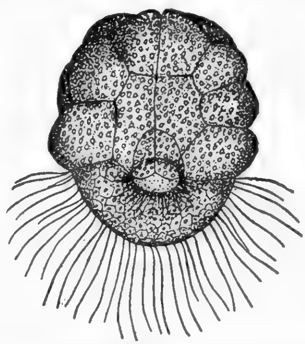


Fig. 6.—A young sponge. (After Burnet.)

**Protective Resemblance.**—Their protective resemblance is exceedingly good. They look so much like the seaweed and other aquatic vegetation that they are well concealed from the animals which prey upon them, such as worms, crustaceans, mollusks, and other marine invertebrates. Their tough, horny texture and their silicious or calcareous spicules are also a means of protection. Their characteristic odor, said to resemble garlic, makes them distasteful to fishes.

[1] See Glossary.

**Symbiosis.**—Examples of symbiosis are found among them, as that of the sponge and the crab. The sponge attached to the crab is carried about by it and given better opportunity of obtaining food and oxygen, while the crab, in turn, is concealed from its enemies by the sponge. In the fresh-water sponge, a green alga sometimes grows, giving the green color to the mass.

Various small marine forms are found in the sponges, giving good examples of *commensalism.* Sponges are never parasitic.

Fig. 7.—Spongers at work. The "sponge hook" is a three-toothed curved hook attached to a pole, the length of which varies with the depth of the water. The sponge-glass is a common water-pail with the bottom knocked out and a pane of window glass put in its place. It is used for seeing below the surface where the water is disturbed by ripples. (Cobb, in Circular 535, U. S. F. C., 1902.)

**Use.**—They are of use as food for other animals, and their skeletons form a very useful article of commerce.

The sponges of shallow water are obtained by men in boats, with a dredge or a long-handled hook or rake (Fig. 7): those of the deeper waters, by divers. They are then exposed to the air for a time and then heaped up in water again in tanks provided for them, where they decay. The animal matter in them is "beaten, squeezed, or washed out," and their skeletons sent to market (Fig. 9).

**Geographic Distribution.**—Fresh-water sponges are found in streams and lakes in all the continents. Marine forms are found in all seas and in all depths, from the shore between tide-marks to the deepest abysses of the ocean. They are most abundant in tropical waters.

**Geologic Distribution.**—Silicious sponges were not uncommon in the Cambrian Period, and are found in the formations from

Fig. 8.—Bringing sponges from the vessels to sponge wharf at Key West. (Report U. S. F. C., 1902.)

that time on. They were abundant in the Jurassic and very abundant in the Cretaceous of Europe; none have been found in that of America.

**Important Biologic Facts.**—Even in this low type there is a differentiation of certain cells for certain purposes, as the skeletal and reproductive cells. True sexual reproduction appears for the first time in the Porifera. Conjugation was noted in the Paramœcium.

**Classification.**—Sponges are of three kinds: (1) The calcareous sponges, containing much lime. They are of little or no commercial value. Example, *Grantia.* (2) The silicious sponges, in which the skeleton is largely silica. Example, *Euplectel'la.* (3) The horny sponges of commerce. Euspongia group. To this group belong the half-dozen species of Florida and the Mediterranean and the Red Seas. Our American supply comes principally from Florida and the Mediterranean Sea

Fig. 9.—A sponge auction at Anclote. (Report U. S. F. C., 1902).

from water not exceeding 30 fathoms deep. Examples of this group are *Spongia,* and the fresh-water forms of the genus *Spongilla.*

Most zoölogists make but one class of porifera; others, two classes:

I. Calca'rea.
II. Non-calca'rea.

## BRANCH CŒLENTERATA

THIS branch comprises our fresh-water *Hydra*, and a few allies, and the marine forms, jelly-fishes, corals, and sea-anemones. This branch finds representatives from the shore line and the surface to the profound depths of the ocean.

The **body,** which is usually radially symmetric, consists essentially of a two-layered sac, which is open at one end and closed at the other, and in which there is a simple or branched gastric cavity. The outer layer is called the ectoderm; the inner layer, the endoderm, and a gelatinous non-cellular layer between them, the mesoglea. Some cœlenterates are soft-bodied, others secrete a calcareous or limy substance called coral. Around the free open end of the sac-like body are a varying number of tentacles.

**Nettle Cells.**—Stinging or nettle cells are characteristic of this branch, except in *Cetenoph'ora,* where they are replaced by adhesive cells. These stinging cells, which are especially abundant on the tentacles, contain a fluid, and a spirally wound thread provided with barbs, which, when the animal is disturbed, are discharged into the body of the intruder, paralyzing it. It is then seized by the tentacles and drawn into the mouth.

**Size.**—Cœlenterates vary in size from the little fresh-water hydra, a fraction of an inch in length and of the diameter of a pin, to the giant jelly-fishes, as the *Cya'nea,* which sometimes reach 7 or 8 feet in diameter and have tentacles more than 100 feet long.

**Locomotion.**—Some members of this branch are free, as the jelly-fishes; some are permanently fixed; as the Corals, while some, as the *Hydras,* are temporarily fixed, moving from one position only to adhere to another, and thus making slow progression.

**Multiplication** is both sexual (by eggs) and asexual (by budding).

**Origin.**—They are of ancient origin, being abundant in the Cambrian Period.

## CLASS I. HYDROZOA

In this class are found the worldwide fresh-water *Hydras* and the marine *Hydroid Colonies,* such as *Campanula'ria* or *Obe'lia.*

The *Hydras* are small fresh-water *Hydrozo'a* from $\frac{1}{8}$ to $\frac{1}{4}$ or possibly $\frac{1}{2}$ inch in length. They may be white or colorless, or green or brown.

The **body** is a simple cylinder (Fig. 10) or sac, closed at one end, and near the other surrounded by six or eight tentacles,

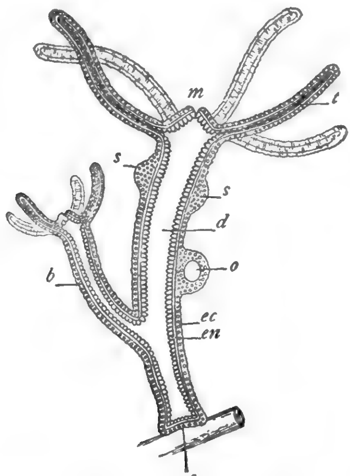



Fig. 10.—Hydra: Longitudinal section of animal, showing *m,* mouth; *t,* tentacle; *d,* digestive cavity; *b,* bud; *s,* spermary; *o,* ovary; *ec,* ectoderm; *en,* endoderm. Magnified. (From Dodge's "General Zoölogy," American Book Co., Publishers.)

above which is the conical *hypostome,* at the apex of which is the mouth. The *muscular fibers* of the ectoderm extend lengthwise, while those of the endoderm extend around the body.[1] If disturbed, the Hydras protect themselves by withdrawing into a tiny sphere, while the tentacles contract until they look like so many small buds. The endoderm has flagellate cells lining the gastrovascular cavity.

[1] Hertwig's "Manual of Zoölogy," Kingsley, p. 230.

The **food** is obtained by the viscid tentacles, which, when the *Hydra* is undisturbed, are extended (as is usually the body), ready to grasp the prey, for this tiny animal is carnivorous, feeding upon small organisms, usually crustaceans. There are nettle cells, or *nematocysts*, in the ectoderm of the tentacles. When an animal comes in contact with a tentacle, the nematocysts near the point touched throw out stinging threads which partially paralyze the animal by the fluid which they discharge into the wound they have pierced. The tentacles then pass the prey to the mouth, which opens into the gastrovascular cavity, in which digestion is carried on and into which the wastes are gathered and thrown out through the only opening, the mouth. The *Hydra*, by its wide-open mouth and enveloping lips, often takes in organisms much larger than itself.

Nerve-cells, sex-cells, and nettle-cells are situated in the ectoderm.

**Multiplication** in the *Hydra* is both sexual and asexual. It reproduces by budding, but as the buds mature they become detached, so that no permanent colony is formed. It also reproduces by eggs, the animal being *hermaphroditic,* that is, *the reproductive organs of both sexes are found in the same individual.* Near the base of the tentacles are found the spermaries from which the sperm cells are discharged into the water; the ovaries are situated farther down, near the lower end of the body. The eggs are cross-fertilized, that is, fertilized by the sperm cells of another individual. After fertilization the ova remain in the ectoderm for some time, when they become encysted in spiny cysts, drop off into the water, and sink to the bottom. They lie here till the following spring, when they break their casing and come forth as minute *Hydras.* In the encysted condition they are able to withstand cold and drouth, thus insuring the perpetuation of the species. *Hydras* also have the power of regenerating the whole body from a part in case of injury.

**Locomotion.**—The *Hydra* is temporarily fixed by adhering to the submerged stems of water plants by means of a sticky secretion from the closed end of the tube. It can detach itself, and, by grasping with its tentacles, can pull itself up and again attach the end of its tubular body to an object. By this caterpillar-like looping it is able to change its position or perform *slight locomotion.*

**Dispersal.**—While the mature *Hydra* has very limited powers of locomotion, or *direct dispersal,* its offspring may be widely

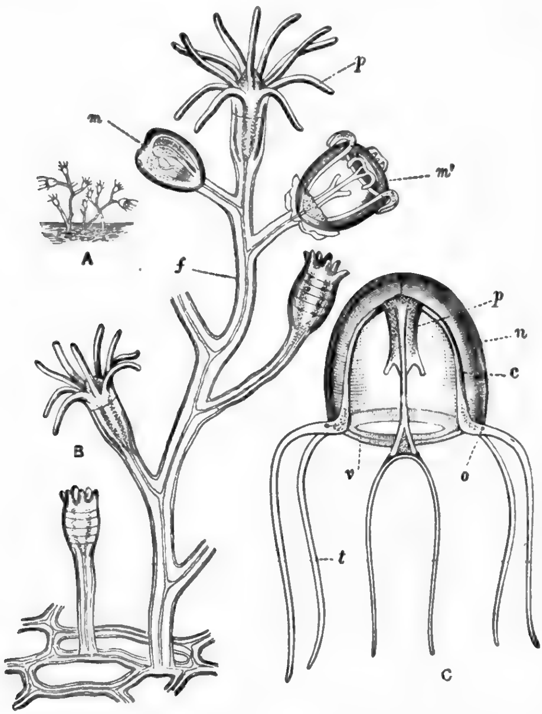



Fig. 11.—A, Part of the colony of *Bougainvil'lea mus'cus,* one of the compound *Hydrozoa,* of the natural size. B, Part of the same enlarged: *p,* A polypite fully expanded; *m,* an incompletely developed reproductive bud; *m',* a more completely developed reproductive bud; *f,* cœnosarc with its investing periderm and central canal. C, A free reproductive bud or medusiform gonophore of the same: *n,* Gonocalyx; *p,* manubrium; *c,* one of the radiating gastrovascular canals; *o,* ocellus; *v,* velum; *t,* tentacle. (After Allman.)

separated from the parent through *indirect dispersal,* or the drifting about of the encysted eggs by means of currents and waves, or the transporting, by the same means, of the débris to which they are attached in later life.

**Symbiosis** is exemplified by *Hyd'ra vir'idis*, or the green *Hydra*, the color probably being due to the presence of small green *algæ*.

Another species found in Russia, *Polypō'dium hydrifor'me*, of which little is known, is parasitic on sturgeon eggs.[1]

**A Hydroid Colony** (Fig. 11).—Suppose a hydra-like animal to bud and branch until it looked like a tiny bushy shrub. This will give you some idea of these plant-like hydroids. These hydra-like animals, or polyps, are connected by a system of tubes, the common stem or axis bearing many individual zoöids.

Fig. 12.—*Obe'lia flabella'ta.* (Hincks.)

Fig. 13.—*Obe'lia commissura'lis.*

*Obelia* (Figs. 12, 13) is a good representative of such colonies. The axis is made up of a creeping horizontal portion and of vertical axes. The short, alternate, lateral branches of these axes bear zoöids at their extremities, or, again branching, the polyps or zoöids are borne on the second set of branches. When these zoöids are immature, they are little, club-shaped enlargements. When mature, the polyps are surrounded proximally by a little glassy, protective cup, the *hydrotheca*, and distally bear about a score of tentacles. These are the nutritive zoöids, for *division of labor* is found here. The tentacle-bearing individuals procure the food, and since the tubes are all hollow

[1] Hertwig's "Manual of Zoölogy," Kingsley, p. 241.

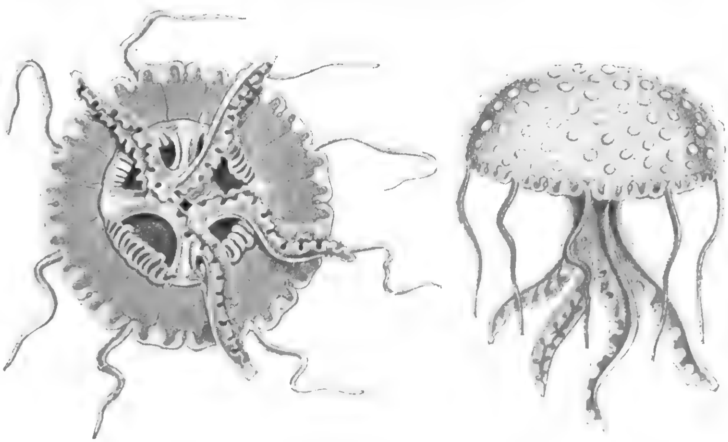
and connected, the whole colony shares the food thus supplied. When disturbed the polyp withdraws into the hydrotheca for protection.

**Blastostyles.**—But while the majority of the members of this colony are hydra-like, tentacle-bearing polyps which reproduce by budding only, and can enlarge the original colony, they have no power of directly producing a new colony in a more favorable position. There is, therefore, another set of individuals (see Fig. 11). These, while forming a part of this tubular colony, are modified in their form for a particular function. They are situated toward the proximal region of the colony and are long, cylindric bodies, known as *blastostyles*, each of which is enclosed in a transparent case, the *gonotheca*. These are the reproductive zoöids, and bear small lateral circular buds called *medusa* buds, which, as they mature, become detached and pass out through an opening now formed at the end of the gonotheca.

**Alternation of Generations.**—These medusa buds are sexual and *diœcious*, i. e., *the sexes are separate, one individual producing the ova and another the sperm cells.* After fertilization, which takes place in the water, the egg develops into a simple, free-swimming *ciliated larva*, the *planula*, which soon attaches itself to some object, develops into a polyp, and, by budding, forms a new colony. *This regular reproduction by budding, and then by eggs, and then by budding again is called alternation of generations*, or *metagenesis*.

**Medusæ.**—Careful study shows that the Medusa is only a highly developed or modified zoöid. The cylindric body has been developed into a disk or umbrella-shaped body (Fig. 14); the long axis has been greatly shortened and is suspended beneath the center of the sub-umbrella, as the under surface of the disk is called, where it takes the name of *manubrium*, or "handle." At the free end of this manubrium is the mouth, which opens into the gastric cavity that occupies the whole interior of the handle.

At the base of the manubrium four *radial canals*, equally distant from each other, are sent out to the circular canal, which runs around the margin of the umbrella, but within its substance. Thus, the food taken into the mouth is distributed to the whole animal. The whole canal system is lined by endoderm, which is ciliated. The endoderm also forms the axes of the tentacles. There is also a layer of endoderm between the radial canals extending from the circular canal to the gastric cavity. Between the endoderm and the ectoderm, which covers the convex surface or ex-umbrella, is a much-thickened jelly-like mass of the mesoglea, while between the endoderm and the ectoderm covering the sub-umbrella there is a thin layer of mesoglea. The ectoderm, of course, covers the tentacles, where it is well supplied with stinging cells. At the margin the ectoderm of both the sub- and ex-umbrellas forms a narrow



1 2

Fig. 14.—1, *Pela'gia panopy'ra,* oral view of mature medusa. 2. The same, side view. (Mayer, in Bull. U. S. F. C., 1903.)

fold or shelf, the *velum,* which hangs down when at rest, but draws up like a diaphragm across the bottom of the umbrella when the bell contracts. By the forcing out of the water the animal is forced forward, and so locomotion is effected. Around the outside of the velum is a row of *tentacles,* usually four or some multiple of four in number.

Muscles of a longitudinal character control the tentacles, while circular striped muscles surround the sub-umbrella and velum, and, by contracting the umbrella and velum, produce locomotion.

The nerve ring surrounds the margin between the circular muscles of the umbrella and those of the velum. At the bases of two of the tentacles of each quadrant there are sense organs. They probably aid the medusa in determining in what direction, with regard to the vertical, it is swimming, that is, whether it is moving up, down, or sidewise. In other medusæ the simplest of eyes, red pigment spots, which may or may not have a lens, are found.

The **food** of the medusa consists of both plants and animals. It is very voracious and grows rapidly after leaving the colony.

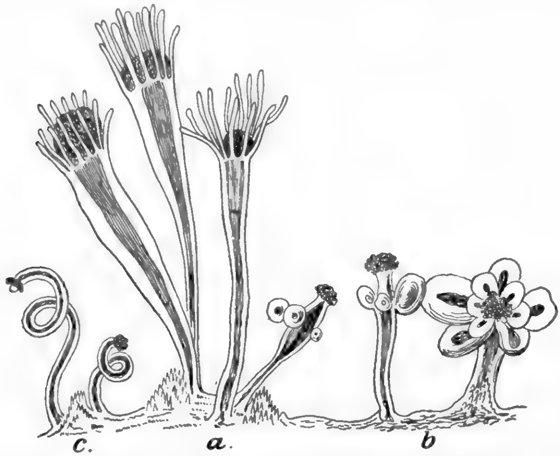



Fig. 15.—*Hydractin'ia polycli'na: a,* Nutritive individual; *b,* reproductive individual; *c,* spiral zoöids or fighting individuals. (Bull. 455, U. S. F. C.)

**Multiplication.**—After a time either eggs or sperm cells develop, and are set free in the water, where they unite with those of some other medusa and develop into the tiny larval form, which soon attaches itself and grows into a hydroid, to bud and branch and produce again the medusæ, thus repeating the life-cycle and the reproduction by alternation of generations.

There are more than a thousand species of the class *Hydrozoa.* In some forms (Fig. 15), as the *Hȳ'dractin'ia,* there are several classes of individuals—the nutritive, the defensive, and the reproductive—with the corresponding division of labor. These *Hydractin'ia* live upon the surface of the shells of sea-snails or whelks, which are inhabited by hermit crabs, and afford another good example of symbiosis. The *Hydractinia* gets free transportation, aiding it in securing food; it also probably feeds upon minute fragments of the crab's food; while the crab, in turn, is protected from intruders by the stinging cells of the *Hydractinia*. If the hydroids are in any way torn from the shell, the crab finds another colony, and, tearing it loose from its supporting object, places it upon its borrowed shell.

*Millep'ora alcicor'nis* is a species of so-called hydroid "corals"—the beautiful elk-horn or stag-horn coral of Florida. The permanent colony numbers thousands of individuals, which differ in their structure according to their division of labor. Their calcareous skeletons are a cuticular product of the ectoderm.

Fig. 16.—A Portuguese man-of-war (*Physalia*), with man-of-war fishes (*Nomeus gronovii*) living in the shelter of the stinging feelers. Specimens from off Tampa, Fla. (From Jordan and Kellogg, "Animal Life," D. Appleton and Co., Publishers.)

Another order of the class of Hydrozoa is characterized by a closed float containing air or gas which serves to keep the colony vertical in the water. In the "Portuguese man-of-war" (Fig. 16), found as far north as New England, there are suspended from the large float (3 to 12 cm.)[1] peacock blue, or, in some cases, orange in color, several kinds of individuals; some of them, many feet in length and armed with nettle cells, capture the food and bear it to the mouth-bearing or nutritive polyps, which digest the food and distribute it to the colony. Others, the feelers, are groups of deep blue medusoids resembling bunches of grapes, while others, with swimming movements, aided by the wind, drive the colony from place to place.

[1] Parker and Haswell.

### CLASS II. THE SCYPHOZO'A

Jelly-fishes are soft umbrella-like creatures resembling molds of jelly or gelatin, as one sees who picks them up along the beach, where they have been cast ashore by the waves. Their tissues are very watery, hence the scarcity of their fossil remains. However, very perfect impressions of jelly-fishes are found in the upper Jurassic Period. Most jelly-fishes are marine and free swimming, though a few are temporarily attached. They are most abundant in the tropics. Great schools of them are sometimes seen. Sometimes they are phosphorescent. They vary in size from about 4 mm., in the simple little, bell-like *Tessera,* to 1 foot in the *Aurelia,* and 7 or 8 feet in diameter in the *Cyanea,* whose tentacles sometimes reach the length of 130 feet. A small form, *Gonionemus,* found at Wood's Holl, Mass., is green and about 1 inch in diameter. It grows on eel-grass. All are carnivorous, feeding mostly upon crustaceans, though some of the larger ones capture fishes of considerable size.

The **food** is captured by the tentacles, which are suspended from the margin of the umbrella and which are armed with stinging thread cells.

**Locomotion** is effected by the flapping of the umbrella-like body, there being usually no velum.

Minute colored " eye-specks " are around the rim.

**Multiplication** usually is by alternation of generations, but the young medusa or *ephyra,* as it is called, undergoes a *metamorphosis* or change of form as it matures. In some cases the egg develops directly into the larval medusa and there is no alternation of generations, but simple metamorphosis.

### CLASS III. ACTINOZO'A

This class includes sea-anemones, sea-pens, and corals. Only the polyp form is found in this class, no medusa being known among them. They are exclusively marine. They are usually fixed and many form permanent colonies.

One point in their development is a step in advance of the Hydrozoa, *i. e.,* the development of a gullet, esophagus, or *stomodæum,* the beginning of which is seen in the Scyphozoa. The hypostome, which in Hydrozoa bore the mouth at its apex, is here inflected and forms a tube dipping down into the body cavity, but not reaching the bottom of it. The lower end of this tube or esophagus (which is really the beginning of the alimentary tube of higher animals) corresponds to the mouth of the *Hydra*, so that the tube is *lined with ectoderm*. The mouth is the only external organ, and serves both for the entrance of food and the ejection of waste. The body cavity about this tube is divided by thin partitions into radiating spaces.

No actinozoan is microscopic. All are long lived. One in an English aquarium lived more than sixty years.[1] The sea-anemones and all true corals producing reefs and islands have the number of their tentacles in multiples of six.

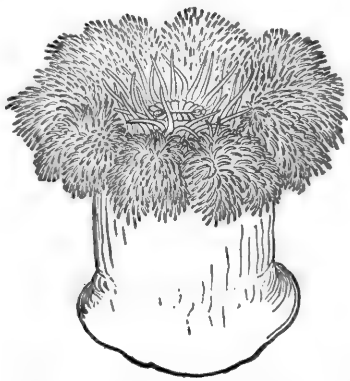


Fig. 17.—Sea-anemone (*Metrid'ium*). (Emerton.)

**The Sea-anemones** (Fig. 17).—As one gazes in wonder at the sea-anemones in their marine home, he can scarcely persuade himself that those beautifully colored objects, so flower-like—hollow cups with their petals and sepals of such wonderful tints—are else than flowers. But he touches one, the " sepals and petals " close in upon his fingers, they tingle, and he finds that this flower-like object is an animal and that the " sepals and petals " are tentacles. A very different appearance it makes when the body has been drawn down close to its attachment by the longitudinal muscles, while the circular muscles shut in the

[1] "General Zoölogy," Dodge, p. 75.

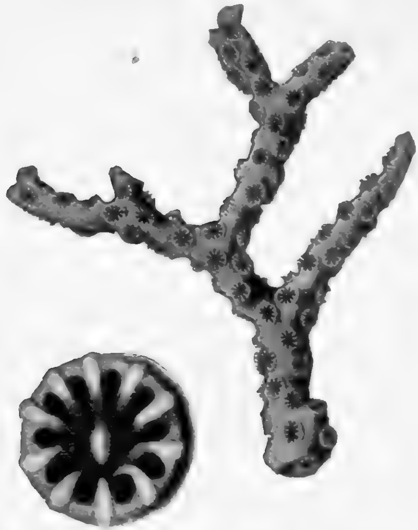


Fig. 18.—*Athe'lia mirab'ilis.* General view of branch. View of a calice. (Vaughan, in Bull. U. S. F. C., 1900.)

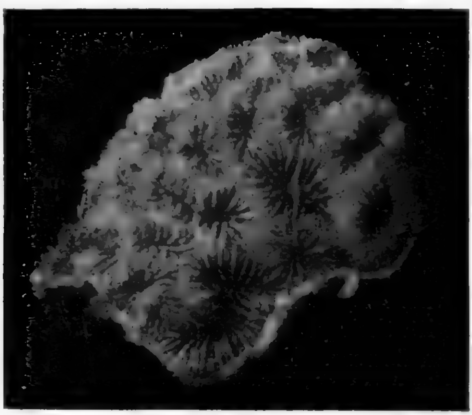


Fig. 19.—*Favia fragum* (Esper). View of a corallum from the side. (Vaughan, in Bull. U. S. F. C., 1900.)

retracted tentacles until it looks like a round mass of flesh. The tentacles are hollow and are armed with lasso cells, which are useful not only for defense, but for capturing crabs and small fishes which form the anemone's food.

Sea-anemones are solitary, that is, they form no permanent colony. They have no true skeleton. There is no alternation of generations. They vary in size from $\frac{1}{8}$ inch to 2 feet in diameter, and, though attached, have the power of changing their position.

**The Stony Corals** (Fig. 18).—The coral polyps resemble small sea-anemones on a much-branched stem. The calcareous skele-

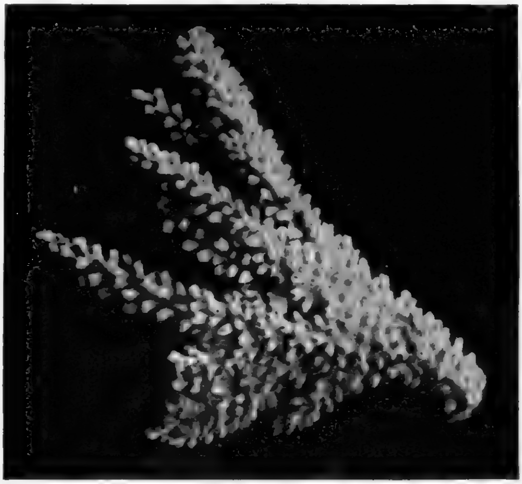


Fig. 20.—*Isopo'ra murica'ta forma prolif'era lam.* End of branch, height 9 cm. (Vaughan, U. S. F. C. Bull., 1900.)

ton is secreted by the ectoderm. The branched form arises from the continual budding and branching from a parent stem. The different forms (Fig. 19) of coral are caused by the different modes of budding in the various species. Corals are of various colors and some are said to be phosphorescent.

The members of a coral colony are organically connected. Each feeds himself, it is true, but no individual of the colony is independent of the others.

The **size** varies from that of the head of a pin to $\frac{1}{2}$ inch, the solitary mushroom coral being sometimes of the exceptional size of 1 foot in diameter.

These myriads of coral polyps (Fig. 20) secrete great quantities of lime, the waves break off the branches, grind them up, mix them with sand and shells, and thus build up coral reefs and islands of vast extent. These are confined to warm regions

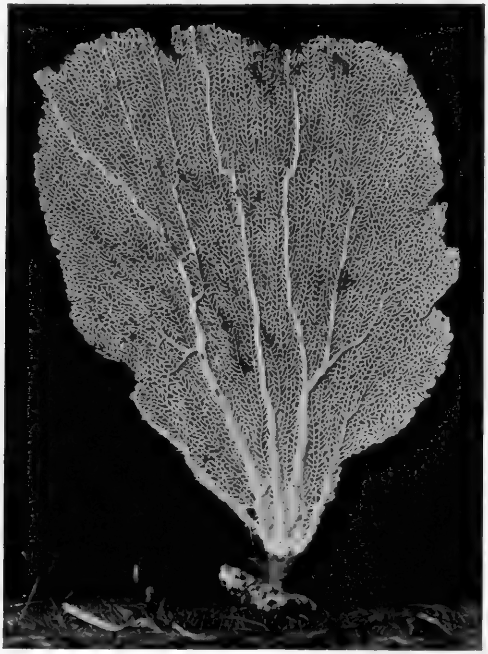


Fig. 21.—A sea-fan.

about 30 degrees on each side of the equator, since coral colonies cannot live in temperature below 60° F., and for a full luxuriance a higher temperature is necessary.[1] They are also shallow water animals, living from the high-water-mark to a depth of not more than 20 fathoms. They must also have salt water, hence they cannot live at the mouth of a river.

[1] Scott's "Geology."

The *Octocoral'la*, or those forms which have eight tentacles, are found in all seas, both in shallow water and at great depths. They include the organ-pipe coral, the precious red coral (*Corallium rubrum*) of the Mediterranean Sea, and the sea-pens and the sea-fans. The mesoglea of many octocoralla contains irregular calcareous spicules.

The **sea-pens** (*Pennatula'cea*) usually form an elongated colony. The stem, one end of which is embedded in the sand or mud of the sea bottom, is supported by a calcareous or horny skeleton. The distal portion is distended like a feather and bears the dimorphic polyps.

Fig. 22.—Photograph taken with the camera submerged, to show aquatic animals in their natural environment. In the background are seen sea-fan and branching gorgonian. (Bull. U. S. B. F., 1907.)

The **sea-fans** (*Gorgona'cea*) (Fig. 21) have a branched colonial axis formed of horny or calcareous substance from the ectoderm, with spicules in the mesoglea.

In some cases the skeleton formed by the spicules forms a branched axis, as in *Corallium rubrum*, or it may form a " series of connected tubes for the individual, as in the organ-pipe coral (*Tubip'ora*)." "The red coral is found only in the Mediterranean Sea at a depth of from 10 to 20 fathoms."[1]

## CLASS IV. CTENOPHORA

The **Ctĕnŏph'ora,** or " comb-jellies," are so-called from eight bands of comb-like cilia fused at their bases, which surround their nearly transparent bodies. The body is non-con-

[1] Parker and Haswell's "Zoölogy."

tractile, and these cilia accomplish locomotion. They are free and single, there being no polyp stage. They are found from the tropical to the arctic seas. They are small—from 5 to 20 mm. in diameter—and their shape varies from that of a pear to a sac-like or ribbon-like form. They have but two tentacles. They are hermaphroditic, multiplying by eggs.

The central nervous system is represented by a ciliated area on the aboral pole, and is connected with a single sensory organ.

**Economic Value.**—The animals of this branch are of great use to man, indirectly, by furnishing food for other animals, and, directly, by the formation of great beds of limestone and of coral reefs and islands, also by forming an article of commerce of no small value.[1]

" The red coral of commerce is obtained in the Mediterranean Sea off the coast of Africa and the west coast of Italy. The price varies according to the color. The finest rose pink in large pieces is valued at $400 or more an ounce. The common article brings from $1 to $1.50 an ounce."[2]

**Geologic Distribution.**—The hydrozoa are believed to be represented by the *Graptolites*, which appeared in the Cambrian Period, were numerous in the Ordovician, greatly diminished in the Silurian, and almost extinct in the Devonian. Large numbers of casts of jelly-fishes are found in the Cambrian rocks.[3] Hydroids and true corals were important. Marine life and reefs were formed in the Silurian Period. Corals vastly increased in size and number in the Devonian Period, and were abundant in the Carboniferous, contributing largely to the limestone. Hydractinia were found in the Cretaceous Period.

**Important Biologic Facts.**—In the Ctenophora is found for the first time a true middle layer of mesoderm cells.[4]

In the hydroid colony is found the division of labor among the different sets of individual zoöids and a differentiation of structure according to their function.

[1] " The fishing for the red coral (*Corallium rubrum*) at Naples amounts yearly to half a million dollars."—Kingsley.

[2] Adam's "Commercial Geography."

[3] Scott's "Geology," p. 371.

[4] Parker and Haswell's "Zoölogy," vol. i, p. 207.

**Classification.—**

| *Class.* | *Examples.* |
|---|---|
| I. Hydrozō′a. | Hȳ′dra, Hydroid Colonies. |
| II. Scȳphozō′a. | Jelly-fishes. |
| III. Actinozō′a. | Sea Anemones and Coral Polyps. |
| IV. Ctĕnŏph′ora. | "Comb-jellies." |

## BRANCH PLATYHELMINTHES

**Plătyhĕlmĭn'thes,** or Flat Worms, have three germ layers, the *ectoderm*, the *mesoderm*, and the *endoderm*. They are flattened dorsoventrally and are bilaterally symmetric. They have no skeleton, no circulatory system, and no cœlom or body cavity. They have an *anterior* and a *posterior end*, but rarely a distinct head.

The **nervous system** is composed of superesophageal ganglia and lateral nerve-trunks.

The **excretory system** consists of water-vascular tubes. There is no anal opening.

**Development** is sometimes with and sometimes without a metamorphosis.

**Habitat.**—Some, as the liver-fluke and the tapeworm, are parasitic; others, as *Planaria,* live in fresh water. Some live in moist places or in the mud at the bottom of ponds and streams; while others, as *Leptoplana*, are marine.

**Size.**—The parasitic forms are sometimes 30 or 40 feet in length, while the free forms are but 2 or 3 inches in length. These are often found under stones, and are exceedingly delicate.

**Protective resemblance** is very great in some species, while a few are nearly transparent.

### CLASS I. TURBELLARIA

The class **Turbellā'ria** consists principally of non-parasitic forms which are ciliated externally. There is usually a digestive cavity. The prevailing shape is leaf-form, like that of *Plana'ria*. Some marine forms, however, are shaped like "a thin ribbon with puckered edges," others may be thickened and band-like, as in the land planarians, while others approach the shape of a cylinder. Locomotion is performed by the fine vibratile cilia which cover the surface. The ectoderm contains sensory and gland-cells.

## CLASS II. TREMATODA

The class **Trĕmatō′da** is comprised of worms either internally or externally parasitic. The body is usually thicker than that of the turbellarians. The form is usually leaf-like, though it is sometimes elongated. The anterior end is distinguished by the arrangement of suckers, and, in some of the external parasites, by eyes.

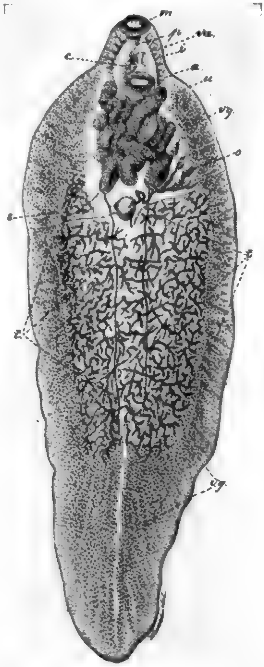


Fig. 23.—The common liver-fluke (*Fasci′ola hepat′ica*) enlarged to show the anatomic characters: *ac*, Acetabulum; *c, p.*, cirrus pouch; *i*, intestinal ceca; *m*, mouth with oral sucker; *ov*, ovary; *p. b.*, pharyngeal bulb; *s. g.*, shell gland; *t*, profusely branched testicles; *ut*, uterus; *va*, vagina; *v. g.*, profusely branched vitellogene gland. (After Stiles, 1894, p. 300.)

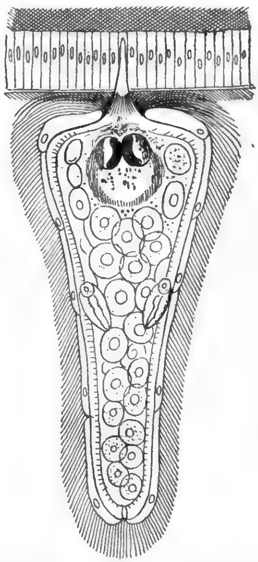


Fig. 24.—Embryo of the common liver-fluke (*Fasciola hepatica*) boring into a snail—x 370. (After Thomas, 1883, p. 285.)

The suckers are organs of adhesion and are sometimes armed with bristles or hooks. They are also used in locomotion, which is a sort of looping, like that of the leech. Except in two cases the vibratile cilia are not found on the surface.

The trematodes are hermaphroditic, and the development may be either with or without a metamorphosis.

The **Liver-fluke** (Fig. 23) is parasitic in sheep. The eggs pass down the bile-ducts of the sheep into the intestine, and from there to the exterior, when the embryo escapes by the separating of the lid, or operculum, from the egg-shell.

The ciliated larva swims about in the water or remains in the damp vegetation until it comes in contact with a pond or land snail (Fig. 24). It then bores into the body of the snail, where it develops into a *sporocyst* (Fig. 25), which produces *rediæ*. These *rediæ* possess a mouth, a pharynx, an intestine, and an opening for the escape of the young, which are internally produced. According to the season, these young are *cercariæ* or *rediæ*, several generations of which may follow before the *cercariæ* appear. The *cercariæ* are adapted for aquatic life.

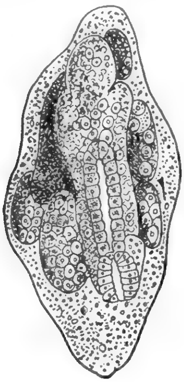


Fig. 25.—Sporocyst of the common liver-fluke from the body of a snail, containing rediæ in course of development—enlarged 200 times. (After Leuckart.)

Fig. 26.—Free-swimming cercaria of the common liver-fluke, greatly enlarged. (After Leuckart.)

The *cercariæ* (Fig. 26) escape from the snail, swim about with their vibratile tails for a time, when the tails drop off and the *cercariæ* become encysted on a plant. When this plant is eaten by a sheep, cow, or hog, the young escapes from the cyst and makes its way up the bile-ducts to the liver, where it develops into the mature worm and produces reproductive organs, thus completing the life-cycle.

Sheep pastured in swampy places are likely to be infected by this parasite, and wet seasons cause epidemics.

In England the annual loss of sheep killed by the liver-flukes is estimated at $1,000,000, and it has been known to reach $3,000,000 in one year. There have been a few cases of this parasite found in man.

## CLASS III. CESTODA

A **tapeworm** (*Tæ'nia so'lium*) is a parasite in the intestine of man. It is ribbon shaped (Fig. 27), being much narrower at the attached end, the head, or *scolex*.

The *scolex* is knob-shaped and bears the organs of attachment, a circle of hooks at the end, and a sucking disk or cup-shaped sucker on each of the four sides. The attachment is temporary.

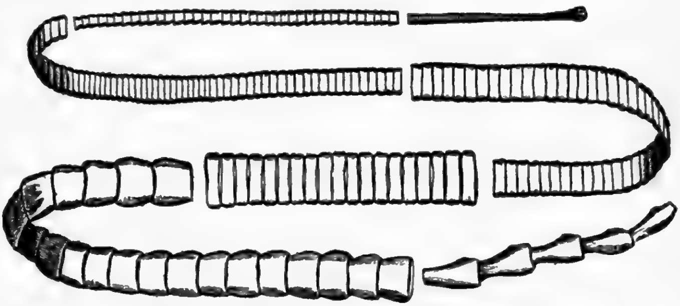


Fig. 27.—*Tæ'nia sagina'ta.* (Eichhorst.)

*Segments.*—The remainder of the tapeworm, except a short portion immediately posterior to the head, is made up of a series of segments or *proglottides*, the number of which varies in different species. In Tænia solium there are about eight hundred and fifty segments, while in the smaller species there are three or four hundred, and in the larger species, several thousand. These segments or proglottides are derived from the head by a kind of budding. Thus it is that so long as the head remains the tapeworm continues to grow.

**Digestion.**—There is no digestive system, the nutrition simply being absorbed from the liquids of the host.

The **nervous system** consists of a pair of ganglia, from which two main nerve-cords extend back through the length of the worm.

The **excretory** or **water-vascular system** consists usually of four principal trunks extending throughout the scolex and proglottides.

**Multiplication and Development.**—Each proglottis, as it matures, becomes hermaphroditic. Since these proglottides are originally developed from the head, the posterior ones are oldest. When filled with embryos, they are detached and pass out with the waste material from the intestine. When taken into the alimentary canal of the hog with its food, the hooked embryos bore through the intestinal wall and into the voluntary muscles, where they grow and continue to develop until they

Fig. 28—*Tænia echinococ'cus*, enlarged. (Mosler and Peiper.)

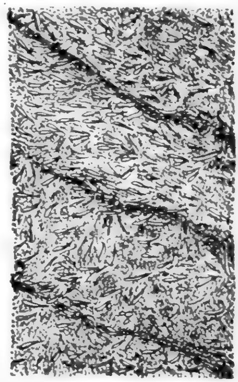


Fig. 29.—Portion of the intestine of a dog infested with echinococcus tapeworms, natural size. (Ostertag.)

reach the bladder-worm stage, or *cysticercus*. When pork containing a cysticercus is eaten, unless it has been killed by thorough cooking, the head is everted from the bladder-like covering and is attached to the intestinal wall of the host, where proglottides are rapidly developed. These mature in ten or twelve weeks.

**Species.**—There are many species of tapeworms. One form, *Tænia saginata*, which occurs in man, is obtained through eating beef cooked rare; another form, *Tænia solium*,[1] already mentioned, from eating pork; and another, *Bothrioceph'alus*

[1] *Tænia solium* is sometimes found in the encysted or intermediate stage in the muscles, eye, or brain of man. The eggs are thought to have been taken into the stomach with lettuce, cress, and the like, which had been watered with liquid manure.

*latus*, from eating fish. The latter species is the largest tapeworm found in man and sometimes reaches a length of 40 feet, and is composed of more than four thousand proglottides. It is rare in America, but is abundant in Russia, Switzerland, and the eastern provinces of Prussia. Another form (Fig. 28), perhaps the most formidable, is a small one, *Tæ'nia echinococ'cus*, which lives, in the adult stage, in dogs (Fig. 29), and the eggs are easily taken into the human stomach by a person fondling and kissing infested dogs. The embryos (Fig. 30), when set

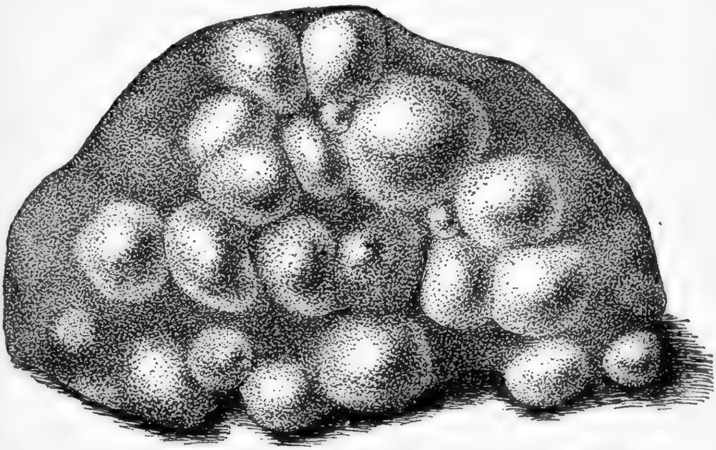


**Fig. 30.—Portion of hog's liver infested with echinococcus bladder-worm. (Stiles.)**

free, work their way into the liver, lungs, brain, or other organs, and produce tumors which sometimes reach a large size. Several species are found in domestic birds, one causing epidemics among chickens. A variety of *Tæ'nia cœnu'rus*, in the brain of sheep, causes "staggers." Rabbits, horses, cats, mice, and rats are also infested by tapeworms.

## CLASS IV. NEMERTINEA
(Doubtful Platyhelminthes)

The **Nemertineans** are most abundant in the mud or under stones along the seashore, only a few species living in fresh water. They differ from all other Platyhelminthes in having an alimentary tract with an anal opening and a distinct blood-vascular system.[1] They are usually diœcious.[2]

**Geographic Distribution.**—This branch of animals is the most widely distributed of any above the protozoans. They are found on land, in streams, and in the depths of lake and sea. The parasitic forms are found in some stage in almost every class of metazoans, while others have a commensal life with ascidians. All are carnivorous.

**Economic Importance.**—Many domestic animals are hosts for these parasites and much loss is occasioned thereby. A number of class Cestoda are parasitic in man and cause annoying if not dangerous diseases. The only sure preventive of these parasites is to have *all meats thoroughly cooked and fruits and vegetables well washed.*

**Important Biologic Facts.**—An anterior end—one placed foremost in locomotion—and a posterior end appear for the first time in platyhelminthes. Also right and left and dorsal and ventral sides are found.

In the Nemertinea there is an alimentary tract with a mouth and an anal opening. There is no distinct cœlom.

Class Turbellaria is the most primitive and the most closely related to the Cœlenterates, but it is not thought to be derived from them, though it shows special points of resemblance to the Ctenophora. It is thought that Trematoda and Cestoda are descendants of Turbellaria. In Trematoda is seen an alternation of generations consisting of the succession of several distinct generations in regular series. Such an alternation of generations is termed *heterogeny.* The simple structure of parasitic forms illustrates the principle that easy life—one requiring little exertion—is accompanied by a low stage of development.

**Classification.**—

| *Class.* | *Examples.* |
|---|---|
| I. Turbellā′ria. | Planarians. |
| II. Trĕmatō′da. | Liver-fluke. |
| III. Cĕstō′da. | Tapeworms. |
| IV. Nemertin′ea. | Carinella, Tetrastemma, etc. |

[1] McMurrich, p. 160; Osborn's "Economic Zoölogy," p. 85; Kingsley's Hertwig, p. 289.

[2] "Invertebrate Zoölogy," McMurrich, p. 162; Parker and Haswell, p. 279.

## BRANCH NEMATHELMIN′THES

**Round- or Thread-worms.**—The worms of this branch are elongated and cylindric and have a cœlom or body cavity. The vinegar-eel affords a good example. They differ from annelids in that they are not divided into segments or rings.

### CLASS I. NEMATODA

The members of class Nĕmatō′da are best known as parasites, but there are many fresh-water and marine forms.

The tough body wall encloses a body cavity which surrounds a straight alimentary tube having a terminal mouth and a ventral anal opening. An excretory system is usually present. The nervous system consists of an *esophageal* nerve ring which sends out six nerves anteriorly and six posteriorly. The only sense organs are sensory papillæ on the lips. The sexes are usually separate. Many of the aquatic forms are free. Some of the parasites infect plants, as *Tylen′chus trit′ici*, which does great damage to wheat, and *Heterode′ra schach′tii*, to turnips in Europe.

One form, Ascaris nigrovenosa,[1] living a parasitic life in the lungs of frogs and toads, is hermaphroditic. The embryos reach the alimentary canal and pass out with the waste material. In water they develop into a stage in which the sexes are separate. The eggs develop in the body of the female and devour the entire substance of the tissue of the mother, leaving only the cuticle. When set free they live in the mud until they are taken into the mouth of a frog, when they pass into the lungs and develop into the hermaphroditic stage. Here, again, is a peculiar alternation of generations (heterogeny), the alternation of an hermaphroditic with a diœcious form.

**Trichinel′la spira′lis** (Fig. 31) is another member of this class. In the adult stage it lives in the alimentary canal of man or of other mammals. The length of the adult male is about $\frac{1}{18}$ inch, and that of the female about $\frac{1}{8}$ inch. The sexes are separate. The young, at least one thousand, are born alive. The young worms (Figs. 32, 33) pass through the intestinal wall and make their way to the voluntary muscles, where they penetrate the *sarcolemma* and become encysted.

[1] Parker and Haswell, vol. i., p. 286. McMurrich, p. 176.

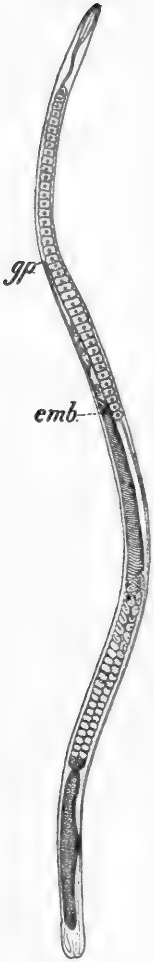



Fig. 31.—*Trichinella spiralis.* Adult female, showing embryos, *emb.*, in uterus; *gp.*, genital opening through which the embryos are discharged; enlarged. (Leuckart.)

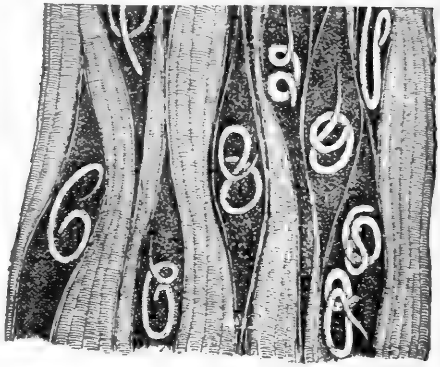


Fig. 32.—Larvæ of *Trichinella spiralis* in muscle, not yet encysted; enlarged. (Leuckart.)

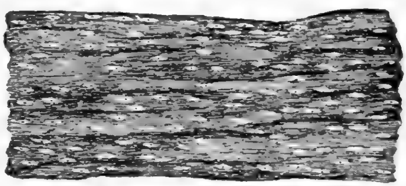


Fig. 33.—Piece of pork showing larvæ of *Trichinella spiralis* encysted in the muscle-fibers; natural size. (Ostertag.)

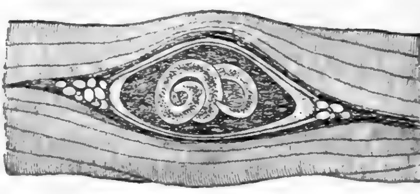


Fig. 34.—Encysted larva of *Trichinella spiralis;* enlarged. (Leuckart.)

When the infested flesh, unless thoroughly cooked, is eaten by man the cysts are dissolved, the young entering the small intestine, the worms continue developing and become sexually mature in a few days, the female penetrates into the superficial layer of the intestinal villi, and in the course of a month gives birth to young, and then dies. The young wander through the lymph-vessels and blood-vessels into the capillaries, pass into the muscle and become encysted (Fig. 34), as did the parents in the former host; 1 ounce of infested pork, unless thoroughly cooked, may liberate 80,000 worms. If half of these were females, each producing 1000 embryos, 40,000,000 worms would shortly begin to migrate into the muscles, causing *trichinosis*, which may be fatal. The worst epidemic known was in Emmers Leben, Saxony, in 1884, where 364 persons were infected from eating one pig, and 57 persons died within a month.

The **Guinea-worm** (*Dracun'culus medinen'sis*) is an East India parasite in the subcutaneous connective tissue of man. It is long and slender, sometimes 1 yard long. It forms abscesses under the skin. When the newborn young pass out of their host, if they pass into water, they enter the body of a small crustacean (the Cyclops), which is necessary to their development. It is supposed that they reach the human system through the Cyclops, which is swallowed in unfiltered drinking-water.

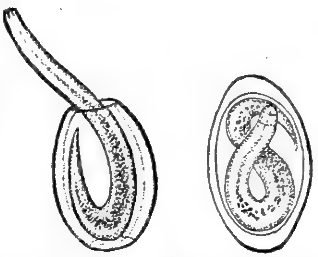


Fig. 35.—Eggs of the gape-worm (*Syn'gamus trachea'lis*), one of them hatching; enlarged 260 times. (After Mégnin.)

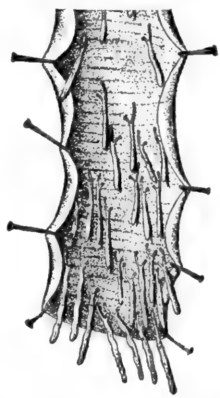


Fig. 36.—Windpipe of chicken split open to show gape-worms attached to its inner surface; enlarged. (After Mégnin.)

The **hook-worm** (*Neca'tor america'nus*), of the Southern United States and the West Indies, is thought to have been introduced from Africa by slaves.

" In hook-worm disease we have ground-itch, tibial ulcer, anemia, interference with physical and mental development, and, in bad cases, dirt eating."[1]

**Other Species.**—There are various other species. Some, as the pin-worm (*Oxyuris vermicularis*) and the round-worm (*As'caris lumbricoi'des*), are parasitic in man. Some are parasitic in other mammals and some in birds. One of the latter, *Syn'gamus trachea'lis* (Fig. 35), about $\frac{1}{2}$ inch in length, causes " gapes " in poultry (Fig. 36).

[1] Stitt, 244.

*Gordius,* the " hair-worm," is found in watering-troughs and erroneously believed by superstitious people or those ignorant of biologic principles to be horse hairs transformed into live worms. The larvæ are parasitic in the grasshopper, the adults live in water. Agassiz tells of experimenting with one 18 inches long which was wrapped in and out of its eggs, which were rolled up into a ball about the size of a coffee bean. He disentangled it and it " sewed " itself through and through the little white mass. Three times he separated the worm from its eggs, and each time the process of entangling was repeated, convincing Agassiz that there was a definite purpose in its attempts, and that even a being so low in the scale of animal existence has some dim consciousness of a relation to its offspring.[1]

He placed a small portion of the egg mass under the microscope, and estimated that there were not less than 8,000,000 eggs in the whole mass, which, when unwound, made a string 12 feet long.

## CLASS II. ACANTHOCEPHALA

Most of the class Acan'thocĕph'ala are small parasites. The chief genus (*Echinorhyn'chus*) is parasitic in the intestines of mammals, birds, reptiles, amphibians, and fishes. The largest species is found in the pig, and one species, *Echinorhynchus hominis,* is extremely rare in man.

## CLASS III. CHÆTOGNATHA

This class contains but two genera of curious arrow-shaped worms, all but one species of which are pelagic. They are hermaphroditic and have three pairs of cœlomic pouches, " fins," and bristle-like jaws.

**Economic Importance.**—In this branch may be found worms which are harmful and those which are helpful to man. Those forms like *Trichinella spiralis,* which are parasitic in man, are very injurious. The only preventive upon which it is safe to rely is *thorough* cooking.

Those forms which infest wheat and turnips are also harmful to man, in that they destroy his food; while Gordius, which is parasitic in the grasshopper, is indirectly beneficial to man.

**Important Biologic Facts.**—For the first time in the scale of animal life, a *cœlom,* or body cavity, appears. It is filled with a clear fluid, and through it extends the straight alimentary tube which consists of pharynx or stomodeum, an intestine, and a rectum. There are no circulatory and no respiratory organs.

[1] " Methods of Study in Natural History," Agassiz, pp. 63, 64.

This branch presents similarities to both Platyhelminthes and Annulata, but the relationship with either is not close.

**Classification.**—

| | *Class.* | *Examples.* |
|---|---|---|
| I. | Nĕmato′da. | Trichina, Gordius. |
| II. | Acan′thocĕph′ala.[1] | Echinorhynchus. |
| III. | Chætog′natha.[1] | Sagitta. |

[1] "The affinities of the Acanthocephala and Chætognatha with the Nematoda are somewhat doubtful," Parker and Haswell's "Zoölogy," vol. i, p. 275.

## BRANCH TROCHELMIN′THES

The animals associated together in this group may have developed independently from trochosphere-like ancestors, but since they agree in general characteristics, they have been regarded by some as constituting a well-marked phylum. On account of their size they were formerly regarded as protozoans, but they are multicellular and possess well-defined digestive, excretory, nervous, and reproductive systems. They have no circulatory system. Respiration takes place through the surface of the body.

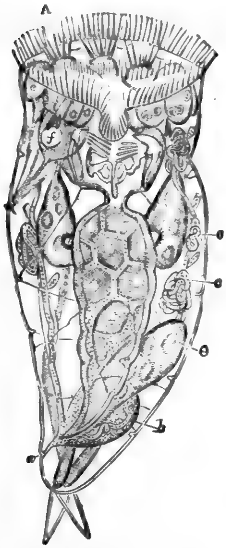


Fig. 37.—A rotifer, highly magnified (*Hydatina senta*): *A*, cilia; *a*, anus; *b*, contractile vesicle; *c*, water-vessels; *e*, ovary; *f*, ganglion. (From Holder's "Elements of Zoölogy," American Book Co., Publishers.)

### CLASS I. ROTIFERA

The Rotĭf′era (Fig. 37), or "wheel animacules," are many-celled, microscopic, unsegmented animals, most of which are worldwide inhabitants of fresh-water ponds and streams, or even of mud-puddles and water-troughs. A number of forms are marine.

The anterior end is a retractile disk surrounded by cilia, which are locomotive organs as well as aids to securing food. The mobile tail is often composed of telescopic rings, rendering it retractile into the trunk. The posterior ring of the tail frequently has a pair of pincer-like stylets. These and the adhesive glands enable the rotifer to attach itself to objects. There is a cœlom. The alimentary tube consists of a ventral mouth, an esophagus, a chewing apparatus (*mastax*), a glandular stomach, and an intestine which ends in a dorsal anal opening.

The nervous system consists of a dorsal ganglion with which are connected one or more eye-spots. There are peculiar tactile organs which consist of "rod-like structures tipped with delicate sensory hairs." There are excretory and reproductive organs.

They are *dimorphic* (of two forms). The sexes are separate. The males are rarer, much smaller, and less highly developed than the female. The female lays thin-shelled summer eggs of two sizes—the larger developing into females, the smaller into males—and thick-shelled winter eggs, which in the spring develop into females.

The majority are free swimming, being propelled by the trochal disk, but the Bdelloida also have a looping movement like that of the leech.

The rotifers may be dried up in the mud for several months, and upon being brought into contact with water they revive, or, some think, their contained eggs bring forth live animals. When in the dry condition they may be carried long distances on the feet of birds or by the wind.

## CLASS II. DINOPHILEA

These, like the rotifers, are modified trochospheres. They are minute and worm-like. They have a prostomium or head, a body of five to eight segments, and a short tail. Both the body and the head are ciliated. The Dinophilea are marine. In the arrangement of the nephridia in pairs, corresponding to the imperfect segments, and in the tendency to segmentation, they resemble the Annulata.

## CLASS III. GASTROTRICHA

This class resembles the Rotifera, though the relationship is not close. The class comprises a small number of minute fresh-water forms with spindle-shaped bodies, flattened ventrally. The dorsal surface bears several rows of cuticular processes, while the ventral surface has two rows of cilia.

**Classification.**—

| *Class.* | *Examples.* |
|---|---|
| I. Rotĭf′era. | Brachionus. |
| II. Dīnōphĭl′ea. | Dinophilus. |
| III. Găstrŏt′rĭcha. | Ichthydium. |

## BRANCH MOLLUSCOIDA

In this branch there is usually a body cavity, with the alimentary tube suspended by mesenteries. The mouth and anal aperture are near together, the dorsal surface being shortened. In the adult there is a tentacle-bearing ridge, or *lophophore*, about the mouth, containing a compartment of the body cavity. The tentacles are used not only in securing food, but in respiration. The nervous system consists of one or two ganglia or of a nerve ring.[1]

### CLASS I. POLYZOA

**Molluscoi′da,** which usually form colonies of zoöids by budding, are *Pŏlyzō′a*. The character of the colony differs, according to the mode of budding in the different species and the character of the exoskeleton. It varies from a bush-like colony to a calcareous or gelatinous sheet. Each zoöid has a crown of ciliated tentacles which can be extended or withdrawn. They are held together by the common exoskeleton formed by the ectoderm. There is no vascular system. The digestive tract is bent like the letter U, the anal opening being near the mouth, within or just outside of the ring of tentacles. The nervous system consists of a ganglion situated between the mouth and the anal opening. Polyzoans are usually hermaphroditic.

### CLASS II. PHORONI′DA

The classification of this group of worm-like forms of the sea is doubtful.

The worm is covered by a leathery cylindric tube into which it may withdraw. The body is unsegmented and bears a crown of tentacles. The mouth and anus are close together and are situated at the tentacle-bearing end of the body. The body cavity is divided into three chambers. There is an alimentary tract and a closed system of blood-vessels containing red blood-corpuscles. The central nervous system consists of a horseshoe-shaped nerve ring at the base of the tentacles. The Phoronis is hermaphroditic. There is a metamorphosis.

### CLASS III. BRACHIOP′ODA

Brachiopods are marine and were abundant in former geologic times, being very plentiful as early as the Cambrian Period. There are a few living species.

They are enclosed in a bivalve shell (Fig. 38), the valves being dorsal and ventral instead of right and left, as in the mollusks. They are attached to foreign objects by a *peduncle* or stalk, which passes through the larger or ventral valve near the hinge. They do not form colonies.

[1] Parker and Haswell, p. 313.

The shell is only partially filled by the body, and the valves are lined by the mantle lobes, whose free edges are bristled. The mantle lobes enclose a large mantle cavity. In the body is a spacious cœlom, which is extended into the mantle lobes. The cœlom contains the digestive tract, the liver, and the reproductive organs. The latter are chiefly in the mantle lobes. The digestive tract, which is bent much as in the Polyzoa, consists of gullet, stomach, and intestine. The mouth is surrounded by the tentacled lophophore or "arms." The inner surface of the tentacles is covered with cilia, which set up currents in the water and sweep minute animals and algæ into the mouth for food. The heart, usually present, lies

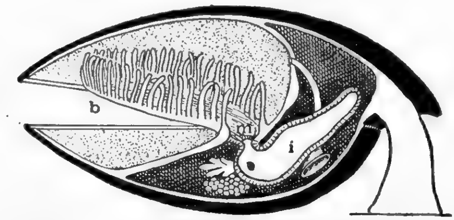



Fig. 38.—Diagram of a brachiopod: *b*, Tentacles around mouth, *m; i*, intestine; the shell black, the stalk to the right. (Kingsley's "Comparative Zoölogy," Henry Holt & Co., Publishers.)

dorsal to the stomach, to which it is attached. The nervous system consists of an esophageal ring. Sense organs are usually wanting in the adult.

**Important Biologic Facts.**—For the first time, according to the classification used, a closed system of blood-vessels and red blood-corpuscles are found.

The digestive tract has been developed into gullet, stomach, and intestine, and a liver also appears.

The Brachiopoda were formerly supposed to belong to branch Mollusca. But the valves of the shell are dorsal and ventral, not right and left, while the tentacled lophophore, the character of the nephridia, and the modified trochosphere larva all tend to show relationship with members of branch Molluscoida.

**Classification.**—

| *Class.* | *Example.* |
|---|---|
| I. Pŏlyzō′a. | Bugula avicularia (Bird's-head Coralline). |
| II. Phoronī′da. | Phoronis. |
| III. Brăchiŏp′oda. | Magellania. |

## BRANCH ECHINODER'MATA

**Plan of Structure.**—These animals are characterized by their five-rayed or pentameral plan of structure. While the echinoderm is radially symmetric, the development shows that it is derived from the bilateral type. The *larvæ* are bilateral. The

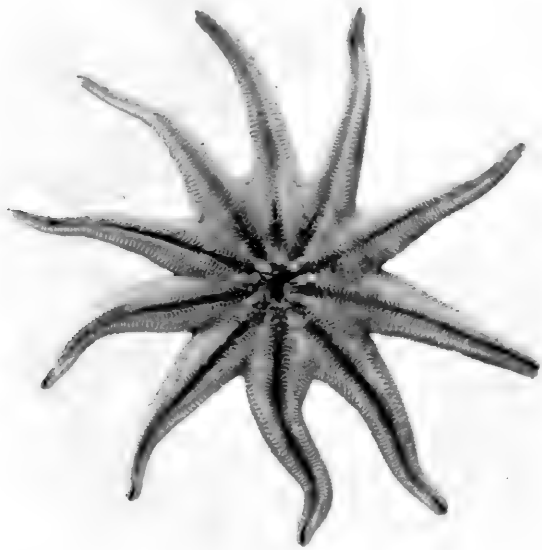


Fig. 39.—*Solas'ter endeca* (small specimen, natural size), oral view. (Bulletin, U. S. F. C., 1902.)

central portion is the *disk*, from which arms or rays project, as seen in the starfish. Close examination will reveal this pentamerous plan in the sea-urchin and in the sea-cucumber. For, suppose the rays of the starfish were flexed and their edges joined, the form of the sea-urchin would appear. Again, lengthen the sea-urchin in the direction of the mouth to aboral surface, and you have the form of the sea-cucumber. The crinoid also reveals this plan, not so clearly defined, but it is to be seen by the careful observer. The number of rays varies in the starfish, the author having found them with four, six, or even as many as twenty-two rays.

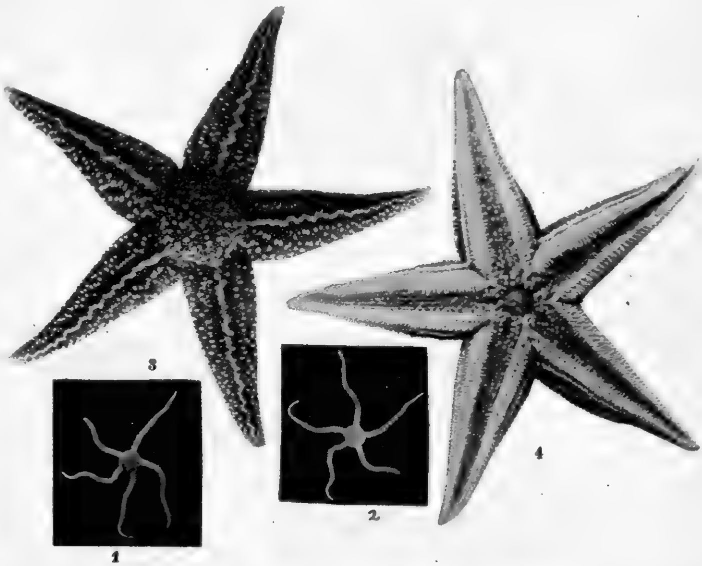



Fig. 40.—1 and 2, *Amphipholis squamata* (adult), aboral and oral views. 3 and 4, *Asterias vulgaris* (small specimen), aboral and oral views. (Bulletin, U. S. F. C., 1902.)

**The Skeleton or "Test."**—The body wall is composed of a thick leathery substance. In the mesoderm, under the epithelium, calcareous plates arise, many of which are armed with spines for protection. They are greatly protected also by their resemblance to their environment.

**Geographic Distribution.**—All echinoderms are marine, being abundant even in the deep sea. They are found in all parts of the globe, but are most abundant in the tropics. At the breeding season most of the free species frequent the shallow waters near the coast, where the ova are fertilized in the water. Echinoderms of the same species are often gregarious.

The **water-vascular system** is a marked characteristic of echinoderms (Fig. 41). It begins externally with the cal-

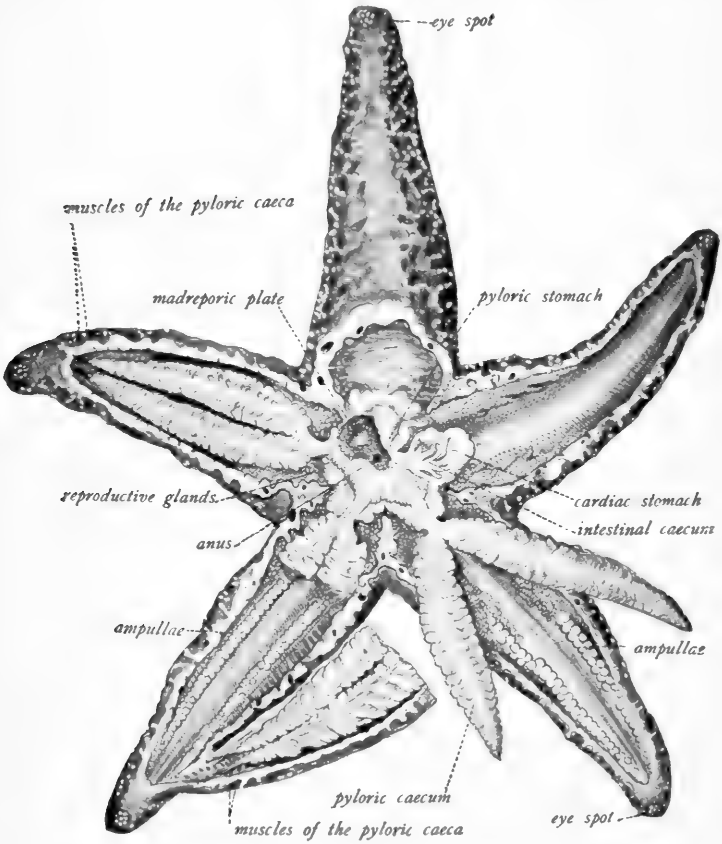



Fig. 41.—Dissection of a starfish (*Asterias* sp.). (From Kellogg.)

careous perforated *madreporic* plate which is connected by a calcareous (Stone) canal with the central ring around the mouth, from which tubes proceed along each arm, in the starfish. On the inside of the floor of each ray are the *ampullæ*, small bulb-like water-sacs, which are connected with the tube-feet on the outside of the ray. "By a contraction of the delicate muscles in the walls of the ampullæ the fluid in the cavity is compressed, thereby forcing the tube-feet out. By the contraction of muscles in the tube-feet they are again shortened, while the small disk-like terminal sucker clings to some firm object. In this way the animal pulls itself along by successive steps." By the aid of these ambulacral or tube-feet the starfish is able to turn over if placed upon its back. They also act as suckers to fasten the starfish to the rocks. When once this is accomplished, arm after arm may be broken off before the animal can be pulled loose or the feet will relax their hold.

So-called **blood canals** accompany the ring and radial canals, and associated with them are sometimes two intestinal blood-vessels.[1]

**Nervous System.**—"There is a nerve ring and radial nerve, frequently in the ectoderm, to which may be added an enterocœlic or apical nervous system, possibly of peritoneal origin."

The **circulating fluid** is somewhat lymph-like and the circulation slow.

"**Respiratory organs** are represented by the *branchiæ*, or thin-walled outpushings of the cœlom, either around the mouth, as in the Echinoi′dea, or on the aboral surface, as in the Asteroi′dea, the *bursæ* of the Ophiuroi′dea, the *branchial trees* of the Holothuroi′dea, and the *various parts of the ambulacral system*."[2]

The **alimentary tube** is complete, that is, shut off from the body cavity and runs *through the body*. Its length depends upon the food of the echinoderm. In carnivorous forms, as the starfish, it is short, but in vegetable feeders, as the sea-urchins and sea-cucumbers, the alimentary tube is two or three times the length of the body.

**Multiplication** is sexual, as a rule, the sexes being separate except in rare cases. Fertilization takes place in the water. They never form colonies by budding.

The **metamorphosis**, or change from the larval to the adult form, is as marked as that from the caterpillar to the butterfly.

[1] Hertwig's "Manual of Zoölogy," Kingsley, p. 331.
[2] Ibid.

The *larva* is bilateral,[1] while the adult is radial, the development being complex.

Generally the young shift for themselves, but cases are recorded of broods being cared for by the female echinoderm in a pouch on the dorsal surface.

## CLASS I. ASTEROIDEA

To this class belong the starfishes, with their central disks and varying number of rays, five being the typical number. They live along rocky seacoasts. Fresh water kills them. The common starfish (*Aste'rias vulga'ris*) is abundant along the Atlantic coast, especially in the vicinity of oyster-beds, to which they do much injury by devouring the oysters. Starfishes are found also on the Pacific coast from Sitka to southern California. They are said to devour small fishes as well as crabs.

The **body wall** is composed of a thick leathery substance in which is embedded a great number of calcareous ossicles (12,000 by estimation), many of which are armed with spines for protection. Between the spines on the aboral surface are soft stalked projections ending in pinchers, called *pedicella'riæ,* with which it cleanses the surface of the body and protects itself from parasites.

The **alimentary tube** extends from the oral to the aboral surface. It consists of a mouth, a short esophagus, and a large sac-like stomach, which is five lobed and fills most of the disk. (See Fig. 41, p. 52.) The stomach is eversible and is furnished with muscles for withdrawing it. From the pyloric, or upper, division of the stomach the *cæca* extend, a pair into each arm. These cæca secrete much fluid, which is emptied into the pyloric portion of the stomach and used in digesting the food. From the stomach a short conical intestine extends *upward to the aboral surface.* The aboral opening from the intestine is not exactly in the center of the disk and is often difficult to find. In a few forms it is wholly obliterated.

**Locomotion.**—The arms are somewhat flexible, and, aided by their tube-feet,[2] enable the starfishes to move slowly along in

[1] Hertwig's "Manual of Zoölogy," Kingsley, p. 331.
[2] See text, Water-vascular System of Echinoderms, p. 52.

search of food. The starfish, by clinging with its sucking disks, can travel along horizontal or vertical walls It can bend its arms or even its central disk, when necessary, to pass through openings or crevices between rocks. As it moves so slowly, its direct dispersal is very limited, but since it is not attached, it is indirectly distributed by the tides and currents. The exceedingly minute young are often borne great distances in this way.

**Foods and Feeding.**—The starfish is carnivorous and very voracious; indeed, it seems to eat continuously. It feeds upon barnacles, clams, oysters (Fig. 42), and, it is said, even small fishes, or, failing of these, it will eat the garbage thrown along the shore, thus acting as a sort of scavenger. The worst damage it

Fig. 42.—Starfish attacking oysters. (From Fifth Report of Connecticut Bureau of Labor Statistics.)

does by its gluttony is to the oyster-beds. Oysters and clams close their shells to the starfish, but it keeps up a steady pull until it gets them open, when it reaches its arms about its prey and extrudes the lower part of its stomach, envelops the soft parts, pours out the digestive fluids about them and absorbs them, then withdraws its stomach, leaving the indigestible parts of its victim outside the body. Further digestion of the absorbed food takes place in the pyloric portion of the stomach, aided by the secretions of the hepatic cæca. The fact that all indigestible parts are " rejected " may account for the shortness of the intestine, and certainly does account for the small or lacking anal aperture, since there is little left to be " ejected."

The **nervous system** consists of a circumoral nerve ring, from which a nerve proceeds along the ambulacral groove of each arm to its tip, where it ends in a so-called " eye-spot " which has been proved sensitive to light.

**Special Senses.**—Besides the general sense of touch and the " eye-spots," already mentioned, there is at the distal end of each ray a tentacle-like organ which is supposed to be the organ of smell.

**Multiplication** is sexual. Fertilization takes place in the water. The starfish may reproduce asexually, for if a ray be broken off,[1] either accidentally or purposely by the animal itself, it has the power of reproducing a new disk as well as the rest of the arms, with their internal organs. Similarly, if all the arms are torn off, the disk has the power of growing out new ones. The young are bilaterally symmetric, free-swimming animals. The metamorphosis is complicated, resulting finally in the radial plan of structure of the adult.

The starfish, *Linckia linckia*, is a host for a parasitic gastero-pod (*Thyca*). Some starfishes are gregarious.

In size they vary from less than 1 inch to 3 feet in diameter. In color they may be yellow, brown, red, or purple.

**Geologic Distribution.**—The starfishes appeared before the close of the Cambrian Period, and have been represented in every age up to the present.

## CLASS II. OPHIUROIDEA

These echinoderms resemble the starfish. The arms are slender, jointed, muscular, and are used for locomotion (Fig. 43). The arms may be much branched, as in the basket-fish, and are not hollow as they are in the starfish. The ambulacral groove is closed, the tube-feet are on the sides of the arms, and have no suckers at their distal ends.

The **arms** are much more slender and more flexible than those of the starfish, and locomotion, which is faster than that of the starfish, is accomplished by the lateral movements of the arms, Some species have the power of throwing off pieces of their arms when disturbed.

The **digestive organs** are confined to the disk, the hepatic

[1] Parker and Haswell, p. 400.

cæca are absent, and the anal opening is lacking. The madreporic plate is on the oral side.

**Food.**—They are carnivorous, feeding upon worms, crabs, and shell-fish. They are also scavengers.

**Multiplication.**—Some lay their eggs in the water, where they are fertilized and develop into a pluteus stage like that of the

Fig. 43.—*Gorgonoceph'alus agassiz'ii* (one-fourth natural size). Oral view. (Clark, in Bulletin 550, U. S. F. C., 1902.)

Echinoidea, while others are viviparous and care for their broods. In many species there is also a kind of asexual reproduction, the animal dividing through the disk and each half regenerating its " other half."

There are several hundred species known. These echinoderms are variously called brittle-stars, serpent-stars, and sand-stars. The one most common on our shores (*Ophiopholis*) is of a "general red hue spotted with brown and paler red."

## CLASS III. ECHINOIDEA

The globular or disk-like sea-urchins have the pentameral plan, as a cleaned "test" or shell (Fig. 44) will show.

The **body wall** is composed of several hundred pentagonal calcareous plates arranged in regular order in twenty rows, the whole forming a sort of thin case or shell (see Fig. 44).

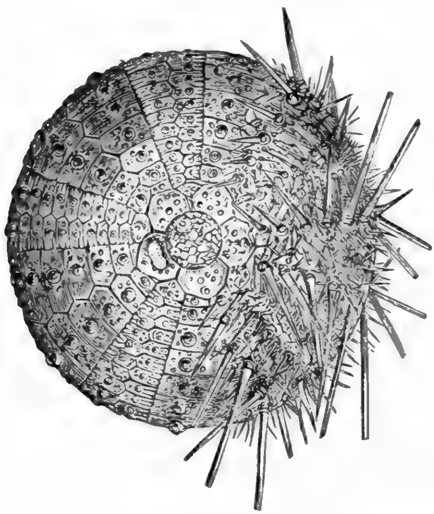


Fig. 44.—Sea-urchin (*Echi'nus micros'toma*) with spines nearly all removed from "test." (Chapin and Rettger.)

The ossicles, or plates, are armed with very long sharp spines for defense (Fig. 45). Alternate rows of plates are perforated for the passage of the tube-feet, there being no grooves. These ten rows of perforated plates constitute the ambulacral areas, and the ten rows of unperforated plates constitute the inter-ambulacral areas.

**Color.**—The colors are brown, olive, purple, red, green, or blue.

The **protective resemblance** is good.

The **ambulacral system** of the sea-urchin is similar in plan to that of the starfish. Locomotion is very slow and is performed by the tube-feet, aided by the long spines.

The **pedicellariæ** are similar to those of the starfish, but are more fully developed, having three pinchers instead of two.

The **food** consists largely of green *algæ* and brown seaweed, for the sea-urchin is a vegetable feeder, though it eats small marine animals also.

**Digestive System.**—There are five hard white teeth with which they gnaw their food. These teeth are connected with a

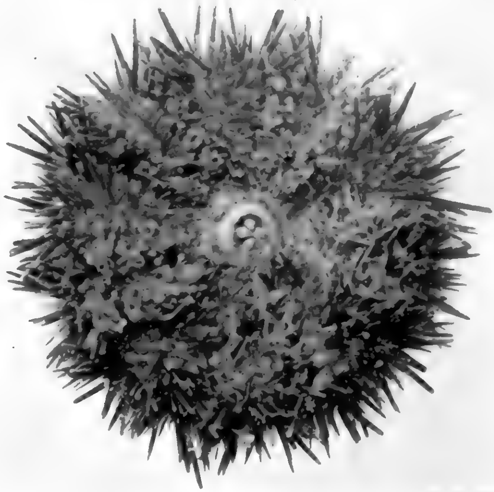


Fig. 45.—*Strongylocentrotus drobachiensis.* Oral view, showing spines, " feet," and teeth. (Clark, in Bulletin 550, U. S. F. C., 1902.)

complicated calcareous framework under muscular control. The whole apparatus is called " Aristotle's lantern."

The intestines are long, coiling about two and a half to three times, instead of being short like those of the carnivorous starfish.

The hepatic cæca and gastric pouches are absent. This lack, as well as the structure of the mouth parts and the long coiled intestine, correlates with the feeding habits of these herbivorous animals.

The **nervous system** is upon the same plan as that of the starfish.

**Multiplication.**—The eggs are laid in the water and fertilized by the tadpole-like sperm cells. Some forms have a marsupium, or brood-pouch, in which the eggs are hatched.

**Development.**—After fertilization, segmentation of the egg takes place until the bilaterally symmetric young "pluteus," which is very unlike the adult, appears. It is free swimming and lives on minute organisms it can procure in the water. As it develops it takes on the radiate or pentameral plan of its branch. The "sand dollars" so common on both the Pacific and the Atlantic coasts are *flat* sea-urchins with short spines.

**Geologic Distribution.**—A primitive type of sea-urchin appeared in the Ordovician period.[1]

## CLASS IV. HOLOTHUROIDEA

Holothurians are free, and a close examination reveals the pentameral plan of the branch, although they are more or less bilaterally symmetric.

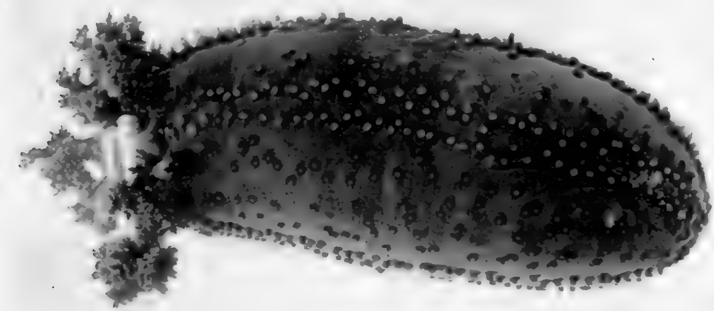


Fig. 46.—*Cucuma'ria frondo'sa,* side view. Note tentacles and rows of feet. (Clark, in Bulletin 550, U. S. F. C., 1902.)

The **shape** (Fig. 46) is much like that of the garden cucumber in our common varieties, but some are long and slender and

[1] Scott's "Geology," p. 381.

more worm-like in appearance. Some are so long and slender that they are sometimes thought to be worms.

The **size** varies from ½ inch in one species found upon the Massachusetts coast, to 3 feet, in another species found in Monterey Bay, California.

The **body wall** is tough, leathery, muscular, and not so rigid as in the starfish or sea-urchin, although minute calcareous spicules are scattered throughout it.

The **tube-feet** may be in rows, or scattered, or entirely wanting, depending upon the species, of which several hundred are recorded. The sea-cucumbers move with their long axis parallel to the ground. They creep along with the help of the tentacles.

**Protective Resemblance.**—Their colors, which are reddish brown or yellowish, harmonize so closely with those of their environment that their protective resemblance is almost perfect. As the animals rest on the bottom of the sea with their feathery tentacles spread out they closely resemble the vegetation of the sea bottom. A person may stand within a foot of the sea-cucumber and not see it.

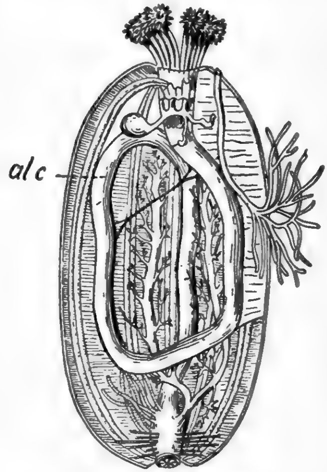



Fig. 47.—Sea-cucumber (*Holothurian*) dissected to show alimentary tube, *al.t.* (Leuckart.)

The **alimentary tube** (Fig. 47) is several times the length of the animal, and the intestine is coiled in a uniform manner.

The **food** of the holothurians consists of organic matter obtained from the sand which they swallow, or of small animals which they capture with their tentacles. They are nocturnal in their feeding habits, resting quietly during the day on the bottom of the sea or buried in the sand.

The **respiratory system** consists, probably, of the so-called "respiratory trees," two hollow, much-branched organs opening into the cloaca, which is periodically filled with water.

They are probably excretory organs also, and are connected with the manipulations of the tentacles.[1]

**Multiplication** is generally similar to that of the starfish, except in rare cases of *hermaphroditism*. There are also cases recorded of the female caring for her brood in dorsal pouches. In unfavorable conditions they void the whole viscera and yet live and replace the lost parts.[2]

In the development from the bilateral larva to the radial adult there is a marked metamorphosis.

Several species are hosts for certain parasites. A small fish infests the cloaca and branchial trees of one or two species. A snail lives in one species and a mussel in another.

**Use.**—They are used for food by the Malays, who call them "trepang," and use them principally for soups. Millions of them are captured in the south seas, where hundreds of vessels are engaged in the trepang fisheries.

**Distribution.**—Holothurians are widely distributed, being found from the arctic to the tropical regions.

Geologically, they date from the Carboniferous Period.

## CLASS V. CRINOI′DEA

Crinoids are fixed echinoderms with a flexible stem or stalk of calcareous perforated disks, bearing a flower-like body at the top of the stem (Fig. 48). This body consists of a cup-shaped center bearing five or ten arms, usually branched. The "feather stars," found at a less depth, later become detached and float around in the water.

**Ambulacral Grooves.**—Five ciliated ambulacral grooves (Fig. 49) extend from the mouth out on the arms and their branches, and give off branches to the pinnules. They serve as channels through which the food passes to the mouth, and also for the purpose of respiration.

**Food.**—They feed on small crab-like animals and on marine unicellular animals and plants.

The **nervous system** consists of a nerve ring surrounding the mouth, and given off from this nerve ring are a series of ambulacral nerves which extend the entire length of the arms and pinnules.

[1] Parker and Haswell's "Zoölogy," vol. i, p. 372. [2] Ibid., p. 400.

Fig. 48.—Crinoid (*Pentac'rinus*), half natural size. (Brehm.)

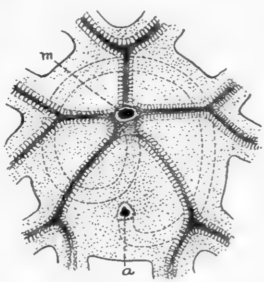



Fig. 49.—Mouth area of a crinoid (*Comat'ula*), showing the course of the intestine leading from the mouth (*m*) to the vent (*a*); *g*, grooves leading from arms to mouth. (From Kingsley's "Comparative Zoölogy," Henry Holt and Co., Publishers.)

**Digestive System.**—The mouth is directed upward and leads into the digestive tract, consisting of esophagus, stomach, and intestines. The interradial anal opening (see Fig. 49) is situated near the mouth.

**Multiplication.**—Crinoids multiply by eggs, which pass through complex changes before reaching the adult stage.

**Habitat.**—The living crinoids are deep sea animals with the exception of two genera, which live at a less depth. Some have been dredged from a depth of 11,100 feet. At this depth the water pressure must be enormous.

**Geologic Distribution.**—Primitive types (the cystids and blastoids) of this group are among the most ancient fossils. True crinoids appeared before the close of the Cambrian Period. They reached their culmination in the Carboniferous Period. The crinoid fossils of this period are so numerous that many beds of limestone are composed principally of them. Burlington, Iowa, and Crawfordsville, Indiana, are noted for their numerous and well-preserved fossil crinoids. Crinoids, though formerly of such vast numbers, are now almost extinct.

**Important Biologic Facts.**—Echinoderms are radially symmetric, but embryology shows that they have developed from the bilateral type. It is reasonable to regard those classes of echinoderms as the more ancient which have the radial symmetry less completely developed.[1]

The locomotor-ambulacral system is found in no other branch.

The echinoderms are a singularly isolated group, and we look in vain among the known members, living and fossils, of other branches for any really close allies.

**Classification.**—

| *Class.* | *Examples.* |
|---|---|
| I. Asteroi′dea. | Starfishes. |
| II. Ophiuroi′dea. | " Brittle-stars." |
| III. Echinoi′dea. | Sea-urchins. |
| IV. Holothuroi′dea. | Sea-cucumbers. |
| V. Crinoi′dea. | Sea Lilies, " Feather-stars." |
| VI. Cystoi′dea. | Fossil. |
| VII. Blastoi′dea. | Paleozoic fossil, as in Class VI. |

[1] Parker and Haswell's "Zoölogy," vol. i, p. 401.

## BRANCH ANNULATA

The branch Annūlā'ta is distinguished from the other branches of worms by having external and internal segmentation, that is, being divided into rings or segments (metameres) "containing homologous organs or similar portions of a continuous organ."[1]

They have, usually, a well-developed cœlom or body cavity, divided into segments by muscular partitions or septa.

These worms are bilaterally symmetric. The body is usually elongated.

### CLASS I. CHÆTOPODA

Class Chætŏp'ōda consists of fresh-water and marine annelids which bear setæ, or bristles. The setæ arise from special follicles, and may occur singly or in bunches. These setæ, which are controlled by special muscles, act as tiny levers in locomotion.

They have a body cavity which is partially divided into compartments corresponding to the segments. The alimentary tube extends through the body and is usually constricted at the septa. There is usually a well-developed circulatory system. Respiration is usually through gills or branchiæ and through the body wall. In some forms the sexes are distinct, while other forms are hermaphroditic. Fresh-water annelids develop without a metamorphosis, but in many marine forms the trochosphere larvæ occur.

Few are true parasites, but a number are *commensal*, habitually associating with other animals for their food and shelter. Many sea-worms are phosphorescent.

The **earthworm** (*Lum'bricus*) has an elongated cylindric body of many segments or metameres.

**Digestive System** (Fig. 50).—The mouth is covered by a rounded, lobe-like projection, the *prostomium*. The mouth leads into a small buccal cavity, back of which is the larger, thick-walled, muscular pharynx. This pharynx can be pro-

[1] Galloway's "Zoölogy."

truded and retracted. The radially arranged muscular fibers which run from the pharynx to the body wall retract the pharynx and at the same time dilate it. Back of the pharynx is the narrow esophagus, with a pair of pouches and two pairs of calciferous glands, which communicate with these pouches and which contain a limy fluid. Posterior to the pharynx is the thin-walled crop, and back of this is the very thick-walled rounded gizzard, with its tough, chitinous lining, in which the food is ground by sand, and from which the intestine extends to the anal opening in the posterior segment.

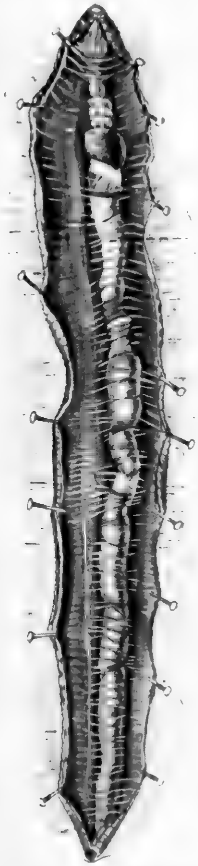



Fig. 50.—Earthworm dissected to show alimentary tube, *al. t.* (From Jordan and Kellogg, "Animal Life," D. Appleton and Co., Publishers.)

The *typhlosole,* a prominent ridge extending along the middle of the dorsal surface of the intestine and dipping down into the interior, renders the hollow of the intestine crescent shaped. This typhlosole increases the absorbing surface and is well supplied with blood-vessels.

The **circulation** is carrried on in a well-developed system of blood-vessels. The dorsal tube extends along the median line of the dorsal surface and is plainly seen in the live earthworm. The forward movement of the blood can usually be seen. The ventral blood-vessel lies below the alimentary tube. In this ventral blood-vessel the blood is propelled backward by the peristaltic action of the tube. The three smaller blood-tubes, the subnural and two lateral nural tubes, lie close to the nerve cord.

Each segment has a transverse vessel connecting the dorsal and ventral blood-vessels. Those from the sixth to the eleventh segment are dilated and pulsate ryhthmically, hence are sometimes called hearts. The blood is red, the color being due to the presence of hemoglobin (the same substance which makes our blood red) in the liquid itself, though the blood contains colorless corpuscles.

The **nervous system** consists of a double cerebral ganglion connected with a double ventral chain of ganglia by a pair of commissures which pass around the esophagus.

The earthworm has no eyes, yet it can distinguish not only light, but the direction from which it comes, and it will crawl " away from the light of high intensity and toward a light of low intensity." This tendency, and the fact that the moisture of the skin would be rapidly evaporated in daytime, and the absence of enemies, induce the earthworms to feed at night.

The earthworm has no organs of hearing, but its general sense of touch is so delicate that it detects the approach of danger by the jarring of the earth about its burrow.

It can distinguish and choose between different kinds of food, so it must have a sense akin to smell or taste. It is thought that the " goblet-shaped bodies " on the prostomium and on the anterior segments are the seat of this sense.

The **body wall** is composed of, first (on the outside), the cuticle, then the epidermis, the dermis, a muscular layer of circular fibers, a layer of longitudinal muscle-fibers, and underneath this the cœlomic epithelium which lines the body cavity.

**Respiration** takes place through the thin moist skin which is everywhere underlaid by a network of blood-vessels. These absorb the oxygen from the air and give off the carbonic acid gas through the skin.

**Locomotion.**—Each segment, except the one at each end of the worm, is furnished with four pairs of setæ, or short, stiff, chitinous bristles. They arise from the setigerous glands or sacs made by the infolding of the cuticle. By special muscles, attached to the base of each of these sacs, the setæ can be turned in different directions. In locomotion the earthworm uses these setæ as levers. When it moves forward the setæ are turned backward and stuck into the soil, the longitudinal muscles contract, pulling the body together, then the circular muscles contract, making the body smaller and longer and forcing it forward, since the setæ prevent its moving backward. When the earthworm moves backward the setæ are directed forward, and the same processes propel the worm backward.

**Excretion.**—In all the segments of the body except the first three and the posterior one is a pair of tubular kidneys (*nephridia*). Each begins in a ciliated funnel—which opens into and takes up the waste from the body cavity—in the back part of a segment, and continues in a long, much-looped tube, which opens externally by a small excretory pore on the ventral surface of the segment posterior to the one in which the funnel-shaped beginning is situated.

**Multiplication.**—The earthworm is hermaphroditic, but cross-fertilization takes place. The lateral and dorsal portions of the segments from the thirty-second to the thirty-seventh are swollen and somewhat fused together, forming a sort of girdle (the *clitellum*). The glands of this clitellum secrete a viscid fluid. This secretion hardens, upon exposure to the air, and forms a band or collar about the clitellum. This collar moves forward, gathers the eggs and sperms[1] as it passes the openings, and finally is slipped off over the head.[2] The ends of the collar now close and it forms a tough egg-capsule. The egg-capsules are hidden under stones, boards, or logs, or are buried in the earth, especially about barnyards and compost heaps. "The worms are about 1 inch long when hatched."[3]

They hibernate below the frost line in winter.

**Enemies.**—The chief enemies are moles and birds. To avoid the birds they feed at night or early morning, and sometimes drag a pebble into the mouth of the burrow, closing it after them.

The **marine worms** (*Polyche'ta*) are diœcious, and the young undergo a more or less complete metamorphosis. The larva is a *trochosphere*.[4] Some burrow in the sand; some are free swimming; some secrete a mucus which hardens and forms tubes; others form tubes by sticking together with mucus pieces of shell, sand, mud, or limestone. Most of the tube-building species are fixed to some object, but a few carry their tubes about. Many of these marine worms live in shallow water, but some have been found at a depth of 3000 fathoms.

[1] These have been obtained from another earthworm.
[2] Shipley and MacBride, p. 100.
[3] Colton, "Descriptive Zoölogy."
[4] See Glossary

The **nereis,** or sand-worm, which is found on the seashore, has a distinct head, bearing eyes and tactile sense organs, such as tentacles and palpi. Each segment has a fleshy outgrowth, the *parapodium,* bearing *many bristles.* " This is the first appearance of true appendages, though they are not jointed to the body nor in themselves."

The sand-worm varies in color in different stages, and the length varies from 6 inches to 2 feet.

It has an eversible pharynx, which, when infolded, conceals two horny jaws. These jaws are deeply notched and the ends are incurved. When food is taken the pharynx is everted, the jaws thrust forth, and the prey seized and swallowed.

## CLASS II. GEPHYR'EA

Class *Gēphyr'ea* is composed of oval or spindle-shaped worms, which are unsegmented in the adult form. Setæ are entirely wanting. The mouth, which is at the anterior end, is either surrounded by tentacles or overhung by a " proboscis " which may be several times the length of the body.

These worms are widely distributed. They live in both deep and shallow water and, " for the most part, either in natural rock-fissures or in burrows which they excavate in sand or mud or in coral or rock."

## CLASS III. HIRUDIN'EA

The body of the leech tapers at both ends and is flattened dorsoventrally. It is composed of many segments which are superficially divided into several rings, so that there are not so many true segments as there are surface rings.

The principal order of this class contains the common fresh-water leech familiar to barefoot boys. It is a temporary parasite on vertebrates.

The leech (Fig. 51) has no setæ nor appendages, but is provided with two suckers. The one on the posterior ventral surface is used for attachment in locomotion, and the other, which surrounds the mouth and is not well developed, is used in sucking the blood into the large crop. In the pouches of this crop, it is said, enough blood can be stored to last a year. A narrow stomach and a short intestine follow the pouched crop. The cœlom is considerably obliterated by a growth of muscle and connective tissue, called *parenchyma.*

Leeches are hermaphroditic. The eggs are usually laid in small packets or cocoons, and these are deposited in moist soil. The eggs are hatched in four or five weeks, but it takes them several years to mature. Some leeches are said to live twenty years.

Leeches are widely distributed. Many of them are inhabitants of fresh water. Some live in salt water, while others live in the forests of many regions, especially those of the tropics, where they are the terror of men and beasts.

One species (*Hiru'do sanguisu'ga*) is a parasite in the nasal passages of man. Another (*Hæmop'sis vo'rax*) lives in the pharynx or trachea of the horse, being taken in with water when small. Another form (*Branchel'lion*) is a permanent external parasite on fishes.

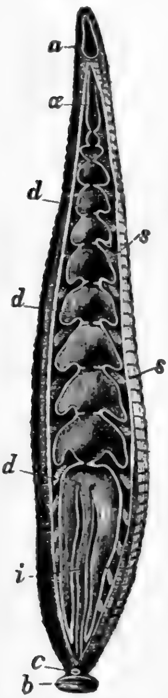



Fig. 51.—Section of a leech: *a*, Anterior sucker; *b*, posterior sucker; *c*, anus; *d*, *d*, *d*, stomach; *æ*, esophagus; *i*, intestine; *s*, *s*, glands of the skin. (Holder.)

**Distribution.**—The members of branch Annulata are widely distributed, the representatives of its many species being found from frigid to tropical regions, and even in the isolated islands of the sea.

It is known that marine worms existed in the Cambrian Period by their " tracks and borings in the sand, which are now consolidated into hard rocks."

**Economic Importance.**—The earthworm swallows the soil which it excavates for the sake of the partially decayed organic matter it contains, which the worm appropriates to the building up of its body tissue. The indigestible portions it deposits on the surface at night as coiled castings. They also feed on fresh or decayed leaves which they drag into their burrows, and sometimes upon young seedlings and tender roots.

Darwin, who studied the earthworm for forty years, estimated that in the tillable soil of England there were fifty thousand earthworms to the acre, and that they brought to the surface from 10 to 18 tons of soil annually. In this way the whole superficial layer would be enriched by passing through their bodies in a few years. Their burrows may extend vertically or obliquely for several feet underground, their depth depending upon the distance of the moist soil from the surface. "They are connected by underground tunnels, so that the soil is thoroughly exposed to the chemical action of the gases and acids of the air and water."[1] Thus the action of the earthworm has both a chemical and a mechanical effect upon the soil.

Leeches were formerly used very frequently by doctors when bleeding was more often practised. They are still sometimes thus used. They are raised in France for commercial purposes. Swamps are stocked with them and they are fed upon old and worn out farm animals.

**Important Biologic Facts.**—This branch is distinguished from all preceding groups by its metameric segmentation. The excretory system is characterized by the peculiar nephridia. There is a well-developed circulatory system and a circulating fluid containing hemoglobin. In leeches eyes are found, while the "goblet-shaped organs" in leeches and earthworms are thought to be the seat of smell or taste. True appendages appear in the Nereis.

The trochosphere larvæ show relationship between Chætopoda and the Turbellaria and the Nemertinia.

**Classification.**—

| *Class.* | *Examples.* |
|---|---|
| I. Chætŏp′oda. | Earthworms, Sand-worms. |
| II. Gēphȳr′ea. | Sipunculus. |
| III. Hĭrudĭn′ea. | Leeches. |

[1] Jackson and Daugherty, "Agriculture Through the Laboratory and School Garden."

## BRANCH MOLLUS'CA

These animals have soft, unsegmented bodies, as contrasted with the segmented Arthropoda. The body is generally bilaterally symmetric, but it may be asymmetric, as in the snail. They vary in size from a fraction of an inch to from 2 to 5 feet in length; and in weight from a fraction of an ounce to 500 pounds. The body may be naked, as the slug; or covered

Fig. 52.—Part of a bunch of oysters from Great Point Clear Reef, showing attachment of barnacles and mussels. (Bulletin, U. S. F. C., 1895.)

with a univalve shell, as the snail; or with a bivalve shell, as in the common mussel; or it may have an internal horny pen, as in the squid. The structure and form of the Mollusca are very various, and the number of known living and fossil species exceeds forty thousand. Some mollusks are marine, some are fresh-water forms, and others are terrestrial.

The **circulatory system** consists of a dorsal heart of one ventricle and one or more auricles, enclosed in a pericardium. Aortæ carry the blood from the ventricle to different parts of the body, but the blood-vascular system is not entirely closed.

**Respiration** is carried on through the body wall in a few Mollusca, but most of them breathe through gills or lungs.

The **nervous system** is characterized by three pairs of ganglia which are joined by connective nerve cords. The cerebral ganglia are situated dorsal to the esophagus and supply the tentacles and eyes. The pedal ganglia lie ventral to the mouth and supply the foot and otocysts. The visceral ganglia, also ventral, but farther back, supply the body, the mantle, and the so-called "osphradia," or olfactory organs. Some mollusks lack special sense organs.

**Locomotion** is accomplished by the single so-called "foot," a muscular plowshare-shaped thickening of the body.

**Multiplication.**—The Mollusca may be sexually separate or hermaphroditic.

This branch includes some very valuable food animals for man, as clams and oysters. Other examples are snails, slugs, scallops, cuttle-fishes, squids, and fresh-water mussels.

## CLASS I. PELECYPODA

This class is called by various names by different zoölogists, depending upon the character taken for the basis of classification—as Aglossa (without a tongue), Acephala (without a head), Bivalva (of two valves), Pĕlēcy̆p′oda (hatchet-footed), Lamellibranchiata (leaf-like gilled). We may then characterize this class as the hatchet-footed, headless, tongueless, bivalved, leaf-like gilled mollusks. Mussels, clams, and oysters are common examples of this class.

The body is soft, unsegmented, and is modified into the large "foot" used for locomotion. The mantle, a great fold of skin, covers the body, one lobe over each side. Between the mantle lobes and the body are the four large leaf-like gills. The labial palpi are the small leaf-like structures anterior to the gills, and lead into the mouth.

**Food** consists of small organisms which the water carries into the mantle cavity and to the ciliated labial palpi, which pass the food into the mouth. From thence the blood passes into the stomach and to the long coiled intestine which passes through the pericardium, usually perforates the ventricle, and ends dorsal to the posterior adductor muscle.

The Pelecypoda are sexual and sometimes hermaphroditic. There is a metamorphosis, there being usually a trochosphere stage.

The **sea mussel** (*My'tilus*) is an example of this class. Great clusters of this edible mussel are found just below low-tide marks. The shell is generally of a purple or dark color. The long slender foot (Fig. 53) throws out yellowish horny fibers (the *byssus*), by which the mussel attaches

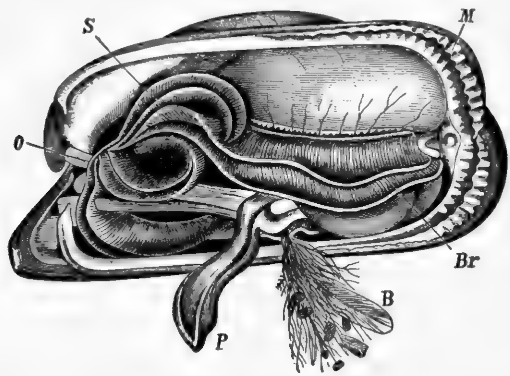



Fig. 53.—*Mytilus edulis: O*, Mouth; *S*, labial palps; *P*, foot; *B*, byssus secretion; *Br*, gills; *M*, thickened edge of mantle. (After Claus.)

itself to foreign objects. If food becomes scarce or conditions unfavorable, it can detach itself and slowly move to another position by stretching out the threads of the byssus and attaching them ahead or above, and then drawing itself up to them, hence it is sometimes called the "climbing mussel."

*Ano'mia*, of the same order as *My'tilus*, is permanently fixed.

The **oyster** (*Os'trea*) is a member of this class, which in adult life is fixed to the sea bottom or to some foreign object—very often the shell of another oyster. Great clumps (see Fig. 52, p. 72) may be thus fastened together, but their union is not organic. Oysters vary in size from a few inches to 2 or 3 feet, the largest being a Japanese species.

The shell of the oyster (Fig. 54) is rougher than that of the clam, and the hinge is at the pointed end, which corresponds to the anterior end of the clam. Its two valves are not alike, but the lower or left one is much larger and becomes deep enough to contain the body, while the upper or right valve is flat and serves as a lid. There is but one adductor muscle.

By its contraction the shell is closed. Its location is changed from year to year as the animal grows. A brown scar in the shell indicates where the attachment has been. The oyster can open its shell but little.

The oyster, since it is fixed, needs no organ of locomotion, and so has no foot. Neither has it any siphon, but the food-bearing water (Fig. 55) enters along the curved border of the shell and passes out near the larger

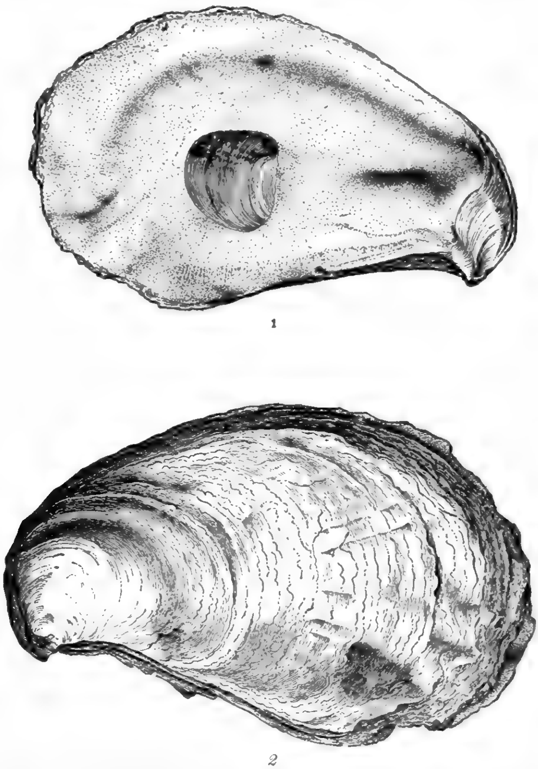



Fig. 54.—Shell of typical American oyster: 1, Inner face; 2, outer face. (Report U. S. Geol. Survey.)

end on the straight side. A fresh supply of sea-water is necessary to furnish it with food and oxygen. If the oysters settle too deep in the mud or if they are covered by silt and sand in time of storms they smother.

Our species of oysters (*Ostrea virginiana*) is bisexual, while the European species are hermaphroditic.[1] The reproductive organ is attached to the

[1] "Hertwig's Manual of Zoölogy," Kinglsey, p. 367.

large adductor muscle. The eggs are deposited in the water. They are very numerous. It has been estimated that one female will produce from 9,000,000 to 40,000,000 eggs in a single season. The breeding season is from May to August. If the eggs are not eaten by enemies or carried away by currents, they sink to the bottom. After a few hours of development the larvæ swim to the surface. Multitudes of these larvæ are devoured by surface-living fishes. The larvæ (Fig. 56) swim by means of cilia. In a few days the larvæ or fry, as they are called, sink to the bottom

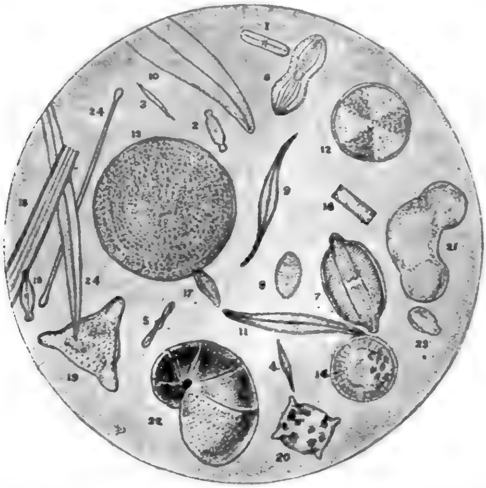


Fig. 55.—Food of South Carolina oyster. A few typical organisms (x 225). Numbers 1 to 20 are diatoms. 1–5, Navicula (Bory); 6, N. didyma (K.); 7, Pinnularia radiosa (?) (K. S.); 8, Amphora sp. (K.); 9, Pleurosigma fasciola (E. S.); 10, P. littorale (S.); 11, P. strigosum (S.); 12, Actinocyclus undulatus (K.); 13, Coscinodiscus radiatus (E.); 14, Cyclotella rotula (E.); 15, Synedra sp. (E.); 16, Diatoma sp. (De C.); 17, Cymbella sp. (Ag.); 18, Mastogloia smithii (Thw.); 19, Triceratium alternans (Br. Bai.); 20, Biddulphia sp. (Gr.); 21, Grain of pine pollen (Pinus rigida); 22, Foraminifera (Rotalia); 23, Zoöspore (Ulva?); 24, Spicules. (After Bashford Dean.) (From Moore, U. S. Com. of Fish and Fisheries.)

and attach themselves by the mantle-fold to some other oyster or to any object with which they come in contact. It takes them from three to five years to attain their growth. The blue crab (see Fig. 74, p. 101) is very destructive to the young oyster.

One of the greatest enemies of the oyster is the starfish (see p. 55). Other enemies (Fig. 57) are boring snails, boring sponges, and internal parasites. One little crab (*Pinnothe'res*) which lives in the mantle cavity seems to be an example of symbiosis rather than a parasite; at least it does not appear to harm the oyster.

Oysters abound in quiet, shallow inlets of the Atlantic coast south of Cape Cod, and of the Gulf of Mexico. We have the best oysters in the world.[1] Our most extensive oyster-beds are on the Chesapeake Bay, at Baltimore, where they cover 3000 acres and furnish millions of bushels yearly. We not only supply the markets of our own great cities, but send large quantities to British markets. Oysters are found also on the Pacific coast, on the coasts of Europe, of Australia, and of Japan.

The **scallop** (*Pecten*) has an almost round, fluted shell with a straight hinge without teeth, and with unequal valves, one being more nearly flat than the other. The shell is usually brilliantly tinted. The foot is rudimentary or altogether lacking. The mantle-folds are fringed with slender tentacles and the edge of each lobe is set with a row of brilliant bluish "eyes." When at rest the scallop lies on the sea bottom with its one adductor muscle relaxed and its shell open. If disturbed, it quickly closes the shell by contracting the strong muscle. This catches a quantity of water which is forcibly ejected through a round aperture at either end of the straight flange of the hinge. The reaction caused by forcing this water against the great body of water outside propels the animal forward. Thus, by rapidly opening and closing its shell, it swims through the water with comparative ease.

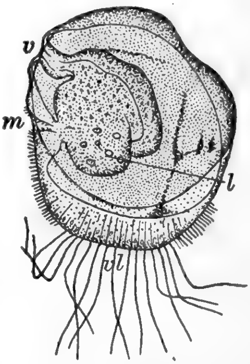



Fig. 56.—Right side of embryonic oyster, six days old: *m*, Mouth; *s*, vent; *l*, right lobe of liver; *vl*, velum. (Moore, Bull. U. S. F. C., 1897.)

The edible scallop (*Pec'ten irra'dians*) is about 2½ inches in diameter and its color varies from a whitish to a reddish or purple hue. The adductor muscle is the portion used by man for food. This scallop is found on the Atlantic coast south of Cape Cod.

*Pec'ten max'imus*, found on the coast of Great Britain, in water 30 to 40 fathoms deep, is much larger. Its deeper shell was formerly used as a baking-dish for oysters, hence the origin of the term "scalloped oysters."

The shell of another form common in the Mediterrnaean Sea (*Pec'ten jacobæ'us*) was worn as a badge by the crusaders returning from the Holy Land.

The so-called **pearl-oyster** (*Meleagri'na*), which does not belong to the oyster family at all, has a shell which is more nearly circular, a little convex, and sometimes a foot in diameter. They are found in Madagascar, Panama, Ceylon, East Indies, Australia, South Sea islands, Philippines, and the West Indies.

Pearls are deposits of nacre formed about some foreign substance. Prof. Jameson has discovered[2] by investigation upon the sea-mussel that, in their case, pearls are caused by a parasitic worm (*Trematode*). Pearls are collected by divers who go down from 6 to 8 fathoms for them. Hun-

[1] "On the coasts of Holland, Belgium, and France far greater care is taken of their species (*Os'trea ed'ulis*) than we take of ours (*Os'trea virginia'na*), but our natural conditions are superior to theirs."—Linville and Kelly, p. 169.

[2] Linville and Kelly's "General Zoölogy," p. 173.

dreds of vessels are engaged in this industry. Pearls of various shapes are found. Their colors may be white, yellow, pink, blue, red, green, or even

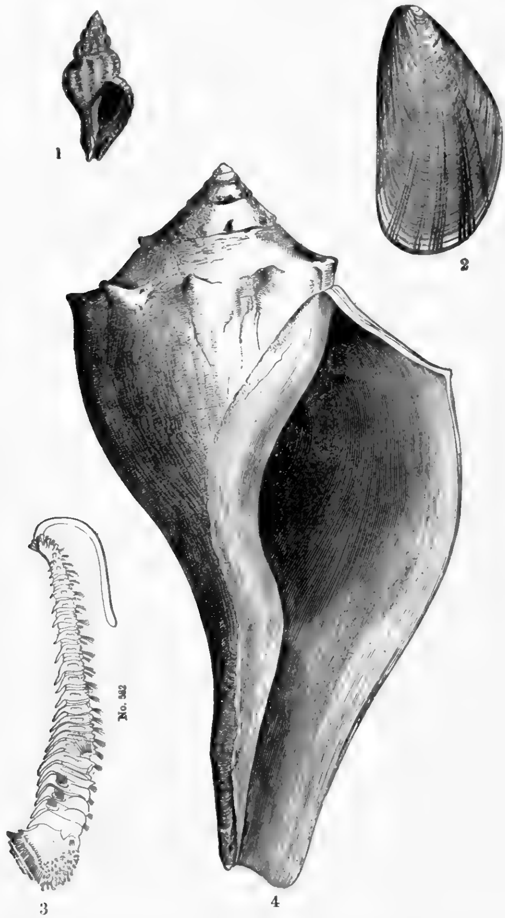



Fig. 57.—Some enemies of the oyster: 1, Drill (*Urosalpinx cinerea*); 2, mussel (*My'tilus edulis*); 3, *Sabellaria vulgaris;* 4, periwinkle (*Fulgur carica*). (Report of Fish Commision for 1897.)

black. Round lustrous white ones are most prized in Europe and America, but those of the yellowish hue are preferred by Asiatics

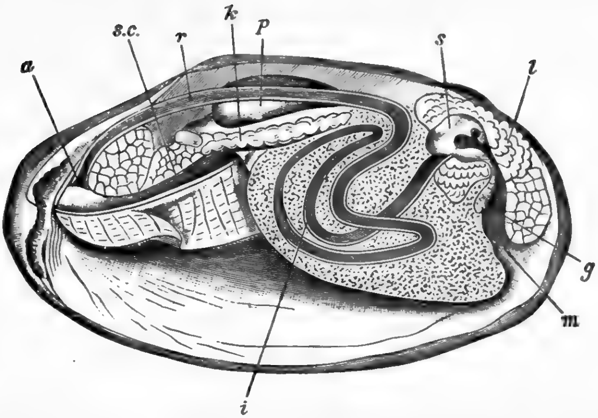



Fig. 58.—Section of *Anodon'ta*, showing the digestive tube: *m*, Mouth; *g*, gullet; *l*, liver; *s*, stomach; *r*, *i*, intestine; *a*, anus; *p*, pericardium; *k*, kidney; *s.c.*, chamber above the gills. (Furneaux.)

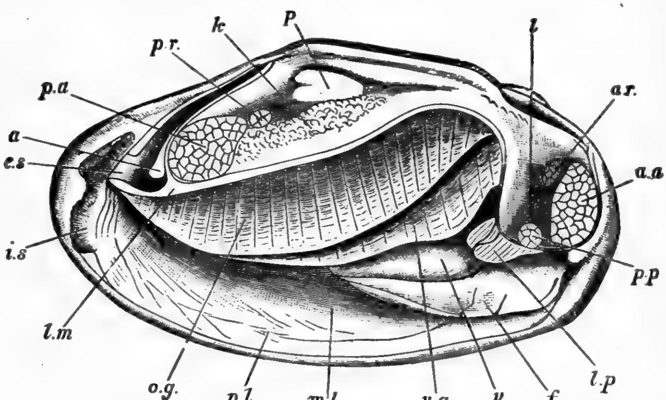



Fig. 59.—*Anodon'ta*, lying in one valve, with upper lobe of the mantle removed: *p*, Pericardium; *k*, kidney; *p.r.*, posterior retractor muscle; *p.a.*, posterior adductor muscle; *a.a.*, anterior adductor muscle; *a.r.*, anterior retractor muscle; *p.p.*, protractor pedis muscle; *a*, anus; *e.s.*, exhalent siphon; *i.s.*, inhalent siphon; *l.m.*, cut edge of the mantle; *o.g.*, outer gill-plate; *m.l.*, mantle lobe; *v.g.*, inner gill-plate; *v*, internal organs; *f*, foot; *l.p.*, labial palps; *l*, liver; *p.l.*, pallial line. (Furneaux.)

**Fresh-water mussels** (Figs. 58, 59) or **clams** of our ponds, lakes, and streams have firm leaf-like gills and two nearly equal adductor muscles.

The siphon is incomplete and the *pallial* line is entire, that is, without sinus or indentation. The foot is long and compressed. The valves of the shell are held together by the strong adductor muscles, and opened, when these relax, by the elastic spring or hinge ligament. The shells are a dull black on the outside, and pearly white, tinted with iridescent hues, on the inside. The shell of the Unio is not so large and strong as that of Anodonta, while the latter genus has no hinged teeth. Clams are found in ponds and large streams (which do not dry up in the summer), distributed along the direction of the strongest currents to insure food supply. They are partly buried in the mud, the open edge of the shell down and the valves slightly apart, with the fleshy foot protruding from the anterior ventral margin. When disturbed, the foot and edges of the mantle-lobes are retracted and the valves tightly closed.

Fig. 60.—*Tere′do na-val′is*, removed from its calcareous tube, with elongated siphons. (Quatrefages.)

The shell is the mussel's principal means of defense. It has many enemies besides man, such as the musk-rat, raccoon, mink, otter, and other mammals that live in and about the streams where the clam is found. Such animals as the musk-rat gnaw off the hinge ligament to get the shell open.

The young clams are carried in the gills, and were formerly mistaken for parasites, and are called *glochidea*. They differ much in shape from the adult. The glochidea, or young clams, pass out through the exhalant siphon and attach themselves by hooks on the valves to the gills or fins of fishes, by which they are protected from enemies and kept supplied with fresh water until sufficiently mature for independent existence, when they detach themselves from their host and drop to the bottom of the stream.

The **giant clam** (*Tridac′na gi′gas*) of the tropics has a shell from 2 to 4 feet long, which may weigh from 300 to 500 pounds.

The **soft-shelled clam** (*My′a arena′ria*) abounds in the mud flats of the Atlantic coast north of Cape Cod. The young clams swim about on the surface of the water. After the shell appears, they sink to the bottom and attach themselves by the byssus. When the clam is about $\frac{1}{5}$ inch long, the byssus disappears and the animal buries itself in the mud. As it grows, it keeps enlarging and deepening its burrow until it may extend from 8 to 12 inches below the surface of the mud. The long siphons are extended up to within reach of the sea-water, whose currents bring to the clam food and air. The water enters through the ventral siphon, is driven through the gills, and finally passes out through the excretory tube, the dorsal siphon.

Another form much used for food is the "**Quahog**" (*Venus mercenaria*), which is characteristic of warmer waters, and is found from Cape Cod to **Texas.** It burrows a little way below the surface, but is often found with its shell partly exposed. Along the Atlantic coast people use the *Mya* or *Venus* for their "clam-bakes." Many hundred bushels are used every year for this purpose.

The **razor-shell clams** have similar habits. They are concealed in vertical holes in the sand with the posterior end of the shell uppermost. They have a powerful club-shaped foot, and can dig so rapidly that unless one approaches very cautiously they escape from view. They seem to be sensitive to light and to the "jar" made by approaching footsteps.

The **borer** (*Pho'las*) has its brittle but very hard shell marked like a file, with which it bores into the hardest rocks. The united siphons are longer than the rest of the body. Some forms are phosphorescent, emitting bluish-white light.

The **ship-worm** (*Tere'do*) (Fig. 60), another borer, works into wood, doing much damage to ships in the tropics. The larva enters the wood when it is extremely small and enlarges the tunnel as it grows. The wood which it excavates is not used for food, but is carried off by the excretory siphon. Its food, which consists of microscopic organisms, is brought in by the currents. The amount of damage these borers do seems incredible. They completely honeycomb the hull of a wooden vessel. The best protection against them is the sheathing of the hull with copper. Palmetto is the best resistant among woods. The ship-worms caused the destruction of a dam in Holland, threatening destruction to the country. Their dispersal is wide, since they are carried all over the world in the floating wood which they attack.

## CLASS II. GASTEROP'ODA

These are asymmetric, usually univalve mollusks, and the head region bears either one or two pairs of tentacles. As in the snail (Fig. 61), the eyes are borne either at the bases or at the

Fig. 61.—A snail. (After Tenney.)

tips of the tentacles. The shorter tentacles are probably organs of smell. The head contains the mouth, in which is the tongue, covered by the radula, a ribbon-like organ supplied with chitinous teeth and used for rasping the food.

The *mantle* is not divided into two parts as in the mussel, but unites around the neck, leaving but a small respiratory aperture into the mantle cavity. The foot is broad and flat and is used for locomotion. Respiration is accomplished through the wall of the mantle cavity, or by one or two plume-like gills or *ctenidia* in the mantle cavity. In the air-breathing forms there may be simply a pulmonary sac.

The shell is a spiral, either flat or elongated (Fig. 62), and is usually closed by a flap or operculum (a horny plate growing on the posterior portion of the foot) for protection.

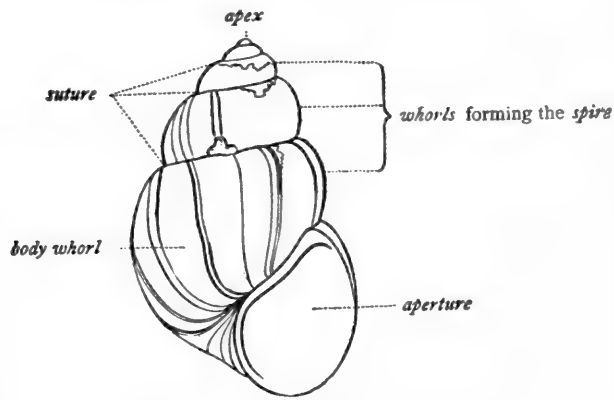



Fig. 62.—A snail shell. (Morse.)

Some Gasteropods are marine, some are fresh-water forms, and still others are terrestrial.

The **limpets** (*Patel'lidæ*) are uncoiled forms with open conical shells. They are found adhering to rocks between tide-marks. The foot acts as a sucker, enabling the animal to resist a force of a thousand times its weight when one attempts to detach it. The common limpet (*Patella vulgata*) is used as food. It feeds upon seaweeds.

The **ear-shells** (*Haliot'idæ*), found on our western coast, have a row of perforations near the margin of the shell through which the tentacles pass to the exterior. The shells are much used in inlaid work on account of their beautiful iridescent color. They are also used as food, and the shells are used for making buttons.

The **cowries** (*Cypræ'idæ*) have richly enameled shells with small openings. They are beautiful and are sold for ornaments, some species being much prized. A beautiful yellow shell, an inch or less long, which abounds in the East Indies, is used as money in Siam and in parts of Africa: 6400 cowries are equal to about 36 cents. The cowries are tropical, but a few species are found in temperate seas.

The **helmet-shells** (*Cassid'idæ*) are composed of layers of different colored material and are used for carving cameos.

The **tritons or sea conchs** (*Triton'idæ*) have handsome shells, frequently more than a foot in length. The shells of one species is used by the South Sea Islanders as a trumpet. The *Triton'idæ* have a proboscis, a well-developed siphon, and a short foot.

"The long, nearly cylindric shells of the Cavolinidæ make up much of the 'pteropod ooze' of the deep seas."

The **common periwinkle** (*Littori'na*) (see Fig. 57, p. 78) abounds on the coast of New England and southward, where it is used as food. It is a native of Europe. It is a vegetable feeder, and is valuable in cleaning up the seaweeds from oyster-beds.

The **oyster drill** (*Urosal'pinx ciner'ea*) (see Fig. 57, p. 78) bores a hole through the shell of the oyster and feeds upon its soft parts.

**Natica** is another drilling sea-snail common on our Eastern coast. It burrows in the sand for clams and bores a hole with its radula, rotating its own body in the action.

**The Nudibranchs.**—In the Nudibranchs the shell is entirely absent in the adult. True ctenidia are replaced as breathing organs by a number of secondary branchiæ, sometimes simple, sometimes branched processes or leaf-like tufts, which may be distributed over the dorsal surface (as in *E'olis*), or placed in a row on each side beneath the mantle-flap (as in *Pleurophylli'dia*). These soft naked sea-slugs live in shallow water near the shore, crawling about and feeding upon the seaweeds. Their protective resemblance is very great on account of both color and form. They move very slowly. This also aids them in escaping the notice of their enemies.

The **land snails** and **slugs** (*Pulmona'ta*) are air breathing. The air enters the mantle cavity through a small opening which is near the right side in the *dextral* forms (that is, the spiral of the shell turns like the hands of a clock from left to right), and on the left side in the left-handed (*sinistral*) forms.

**Land snails** (*Helic'idæ*) are common in moist woods. They come out at night or in cloudy weather to feed on succulent vegetation. When they are numerous they do much damage. They, in common with the pond snails, have thin spiral shells. They have two pairs of tentacles. The upper and larger pair bears the eyes at their tips, and the shorter pair is the organ of touch. (See Fig. 61, p. 81.)

The land snail (*Helix*) has no operculum, and when frost comes it withdraws into its shell, fitting the opening to some smooth object, and secretes a layer of mucus. This hardens upon drying and forms a tough membrane. the epiphragm, which closes the opening. In at least one species of *Helix* a small hole is found just below the lung aperture, through which an exchange of gases may take place.

As a rule, snails lay their eggs in strings or masses, but the land snails bury their eggs singly or deposit them thus in moist places. Snails are used as food, being even shipped to the United States from Europe.

**Land slugs** (*Limac'idæ*) are naked. The shell is vestigial and concealed by the mantle. They have a rasping tongue like the snail's. The giant yellow slug of California reaches a length of 12 inches.

The Pulmonata are hermaphroditic. The garden snail hibernates by coiling up in its underground burrow in winter.

**Pond Snails.**—The common pond snails have but one pair of tentacles, and the eyes are situated at the bases of these. They breathe by means of a lung-sac instead of by gills, and must come to the surface occasionally for air. In genus *Physa* the spiral of the shell is left-handed; in *Limnæ'a*, right-handed, and in *Planor'bis* the shell is discoid or a flat spiral.

The eggs of genus Physa are deposited in gelatinous, transparent, oblong capsules of an inch or less in length attached to submerged sticks or leaves. Genus *Limnæ'a* lays the eggs late in spring in capsules surrounded by a mass of jelly. The young pass through a metamorphosis.

Still other pond or river snails breathe by means of gills. They live in the bottom of ponds or streams and are carnivorous.

## CLASS III. CEPHALOPODA

Class Cephalop'oda (head-footed) consists of such forms as the squid, cuttle-fish, octopus, and nautilus. They are all marine, and, in many respects, the most highly developed of all mollusks. There is a distinct head, bearing a pair of large well-developed eyes, and surrounded by arms or tentacles which are modifications of the anterior margins of the foot.[1] The posterior part of the foot is transformed into a funnel-like siphon.

The body is bilaterally symmetric. Respiration is through gills which line the mantle cavity. The shell may be external, as in the nautilus; or internal, as the pen of the squid; or lacking, as in the octopus.

They are usually carnivorous. Some are solitary, as the devil-fish; others, as the squid, go in immense shoals. The senior author has seen acres of ground covered with the catches of them on the Pacific coast.

The circulatory system is closed and consists of a somewhat complete heart and arteries, capillaries and veins.

The principal ganglia are grouped about the esophagus. The nervous system is the most highly developed of any of the branch, consequently they are the most intelligent of all mollusks.

They have the power of quickly changing color to harmonize with their environment.

**Cuttlefishes** are rapid-swimming Cephalopoda living at a depth of several fathoms, but sometimes coming into shallower water. The cuttlefish has a distinct head bearing ten long arms, and a pair of highly developed eyes resembling those of a fish. The free end of the head bears the mouth. The inner surface of each arm or tentacle is flat and bears four longitudinal rows of suckers. The fourth pair of tentacles is much longer and more slender than the others, and the club-shaped end bears suckers. The

[1] See McMurrich, p. 341.

body is covered by the thick integument of the mantle. The internal shell is calcareous and furnishes the cuttlebone used for canary birds.

Cuttlefishes are carnivorous, feeding upon crabs, clams, or fishes. They delight in the daylight and in the open sea, so they need to be protected from the view of their enemies. For this purpose they discharge an inky fluid to cloud the water so as to escape detection. The dark-colored secretion is carried in the ink-bag connected with the siphon. The ink was used in ancient times as a writing fluid. The sepia ink used by artists in making the sepia pictures is manufactured from this fluid of the cuttlefish. The cuttlefish is also used as an article of food in the Old World.

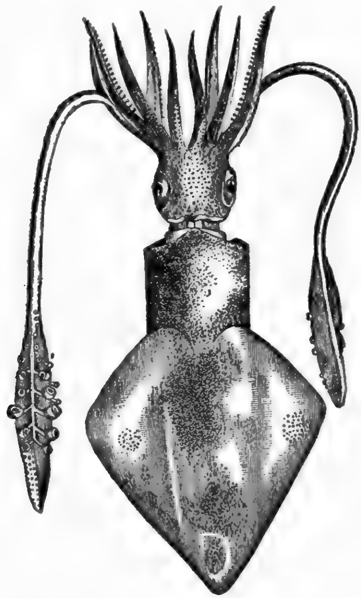


Fig. 63.—*Loli'go vulga'ris.* (After Verany.)

**Squids** (Fig. 63) swim in schools. They, unlike cuttlefishes, are nocturnal. They are carnivorous, feeding upon young fishes. The common squid is a foot or less in length. The internal shell is a horny " pen " shaped something like a feather, which is embedded in the dorsal portion of the mantle. By alternately taking water into the mantle cavity and forcing it out, the squid is driven rapidly backward. It avoids detection by its color changes and by an inky discharge like that of the cuttlefishes. It feeds upon small fishes and crabs, which it kills by biting with its powerful horny beak. Its enemies are large fishes and man. Giant squids are over 9 feet long, with arms 20 or 30 feet in length.

The **octopus** is another member of this class. It has a short subspherical body without any shell. It has eight sucker-bearing arms, with which it

Fig. 64.—The chambered nautilus.

"Year after year beheld the silent toil
That spread his lustrous coil;
Still, as the spiral grew,
He left the past year's dwelling for the new,
Stole with soft step its shining archway through,
Built up its idle door,
Stretched in his last-found home, and knew the old no more.

"Thanks for the heavenly message brought by thee,
Child of the wandering sea,
Cast from her lap, forlorn!
From thy dead lips a clearer note is born
Than ever Triton blew from wreathed horn!
While on mine ear it rings,
Through the deep caves of thought I hear a voice that sings:—

"Build thee more stately mansions, O my soul,
As the swift seasons roll!
Leave thy low-vaulted past!
Let each new temple, nobler than the last,
Shut thee from heaven with a dome more vast,
Till thou at length art free,
Leaving thine outgrown shell by life's unresting sea."

*Oliver Wendell Holmes.*

grasps its prey. "Devil-fishes" are found in all seas. They are gregarious when young, but the adult is solitary. They creep about among the rocks upon the extremities of their arms, generally moving sideways; or swim rapidly, either forward or backward. The arms are somewhat webbed at the bases.

Some **devil-fishes** measure 12 to 15 feet, others but a few inches. They are found on our western coast and in the Pacific islands. They are much used for food along the Mediterranean Sea and by the Chinese and Italians of San Francisco.

**The Nautilus** (Fig. 64).—This Cephalopod has a many-chambered, spiral, univalved shell, lined with pearly nacre, hence is often called the "pearly nautilus." It has four gills instead of two. It crawls about on the sea bottom by means of its many (about forty) small tentacles. It has no suckers. The outer chamber of the shell is a large compartment in which the animal lives. As it grows, the nautilus partitions off the space behind it and moves forward. A calcareous tube containing the *siphuncle*, a slender tubular continuation of the body, extends through all the septa. The abandoned compartments are filled with air.

The nautilus has a beak and a rasping tongue, like those of the squid. Each of its two disk-shaped eyes is attached by its convex side to a short thick stalk. The aperture of the eye is small, and there is no cornea, no iris, nor vitreous humor, but simply the retina at the base of a disk or pit. The nautilus has not the power of changing its color, and has no ink sac.

It lives in the deep water in the south Pacific Ocean, and has been but little studied. Many of the species of former ages are extinct. This is the "chambered nautilus," immortalized by Oliver Wendell Holmes.

**Economic Importance.**—Mollusks are probably of more direct use to man than any other invertebrate branch. The oyster industry is of vast importance, giving employment to thousands of persons and bringing an annual income of millions of dollars. Clams are also used extensively for food, and periwinkles and snails less extensively. We get also pearls, and the mother-of-pearl for the making of buttons, knife-handles, and novelties. Factories have been established in Illinois and Iowa for making buttons on a large scale from the fresh-water mussel shell. This industry threatens to exterminate these bivalves unless means are taken to protect and perpetuate them.

The squid is extensively used as bait in cod-fishing, while both the squid and the cuttlefish furnish the sepia ink used by artists. The cuttlebone used for canaries is another product of the cuttlefishes.

The ship-worm does much harm to dikes, wharves, and piles, or any wooden structures which have been in water some time.

**Important Biologic Facts.**—The mollusks are the most highly organized of any of the invertebrates except the Arthropoda, and many zoölogists place them above the Arthropoda. They have a well-defined circulatory system and nervous system and especially highly developed eyes. They usually have a metamorphosis, some of the stages of which show indications of affinity with "worms."

**Classification.**—

| *Class.* | *Examples.* |
|---|---|
| Pĕl′ecy̆p′oda. | Sea-mussel, Oysters, Scallop, Fresh-water mussel. |
| Găs′tẹrŏp′oda. | Limpets, Periwinkle, Snails. |
| Cĕph′alŏp′oda. | Cuttlefish, Octopus, Nautilus. |

## BRANCH ARTHROPODA

ARTHRŎP′ODA may be characterized as animals having bilaterally symmetric segmented bodies with jointed appendages and a chitinous exoskeleton. The segments of the body are not so numerous as in the worms.

This branch includes a vast assemblage of animals which are widely distributed over the earth. They vary in habitat, being aquatic, terrestrial, subterranean, aërial, or some combination of these.

Some are of direct use in furnishing food for man, as the lobster and the bee. Many cross-fertilize plants, and are thus of indirect use to man. As common examples of this branch may be named the lobsters, crabs, crayfishes, spiders, "thousand-legs," and insects.

The **digestive system** is between the circulatory system and the nervous system. It is not much coiled, but runs almost straight through the body. (See Fig. 69.)

The **circulatory system** consists of a dorsal blood-vessel open at the anterior end. The blood is pumped forward. It fills all the irregular spaces of the body, through which it bathes all the tissues and makes its way back to the dorsal vessel. The corpuscles are colorless and ameboid.

The **respiratory system** consists of gills in the aquatic forms, and of air-tubes or tracheæ in the insects and other terrestrial forms.

The **nervous system** consists generally of a double chain of ganglia, connected by a double nerve cord, running along the ventral side of the body. (See Fig. 69, *N*.) We should expect to find a pair of ganglia to each segment, but several ganglia may be united, as in the crayfish, where there are thirteen well-marked ganglia, the three anterior ones uniting to form the so-called brain.

**Multiplication.**—The sexes are usually distinct. Multiplication is generally by fertilized eggs.

## CLASS I. CRUSTA'CEA

As examples of this class may be named crayfishes, lobsters, crabs, and "pill-bugs." The body has a limited number of segments, about twenty in the crayfish. Each pair of appendages is regarded as being attached to a different segment. The head and thorax are united and called cephalothorax. The chitinous covering, rendered hard by deposits of carbonate and phosphate of lime, is called the carapace.

Respiration is by gills, or branchiæ, though some breathe through the skin.

The appendages are biramous, as seen in the swimmerets of the crayfish. A typically developed appendage, as the third pair of swimmerets, consists of a main stalk (protopod) and two branches, the outer (exopod) and the inner (endopod). Several of the appendages lack some of these parts. The student should homologize the appendages and tell or demonstrate which ones have missing parts.

The class Crŭstā′cea is usually divided into two sub-classes, the *En′tomŏs′traca* and the *Măl′acŏs′traca,* with several orders under each.

**Sub-class Entomostraca** is composed of crustaceans with a varying number of joints or segments. They are usually small or microscopic. There is a metamorphosis, the first stage being the free-swimming *nauplius.*

**Order I. Phÿllŏp′oda** are small aquatic crustaceans with segmented bodies and leaf-like appendages. The brine shrimp, fresh-water Branchipus, and Daphnia are examples of the order. Daphnia is shelled and looks like a very small clam.

The animals of this order form an important part of the food of fresh-water fishes. The eggs of many species can resist the drought, which is a valuable means of perpetuating them in small streams which dry up in summer.

**Order II. Ostrăc′oda** are small crustaceans with apparently unsegmented bodies enclosed in a bivalve shell, as the fresh-water *Cypris.* The abdomen is rudimentary. There are only two pairs of thoracic appendages, two pairs of maxillæ, one pair of mandibles, one pair of antennæ, and one pair of antennules. The antennæ and antennules are used for locomotion. The antennules are also provided with olfactory hairs. Many of this order are marine. Some, however, live in brackish or in fresh water. They live usually at the bottom of their aquatic habitat.

**Order III. Cōpĕp′oda.**—As examples may be named parasitic fish lice and the fresh-water cyclops. Respiration takes place over the entire body surface.

The **Cyclops** (Fig. 65) is a small, white, shelless animal with elongated segmented body. It has a rather large eye in the center of its head.

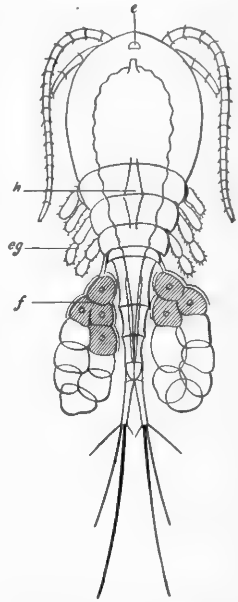


Fig. 65.—Cyclops: *e*, Eye; *h*, heart; *eg*, feet; *f*, eggs. (Clark.)

**Order IV. Cĭrrĭpe′dia or Barnacles.**—These fixed, marine, shelled crustaceans are very abundant along the seacoast, the rocks being covered with them in places. Their food consists of small animals in the water. One may see thousands of barnacles snapping their food as the waves and tides dash over them.

Some forms attach themselves to crabs, mollusks (Fig. 52), or even to whales, while others are true external parasites, sucking the juices of the animals to which they are attached. The parasitic forms are extremely degenerate.

Since they have no power of locomotion by which to escape their enemies, the barnacles (Fig. 66) are protected by shells capable of "complete closure." The body is flexed ventrally and bears six pairs of *cirri*, which are used in straining small organisms from the water and in carrying them to the mouth. The mouth is surrounded by a pair of mandibles and two pairs of maxillæ. Barnacles are hermaphroditic, but cross-fertilization may occur. They have a metamorphosis, having first a nauplius and then a cypris stage, the latter developing into the fixed adult (Fig. 67). This order furnishes a good illustration of the principle that inactivity leads to degeneration.

The barnacles (*Lepas*) are found in clusters on the bottom of ships and often greatly impede their progress.

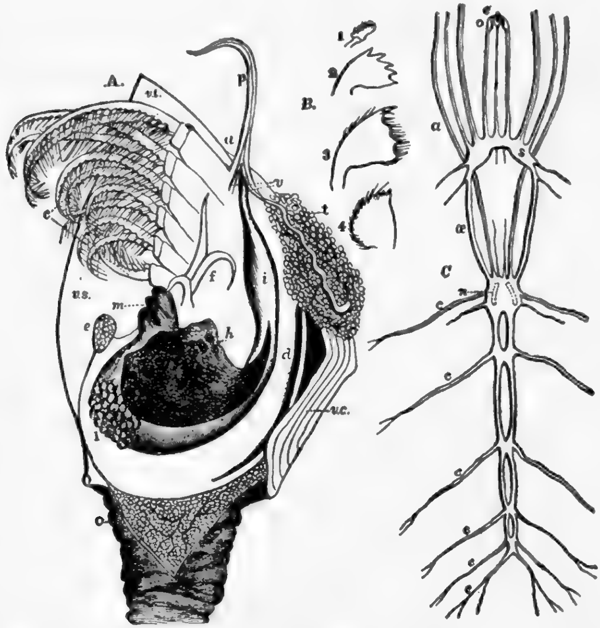


Fig. 66.—Anatomy of *Lepas fascicularis* (Packard): *A*, *c*, Six pairs of legs or cirri; *f*, filamentary appendages; *m*, mouth; *s*, stomach; *h*, openings of the liver (*l*) into the stomach, which is represented as laid open; *i*, intestine; *a*, vent; *t*, testis; *v*, vasa deferentia, one cut off; *p*, male appendage; *o*, ovary; *e*, adductor muscle connecting the two basal valves; *vs*, scutal valve; *vc*, carinal valve; *vt*, tergal valve. Enlarged twice. *B*, 1, Palpus; 2, mandibles; 3 and 4, first and second maxillæ. *C*, Nervous system: *s*, Brain, sending the optic nerves to the rudimentary eye (*e*), each optic nerve having an enlargement near the eye, *i. e.*, the ophthalmic ganglion (*o*); between *o* and *a* are the nerves which go to the peduncle; *a*, nerve sent to the adductor scutorum; *æ*, commissure between the supra- and infra-esophageal ganglia (*n*); *c*, *c*, *c*, *c*, *c*, *c*, nerves to each of the six feet. Enlarged four times. (After Kingsley.)

**Sub-class II. Măl′acŏs′traca** is composed of crustaceans of a definite number of segments, usually twenty—the head of five segments; the thorax, eight; and the abdomen, seven. These segments are sometimes so fused as to puzzle one to distinguish twenty segments, as in the crayfish, but by regarding one pair of appendages to each segment one is able to count the number of segments present in the specimen. There is a number of orders under this sub-class, but only a few can be mentioned.

**Order I. Phy̆llōcar′dia** is marine. The genus *Nebalia*, with its bivalve carapace, its leaf-like thoracic feet, and biramous

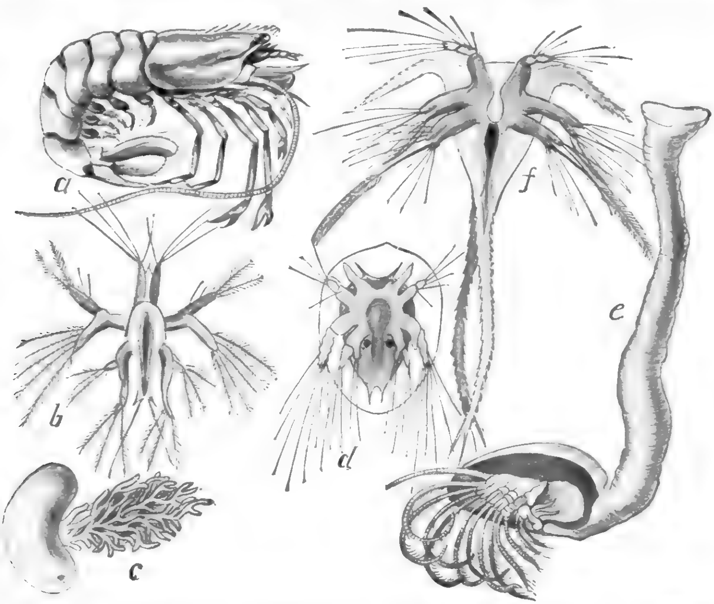



Fig. 67.—Three adult crustaceans and their larvæ: *a*, Prawn (*Peneus*), active and free living; *b*, larva of prawn; *c*, *Sacculina*, parasite; *d*, larva of *Sacculina; e*, barnacle (*Lepas*), with fixed quiescent life; *f*, larva of barnacle. (After Häckel.) (From Jordan and Kellogg, " Animal Life," D. Appleton and Co., Publishers.)

abdominal appendages, may be taken as an example of this order.

**Order II. Dēcăp′oda.**—This order consists of both marine and fresh-water crustaceans. It contains the best-known forms as well as the most useful ones to man, as the crayfish, lobster, shrimp, prawn (Fig. 67), and crab. As the ordinal name sug-

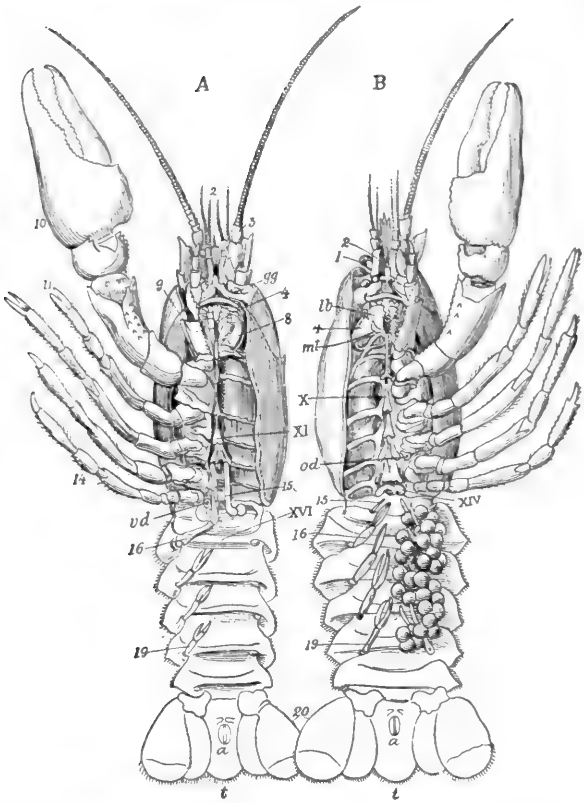



Fig. 68.—*Astacus fluviatilis*. Ventral or sternal views (nat. size). A, Male; B, female: *a*, Vent; *gg*, opening of the green gland; *lb*, labrum; *mt*, metastoma or lower lip; *od*, opening of the oviduct; *vd*, that of the vas deferens; 1, eye-stalk; 2, antennule; 3, antenna; 4, mandible; 8, second maxillipede; 9, third or external maxillipede; 10, forceps; 11, first leg; 14, fourth leg; 15, 16, 19, 20, first, second, fifth, and sixth abdominal appendages; x, xi, xiv, sterna of the fourth, fifth, and eighth thoracic somite; xvi, sternum of the second abdominal somite. In the male, the 9th to the 14th and the 16th to the 19th appendages are removed on the animal's left side; in the female, the antenna (with the exception of its basal joint) and the 5th to the 14th appendages on the animal's right are removed; the eggs also are shown attached to the swimmerets of the left side of the body. (Huxley.)

gests, they have ten "feet." The first pair is very large and armed with large strong pincers or *chelæ*, for defense or for securing their prey. Their eyes are on movable stalks and can be withdrawn under the rostrum or beak for protection. The anterior thirteen segments are covered by a chitinous calcareous shield called the carapace.

The **Crayfish** (Fig. 68) is the best known inland example of this order. The twenty segments may be discerned by counting one segment to each pair of appendages, which are arranged in the following order: one pair of antennules, one pair of antennæ, one pair of mandibles, two pairs of maxillæ, three pairs of maxillipeds, five pairs of legs, six pairs of swim-

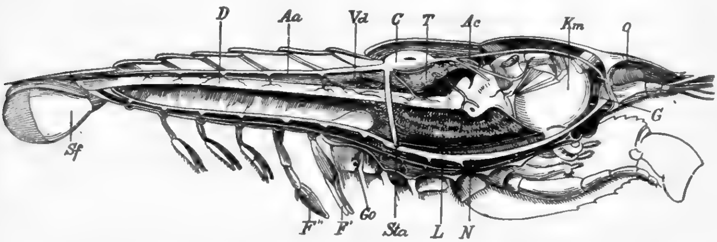



Fig. 69.—Longitudinal section through *Astacus fluviatilis*: *C*, Heart; *Ac*, cephalic aorta; *Aa*, abdominal aorta; the sternal artery (*Sta*) is given off close to its origin; *Km*, masticatory stomach; *D*, intestine; *L*, liver; *T*, testis; *Vd*, vas deferens; *Go*, genital opening; *G*, brain; *N*, ganglionic cord; *Sf*, lateral plate of the caudal fin; *o*, eye stalk. (Huxley.)

merets, or nineteen pairs of appendages and a terminal segment without appendages, called the *telson*, which contains the vent or posterior opening of the alimentary tube.

Its *locomotion* on four pairs of legs may be forward, sideways, or backward. Its backward locomotion by its "tail fin" is probably its best and most rapid mode of locomotion.

*Digestion.*—The food is seized by the cheliped and may be conveyed directly to the mouth, or, after being torn into bits, may be transferred to the pincers of the second and third pairs of legs and from there to the mouth. The jaws move from side to side instead of up and down. From the mouth the food passes into the esophagus, which is very short, as the stomach is in the head (Fig. 69). In the inner walls of the stomach are three "teeth" or hard processes which are controlled by muscles attached to them and to the carapace. By the action of these muscles the food is ground between these teeth, which are sometimes called the "gastric mill." In the posterior part of the stomach there is a series of filaments or stiff hairs which prevent any coarse or unground food from passing into the intestine. So the stomach is a masticating rather than a digestive organ. When the food is ground fine it passes into the intestine, a straight tube extending from the stomach to the vent. The food is acted upon by the digestive fluids from the glands which lie on each side of the stomach and whose ducts enter just back of the stomach. Digestion and absorption take place in the intestine.

*Circulation.*—When the heart (Fig. 71) contracts the blood flows both forward and backward. Five tubes, or "arteries," carry it forward, and two, backward. These "arteries" keep dividing until they form minute capillaries with open ends. The blood runs into the irregular body spaces, or sinuses, and

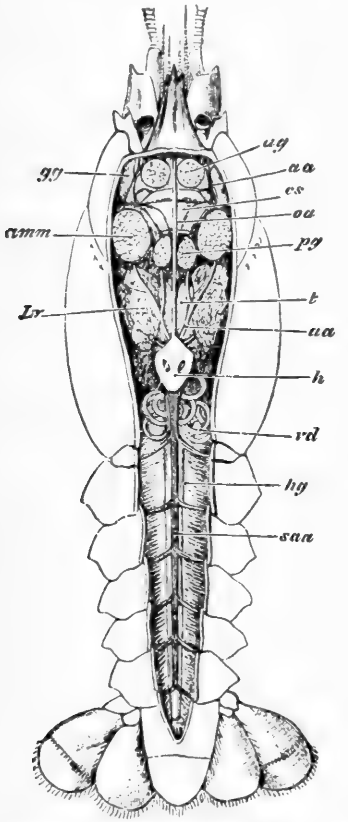



Fig. 70.—*Astacus fluviatilis.* A male specimen, with the roof of the carapace and the terga of the abdominal somites removed to show the viscera (nat. size): *aa*, Antennary artery; *ag*, anterior gastric muscles; *amm*, adductor muscles of the mandibles; *cs*, cardiac portion of the stomach; *gg*, green glands; *h*, heart; *hg*, hind gut, or large intestine; *Lr*, liver; *oa*, ophthalmic artery; *pg*, posterior gastric muscles; *saa*, superior abdominal artery; *t*, testis; *rd*, vas deferens. (Huxley.)

bathes the tissues, then goes into the larger median ventral sinus below the thorax and abdomen, from which it is conducted to the gills. After being conveyed to the gill filaments, where it is aërated, it is returned to the heart through the pericardial sinus. The blood enters the heart, or dorsal vessel, through three pairs of openings, one on each side, a pair on the top, and another pair below. Valves prevent the blood from returning through these openings.

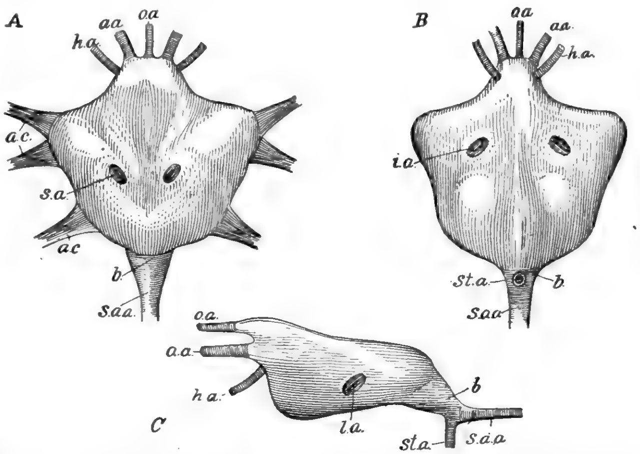



Fig. 71.—*Astacus fluviatilis*. The heart (x 4). *A*, From above; *B*, from below; *C*, from the left side: *a.a.*, Antennary artery; *a.c.*, alæ cordis, or fibrous bands connecting the heart with the walls of the pericardial sinus; *b*, bulbous dilatation at the origin of the sternal artery; *h.a.*, hepatic artery; *l.a.*, lateral valvular apertures; *o.a.*, ophthalmic artery; *s.a.*, superior valvular apertures; *s.a.a.* superior abdominal artery; *st.a.*, sternal artery, in *B* cut off close to its origin. (After Huxley.)

*Respiration.*—The plume-like gills are attached to the basal joints of the legs. They are situated in partially closed chambers between the body wall and the carapace. The water is drawn in and out by the "gill-bailers," parts of the second maxillæ, in their vibration back and forth. In passing over the gills the water is separated from the blood by an extremely thin membrane. Through this membrane the carbon dioxid is thrown off and oxygen taken into the blood.

*Nervous System.*—Several ganglia unite to form the supra-esophageal ganglion or "brain," from which a nerve cord passes on each side, uniting below the esophagus in a double (apparently single) ventral nerve cord (Fig. 69), which extends the whole length of the body and connects the ganglia. We should expect to see a ganglion for each segment, but there are but thirteen ganglia, some of these being formed from a union of several. On each side of the esophagus is a large ganglion; there are five more ganglia in the thorax and six in the abdomen.

The stalked eyes are compound, being composed of many facets. The sense of touch is well developed. The surface of the body is sensitive and the antennæ are especially adapted for "feelers." The sense of smell is thought to be seated in the hairs or setæ on the antennules.

*Multiplication.*—In the spring the little brown or black eggs may be found attached to the swimmerets of the female. For some time the young crayfishes, by means of hooks on their claws, cling to the swimmerets of the mother for protection.

*Molting.*—The young crayfish, which is of much the same appearance as the adult, grows rapidly. Since the shell is hard the animal cannot enlarge except when it sheds its skin or molts, which it does periodically. Even the hard lining of the stomach is cast. Growth takes place while the new skin or shell is forming.

*Restoring Lost Parts.*—Crayfishes have the power of growing a new leg to replace one broken off by accident or in a fight. This accounts for the unequal size of the chelipeds in many specimens.

*Habits.*—Crayfishes inhabit fresh-water streams and ponds, lurking under stones or ledges in daytime and feeding at night. When the streams dry up, they dig holes in the ground until they reach water. These are sometimes many feet deep. The clay dug out around the hole is deposited in a "chimney." In these holes they probably live till the next spring. Some species do not live in the water, but burrow in the soft moist earth, and one species has been found in the sea. Crayfishes are omnivorous, eating anything they can get, but they prefer worms, insect larvæ, and snails.

The *protective resemblance* is excellent, the colors varying from a delicate pink or tan to a dark green or purple.

*Use.*—Crayfishes are used by the million in France, and to a limited extent in the United States, for food. They also furnish food for fishes. Raccoons, muskrats, and crows prey upon them.

The **lobster** (Fig. 72) is marine and is very much like the crayfish, only much larger. Specimens weighing twenty-five

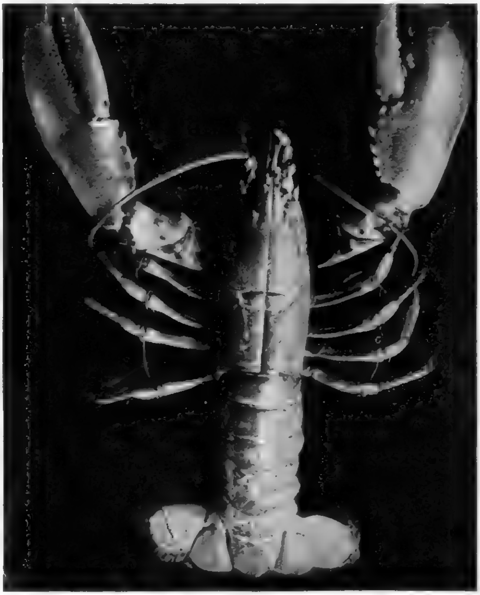


Fig. 72.—A small lobster (dorsal view) mounted on a glass so as to show both dorsal and ventral views. Students' work.

pounds have been captured. Among the invertebrates the lobster ranks next to the oyster as an article of food for man.

Prawns and shrimps look like our common crayfish and are used to some extent for food. They are small. The common prawn (*Palæmone'tes vulga'ris*) is about 2 inches long. It is transparent, so that the viscera can be seen through the thin leathery carapace.

**Hermit Crabs** (Fig. 73).—There are a number of species of hermit crabs which are not true crabs, but are more like the lobster and crayfish. They have the habit of backing into empty univalve shells which they carry about with them and into which they may withdraw for protection. This habit has resulted in a soft-skinned, reduced abdomen, with a spiral twist and with no appendages except a pair of hooks for holding on to the inside of the shell. The abdomen is always hidden in the shell. The head, thorax, and legs project when the animal is active, but are withdrawn when danger approaches.

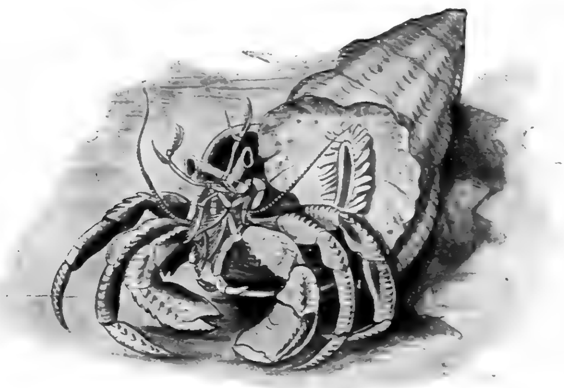


Fig. 73.—Hermit crab (*Pagu'rus*) in shell, with a sea-anemone (*Adam'sia pallia'ta*) attached to the shell. (After Hertwig.) (From Jordan and Kellogg, " Animal Life," D. Appleton and Co., Publishers.)

As it grows it discards its shell and hunts a larger one. Some of these hermit crabs have a peculiar commensal life with certain sea-anemones (Fig. 73), which they carry about on their shells. If the sea-anemone becomes detached the crab hunts another and places it on its shell. The crab is protected from its enemies by the stinging threads of the anemone, also by its resemblance to the seaweed, while the anemone is assured of a fresh food supply by being carried from place to place by the crab.

**Crabs** are other examples of this order. The cephalothorax is much broader than that of the crayfish, and the abdomen, which is used only to protect the eggs of the female, is folded under the cephalothorax. They are great scavengers. Many kinds are used as food. One of the best for this purpose is the

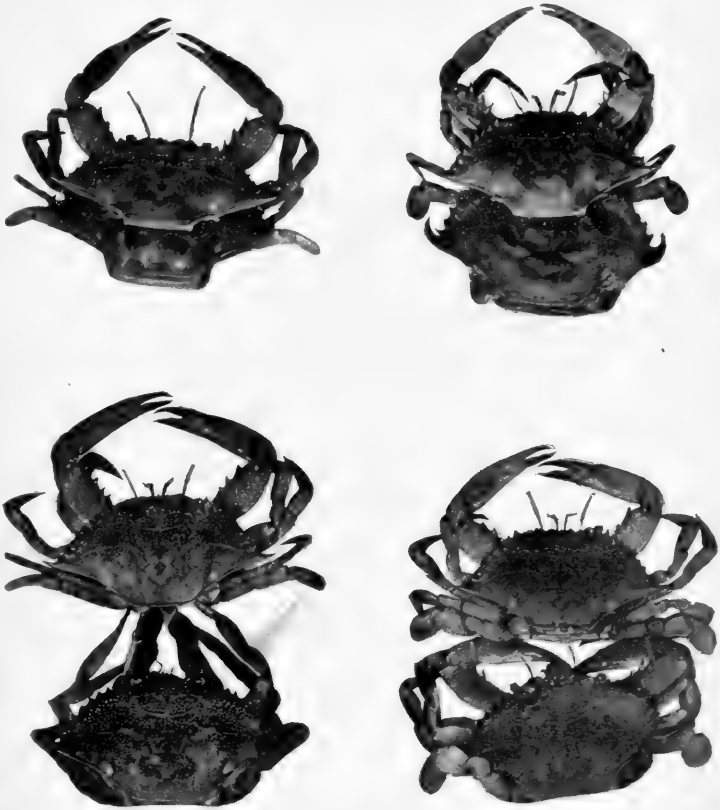


Fig. 74.—Successive stages of the molting of one individual of the blue crab, *Calli'nectes sa'pidus*. (G. Hay, in Doc. 580, Bureau of Fisheries.)

edible or "blue crab" (*Callinectes sapidus*), great numbers of which are caught along the Atlantic and Gulf coasts. They are best liked for food just after their molting (Fig. 74), and are then called "soft-shelled crabs." They are sometimes called "swimming crabs" because they have the last pair of thoracic legs flattened and paddle-like, adapted for swimming sideways quite rapidly. They have large sharp lateral spines. The strong chelipeds are adapted for cutting. Each of the other thoracic appendages ends in a point with no forceps.

The **little "fiddler-crab"** lives in salt marshes along the Atlantic coast. The male has one big and one little cheliped, which he brandishes grotesquely when disturbed.

The **spider crab** (*Macrochei'ra*) of Japan sometimes measures from 12 to 16 feet from tip to tip of legs, but the body is only a few inches—about a foot—in width, making them very peculiar creatures. At a little distance they look like immense sprawling spiders.

The little **oyster crab,** found so often in our dish of oysters, does no harm to the body of the oyster, but its life within the shell insures its food being brought to it by the currents of water made by the oyster to bring its own food. This is a case of commensalism[1] where there is a decided advantage to one animal and none, so far as known, to the other, yet the intruder does no harm.

**Order III. Arthrŏs'traca** comprises both marine and fresh-water forms. The first thoracic segment, and sometimes the

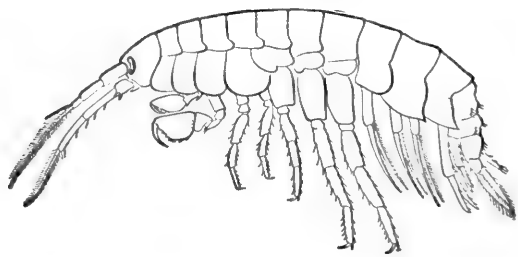


Fig. 75.—Beach flea, *Gam'marus orna'tus.* (After Smith.)

second, is fused with the head and bears maxillipeds. The eyes are usually sessile. *Gammarus* (Fig. 75) is a fresh-water form.

**The Pill-bug.**—If one searches under old boards or logs he will find a small gray or brownish fourteen-footed crustacean, truly terrestrial, with depressed body and with gills on the abdominal appendages. It is called "pill-bug" from its habit

[1] See Jordan and Kellogg's "Evolution and Animal Life," p. 370.

of rolling up into a ball when surprised. Its protective resemblance is good. Its locomotion is by crawling or running.

Some of the marine *Arthrostraca* are parasitic on crabs and in the mouths of fishes.

## CLASS II. ARACH′NIDA

Arachnids are arthropods with the head and thorax generally fused into a cephalothorax, bearing six pairs of appendages. The first and second pairs are for biting. Then follow *four pairs of walking legs*. There are no antennæ, the eyes are simple, and the abdomen is apodal.[1]

The abdomen varies much. It is short in the spiders, long in the scorpions, or is fused with the thorax, forming a stout body in the mites.

They are usually oviparous. However, some scorpions and some mites are viviparous. They are generally terrestrial, but some live in the water. There is no well-marked metamorphosis.

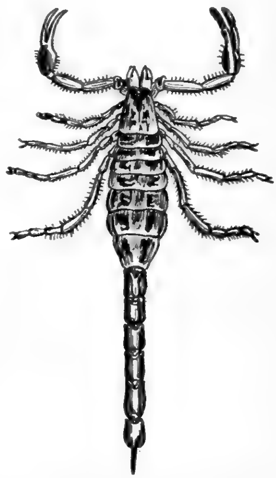


Fig. 76.—Carolina scorpion (*Bu′thus carolinia′nus*).

**Order I. Scorpion′ida.**—Scorpions (Fig. 76) are arachnids with long slender bodies ending in a poison fang. The head and thorax are fused and bear several pairs of jointed appendages. The abdomen consists of a broad anterior and a narrower posterior portion. There are several pairs of eyes.

*Respiration* is by means of four pairs of lung-sacs opening on ventral side of abdomen from the third to sixth segments.

*Food.*—They are carnivorous, feeding upon spiders and insects, which they seize with their pincers and sting to death.

*Multiplication.*—They are viviparous. The mother cares for the young with great solicitude, carrying them about attached to her body.

[1] See Glossary.

*Size.*—One giant species in Ceylon is 12 inches in length, while American species are about 4 inches long.

*Habits and Distribution.*—Scorpions are nocturnal. They live in tropical and subtropical countries. Their sting is dreaded by man, but seldom proves fatal. About twenty species are found in North America.

**Order II. Phalangid'ea.**—The members of this order look like long-legged spiders, with small bodies. Closer observation shows that the abdomen is fused with the thorax and not

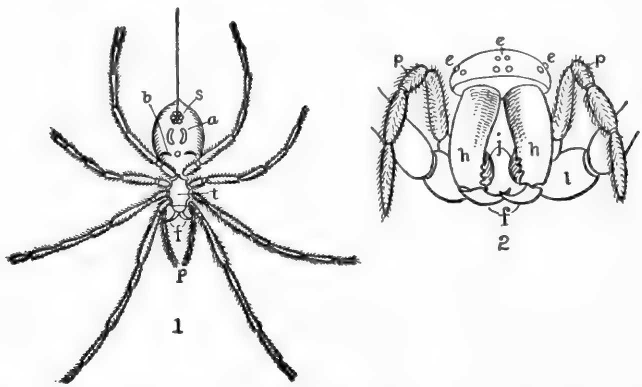



Fig. 77.—Parts of a spider. 1, Under part of a spider's body: *t*, Thorax, or chest, from which the eight legs spring, and to which the head is united in one piece; *f*, fangs; *p*, palpi, or feelers, attached to the jaws; *a*, abdomen; *b*, breathing-slits; *s*, six spinnerets with thread coming from them. 2, Front of spider's head: *e*, Eyes; *p*, palpi; *l*, front legs; *h*, hasp of fangs; *f*, poison-fangs; *j*, outer jaws. (From Holder's "Zoölogy," American Book Co., Publishers.)

joined by a pedicel, as in the spiders. The "harvest-man" or "daddy-long-legs" is a familiar example. It frequents shady places and feeds on small insects.

They are a dull color, to fit their environment. So long as they remain motionless their protective resemblance conceals them very effectively from their enemies. The respiration is by tracheæ.

**Order III. Arane'ida, or Spiders** (Fig. 77).—These are arachnids with unsegmented abdomen joined by a pedicel to the thorax.

*Appendages.*—There are two pairs of mouth-parts. The mandibles or cheliceræ are strong and composed of two portions, the basal falx and the sharp-pointed fang, in which is a small opening, the outlet of the poison gland. The palpi are

Fig. 78.—The bird-spider (*Myg'ale avicular'ia*) capturing a humming-bird. (From Holder's "Zoölogy," American Book Co., Publishers.)

long and limb-like and are often mistaken for a fifth pair of thoracic legs. The basal joints are broad and adapted for chewing the food. They are called the maxillæ. Then follow four pairs of seven-segmented legs used for locomotion. The spinnerets on the abdomen are homologous to paired appendages.

*Color.*—Almost all spiders are covered with hair. The color is partly in the skin and partly in the hair. The most common colors are grays and browns, but the colors are very varied, and in some species, as the jumping spider, they are almost as bright and gorgeous as those of butterflies.

*Foods and Feeding.*—They are generally carnivorous, sucking the juices from their prey. Some spiders spin webs, others do not. The spider's thread is composed of many fine threads, each passing from the body by a separate tube and then uniting. The united thread forms a cord finer than the finest silk of the silkworm, hence it is often used for the " cross-hairs " of the telescope.

*Respiration* is by lungs or lung-sacs containing bookleaf-like plates, and by tracheæ.

*Senses.*—The sense of sight is well developed, but they seem to be shortsighted, seeing clearly only at a distance of 4 or 5 inches. The palpi are organs of touch.

*Dimorphism.*—Male spiders usually have longer legs and smaller bodies than the females.

**Sub-order Tĕt′răpneū′mōnes.**—These spiders have four lungs and eight eyes. The most important members of the group spring upon their prey, often catching mice and small birds (Fig. 78). The large, dark, hairy spiders (*Myg′ale*) found in bunches of bananas belong here. The claws of the mandibles or jaws work up and down instead of from side to side.

The **trapdoor spiders** (*Cteni′za*) of the Southwest dig tunnels in the soil, line them with silk, and cover them with a close-fitting hinged lid.

**Sub-order Dipneu′mones.**—The members of this sub-order have two lungs and a pair of tracheæ. This group includes the majority of living spiders.

The **ground spiders** (*Dras′sidæ*) do not spin a web, but hunt their prey at night. Many species make silken tubes in which they lay their eggs or hide when molting or in winter. An eastern species lives in a bag of silk hidden under stones.

The **tube-weavers** (*Clubion′idæ*).—These are also species which spin no web. In summer they live in flat tubular nests on plants, sometimes in rolled leaves. In winter they live in tubular nests under bark and stones.

**The Funnel Web Weavers** (*Agalen′idæ*).—They weave a concave sheet of silk with a funnel-like tube on one side, and with threads extending in all directions attached to blades of grass for support. In the morning dew these webs form a shimmering silken sheet. The spider runs about on the upper surface of the " sheet " and catches any insects which light upon it. The tube or hiding place opens below, so that the spider can escape if an enemy appears upon the web. These are long-legged brown spiders, of which the common grass spider is a familiar example.

The **"curled-thread weavers"** are of two kinds, those which spin regular webs and those which spin irregular webs. The curled thread is composed of silk spun from a special organ, the *cribel'lum,* in front of the spinnerets. It is combed into shape by means of stiff hairs called the *calamis'trum* on the metatarsus of the hind legs, as the spider moves the hind legs rapidly back and forth.

Those spiders which spin irregular curled threads (**Dictyn'idæ**) usually make variously shaped webs on fences, under stones, in rotten logs, or upon plants having clusters of small flowers like the golden-rod.

There are but two genera of these spiders which spin regular webs (**Ulobor'idæ**). The " triangle spider " is found all over the country in pine woods. Its web is usually stretched between the twigs of a dead branch of pine or spruce, and consists of four plain radiating lines and a series of double cross-lines. The spider, which rests near one of the twigs from which a strong line is drawn to one of the other twigs, pulls the web tight, so that the cross-lines are separated as far as possible. When an insect lights upon one cross-line the spider suddenly lets go, so that the whole web springs forward and the insect becomes tangled up in the other cross-lines.

The **cobweb weavers** (*Theridi'idæ*) build their webs, which are apparently only a shapeless maze of threads, in the corners of rooms—as the house spider—or out in the fields between the leaves of bushes, or in the fence corners, or among rocks. They are generally rather light colored, small, and soft. They live in their webs, hanging by their feet, with the back downward. The cocoons, several of which are made in one season, are soft and round and hang in the web.

The **orb weavers** (*Epei'ridæ*) construct some of the most wonderful homes built by any animal. First, there is an irregular outer framework of supporting lines; then there is a number—from twelve to seventy—of dry and inelastic lines radiating from the center. There is an inner spiral of these inelastic threads which begins at the center and winds outward. The rings of this spiral are about as far apart as the spider can reach. Its use is merely for support. The spider then begins at the outermost part of the web and spins an outer spiral of sticky elastic threads, winding inward, the concentric circles being close together. As it becomes necessary, in forming this outer spiral, the threads of the inner spiral are destroyed. When an insect touches one of the outer sticky threads the thread not only sticks to it, but it stretches so that the insect becomes tangled up in the other circles, which is all the easier to do since the threads are so close together. Many species strengthen the web by spinning a zigzag ribbon across the center. The making of the entire web seems to be done altogether by feeling and can be done in the dark as well as in the daylight.

Most of the orb-weaving species have large, nearly spheric abdomens and stout legs, sometimes " with humps and spines." These spiders are often brightly colored, the colors of the abdomen being arranged in a triangular or leaf-shaped pattern. Some species live near the center of the web, hanging head downward, others hang back downward near one edge of the nest. In some species the male is smaller than the female.

The **crab spiders** (*Thomis'idæ*) are so-called because of their short broad form and peculiar habit of walking sidewise or backward. "They spin no webs, but lie in wait for their prey."[1] Some brightly colored species conceal themselves in flowers. Their protective resemblance is so good that insects visiting the flower often light within reach of the spider before seeing it. They live about plants and fences and hibernate in winter under stones and bark.

The **jumping spiders** (*At'tidæ*) have stout bodies and short legs, bright colors, and conspicuous eyes. They jump quickly sidewise or backward for a long distance. They make no webs except those in which they hibernate or lay their eggs.

**The Running Spiders** (*Lycos'idæ*).—These are the familiar hairy dark-colored spiders found under stones and logs. They depend upon their speed for the capture of their prey and run very swiftly. They resemble in appearance and habits the so-called tarantulas of the Southwest, but are smaller. The claws of their mandibles move horizontally. Their eyes are

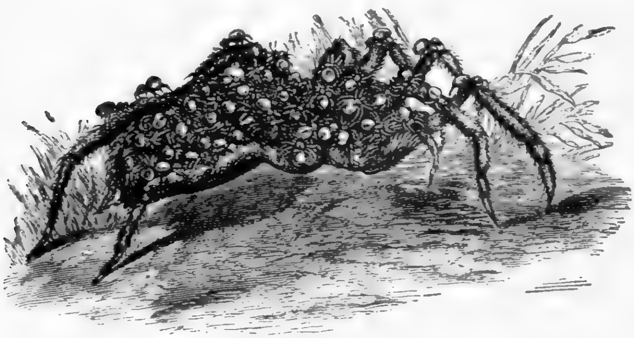


Fig. 79.—Female spider with young ones. (Cooper.)

of different sizes. Some of these spiders build tubular nests in the ground and line them with silk. They sometimes conceal the entrance with leaves and sticks. They often drag the egg-sac, a large gray ball, after them. In genus *Lyco'sa* the young (Fig. 79) climb upon their mother's back. The female of another genus, *Dolome'des*, carries the egg-sac "in her mandibles until the young are ready to hatch, when she fastens the sac in a bush and spins a web of irregular thread about it in which the young remain for a time."

**Order Acarī'na.**—These arachnids have stout bodies, there being no apparent segments, the abdomen being united with the cephalothorax. There is no heart nor blood-vessels. The respiration is performed by means of tracheæ. They are generally oviparous; some are viviparous. Many are parasitic (Fig. 80).

[1] Comstock.

The mouth parts are more or less united to form a beak. The common red mite sucks the juices of the house plants which it

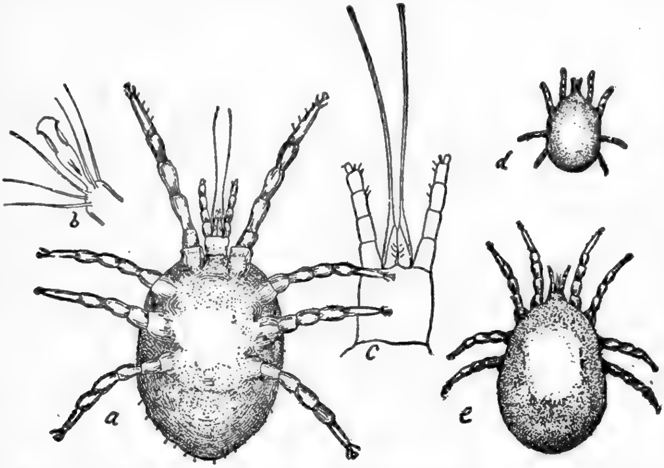



Fig. 80.—The chicken mite (*Dermanys'sus galli'næ*): *a*, Adult; *b*, tarsus; *c*, mouth parts; *d* and *e*, young. All much enlarged. (Osborn, U. S. Bureau of Ent., 1907).

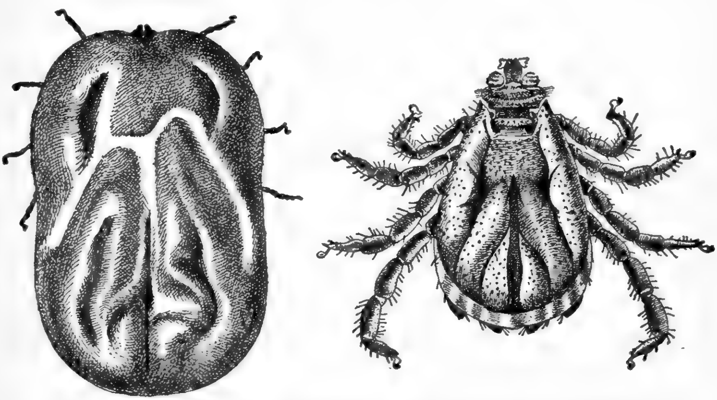


Fig. 81.—Cattle tick (enlarged). (After Salmon and Stiles.)

infests. One mite (*Dem'odex*) is parasitic in the hair-follicles of the dog, cat, sheep, cow, horse, and man. Another mite

(*Sarcop'tes scab'ei*) is the itch mite, causing the disease called the itch. Still another is called the cheese-mite.

**Ticks** (*Ixo'des*) are parasitic, blood-sucking *Acarina* which attack man and other mammals. They do not exceed a centimeter in length, the males being the smaller. The so-called "Texas fever" of cattle is transferred by the common cattle tick (Fig. 81).

Fig. 82.—Horseshoe or king crab (slightly damaged on left). (From specimen.)

**Order IV. Xĭph'osu'ra.**—The *Lim'ulus*, or horseshoe crab (Fig. 82), is a marine arachnid living on the bottom of the sea in shallow water, creeping along in the mud and sand and feeding on worms. The body has a chitinous covering. The cephalothorax is arched and bears the large compound eyes and two simple eyes. The abdomen is almost hexagonal and ends in a long caudal spine. On the ventral side of the cephalothorax are six pairs of appendages, used for securing food and for locomotion. The last pair, the operculum, is broad and leaf-like and covers the five pairs of leaf-like branchial appendages of the abdomen. These appendages are for respiration. The shape of the body, its hard covering, marginal spines, and its color, which harmonizes with its environment, afford it ample protection and defense.

There are several other orders, but these will suffice for our purpose in the present work.

## CLASS III. MYRIAP′ODA

The name indicates myriad footed, hence the common name, thousand-legs. A myriapod is a worm-like tracheate arthrŏpod with a distinct head, a round or flattened body composed of many similar segments, to each of which is attached one or two pairs of appendages. Myriapods have one pair of mandibles, one pair of antennæ, and numerous ocelli. "A few species are injurious to agriculture, while others are to be classed among our friends."

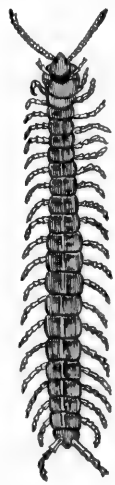


Fig. 83.—A centipede.

**Order I. Chīlop′oda.**—These are myriapods with the body flattened, with fifteen to one hundred and seventy or more segments, each bearing a single pair of legs, and with long, many jointed antennæ (Fig. 83). The mouth parts are adapted for biting. The opening of the poison gland is on the first pair of legs, which are used with the mouth parts. This order includes the centipedes, as *Litho′bius*, common under stones. The bite of the true centipede (*Scolopen′dra*) is fatal to insects and to other small animals, their prey, and painful or even dangerous to man.

**Order II. Diplop'oda.**—These are myriapods with dorsally convex bodies. Each apparent segment, beginning with the fourth or fifth, bears two pairs of appendages. There are no poison fangs. The antennæ are short and few jointed. This order includes the millipeds. An example is *Iulus*. They are found under old stumps or about rotten logs. Their food consists usually of decaying vegetable matter, but some forms

Fig. 84.—Class collecting insects.

feed upon growing plants, otherwise they are harmless. They have a habit of rolling up into a helix-like coil when disturbed.

They are bisexual. When hatched the young have but three pairs of legs. "By successive molts new segments and appendages are added" until the adult form is reached.

## CLASS IV. INSEC'TA

This class of Arthropoda comprises a very large number of species. Three hundred thousand, according to Kellogg, are known.

**Habits and Habitat.**—Insects vary in their habitat. Most of them are terrestrial, some are aërial, others are aquatic, a few even being marine, while still others are subterranean.

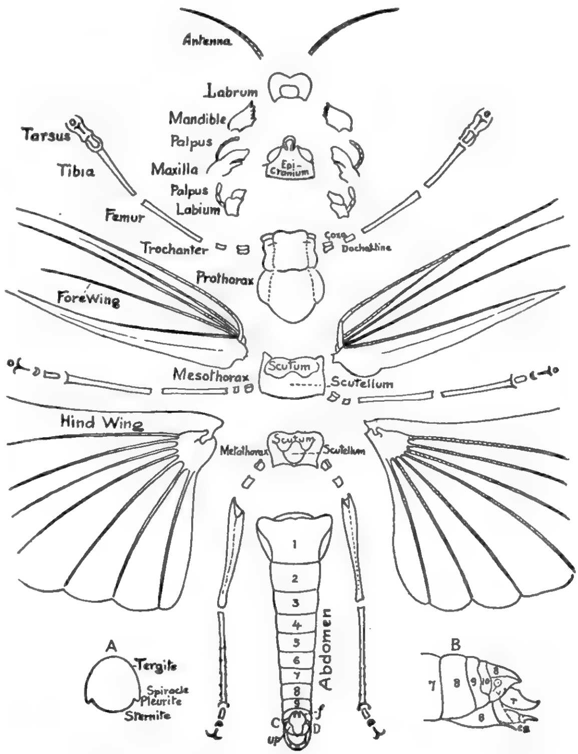



Fig. 85.—External anatomy of *Calopte'nus spre'tus*, the head and thorax disjointed: *up*, Uropatagium; *f*, furcula; *c*, cercus. (Drawn by J. S. Kingsley.) (From Packard's "Zoölogy," Henry Holt & Co., Publishers.)

Some are diurnal, as our common butterflies; others are nocturnal, as the bed-bug; some, crepuscular, as the moths. Some are solitary; others gregarious, or social, as the ants and bees.

**Plan of Structure** (Fig. 85).—The insect body is divided into three well-marked regions—the head, thorax, and abdomen.

The head bears the compound eyes and simple eyes (when they are present), one pair of antennæ, and three pairs of mouth parts, which vary according to the character of their food. Hence the mouth parts may be adapted for chewing, lapping, sucking, or piercing—"all referable back to the chewing type. These are, in turn, modified legs."[1]

The thorax has usually three well-marked segments—prothorax, mesothorax, and metathorax—as in the grasshopper. Each segment bears a pair of jointed ventral legs. The two pairs of wings, when present, are outgrowths of the dorsal por-

Fig. 86.—"Look out!"

tion of the meso- and metathorax. Sometimes there is but one pair, and in a few cases none.

The abdominal segments vary in number and usually bear no paired appendages except, sometimes, on the terminal segments.

**Covering.**—Over the greater portion of the surface of the body the cuticle or external layer of the skin is made firm and horny by a substance called chitin. This forms an exoskeleton for the protection of the soft parts within, and, by its rough interior surface, provides points of attachment for the numerous small but strong muscles.

[1] Kingsley's Hertwig, "A Manual of Zoölogy."

Those portions of the cuticle which do not contain much chitin are easily bent, thus permitting motion between the segments of the body and of the appendages.

All insects have hairs scattered more or less abundantly or regularly over the body. In Lepidoptera the hairs are modified into scales, as is shown on the wings of a butterfly, where "all the gradations from hair to scale can be found by going from the base out to the distal area of the wing."[1]

**Self-defense** (Fig. 86) is by various methods and organs, which will suggest themselves to the student from his past experience. When insects cannot sting or bite, they often

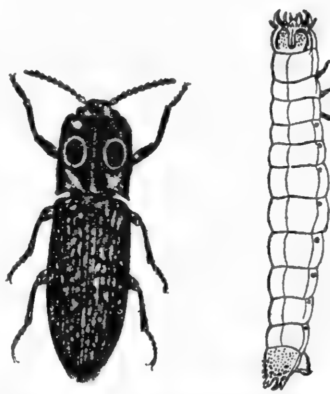


Fig. 87.—*Al'aus ocula'tus* and larva, showing eye-spots. (After Harris.)

defend themselves by threatening attitudes. In some cases one is reminded, at first sight, of a snake's head, and retreats in terror. The "eye-spots" (Fig. 87) and "horns" (Fig. 88) on many insects are probably for the purpose of terrifying appearance.

**Protective Coloration.**—Insects attract attention by the variety and intensity of their colors and by their numerous, interesting, and often beautiful color-patterns. Many naturalists believe, and have confirmed their opinions by observation and experiment, that the variety of color and color-patterns of

[1] Kellogg, p. 592.

insects and of other animals is indirectly due to two causes: first, the advantages given to the individual or species in the struggle for existence by these specific colors and color-patterns, which—as in the case of the gray moth on the tree-trunk or the katy-did among the green leaves—helps to conceal them

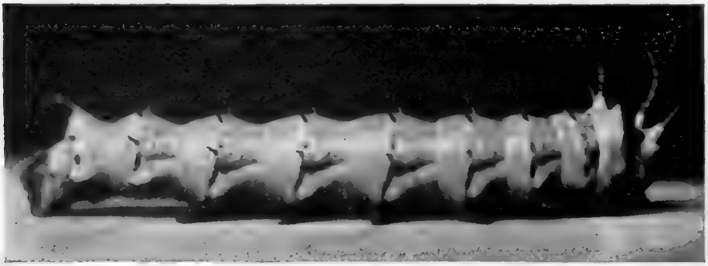


Fig. 88.—Larva of regal walnut moth (*Cithero'nia rega'lis*) extended (two-thirds nat. size). (Photographed from life.)

from their enemies by affording protective resemblance, or—as in the case of the bumble-bee or the milkweed butterfly—to warn the enemy of the danger of sting or of the disagreeable odor and taste. The advantage gained is easy to be seen in each

Fig. 89.—Pupa of regal walnut moth (three-quarters nat. size). (From life.)

case. They believe that these particular color-patterns are due, in the second place, to gradual development " through natural selection of naturally occurring, advantageous variations."

The direct cause of color may be chemical, depending on the chemical composition; or physical, depending upon the structural or physical make-up; or it may be due to a combination of both of these. In the most highly colored group of insects, the Lepidoptera, the color is due to the chemical substances (pigment granules), to the structural character of the scale

Fig. 90.—The protective resemblance of the leaf-butterfly (*Kal'lima*). (Holder, after Wallace.)

walls (striæ), and to the overlapping (lamination) of the scales laterally, as well as to the overlapping of the tips of the scales in one row over the bases of the scales of another row.

" The blacks, browns, yellows, and dull reds of butterflies and moths are produced chiefly by the pigments (chemical colors), while the brilliant metallic colors, the iridescent blues and greens, . . . are due to the structural or physical make-up of the scale covering."[1]

*Variable Protective Resemblance.*—Often the different individuals of the same species are of slightly different colors, the colors varying to harmonize with the particular environment of the individual during its development, being fixed in the adult.

*Special protective resemblance* (Fig. 90) is illustrated by *Kallima*, which resembles a dead leaf, and *Phyllium*, resembling a green leaf (Fig. 91), and, more commonly, by the measuring-worm, as it holds the body out stiff, imitating a short or broken twig. Thus in many cases " the insect's appearance simulates in more or less nearly exact ways some particular part of the habitual environment."

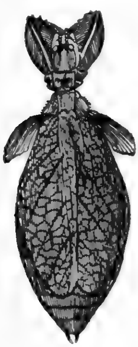


Fig. 91.—*Phyl'lium siccifo'lium* feeds on leaves, and mimics fresh leaves. (Holder.)

*Warning colors* are possessed by many insects having a special organ of defense —as the sting of that wonderful little stimulator, the hornet—or a disagreeable taste or odor, as that of the milkweed or " monarch " butterfly (*Anosia plexippus*) (Fig. 92, *a*). Other examples of insects having conspicuous or warning colors are the black and yellow wasps and bees, the lady-bird beetle, and the swallow-tail butterflies. Many others might be mentioned. Since the bodies of insects are soft, one can easily see why these conspicuous colors are of natural advantage. A single stroke of the beak of a bird might prove fatal to any of them. The bird must learn by experience that the insect is armed or distasteful, but if the insect is conspicuously colored, it will be noticeable and easily remembered, so that the bird will not attack another of this brightly colored kind. Hence the species will be perpetuated and the characteristic colors handed down to the next generation, or, in other words, " preserved and accumulated by natural selection."

*Alluring or directing colors or forms* may be found among in-

[1] Kellogg.

sects, according to Poulton. The apical portion of the fore-wing and the hind portion of the posterior wing are especially marked with borders or eye-like spots, and are often prolonged, as in the swallow-tail butterfly, into antennæ-like processes or tails. These, resembling the head with eyes and antennæ, direct the stroke of the enemy to this part. The insect thus escapes with the loss of the tip or a scrap of the wing, thus saving its head or its soft body.

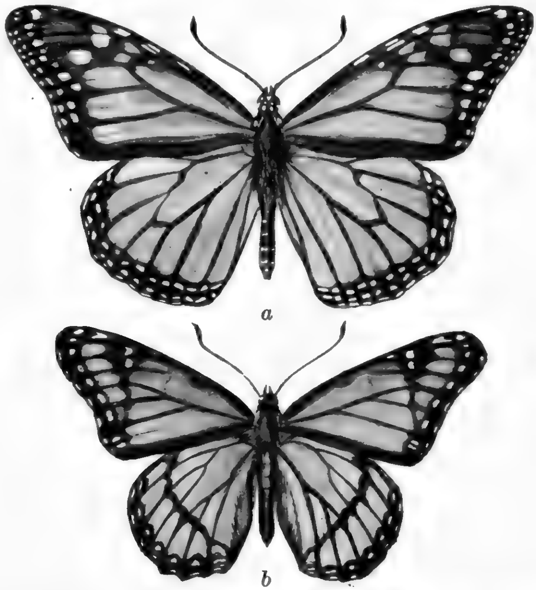



Fig. 92.—*a*, Monarch butterfly(*Ano'sia plexip'pus*), distasteful to birds. *b*, Viceroy (*Basilar'chia archip'pus*), which mimics it. (From Kellogg's "Zoölogy," Henry Holt & Co., Publishers.)

**Mimicry.**—The viceroy butterfly (Fig. 92, *b*) imitates, unconsciously, of course, the common "monarch" or milkweed butterfly, since the latter is seldom eaten by birds, owing to a disagreeable taste or odor. Many bees are mimicked by flies, and distasteful beetles by other beetles.

**Muscular System and Locomotion.**—Locomotion may be in any one or all of three ways—running, jumping, or flying. The muscular system varies widely in the different forms. In the caterpillars there is a "simple worm-like arrangement of segmentally disposed longitudinal and ring muscles," while in the more active forms, as flies and bees, the muscular system is complicated. The muscles are composed of fine, cross-striated fibers, forming masses of various sizes, and are attached to the rough inner surface of the exoskelton. The muscles are transparent and have great contractile power.

**Digestive System.**—The alimentary tube (Fig. 93), which may be coiled much or little, varies greatly. It is about the length

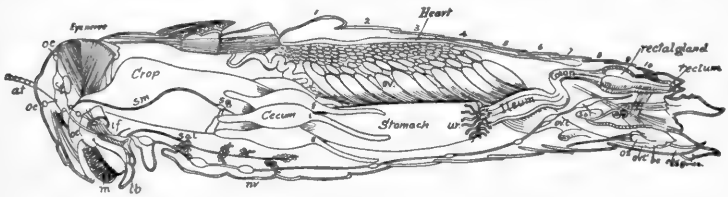



Fig. 93.—Internal anatomy of *Calopte'nus fe'mur-ru'brum: at,* Antenna and nerve leading to it from the "brain" or supra-esophageal ganglion (*sp*); *oc*, ocelli, anterior and vertical ones, with ocellar nerves leading to them from the "brain"; *œ*, esophagus; *m*, mouth; *lb*, labium or under lip; *if*, infra-esophageal ganglion, sending three pairs of nerves to the mandibles, maxillæ, and labium respectively (not clearly shown in the engraving); *sm*, sympathetic or vagus nerve, starting from a ganglion resting above the esophagus, and connecting with another ganglion (*sg*) near the hinder end of the crop; *sal*, salivary glands (the termination of the salivary duct not clearly shown by the engraver); *nv*, nervous cord and ganglia; *ov*, ovary; *ur*, urinary tubes (cut off, leaving the stumps); *ovt*, oviduct; *sb*, sebaceous gland; *bc*, bursa copulatrix; *ovt'*, site of opening of the oviduct (the left oviduct cut away); 1–10, abdominal segments. All other organs labeled in full. (Drawn from his original dissections by Mr. Edward Burgess.) (From Packard's "Zoölogy," Henry Holt & Co., Publishers.)

of the body in carnivorous forms, and longer in the herbivorous insects. It consists of a mouth, esophagus, crop, gizzard (the chitinous lining of which is toothed for grinding the food), a digestive stomach, and an intestine. There may be one or two pairs of salivary glands, and usually two or more pairs of gastric cæca containing glands supposed to supply digestive fluids. The intestine usually consists of a small intestine and a large intestine, the two regions of the latter being the colon and the rectum. The Malphighian tubules, fine tubes connected with the intestine at the beginning of the rectum, take the place of kidneys. There is no liver. The entire viscera are enveloped in the "fat body." The anal opening is in the last segment of the abdomen.

Insects feed upon the juices, leaves, or even the wood of plants, or are parasitic or predaceous upon various forms of insects, and upon other animals as well. Some live upon decaying organic matter.

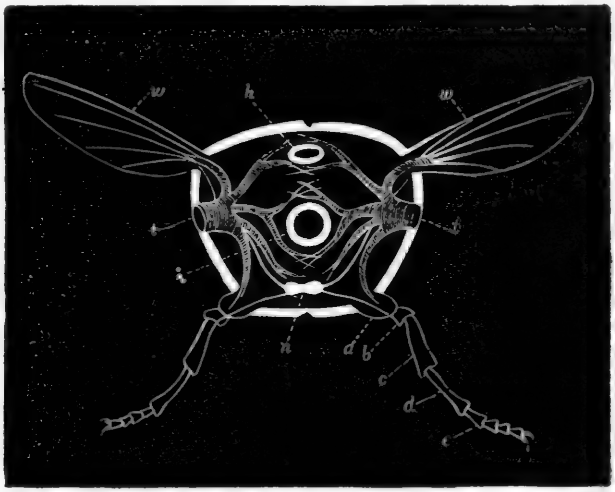



Fig. 94.—Ideal transverse section of an insect: *h*, Dorsal vessel; *i*, intestine; *n*, ventral nerve-cord; *t*, *t*, stigmata leading into the branched tracheal tubes; *w*, *w*, wings; *a*, coxa of one leg; *b*, trochanter; *c*, femur; *d*, tibia; *e*, tarsus. (After Packard.)

The **circulatory organs** are extremely primitive in character. The heart or dorsal vessel extends through the abdomen just underneath the dorsal surface. It is partially divided by valves into chambers, the number of which varies. The anterior chamber extends into or near the head and is sometimes called the aorta. The heart chambers pulsate rhythmically, from the posterior one forward, and force the blood out into the body cavity. There are no veins or arteries, so it flows through the sinuses or open spaces between the organs, bathing the tissues, and finally bathing the walls of the alimentary tube, where it takes up the food supply and then re-enters the heart through the side openings. It does not supply the tissues with oxygen, since it receives only enough for its own use.

**Respiration** is carried on by a series of air-tubes called tracheæ. These tubes are interbranching and penetrate to every portion of the body. The air enters them through a pair of stigmata or pores, one on either side of each segment. The functions of these tracheæ are to take up oxygen from the air and to distribute it to the tissues of the body, since this is not done by the circulation of the blood, and to collect and carry off the carbon dioxid.

Insects which live in water either come up to the surface to breathe and, in some cases, to take down a supply of air held on the outside of the body by a fine pubescence, or they are provided with tracheal gills which will enable them to breathe air mixed with water. Gilled insects, of course, do not have to come to the surface to breathe.

**The Nervous System.**—Besides the central or ventral (Fig. 93) nervous system (see Branch Arthropoda), insects have a small and varying sympathetic nervous system (Fig. 93), consisting of a few small ganglia sending nerves to the automatic-acting visceral organs. Commissures connect the sympathetic system with the brain just at the origin of the subesophageal commissures.

**Touch.**—The sense of touch is located in the " hairs " distributed over the various parts of the body, but most numerous on the feelers.

**Taste** is located on small papillæ or in pits on the mouth-parts, particularly on the tips of the palpi and on the upper wall of the mouth.

**Smell** is probably the most used sense of insects. The organs of this sense are minute papillæ and " microscopic pits " on the antennæ and mouth parts. It has been proved that most insects find their food by this sense. " It is believed that ants find their way back to their nests by the sense of smell and that they can recognize by scent, among hundreds of individuals taken from various communities, members of their own community."[1]

[1] Kellogg's " American Insects."

**Hearing.**—Many insects have sound-producing organs and auditory organs; and it has been proved by experiment that they hear. The ear of the grasshopper or locust, a small tympanic membrane, is situated at the anterior end of the abdomen, while that of the katy-did and cricket (Fig. 95) is situated on the tibia of the fore-leg. There is a special auditory ganglion. The mosquito has its auditory organs in the antennæ in the segments next to the basal ones, through which the sound or vibrations are carried by many fine auditory hairs, and from which the auditory nerves lead to the "brain." It is thought that the male mosquito finds his mate by her song.

**Sight.**—Insects usually have both simple and compound eyes, though either kind may be found alone; and a few insects are blind by degeneration. The ocelli, or simple eyes, are usually three in number and form a little triangle on the


Fig. 95.—The front leg of the cricket enlarged, showing the ear at *a*.

top of the head. Each of them is supplied with a special nerve from the "brain." It is thought that the ocelli can do little more than distinguish light from darkness and that their range of vision is restricted to an inch or two in front of the head. The compound eyes, two in number (see Fig. 84), are usually large and conspicuous, often composing more than two-thirds of the entire head. Each compound eye presents from twenty to several thousand polygonal facets, or windows, which, altogether, form the cornea. It is thought that the range of vision of the compound eyes is two or three yards. The larger the eyes, the wider will be the range of vision, while the smaller and more numerous the facets, the sharper and more distinct will be the image. Experiment and study of the structure of the eye, says Kellogg, "indicate that, at best, the sight of insects cannot be exact or of much range."

The **psychology** of insects is a very interesting study. Whether the activities of insects are due to reflex action, instinct, or intelligence can be better determined when studying the various species, but one will surely find that insects, as well as being the most numerous and various, are also the most interesting and wonderful of all the classes of invertebrates.

**Multiplication** is by eggs, of which many are deposited in various places. Some are placed on or in another animal's body, others on leaves or stems of plants, which serve as food for the young. However, some insects, as the *Aphides*, show *parthenogenesis, i. e.*, they are supposed to produce young from unfertilized eggs.

**Metamorphosis.**—Insects pass through a more or less complete series of changes, called metamorphosis. The larvæ, whose business it is to feed and grow, are called by various names, as caterpillars, grubs, nymphs, and maggots. Since the larvæ are wingless they are placed in different relations to their environment from those of the adult, and hence often have special larval organs. The larval stage is followed by a quiet stage called the pupa (Fig. 89). In this condition many insects pass the winter and come forth in the spring as adults or imagoes, the reproductive stage. Others remain in the pupa stage but a few weeks, thus giving time for two or more broods in a season.

**Parasitism** is common in insects. Parasites may be external or internal. The natural consequence of a parasitic life is degeneration, as is seen in lice and fleas, whose ancestors were winged insects.

**Environmental Influences.**—Insects are affected by temperature. They become active with the rise of temperature in the spring, and some become dormant or hibernate as the temperature declines in fall and early winter. Most of them die with the advent of frost. The direction and velocity of the wind is a factor in insect life, especially in its distribution.

The amount of precipitation will influence the amount and kind of vegetation, which determines to a large extent the number and kind of insects. Certain kinds of precipitation, as hail, for example, or floods, would destroy large numbers of insects. Any environmental factor would increase or decrease the activity, food, enemies, dispersal, migration, mentality, or other phenomena connected with animal life.

**Geologic Distribution.**—Insects of some kind have existed for a long time geologically, insect remains being found in the lower and upper Silurian.

**Economic Importance.**—Insects devour our crops, carry disease, annoy us when awake and prey upon us when we sleep, injure or destroy our stock, infest our orchards, and in some countries the white ants do much damage to dwellings. The damage to our American crops has been estimated at the enormous sum of $700,000,000 in one year. But when we remember that insects are also dangerous to health and life, how much more is the number of injurious insects to be deprecated. Kellogg says, "Mosquitos help to propagate and are almost certainly the exclusive disseminating agents of malaria, yellow fever," and other diseases; "house-flies aid in spreading typhoid fever and other diseases; fleas are agents in distributing the germs of the bubonic plague." Howard says the germs of the disease known as "pink-eye" are carried by very minute flies of the genus *Hippelates*. Other insects are known to spread other diseases (Fig. 96).

Fig. 96.—Tsetse fly, which causes a disease of cattle in Africa, enlarged. (L. O. Howard.)

However, some insects are valuable to man. The honey-bee makes honey; other insects furnish galls for ink; others, dyestuffs, such as cochineal; while others serve as scavengers, and the silkworm (Fig. 97) furnishes our finest clothes. The bumble-bee fertilizes the clover blossoms, other insects cross-fertilize the flowers of many plants, and many serve as food for birds. Thus, while some insects are very harmful to us, others are very valuable to us. If we (with the help of the birds) exterminate those which are injurious and protect those which are beneficial, our crops will be the larger and more profitable, and our bodies more secure from disease.

**Classification.**—Entomologists vary in their opinions as to the number of orders into which the Class Insecta should be divided. Packard's "Guide" (1883) gives eight orders, while Comstock's "Manual" (1895) and Kellogg's "American Insects" (1905) each give nineteen orders. Kellogg says, "In the first place the author believes that this classification[1] best represents our present knowledge of insect taxonomy; in the second place,

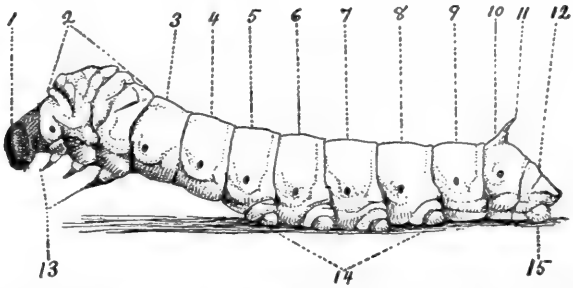



Fig. 97.—Adult silkworm: 1, Head; 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, rings; 11, horn; 13, three pairs of articulated legs; 14, four pairs of abdominal or false legs; 15, a pair of false legs on the last ring. (Farmers' Bull. 165, U. S. Dept. of Agriculture.)

this is the classification taught by nearly all the teachers of entomology in America."

Students wishing to study insects in detail should consult either Comstock's or Kellogg's large work on insects.

### ORDER I. AP'TERA OR THYSANU'RA

These are small or minute wingless insects which undergo no metamorphosis. The body is covered with hairs or scales. There are several pairs of rudimentary abdominal appendages, probably vestiges of abdominal legs in ancestors. The mouth parts are adapted for biting. "Their internal systems of organs have a segmental character corresponding to the external segmentation of the body."[2] They live in sugar boxes and pan-

[1] Comstock's classification. [2] Kellogg, p. 59.

tries or under leaves, and in the spring they are sometimes found in large numbers on the surface of pools of water or upon the snow.

*Campo'dea staphyli'nus,* which is regarded as the most primitive living insect, belongs to this order. It is about ¼ inch long, white, wingless, and flat. Its body is exceedingly soft and delicate. It is widely distributed.

The "**fish-moth**" (*Lepis'ma sacchari'na*) of the house (Fig. 98), which is neither a moth nor a fish, is silvery white, with a yellowish tinge on antennæ and legs. It is about ⅓ inch long, has three long caudal appendages, and feeds chiefly upon sweet starchy materials, often attacking starched clothing and the paste of wall-paper and book-bindings. It may be gotten rid of by sprinkling fresh pyrethrum powder in the places infested or by spraying slightly with nicotin or formalin.

The "**spring-tails**" (*Collem'bola*) have a forked spring attached to the next to the last segment of the abdomen, by means of which they leap from a few inches to a foot in the air. The "snow-fleas" collect in large numbers on the snow in spring. They are often a cause of great annoyance where maple sugar is made.

Fig. 98.—*Lepis'ma sacchari'na,* enlarged. (L. O. Howard, U. S. Dept. of Agriculture.)

Surely the insects of this order, by their simplicity of structure and their similarity of somites, show their worm ancestry, though some species show much more complexity of structure. It will be interesting for the student to consider how, from such a generalized primitive form as *Campodea staphylinus,* nature can produce, by modification of parts, an insect of highly complex structure.

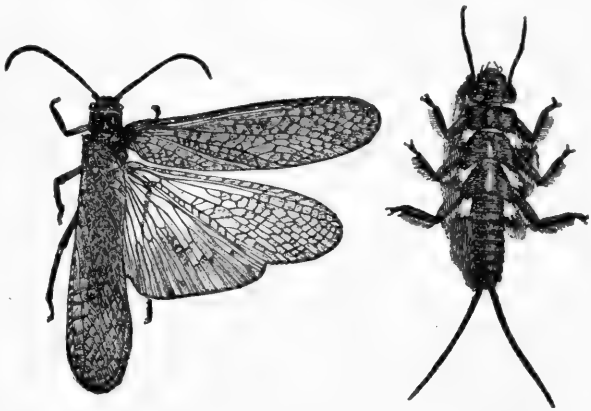
## Order II. Ephemer'ida

The **May-flies,** in the adult form, are insects of a day, but they pass two or three years in the larval stage. When they emerge from their larval condition into their winged form they come forth in myriads along streams. The authors saw their dead bodies piled a foot deep on an Illinois river bridge just under the electric lights. So thick were they that workmen came next day and shovelled myriads of them into the river. They are fragile, soft skinned, and long bodied, with four gauzy wings, of which the anterior pair is much the larger. The abdomen ends in long thread-like anal projections. The mouth parts are rudimentary. Indeed, the adults are said to take no food, but to reproduce and die. The eggs are laid in the water. Soon appear tiny, soft-bodied, wingless nymphs, bearing leaf-like fringed gills arranged segmentally along the sides, and two or three many jointed anal appendages. They have strong legs and can both swim and walk. They lie on the bottom of streams, and, with their powerful mandibles which are adapted for biting and chewing, catch and devour other insects. They eat plants also, and are themselves prized as food by many kinds of fishes and other aquatic animals.

After the ninth molt (some species have twenty-one) the wing-pads begin to develop. The nymph continues to grow and to molt, until finally it leaves behind its " water-nymph skin " and comes forth a winged May-fly. Again it sheds its skin, it may be within a few minutes or within twenty-four hours, a thin layer coming off even from the wings. This is the only known instance of an insect molting after acquiring its wings.

### ORDER III. PLECOP'TERA

The **stone-flies** are comprised of a single family, the *Per'lidæ.* These grayish or brownish insects (Fig. 99) are ½ to 1½ inches long and have four large membranous wings, but the posterior pair folds up like a fan when not in use. Unlike the dragon-flies, in which the anterior and posterior wings are about equal in size, the posterior wings are much wider than the anterior ones. The mouth parts are adapted for biting, but poorly so as compared with those of the dragon-fly. The adults probably eat little. The long antennæ are many jointed and the abdomen is often furnished with a pair of many jointed bristles or filaments. The 5000 or 6000 eggs are probably well scattered in the swift current before dropping to the bottom. The metamorphosis is incomplete. The nymphs, like those of the dragon-fly, are aquatic. They are provided with gills. Those who advocate the aquatic ancestry of insects believe that the spiracles are the openings left when the gills were lost, but certain species of stone-flies retain their gills—though shrivelled and probably functionless—and have wholly independent spiracles.[1]



A B

Fig. 99.—*A*, Stone-fly. *B*, A nymph of a stone-fly. (Comstock.)

The larvæ of stone-flies are flat and cling closely to the surface of stones in the swiftest portion of the stream. They cannot live in stagnant or foul water. Their resemblance to a fossil is almost perfect. This resemblance is their protection from their enemies, the fishes. These larval stone-flies are good bait for trout.

### ORDER IV. ODON'ATA

**Dragon-flies.**—To this order again belongs[2] a single family,[3] the *Libellu'lidæ*, or dragon-flies (Fig. 100). They have many common names, as "mule-killers," "snake-doctors," and "devil's darning-needles," but, in spite of these terrifying names, they are all perfectly harmless to man.

[1] Kellogg, p. 72.
[2] Kellogg includes the damsel flies.
[3] Comstock, p. 90.

The four finely netted membranous wings of the adult dragon-fly are long, narrow, strong, and nearly equal. If unequal, the posterior wings are the larger. Each wing has a joint-like structure near the middle of the front margin. Their mouth parts


Fig. 100.—Dragon-flies in the larval, pupal, and imago state. (After Tenney.)

are adapted for biting. Their compound eyes are very large and the antennæ short. The metamorphosis is incomplete. The eggs are laid in water or attached to aquatic plants. They soon hatch, and the larvæ (Fig. 100), called nymphs, live a predatory existence. They lie in wait for their prey.

"The fierce face of the young dragon is all concealed" by its extensible lower lip, which folds up. With their strong jaws and legs dragon-flies secure and devour their prey. They devour vast numbers of larval mosquitos and are thus of great use to man. Finally, the full-grown nymph creeps up some stem, and the winged form of the imago or adult dragon-fly breaks through the old skin and flies away into the air and sunshine to enjoy its aërial life until the falling temperature ends its existence. These beautiful creatures may be called creatures of the air, for they actually feed upon the wing and may sometimes be seen poised in mid-air as if resting. The adult devours many gnats and mosquitos. There are two types of dragon-flies, one which keeps its wings horizontal and one which folds its wings together vertically over the back.[1]

The breathing of the nymphs is peculiar. "The caudal end of the alimentary canal is lined with tracheæ, and water is alternately drawn into and expelled from this cavity. The water may be expelled with such force as to propel the body forward. So this has a locomotive function also."

## ORDER V. ISOP'TERA

The **Termites** (Fig. 101), or so-called "white ants," are abundant in the tropics, but less so in the United States. Where they are numerous they become pests, destroying houses, furniture, or anything made of wood. They are not ants, as may be seen by their structure.

The body is always soft and usually whitish in color, though sometimes brown. "It is plump and slightly broader than thick." In the union of the abdomen with the thorax the little pedicel or stem found in the ant is lacking, the abdomen being broad at the base. They are blind or have simple eyes. They conceal themselves from the light. The slender antennæ look like strings of tiny beads.

The young are all apparently alike when hatched, but by some means not understood they are afterward developed into soldiers, workers, males (kings), and females (queens). The winged males and females swarm, and each pair which is fortu-

[1] Damsel flies, Kellogg.

nate enough to escape being eaten by birds finds a place for a nest, or is taken possession of by workers, and a new colony is founded. The males and females lose or divest themselves of their wings.

Termites usually feed upon rotten wood, but some species attack soft plants and live wood, or even cloth, paper, and leather. In Africa these insects sometimes build pyramidal nests twenty feet high and form villages of them. They are so numerous

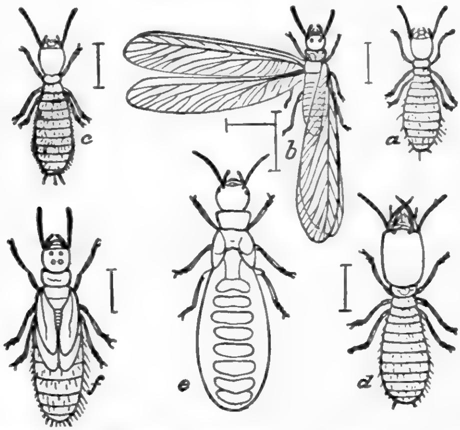



Fig. 101.—White ant (*Termes flavipes*): *a*, Larva; *b*, winged male; *c*, worker; *d*, soldier; *e*, queen; *f*, pupa. (Riley.)

and bold that "nothing can defy the marauders but tin or iron."[1] Many species of insects have been found living a commensal life with termites, "a sort of insect economy termed termitophily."

### ORDER VI. ORTHOP'TERA

This order comprises some of our most familiar insects, as the cockroaches, mantids, leaf-insects, walking sticks, short-horned grasshoppers (locusts), long-horned grasshoppers, and crickets.

The Orthoptera usually have two pairs of wings. The anterior wings are thicker and overlap or cover the posterior wings when the insect is at rest. The walking-stick is wingless.

[1] Drummond.

The grasshopper (see Fig. 85, p. 113) may be taken as typical of this order.

*The Head.*—The mouth parts consist of a *labrum* or upper lip, the mandibles, a pair of crushing or biting jaws, followed by a pair of *maxillæ*, or smaller jaws, each of which consists of three parts—an outer, jointed *maxillary palpus*, and a spoon-shaped piece which covers the brown incurved *maxilla*. Then follows the *labium*, or lower lip, with its jointed *labial palpi*. On the head are two compound eyes and three simple eyes, or *ocelli*, and a pair of antennæ or feelers.

The *thorax* is divided into three well-marked divisions: First, is the movable, cape-like *prothorax*, to which is attached the first pair of legs. Second, is the *mesothorax*, bearing the next pair of legs and the anterior pair of wings, which are straight and rather narrow. Third, is the *metathorax*, with the large third pair of legs and the posterior wings, which fold up like a fan under the anterior wings when not in use.

The segmented abdomen follows the thorax. Close observation with the magnifying glass will show minute openings on the sides of the segments. These openings are the spiracles or breathing pores.

"*Singing*."—This order of insects gives us most of our "singers" and leapers of the insect world, and, strangely enough, the leapers are the singers, and, stranger still, they sing without a voice. Of the six families of Orthoptera, three are composed of these leaping and "singing" insects. The locust or short-horned grasshopper, when at rest, makes a noise by rasping the inner surface of the hind thighs across the thickened and ridged longitudinal vein of the outer surface of the fore wings. In the air, the "clacking" is made by rubbing the upper surface of the anterior margin of the hind wings back and forth past the under surface of the posterior margin of the fore wings. "This can be heard for a distance of several rods."[1]

The male cricket holds his fore wings (Fig. 102) up over his body and rubs together the upper side of their basal region. The male tree crickets, katy-dids, meadow-green grasshoppers with long antennæ, also rub together specially modified portions of the fore wings.

[1] Kellogg, p. 134.

*Hearing.*—The " ears " consist of a pair of small tympanic membranes, situated on the basal segment of the abdomen in the locust and on the tibiæ of the forelegs (Fig. 95, p. 123) of the cricket and katy-did. Associated with each tympanum is a vesicle filled with liquid and an auditory ganglion, which is connected by a nerve with one of the thoracic ganglia.

Fig. 102.—Wing of cricket musician (enlarged), showing the file at *a* and the scraper at *b*.

*Feeding.*—All Orthoptera have biting mouth parts, and bite off and chew their food. Most of them are vegetable feeders, but the mantis is carnivorous. The locusts or grasshoppers have at times wrought great havoc with man's crops, as both sacred and secular history tell us.

*Leaping.*—In the leaping Orthoptera the posterior pair of legs is especially adapted for this purpose. They are large and long, and when walking the knee-joints are much higher than the insect, thus giving leverage for their prodigious leaps, in which they rival the fleas in their athletic records.

The metamorphosis is incomplete, the young (nymphs) (Fig. 103) differing from the parents in size and absence of wings (Fig. 104).

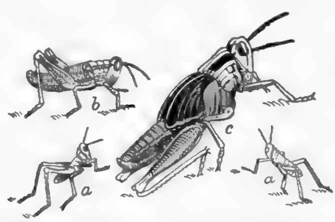


Fig. 103.—*Calopt'enus spre'tus: a, a,* Newly hatched larvæ; *b,* full-grown larva; *c,* pupa, natural size. (After Riley.)

The **cockroaches** (*Blat'tidæ*) are nocturnal insects, found about the pantries and water-pipes of our dwellings, though in the North, according to Comstock, our native species lives in woods and fields. One may often find them hiding under bark, sticks, and stones. The jaws are strong and toothed, and they are greedy little creatures, devouring anything they can get, " eating book-bindings and bed-bugs with equal alacrity." The body is flat and slippery and the legs are adapted for rapid running, enabling them to escape readily into cracks and crevices. Cockroaches were the dominant insects in carboniferous times. There are four common species,

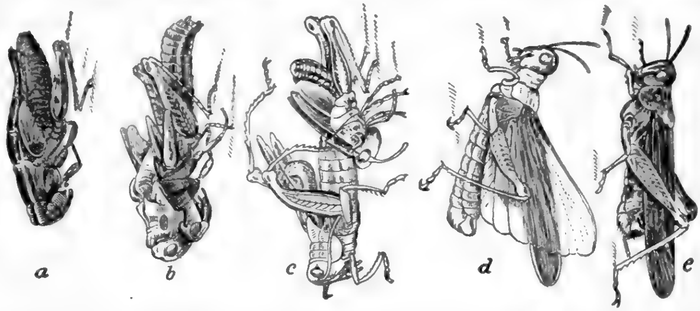



Fig. 104.—*Calopt'enus spre'tus.* Process of acquiring wings: *a*, Pupa with skin just split on the back; *b*, the imago extending; *c*, the imago nearly out; *d*, the imago with wings expanded; *e*, the imago with all parts perfect, natural size. (After Riley.)

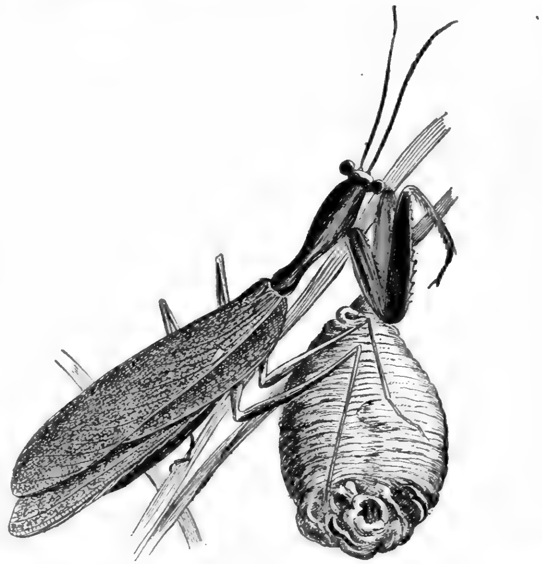


Fig. 105.—African mantis or soothsayer, with its egg-mass. (Monteiro.)

only one being native to the United States. The eggs are laid in small, bean-shaped, horny, brown cases. The young are precocial. Cockroaches may be gotten rid of by dusting fresh insect-powder into the cracks of pantry and kitchen with a little hand-bellows.

The **praying mantids** (*Man'tidæ*) (Fig. 105) are peculiar insects which get their name from the attitude in which they watch for their prey. They stand motionless with the head raised upon the long prothorax and the front legs clasped in front of the face. These front legs are spiny and are used only for seizing and holding their prey. The wings are usually leaf-like in color and texture, and this *special protective resemblance* is very good when the insect rests upon a plant. They are carnivorous and do

Fig. 106.—A walking-stick among the stems of a flower-cluster. (From life.)

much good in destroying insect pests, so much indeed that Professor Slingerland is trying to establish and distribute a European species in the United States. Most of the mantids—less than a score of species—are tropical. Our most common native species, *Phasmomăn'tis caroli'na*, is about $2\frac{1}{2}$ inches long. They are everywhere regarded with strange superstition, and the superstitious say one should "never kill a mantis, as it bears charm against evil." A Japanese mantis (*Tinode'ra sinen'sis*), recently introduced into the United States, is brown. This protection conceals the insect not only from its enemies, but from its prey, for which it "lies in wait," and may thus be called *aggressive resemblance.* Several species from India resemble flowers, and thus attract insects, upon which they feed. This is an example of *alluring colors.*

The **walking-sticks** (*Phas'midæ*) (Fig. 106) afford even better examples of special protective resemblance than the mantids. Our species are wingless and may be either green or brown, and are usually found upon twigs of a color corresponding to that of their bodies. The body, which is long, straight, and slender, looks exactly like a twig, while the slender legs look like so many tiny branches. One may pick up a walking-stick, thinking it a twig until it moves. Although it is so repulsive to the uninitiated, it is a perfectly harmless creature. The only common species in the northern states, *Diapherom'era femora'ta,* "feeds upon the leaves of oaks and other trees. It drops its hundred seed-like eggs loosely and singly on the ground, where they lie through the winter, hatching irregularly through the following summer,"[1] or even the second summer. Over six hundred species of this family are known. They are numerous in the tropical and sub-tropical countries and present many striking resemblances to their environment, one of the most perfect of which is the "green-leaf insect" (Fig. 90, p. 117). Its wings, flat body, expanded legs, and even head and prothorax are bright green flecked with yellow, making it look wonderfully like a leaf attacked by fungi.

Fig. 107.—Carolina locust killed by a fungus. (Bulletin No. 81, New Hampshire Experiment Station Insect Record, 1900.)

"The **locusts** or short-horned grasshoppers (*Acrid'idæ*) include those 'grasshoppers' in which the antennæ are shorter than the body, and in which the ovipositor of the female is short and made up of four separate plates."[2] The tarsi have three joints. The first abdominal segment has a tympanic membrane on each side. It is to this family that the locusts mentioned in the Bible and in history belong, as well as those which have wrought such havoc in our own country. A conspicuous species is the common red-legged locust, *Melan'oplus fe'mur-ru'brum.* There are about five hundred species of this family in the United States, but only three or four of them are migratory. These go in swarms, sometimes so dense as to obscure the sun as a great cloud, and when they alight they literally devour every green thing in that region. The largest, most injurious, and most numerous of these are the Rocky Mountain locusts (*Melan'oplus spre'tus*). Their permanent breeding-grounds are upon the western plateaus, from 2000 to 10,000 feet above sea level, and they cannot endure for successive generations the low, moist land of the Mississippi Valley. "These locusts show a tendency to become gregarious from the beginning of their life as nymphs. A recent method of fighting them is to cultivate

[1] Kellogg.
[2] Comstock.

in a sweet solution a destructive fungous growth (Fig. 107). A few members of the swarm are dipped in the solution and turned loose, spreading the disease.[1] *Melan'oplus atlan'tis* sometimes does much harm in New England.

Locusts lay their eggs, numbering from 25 to 125, in oval masses, covered with a glutinous substance. The female deposits them (Fig. 108) in the ground or in rotten wood, with her strong, horny ovipositor, or they may be laid on the surface of the ground among the grass and weeds. The eggs are usually laid in the fall and hatch in the spring, there being but the one new brood a year. The young resemble the parents in general, having biting mouth parts and long legs. They are paler and wingless. The wings appear as minute scale-like projections and grow larger with each of the five or six molts (Fig. 104) Strangely enough, the hind wings, which are always underneath the fore wings in the adult, lie outside during development. Birds are the best exterminator. The eggs may be plowed up

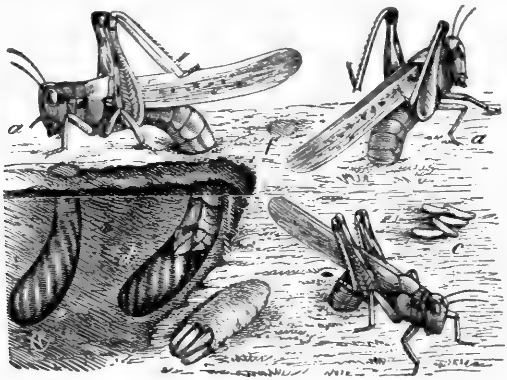



Fig. 108.—Rocky Mountain locust: *a, a, a,* Female in different positions, ovipositing; *b,* egg-pod extracted from ground, with the end broken open; *c,* a few eggs lying loose on the ground; *d, e,* show the earth partially removed to illustrate an egg-mass already in place and one being placed; *f,* shows where such a mass has been covered up. (After Riley.)

in the fall, or when they hatch in the spring the young could be crushed by heavy rollers or burned by scattering straw over the ground and lighting it.[2]

**Locŭs'tidæ.**—This family includes crickets, katy-dids, and long-horned grasshoppers. Unfortunately, the common name of locust is applied only to members of the family of *Acrididæ,* and to the cicada of the order *Hemiptera,* but to none of the *Locustidæ.* The long-horned meadow-green grasshopper has the delicate antennæ longer than the body, the tarsi four jointed, the ovipositor sword shaped, and the tympanum on the tibia (Fig. 95, p. 123) of the front leg. The males call their mates by

[1] Linville-Kelly, p. 15.
[2] Kellogg, p. 139.

rubbing together the specially modified wing covers. These grasshoppers abound in our meadows everywhere. If you would know how perfect is their protective resemblance, try to find one which you have seen on the wing, after it has alighted. Some species found in caves are wingless, colorless, and blind. Their antennæ and hind legs are developed to a great length.

The **katy-dids,** of which there are several genera, are rather large, usually green insects. They live upon trees and shrubs, feeding upon foliage and tender branches, though they sometimes eat animal food. Only the males tell us " Katy did " or " she didn't." They usually " sing " at night from July or August until frost. They are not gregarious. Their thin, finely veined wings are almost indistinguishable in the foliage.

Closely allied to the katy-dids, but looking more like crickets, are the wingless grasshoppers, the cricket-like grasshoppers, and shield-backed

Fig. 109.—Mole cricket (*Gryllotal'pa boria'lis*). (Burmeister.)

grasshoppers. They are dull colored and live under stones and rubbish or loose soil.

The **crickets,** of which there are few species, have the wing covers flat and overlapping above, and bent sharply down at the edge of the body like a box cover. The antennæ are long and the ovipositor is spear shaped. They include the mole crickets, true crickets, and tree crickets.

*Mole crickets* (Fig. 109) are fitted for a burrowing life. The front tibiæ are broadened and shaped somewhat like the feet of a mole. They feed upon the tender roots of plants, and sometimes injure potatoes (Fig. 110).

The *true crickets,* our familiar black species, live in houses or fields. They usually feed upon plants, but some are predaceous. The eggs, laid in the fall, usually in the ground, hatch in summer. Only a few of the old crickets survive the winter.

The *tree crickets* live in trees or on tall plants. The female "snowy tree cricket" does much damage by laying her eggs in grapevines or rasp-

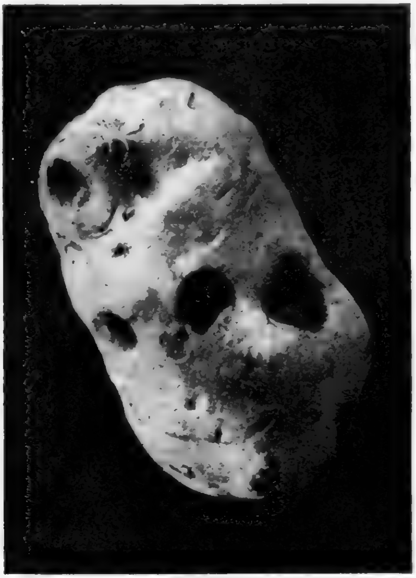


Fig. 110.—Potato injured by mole cricket.

berry canes, causing them to die above the puncture. These canes should be cut and burned in winter or early spring before the eggs hatch.

### ORDER VII. HEMIPTERA

This order contains some of our most common and destructive insects, as the chinch-bug, the grape *phyllox'era*, the San José scale, the bed-bug (Fig. 111), the louse, the squash bug, stink-bugs of various kinds, plant-lice (*Aphid'idæ*), and bark-lice (*Cŏc'cidæ*), which furnish dye-stuffs, as cochineal, stick-lac, from which we get shellac, and China wax.

The Hemip'tera include some five thousand species in North America. All of these species agree in that the mouth parts are modified into a piercing and sucking beak. Their food, consequently, is the blood of men or of other animals or the juices of plants. The sucking beak consists of the *labium*, which, together with the *labial palpi*, is modified into a jointed sheath. This incloses the mandibles and maxillæ, which are changed into long, piercing stylets.[1] The labrum or upper lip is small or rudimentary. There are usually four wings. In the typical Hemiptera, as exemplified in the sub-order *Heterŏp'tera*, the character of the anterior wings is a distinguishing feature. The basal portions of these wings are thickened and parchment-like, while the terminal portions are membranous and overlap when the wings are folded over the back. From the character of these wings the order gets its name—*hemi*, half,

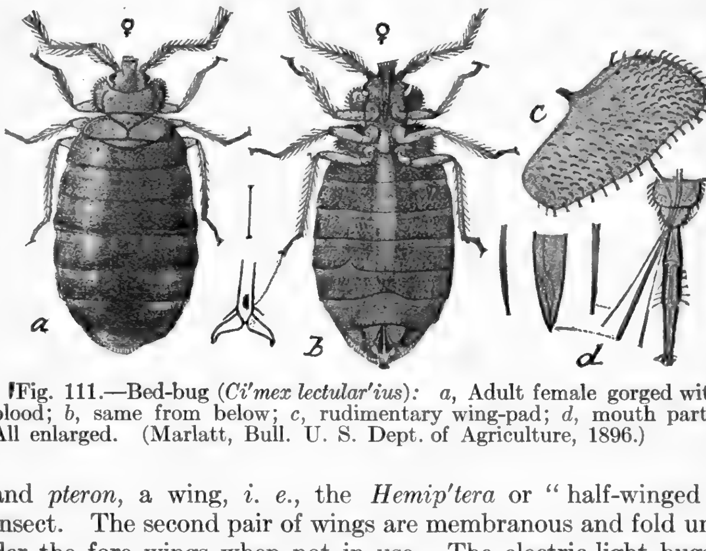



Fig. 111.—Bed-bug (*Ci'mex lectular'ius*): *a*, Adult female gorged with blood; *b*, same from below; *c*, rudimentary wing-pad; *d*, mouth parts. All enlarged. (Marlatt, Bull. U. S. Dept. of Agriculture, 1896.)

and *pteron*, a wing, *i. e.*, the *Hemip'tera* or "half-winged" insect. The second pair of wings are membranous and fold under the fore wings when not in use. The electric-light bugs, bed-bugs, water-bugs, and squash-bugs are familiar examples. In the sub-order *Homop'tera* the anterior wings are not thickened, but are of the same structure throughout, as in the cicada. In the sub-order *Parasī'ta* are found wingless parasitic hemiptera which prey upon certain mammals, for example, the head and body lice of man, dogs, cattle, hogs, sheep, mice, and rabbits.

[1] See Kellogg, p. 164.

The **giant water-bugs** (*Belostom'idæ*) are an example of the largest *Heteroptera* or true bugs. They are often seen about electric lights. They fly from pond to pond and are very rapacious, feeding upon the juices of young fishes, insects, and tadpoles.

The **chinch-bug family** (*Lygæ'idæ*) has nearly two hundred species in the United States. The most destructive is the small but widely distributed chinch-bug (*Blis'sus leucop'terus*) (Fig. 112), and though it measures less than $\frac{1}{6}$ inch in length, it costs the United States $20,000,000 annually, for it is "the worst pest of corn and one of the worst of wheat." There are two generations of the chinch-bug annually. The adults winter under rubbish, and in early spring they lay their eggs in fields of grain upon roots or stems beneath the soil. They hatch in about two weeks, and the little red nymphs attack the root and then the stalk of the wheat. They mature in about six or seven weeks, when they are "blackish, with the wings semitransparent white, and with a conspicuous small triangular black dot near the middle of their outer margin." At about harvest time they migrate by the

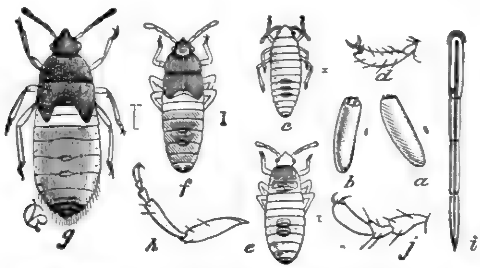



Fig. 112.—The chinch-bug (*Blis'sus leucop'terus*): *a*, *b*, Eggs; *c*, newly hatched larva; *d*, its tarsus; *e*, larva after first molt; *f*, same after second molt; *g*, pupa—the natural sizes indicated at sides; *h*, enlarged leg of perfect bug; *j*, tarsus of same still more enlarged; *i*, proboscis or beak, enlarged. (Riley.)

millions to fields of growing corn, marching in a body like an approaching army. When the bugs of the first brood have reached maturity, they pair, at which time only they use the wings, and the second generation is begun. The adults of the second generation that survive the winter lay the eggs for the spring brood. It is thought that a third brood sometimes appears in Kansas.

Their migration from wheat to corn fields may be hindered by plowing furrows around the fields and pouring crude petroleum or coal-tar into these moats. If this has not been done, when the bugs collect on the first few rows of corn they should be sprayed at once with kerosene emulsion. Predaceous insects, as the aphis-lion and ladybird beetles, and birds hold them in check. But a parasitic fungus (*Sporotri'chum globulif'erum*) will kill the bugs rapidly in moist, warm weather.

The **cicadas** (*Cicad'idæ*) are easy of recognition on account of their large, blunt-headed, robust bodies, the three ocelli, and their shrill "singing" during the daytime in the late summer and early fall. The male does all the talking or singing, if you choose to call it a song, and "his wife cannot talk back." The sound is made by "stretching and relaxing a pair of corrugated tympana or parchment-like membranes by means of a muscle attached to the center of each."[1]

The strangest freak in all insect life is the periodical cicada or seventeen-year locust (Fig. 113). It is the longest lived of all insects, for while other insects pass from the egg to imago form in a few days or weeks, or, at the most, in one to three years, this insect requires from thirteen to seventeen years for this development. In the spring the female cuts slits in tender twigs and lays her eggs therein. In about six weeks they hatch and the nymphs spend the required seventeen years, or, in the case of a southern form, thirteen years, in the ground. They feed by sucking the juices of tender roots. In the spring of the seventeenth or the thirteenth year—as the case may be—they crawl up to the surface of the ground,

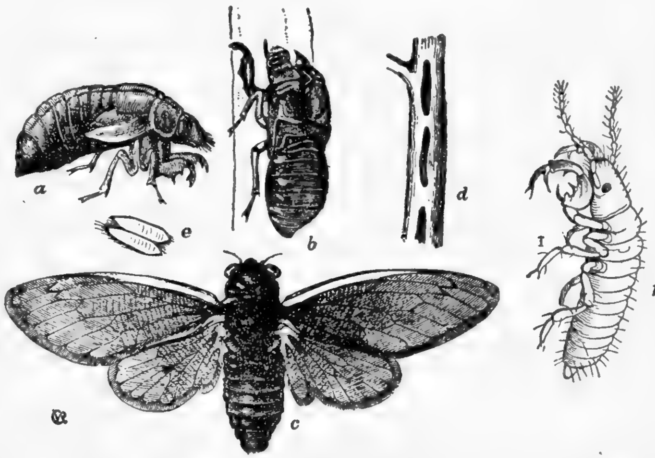



Fig. 113.—The seventeen-year *Cicada* (*c*) and pupa (*a*, *b*); *d*, position of eggs (*e*); *f*, larva. (Riley.)

undergo their last molting, and emerge as clear-winged cicadas. This insect is a fine example of protective resemblance. One may be within a few inches of a "singing" cicada and not be able to see it, so near the color of the tree trunk or ground is it. The adult life is short. They lay their eggs, sing their songs, and die.

The **plant-lice** or **aphids** (*Aphid'idæ*) are among our most common and destructive pests in the green-house, field, and orchard. There are many species, most of which are small, the largest barely reaching the length of ¼ inch. The small, soft, usually green body is somewhat pear shaped. Wingless forms are most numerous, but there are forms in almost every brood which have two pairs of delicate transparent wings, the anterior pair of which is the larger. "The two wings of each side are usually con-

[1] Kellogg, p. 167.

nected with a compound hooklet."[1] The sucking beak is three jointed and may or may not be longer than the body. They have prominent compound eyes and usually ocelli. The long antennæ are from three to seven jointed. Many species have on the sixth segment of the abdomen two tubular processes, long supposed to be the honey tubes, but Kellogg says "from them issues another secretion, not sweetish, about which little is known," and that the "honey-dew" so relished by ants (p. 179) "is now known to be an excretion from the intestine issuing in fine droplets or even spray from the anal opening." It is sometimes produced in large quantities, so that the leaves below the plant lice are coated with it and the walks beneath the trees spotted by it. It is fed upon by bees and wasps as well as by ants. In addition to the "honey-dew," many species secrete another fluid, which is excreted as a liquid through "various small openings scattered over the body." This liquid soon hardens into a wax. The total waxy secretion appears as a mass of felted threads or wool, as in the wooly apple aphis, and probably serves as a protection for the soft, defenseless body.

The aphids are remarkably variable as regards their reproduction sexually or agamically,[2] and as regards their possession of wings, so that the life-history varies not only in different species, but in the same species under different conditions. The eggs are laid in the fall, and from them hatches, in early spring, a colony of wingless individuals which may produce (without pairing) either living young or eggs. This may continue under favorable food supply and temperature for a number of generations. Slingerland, of Cornell University, reared four generations of wingless "agamic" aphids. At any time, especially if food becomes scarce or other conditions unfavorable, winged individuals are likely to appear and fly away to other host plants, where they produce, agamically, new colonies. If temperature becomes low or other unfavorable conditions occur, these asexual individuals produce a brood consisting of both males and females. "The males may be either winged or wingless, but the females are always wingless." These sexual forms pair and produce one or more large fertilized eggs which lies dormant over winter and hatches into a wingless "stem-mother" in the spring, and a series of agamic generations follow. The multiplication of aphids is so rapid that, were it not for predaceous insects, such as lady-bird beetles, aphis-lions, and parasitic Hymenop'tera, and for insect-loving birds (see Birds), they would utterly destroy their host plant and ultimately starve themselves. Professor Forbes made an estimate of the rate of increase of the "corn-louse," and found that if "all the plant-lice descending from a single 'stem-mother' were to live and reproduce throughout the year we should have coming from the egg the following spring 9,500,000,000,000 young. As each plant-louse measures about 1.4 mm. in length and 0.93 mm. in width, an easy calculation shows that these possible descendants of a single female would, if closely placed end to end, form a procession 7,850,000 miles in length."

Aphids vary greatly in their feeding habits, many feeding upon the juices of tender leaves, stems, leaf-buds, or blossom-buds, while others suck the juices of tender roots in the soil, and sometimes the same species lives both above and below ground. Above ground they may be fought by strong solutions of soap, by kerosene emulsion, or by a weak solution of nicotin. Since they suck the juices of plants they cannot be affected by poisoning the food. Underground, carbon bisulphid is sometimes used,

[1] Comstock. [2] Glossary.

but about the best remedy is to destroy the infested tree or vine, and plant one of another species which is not a host-plant for the pest.

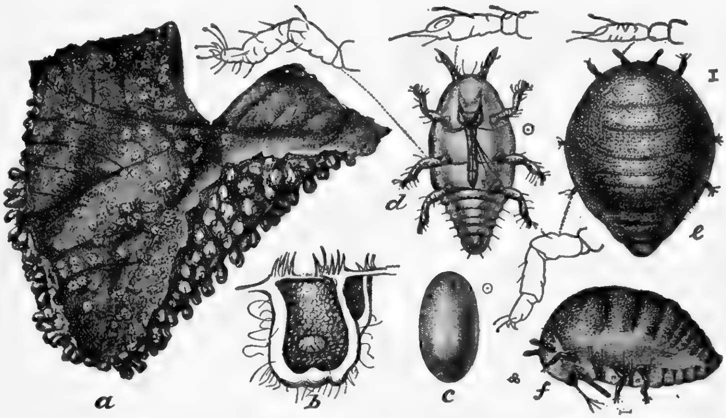



Fig. 114.—*Phyllŏxe'ra vastā'trix: a*, Leaf with galls; *b*, section of gall showing mother louse at center with young clustered about; *c*, egg; *d*, larva; *e*, adult female; *f*, same from side. (*a*, Natural size; *b–f*, much enlarged). (Marlatt.)

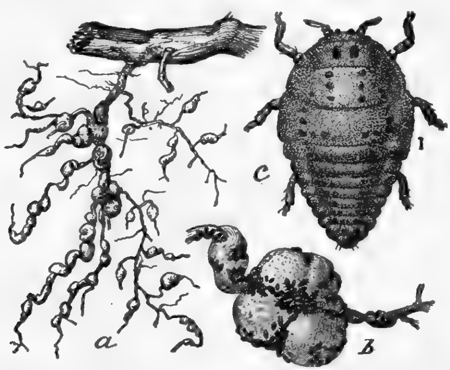



Fig. 115.—*Phylloxe'ra vasta'trix: a*, Root-galls; *b*, enlargement of same, showing disposition of lice; *c*, root-gall louse, much enlarged. (Marlatt.)

The **grape Phyllŏxe'ra** (Fig. 114) is a native aphid found upon the wild grapevines of the eastern United States. It was introduced into the south of France before 1863 upon rooted vines sent from America, and, curiously enough, says Kellogg, "came to California—in which state it has done much more damage than elsewhere in our country—from France, introduced upon imported cuttings or roots" (Fig. 115). Probably not less than 30,000 acres of vineyards have been destroyed by it since it was first noticed in 1874. "The Phylloxera appears in four forms: (1) the gall form, living in little galls on the leaves (Fig. 114), and capable of very rapid multiplication (this form rarely appears in California); (2) the root form (Fig. 115), which is derived from individuals which migrate from the leaves to the roots, and which by the piercing of the roots, sucking the sap, and producing little quickly decaying tubercles on the rootlets, does the serious injury; (3) the winged form (Fig. 116), which flies to new vines and vineyards and starts new colonies; and, finally, (4) the sexual forms,

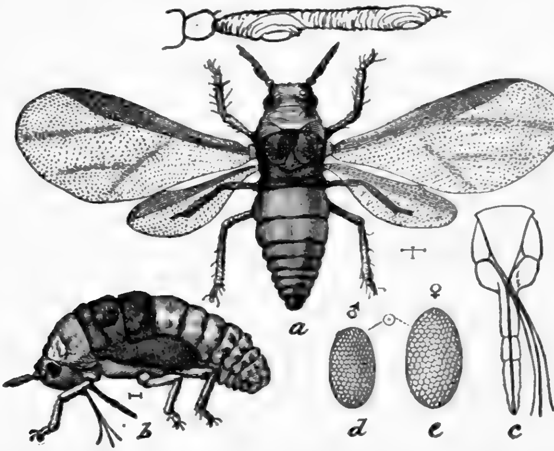



Fig. 116.—*Phylloxe'ra vasta'trix:* *a*, Migrating stage, winged adult; *b*, pupa of same; *c*, mouth parts with thread-like sucking setæ removed from sheath; *d* and *e*, eggs showing characteristic sculpturing; all enlarged. (Marlatt.)

male and female (Fig. 117), which are the regenerating individuals, appearing after several agamic generations have been produced." The gall stage may be omitted, and the individuals hatched from the fertilized eggs go directly to the roots. The gall form can be prevented by spraying to kill the winter eggs. But about the only real cure for the infested roots is to dig them up and burn them and plant out resistant vines. The wild vines of the Mississippi Valley have evolved with the Phylloxera, and are capable of living and growing in spite of the pests. The French vineyards, as well as those of California, are being renewed by grafting French stocks upon the resistant roots, thus rendering the vines practically immune. There are many species of aphids, but this example must suffice for our present work.

**Scale-bugs, mealy-bugs,** and others (*Coc'cidæ*) compose a very anomalous group, the species differing greatly in appearance, habits, and metamorphoses from those of the most closely allied families, and even the two sexes

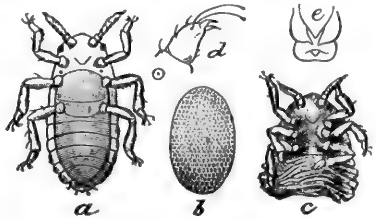



Fig. 117.—*Phylloxe'ra vasta'trix:* *a*, Sexed stage larviform female, the dark-colored area indicating the single egg; *b*, egg, showing the indistinct hexagonal sculpturing; *c*, shriveled female after oviposition; *d*, foot of same; *e*, rudimentary and functionless mouth parts. (Marlatt.)

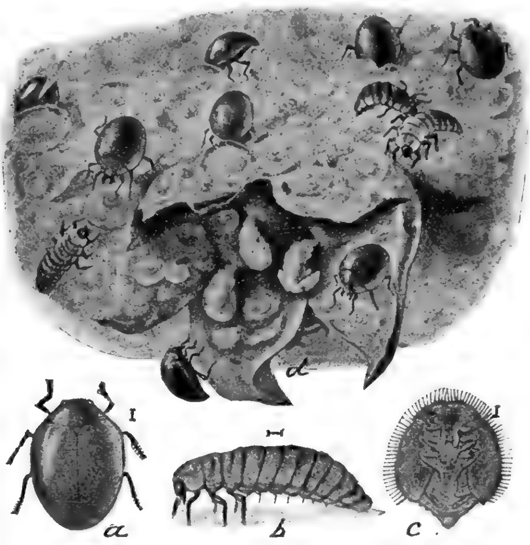



Fig. 118.—Ladybird feeding on scale insects, *Pentil'ia* (*Smilia*) *misel'la:* *a*, beetle; *b*, larva; *c*, pupa; *d*, blossom end of pear, showing scales with larvæ and pupæ of Pentilia feeding on them, and pupæ of Pentilia attached within the calyx; all enlarged. (Howard and Marlatt, Bull. U. S. Dept. of Agriculture.)

of the same species, says Comstock, differ greatly. The males, unlike all other members of the order, undergo a complete metamorphosis. The adult male has but a single pair of wings and has no organs for procuring food. The mouth parts disappear during metamorphosis and a second pair of eyes develops. The adult female is always wingless and the body is always scale-like or gall-like in form, or grub-like and clothed with wax. Those of some species retain their eyes, antennæ, and legs, while others are fixed in adult life and very degenerate, lacking eyes, antennæ, wings, and legs. In speaking of the San José scale, Kellogg says, "it has a long, fine, flexible process projecting from near the center of its under side, this is its sucking proboscis, and serves as a means of attachment as well as an organ of feeding." The San José scale is very prolific. It was ascertained at Washington that there are four regularly developed generations and possibly part of a fifth in a year. It is estimated that about 200 females (and about the same number of males) are given birth to by each female. Thus the descendants of a female amount to 3,216,080,400 individuals. From this it can easily be seen how destructive to fruit trees this pest soon becomes. It is now found in every state and territory and in Canada. Many states have laws to try to prevent its distribution with nursery stock.

Perhaps the most effective remedy is the fumigation of orchard trees by hydrocyanic gas. To do this the tree is entirely enclosed in a large tent and the gas generated under it "by pouring about 50 ounces of water into 5 ounces of commercial sulphuric acid and dropping into it 15 ounces of cyanid of potassium." These amounts are sufficient for a tree 12 feet high with a spread of 10 feet. *The fumes are deadly poison.* Of sprays for leaves and greenhouse plants, crude petroleum and kerosene emulsion are best. Protection of the birds is one great means of holding these pests in check. It has been proved by the examination of 226 stomachs that more than one-fifth of the food of the blackheaded grosbeak (*Zamelo'dia melanoceph'ala*[1]) consists of scale insects. For the work (Fig. 118) of ladybird beetles see p. 147.

## ORDER VIII. COLEOP'TERA

This order consists of eleven or twelve thousand species in America, north of Mexico.

The mouth parts of beetles (Fig. 119) consist of the upper lip or *labrum*, the jaws or *mandibles* for seizing the prey or for gnawing; the complicated many pieced *maxillæ* with usually prominent *maxillary palpi;* the lower lip or *labium* of several parts, and rather large *labial palpi.* These mouth parts are adapted for biting, and are not easy for beginners to identify. The student should identify these parts on a large beetle with the help of a good figure (Fig. 119) and a good magnifying glass.

Compound eyes are present, but usually the simple eyes are wanting.

The wings are four in number, except in some ground beetles, which have only the anterior pair. The anterior wings are

[1] Plate III, Bulletin 32, U. S. Biological Survey.

quite rigid and meet in a line on the back, forming a sheath to inclose the membranous posterior wings, which fold up under the fore wings or *elytra* when not in use.

The body is usually compact. The under surface of the abdomen is hard, but the upper surface beneath the *elytra* is soft and yielding, thus permitting respiration.

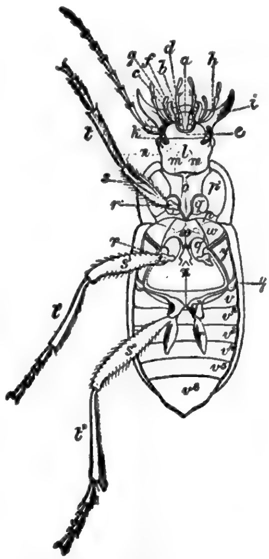


Fig. 119.—Under surface of *Har'palus caligin'osus: a*, Ligula; *b*, paraglossa; *c*, supports of labial palpi; *d*, labial palpus; *e*, mentum; *f*, inner lobe of maxilla; *g*, outer lobe of maxilla; *h*, maxillary palpus; *i*, mandible; *k*, buccal opening; *l*, gula or throat; *m*, *m*, buccal sutures; *n*, gular suture; *o*, prosternum; $p'$, episternum of prothorax; *p*, epimeron of prothorax; $q$, $q'$, $q''$, coxæ; $r$, $r'$, $r''$, trochanters; $s$, $s'$, $s''$, femora or thighs; $t$, $t'$, $t''$, tibiæ; $v$, $v^2$, $v^3$, etc., ventral abdominal segments; *w*, episterna of mesothorax (the epimeron is just behind it); *x*, mesosternum; *y*, episterna of metathorax; $y'$, epimeron of metathorax; *z*, metasternum. (After Leconte.)

*The Young.*—The metamorphosis is complete. The larvæ are usually called grubs. (See Fig. 120, p. 150.) Their habitats vary much. Some live in trees, others, as the larvæ of the tiger beetle, burrow in the gound, and, with the head at the surface, watch for their prey. Their food varies according to the habitat. The burying beetles (Fig. 120) (*Nĕcrŏph'orus*) provide food for their young by burying carrion, as a dead mouse or bird. When it is covered over with earth the female lays her eggs upon the carcass. They soon hatch and the larvæ feed upon the food thus provided for them.

The *food* of the adult Coleop'tera also varies much. Some, as the ground beetles (*Carab'idæ*), are predaceous. Others, as the carrion beetles, feed upon decaying animal matter, while

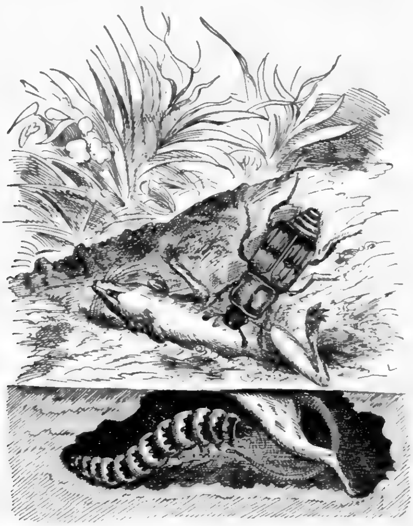


Fig. 120.—*Necroph'orus* burying a mouse, and larva. (Landois.)

others, as the Colorado potato beetles, are voracious plant feeders, making this order of much economic importance.

Other familiar examples are the apple-tree borers, the wire-worms, fruit and grain weevils, and the white grubs of the June beetles (Fig. 121).

The **tiger beetles** (*Cicindel'idæ*) are usually of a beautiful metallic green or bronze, banded or spotted with yellow, though some are black, while those living in white sand are exactly the color of the sand. They are the most active of all beetles, running and flying well. They may be found on bright warm days on dusty roads or along the banks of streams.

Comstock says they remain still until within our sight, but out of reach, and then "like a flash they fly up and away, alighting several rods ahead of us," with eyes toward us. The ugly larvæ live in vertical burrows about a foot deep on beaten paths or in the sand. The larva, with its dirt-colored head which is bent at right angles to its lighter colored body, plugs the entrance to its burrow, and with its wide-open jaws forms a living trap for passing insects. On the fifth abdominal segment there is a hump bearing two hooks curved forward, by which the larva holds fast, thus preventing large prey from dragging it out of its burrow.

The **ground beetles** (Fig. 122) (*Carab'idæ*) are probably the most important family of predaceous insects, though a few species are vegetable feeders. They are usually dark colored and nocturnal, but some are large and brilliantly colored, and the wing covers are generally "ornamented with longitudinal ridges and rows of punctures." They hide in daytime under stones and logs. There are about twelve hundred species in North

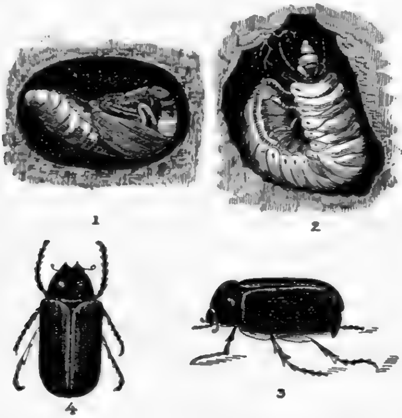



Fig. 121.—June beetles: 1, Pupa; 2, larva; 3, 4, adult. (Riley, Report of State Entomologist of Missouri.)

America. The larvæ of most of them are long flattened grubs, with body of uniform breadth throughout, protected on top by horny plates, ending in a pair of conical bristly appendages. Usually they bury themselves just beneath the surface and feed upon insects which enter the ground to pupate. They destroy large numbers of leaf-feeding beetles or their larvæ. They pupate in small round cells in the soil, from which the adults push their way out.

The **caterpillar hunter** (*Caloso'ma scruta'tor*) is a familiar example of the ground beetles (Fig. 122). Its wing covers or *elytra* are bright green or violet, margined with reddish. It is found on trees at dusk. It is known to climb trees and make raids upon the hairy tent caterpillar, hence it is a friend. Two others (*Calosoma frigidum* and *C. calidum*) are hunters of cut-worms and canker-worms. The latter is sometimes called the fiery **hunter**, from the rows of reddish pits on its black elytra.

Another one (*Agonod'erus pal'lipes*) feeds upon sprouting **corn**.

The **carnivorous water beetles** (*Dytic'idæ*), of which there are three hundred species, are found everywhere in streams and ponds (Fig. 123). They vary in length from $\frac{1}{5}$ to $1\frac{1}{2}$ inches. The diving beetle projects the tip

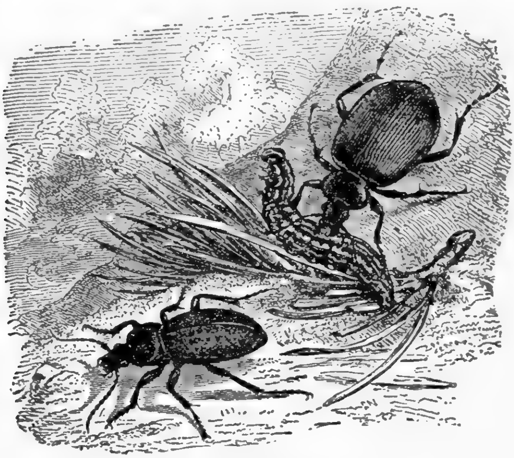


Fig. 122.—Ground beetle (*Calosoma*), similar to *C. scrutator;* below, a *Carabus*. (Brehm.)

of its abdomen through the surface film to breathe. It raises the elytra a little, and the air which is caught under them is held by the fine hairs on the

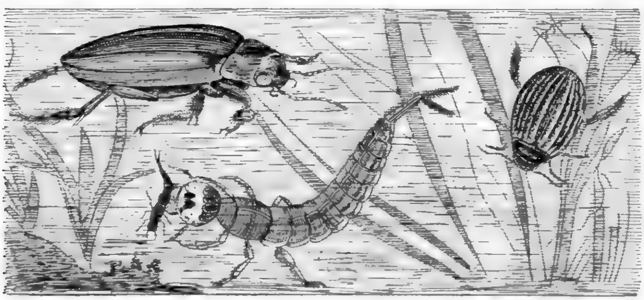


Fig. 123.—Carnivorous water beetles. (Brehm.)

back, where the spiracles are situated. Thus, it carries a supply of air which enables it to breathe under water. These beetles make interesting aquarium specimens.

*Platypsyl'la casto'ris* is the sole representative of the family *Platypsyl'lidæ*. This queerly shaped beetle lives a parasitic life upon beavers. It is wingless and blind, and the elytra are rudimentary and short, exposing five abdominal segments. Its degeneration is due to its parasitic life.

The **lady-bugs** (*Coccinel'lidæ*) are interesting little predaceous beetles, yellow or reddish, with black spots. The cottony cushion-scale (*Ice'rya purchasi*), so destructive to California fruits, was subdued by a lady-bug (*Vedā'lia cardinā'lis*) brought from Australia to feed upon it. The hop louse is destroyed by the larvæ of certain lady-bugs known as "niggers." The lady-bugs, with few exceptions, are predaceous. One (*Epilach'na borea'lis*) is herbivorous. Its larva, which is yellow and clothed with forked spines, feeds upon the leaves of the squash family.

The **little carpet beetle** (*Anthre'nus scrophula'riæ*) is a household pest. Its larva feeds upon carpets, furs, feathers, and woolens.

The **fireflies** (*Lampyr'idæ*) or "lightning-bugs" are not flies, but beetles. The light giving has never been fully explained. "The light-giving organ is usually situated just inside of the ventral wall of the last segments of the abdomen, and consists of a special mass of adipose tissue richly supplied with air-tubes (tracheæ) and nerves. From a stimulus conveyed by these special nerves oxygen, brought by the network of tracheæ, is released, to unite with some substance of the adipose tissue, a slow combustion thus taking place. To this the light is due, and the relation of the intensity or the amount of light to the amount of matter used up to produce it is the most nearly perfect known to physicists."[1]

**Mўrmecŏph'ilous Beetles.**—There are nearly one thousand species of beetles which live in the nests of ants. Many of them are commensal with the ants, deriving perhaps the greater benefit by the association, but others live truly symbiotically with their hosts.[2] They secrete a sweet substance which is eaten by the ants, which in return shelter, clean, and, by regurgitation, feed them. They are strangely modified for this mode of life, usually by degeneration.

## ORDER IX. DIP'TERA

This order contains about fifty thousand species, of which about seven thousand are known in America. It includes some famous flies (Fig. 124).

The *mouth parts* are adapted for piercing and sucking or for lapping. Just what constitutes these mouth parts is a controverted question among scientists. Comstock says, "According to the most generally accepted view the six bristles represent the upper lip (*labrum*), the tongue (*hypopharynx*), the two mandibles, and the two maxillæ, and the sheath enclosing these bristles is the lower lip (*labium*)." Identify these parts on the head of a big fly with the aid of a large figure and a magnifying glass.

[1] Kellogg, p. 269. [2] Kellogg, p. 553.

*The Wings.*—As the ordinal name indicates, these insects have two membranous wings. No fly has more than two wings and only a few are wingless. They have, however, vestiges of a second pair, called *halte'res* or balancers, ending in short knobs. They are used in directing the flight and are believed by some to be auditory organs.

**Family Mus'cidæ.**—The *common house-fly* (*Mus'ca domes'tica*) is too well known for our comfort. It hibernates. One will recall having seen flies about the house during the winter. They breed about stables in the sum-

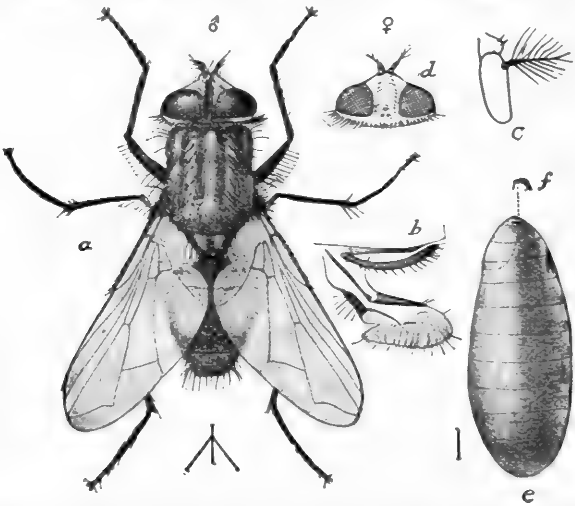



Fig. 124.—Typhoid fever or house-fly (*Mus'ca domes'tica*): *a*, Adult male; *b*, proboscis and palpus of same; *c*, terminal joints of antennæ; *d*, head of female; *e*, puparium; *f*, anterior spiracle; all enlarged. (Howard and Marlatt, Bull. U. S. Dept. of Agriculture, 1896.)

mer. The eggs, numbering about one hundred, hatch in about twenty-four hours. The soft, white, cylindric, footless larva is called a maggot. It feeds and grows for about a week, molting twice, and then pupates within the larval skin, or *puparium*, for another week. It then makes a circular opening in the puparium and emerges as the adult fly, thus giving time for a number of generations. In a summer the offspring of a single fly may reach incredible numbers. It is now known that the principal insect agent in the spread of typhoid fever is the common house-fly, and great care should be taken to prevent its breeding. All human and horse excreta should be kept in fly-tight vaults and sprinkled with chlorid of lime or quick lime at least once a week, unless wanted for fertilizing purposes. All garbage cans and swill pails should be kept covered, and sprinkled with lime when emptied. Chicken pens should be cleaned often and sprinkled with lime.

The many little projections on the feet of the fly are tubular, and secrete a sticky fluid which enables it to walk upside down.

The *blow-fly* and the *flesh-fly*, close relatives of the house-fly, lay their eggs upon meat, cheese, and other provisions or upon decaying animal sub-

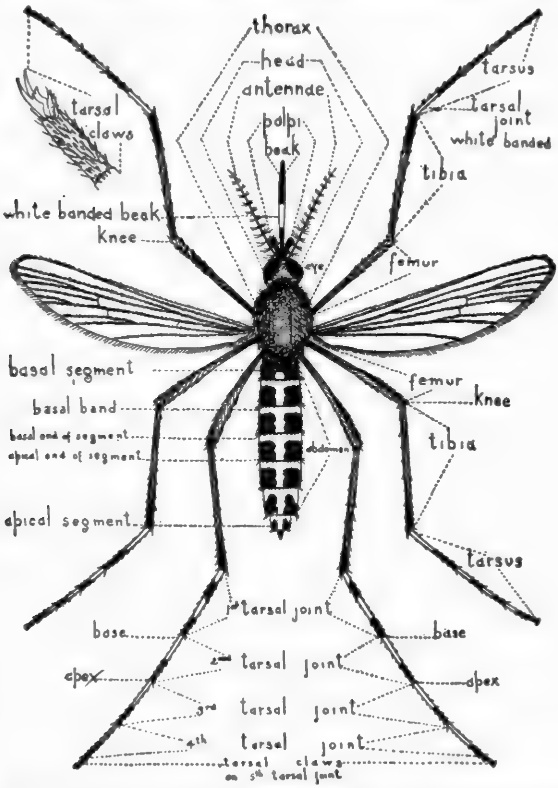



Fig. 125.—An adult mosquito, much enlarged, with all the parts that are used in classification named. (Smith, N. J. Experiment Station, Bulletin 171, 1904.)

stance, on which the maggots feed. Thus, while a great annoyance, they may do some good by acting as scavengers. The most common flesh-fly is perhaps *Sarcoph'aga sarrace'niæ*, which resembles a large house-fly. It furnishes another example of viviparous insects; in other words, the larvæ are brought forth alive.

*Horse-flies* (*Taban'idæ*) are also pests of man and beast. They are most abundant in the hot summer days. The large black-bodied horse-flies, of which there are a hundred species, belong to the genus *Tabanus*.

*The Bot-flies* (*Œ'stridæ*).—"The horse bot-fly (*Gastrŏph'ilus e'qui*) closely resembles the honey-bee in form, except that the female has an elongated abdomen curved under the body." Horses have an instinctive fear of this fly. It attaches its eggs to the hair of the legs and shoulders of the horse, and they are taken into the mouth by biting the irritated place. The larvæ fasten themselves to the lining of the stomach. When grown, during the fall and winter, they pass out and develop within a puparium.

The *oxwarble larvæ* (*Hypoder'ma linea'ta*) live just beneath the skin on the backs of cattle, which are made frantic by their burrowing.

The *sheep bot-fly* deposits its larvæ in the nostrils of sheep, antelope, etc. They work up into the frontal sinuses and horns and cause the "staggers."[1]

Reindeer, deer, rabbits, and squirrels are infested by larvæ of species of bot-flies, and one or two species infest man.

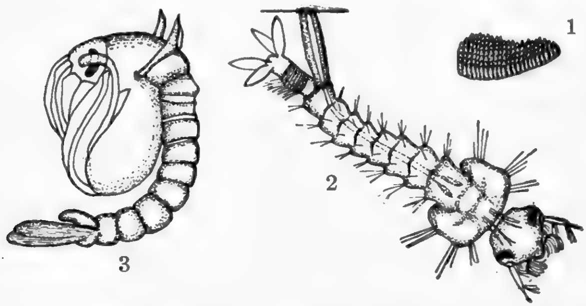



Fig. 126.—1, Egg-mass of the common mosquito; 2, larva breathing at the surface of the water; 3, a pupal mosquito. (From Hampton Leaflet.)

**Mosquitoes** (*Culic'idæ*) (Fig. 125) seem too well known to need description, but there are other insects so similar that they are often mistaken for them. Comstock says "the most distinctive feature of mosquitoes is the fringe of scale-like hair on the margin of the wing and also on all known American forms on each of the wing veins." The males differ from the females in having feathery antennæ and in the absence of the piercing stylets. As a rule they do not sing or bite, and probably feed upon the juices of plants, as do the females if they cannot "get blood." The larvæ (Fig. 126), called "wrigglers" or "wiggle-tails," are too often found near our dwellings in rain-barrels, slop-pails, open cisterns, open sewers, water troughs, lily-tubs, ponds, anywhere where the water is allowed to remain long enough for their development, which requires from eight to eighteen days. Of the three principal genera, *Cūlex* contains most of our mosquitoes whose bite and song are well known. *Anoph'eles* is the genus which is the intermediate host and the transmitter of the malaria germ. Of course it cannot transmit

[1] Comstock, p. 478; Hertwig, p. 493.

these germs unless it has been infected with them itself. *Stegom'yia fascia'ta* (Fig. 127) is the yellow-fever-carrying species, so much dreaded in our southern states. It has been established by observation and experiment[1] that these mosquitoes, if they have bitten persons affected by malaria or yellow fever, actually carry these diseases, also that *Stegomyia fascia'ta* and *Cu'lex fati'gans*, var. *skusii*, and *Anoph'eles rossii* carry certain forms of *filariasis*. These organisms belong to the round worms or Nematoda (see p. 41). The most common form of *filariasis* is *elephantiasis*. In this disease the legs and arms are affected. One leg may become so enlarged as to weigh as much as the rest of the body, or the arm may become a foot thick and horribly repulsive. In Samoa, says Kellogg, fully one-third of the natives are attacked by this incurable disease, which, though slow and almost painless, is certainly fatal. Malaria, so widespread in the United States, becomes even more prevalent and more often fatal in the tropics. Millions die from it every year. In a single year five million persons died of malaria in India alone. Hence the mosquito is to be classed not simply as a great annoyance, but as an insidious foe to health and life.

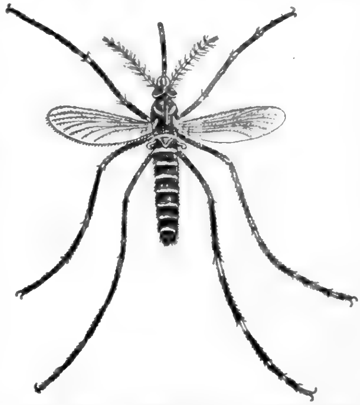


Fig. 127.—*Stegom'yia fasci'ata* (enlarged). (Howard, Bull. U. S. Dept. of Agriculture, 1902.)

Fig. 128.—The common harmless mosquito stands this way on a vertical or horizontal surface. (From Hampton Leaflet.)

Fig. 129.—The malarial mosquito stands with its head pointing downward at an angle of from 20 to 30 degrees from a vertical or horizontal surface. (From Hampton Leaflet.)

The common mosquito, *Culex* (Fig. 128), may be distinguished from the malaria-carrying form (Fig. 129) in several ways. The female *Culex* has

[1] Kellogg, pp. 617, 630.

short palpi, while the *Anoph'eles* has palpi nearly as long as the beak, making three long projections on the head. It may be distinguished also by the way it alights. The *Culex* is "hump-backed" with the beak pointing downward, while in the *Anopheles* the body and beak lie in the same plane. The eggs of *Culex* are laid in a boat-shaped mass, while the eggs of *Anopheles* are laid "singly and at random," but run together, forming irregular groups or strings. The larva of *Culex* hangs with the head down, so as to keep the end of the respiratory tube, which is borne by the next to the last somite, in contact with the air. The larval stage lasts about five or six days or longer in unfavorable conditions. The larva of *Anopheles* has a very short respi-

Fig. 130.—A fine breeding-place for mosquitoes. (Hampton Leaflet.)

ratory tube, and consequently lies in a horizontal position just under the surface film in order to obtain air. (This explains how it is that kerosene oil "poured upon the troubled waters" destroys the larvæ. They are simply drowned or suffocated as the surface film of oil excludes the air.) The larval stage lasts from twelve to fourteen days.

The mosquito larva, after growing several days and molting twice, changes into a club-shaped pupa (Fig. 126), the head and thorax being greatly enlarged, while the abdomen is slender. At the caudal end is a pair of leaf-like locomotor or swimming appendages. It takes no food, and when undisturbed it floats upon the water, but when disturbed it is active, thus differing from the pupal stage of most insects. The pupa of *Anopheles* has a narrower and more pointed head and much shorter and wider breathing tubes than those of *Culex*.

Mosquitoes flourish alike in the heated moist regions of the tropics and in the frigid regions of ice and snow. Many species have their haunts and breeding-places in fresh water, others breed abundantly and some perhaps exclusively in brackish water. They are found even in arid regions far from water, where it is probable they lay their eggs in the ground. So, go where we will, we cannot escape them, we must fight them.

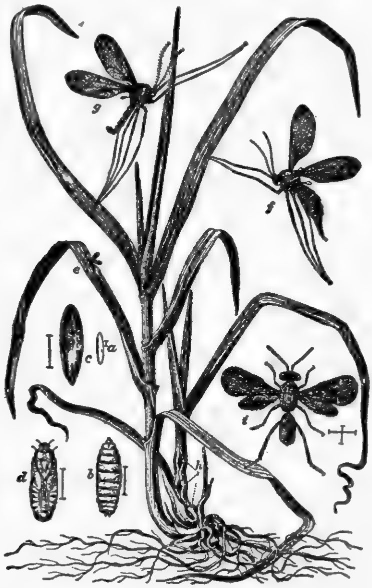


Fig. 131.—Wheat plant, showing injuries by Hessian fly: *a*, Egg of Hessian fly; *b*, larva; *c*, flaxseed; *d*, pupa or chrysalis; *e*, female, natural size; *f*, female; *g*, male; *h*, flaxseed or pupal stage between the leaves and stalk; *i*, chalcidid parasite; all enlarged except wheat stem and *e*. (After Riley, Burgess, and Trouvelot.)

A very easy and successful way of getting rid of mosquitoes in a pond which will sustain fish is to stock it with such fish as the "top-minnow," sun-fish, and stickleback, whose young especially feed upon the larvæ. Dragon-flies also should be encouraged and protected, since their nymphs feed upon the larvæ of mosquitoes, and the adults are voracious feeders upon the mosquitoes. In fact, if it were not for the dragon-flies, life in the Hawaian Islands would be almost intolerable on account of the hordes of mosquitoes. Pools and marshes should be drained, or, if the pool or mudpuddle is small, it may be filled up with less expense. If neither can be done, then spraying with kerosene along the edges of the banks and the surface of the water every two or three weeks should be resorted to. The oil kills by contact many adults and larvæ among the grass and weeds, and by coating the surface of the water with a film of oil the " wiggle-tails " are suffocated. Many females also are killed by this film of oil when they return to the surface to deposit their eggs. All open barrels (Fig. 130) and cisterns should be screened, so that the female mosquito cannot get to the water to deposit her eggs.

The **gall-gnats** (*Cecidomyi'idæ*) are the smallest flies, but their great numbers and their gall-forming habits make them great enemies of plants. There are about a hundred species in the United States, most of which are

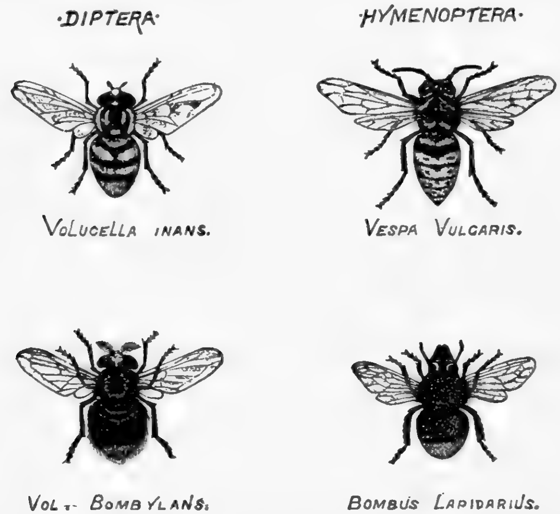



Fig. 132.—Two cases of mimicry: flies resembling a wasp in the one, and a bee in the other. (Romanes.)

destructive to cultivated plants. The minute reddish or white eggs are deposited on or in living plants, and the maggot-like larvæ probably imbibe their food through the skin.

The **Hessian fly** belongs to this family. It is a tiny blackish midge which lays its eggs (Fig. 131) in the sheaths of leaves some distance from the ground. The larva lives between the base of the leaf and the main stalk and feeds upon the sap of the growing wheat. There are four or five broods a year, both spring and winter wheat being infested. It is estimated that the ravages of this insect cost the farmers of this country $10,000,000 annually. Were it not for its natural enemies, a half-dozen hymenopterous parasites, it would soon take the whole crop of wheat, rye, and barley. The chief remedies which the farmer can use are the late planting of winter wheat; the burning or plowing of stubble; the early planting of strips of decoy wheat to attract the egg-laying females to deposit their eggs, and then to be burned; and the rotation of crops.[1]

Another common and conspicuous gall-gnat is the **pine-cone-willow gall-gnat,** which lays its eggs in the newly formed buds of the willow. The stem ceases to grow, but the leaves continue, causing the bud to resemble a pine-cone. In this the larva remains through the summer and winter, pupating in early spring, soon after which the adult emerges. There are a number of others, as the clover-leaf midge, the clover-seed midge, and the wheat midge, each injurious to its respective crop.

The **Syrphus flies** (*Syr'phidæ*), of which there are twenty-five hundred species, differ much. Some species in the adult form imitate bees and wasps (Fig. 132). They can be distinguished by the longitudinal "spurious" vein between veins three and five. Some of the larvæ are found in ants' nests and some in the nests of bumble-bees and wasps. One of the commonest is the yellow-banded species of the genus *Syrphus*, whose larvæ do great good by destroying aphids, in whose colonies they live.

The larvæ of one of the bee-flies (*Bombyli'idæ*) are also friends of man. They destroy many grasshoppers by burrowing into the egg-cases and devouring the eggs. The adults of these maggot-like larvæ are swift, hairy, and bee-like, mimicking the bee in appearance and feeding habits.

## ORDER X. SIPHONAP'TERA

The **fleas** consist of a single family, the *Pulĭc'idæ,* of nearly one hundred and fifty species, about fifty of which are found in the United States. Until recently the fleas were regarded as degenerate wingless Diptera, but entomologists now place them in a separate order. They are found usually as temporary external parasites on the cat, rat, rabbit, dog, poultry, and man.

The *mouth parts* are adapted for piercing and sucking. They are almost wingless, the wings being represented by mere scaly plates. The bodies are naked, smooth, hard, oval, and compressed. The metamorphosis is complete (Fig. 133). The "small, slender, white, footless, worm-like grubs" are composed of thirteen segments. They seem to live on dry dust and the organic matter it contains. When grown they usually spin a silken cocoon and pupate in the dust. In the species infesting cats and dogs the larval life lasts only about a week. The development from the egg to the adult requires but two weeks. Fresh pyrethrum dusted about the rugs where dogs and cats lie, or spraying the rugs with formalin, will help get rid of fleas.

[1] Jackson and Daughterty's "Agriculture through the Laboratory and School Garden."

The **chig'oe,** a small flea of the West Indies and of South America, often causes serious trouble by burrowing under the toe-nail or the skin of the foot of man. The female burrows under the skin, becomes encysted and distended by the eggs which hatch here, and unless the young are carried out by the pus they probably develop here.

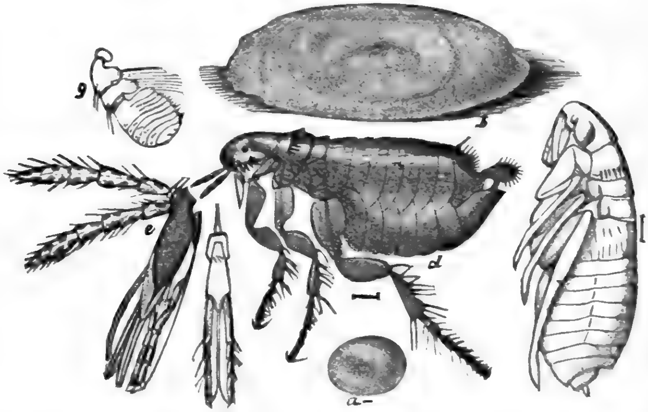



Fig. 133.—Common cat and dog flea (*Pū'lex serrăt'iceps*): *a*, Eggs; *b*, larva in cocoon; *c*, pupa; *d*, adult; *e*, mouth parts of same from side; *f*, labium of same from below; *g*, antenna of same; all much enlarged. (Howard, Bull. U. S. Dept. of Agriculture, 1896.)

**Rat Fleas.**—It is believed that in tropical countries the disease germs of the bubonic plague may be transmitted from rats to men by the bites or punctures of rat fleas.

### ORDER XI. LEPIDOP'TERA

This order includes such common insects as butterflies and moths or "millers." There are more than 6600 species in North America.

The *head* is rather small for the size of the body.

The *mouth parts* are highly complex, a striking example of adaptation of structure to function. The two maxillæ are greatly modified into a long hollow tube (Fig. 141) for sucking the juices of fruits or the nectar of flowers. When not in use this tube, tongue, or proboscis is coiled up between two projections, the labial palpi. Many moths do not feed in the adult stage and the maxillæ are lacking. The other mouth parts are mere rudiments. Find these rudiments on a large specimen and compare with the mouth parts of the grasshopper.

The *compound eyes* are large and conspicuous.

Some of the Lepidoptera have *ocelli*,[1] one on either side above and near the margin of these compound eyes, but they are usually hidden by the scales covering the head.

The many jointed antennæ are very various in size, shape, and color.

The *thorax* bears three pairs of legs and two pairs of wings. The wings are large, membranous, and covered with overlapping scales, which are, in reality, modified hairs. These scales strengthen the wings and give coloration to the species.

The *abdomen* has no paired appendages.

The *metamorphosis* is complete. The larvæ of Lepidoptera are commonly called caterpillars. They are very destructive, being almost without exception injurious to vegetation. Comstock says, "a very few feed upon plants below the surface of the water." The species which destroys scale-bugs, also those attacking woolen cloth, feed upon animal matter. Caterpillars are usually cylindric. The thorax bears six clawed, jointed, tapering legs, which develop into the legs of the adult. The abdomen bears from two to ten thick, fleshy, non-jointed, contractile pro-legs (see figure of silkworm, p. 126), which are shed at the last molt. The pro-legs are usually surrounded at the extremity by many minute hooks. The mouth parts of caterpillars are formed for biting, hence they can be exterminated by the arsenical poisons when it is safe to use them.

The Lepidoptera pupate in chrysalids or cocoons. The adult stage is the familiar winged form. It does no harm except the occasional puncturing of fruit to get the juice.

*Distinctions Between Butterflies and Moths.*—The antennæ of butterflies are filiform or thread-like for most of their length, but the end is thickened into a spindle-shaped enlargement or club. The antennæ of moths are of various forms, usually *filiform* or *pectinate* (feathery), but never clubbed. Butterflies are diurnal, while the moths are crepuscular or nocturnal. Butterflies at rest fold the wings together in a vertical position above the back. Moths spread the wings horizontally, or fold them leaf-

[1] Comstock, p. 199.

like, or wrap them about the body, but never hold them in a vertical position.

The skipper butterflies are diurnal, but, unlike other butterflies, the antennæ are usually recurved, forming hooks. Their bodies are more robust than those of other butterflies. They fold the wings, sometimes only the front ones, vertically when at rest. The skipper caterpillars are distinguished from other caterpillars by the unusually large head and the much constricted neck. Skippers spin thin cocoons of silk in which to pupate.

Authorities enumerate 650 species of butterflies in the United States east of the Mississippi River. Kellogg gives six families of butterflies and forty-four of moths. Of the thousands of species with their various and interesting habits only a few can be mentioned. These should serve to stimulate the student to observe and study others. See "Laboratory and Field Guide" for collecting, breeding, and mounting.

The **carpenter moths** (*Cŏs'sidæ*), of which there are twenty species in North America, are, in the larval stage, wood-borers, burrowing about in the heart-wood of shade and fruit trees. Pepper and salt gray moths, indistinctly or, in a few cases, conspicuously marked with black and white, lay their eggs on the bark of trees, where the naked, grub-like larvæ burrow into the wood. Here they tunnel through the wood for two to four years, according to the species. In this tunnel the pupal stage is spent. When ready for the adult stage the pupa works its way, by backward projecting saw-like teeth on the abdomen, to the opening of the tunnel, from which the moth emerges. The empty pupa skins may often be found projecting from the deserted burrows.

The **meal moth** (*Pyr'alis farina'lis*), whose larva feeds upon meal, flour, or old clover-hay, is a common species. It is usually found near the larva food, but sometimes sits upon the ceiling with its tail curved over its back. Its expanse of wing is about an inch. The wings are light brown with reddish reflections and a few wavy transverse lines. The larva makes long tubes of silk in the meal. Perhaps the most formidable mill pest is the Mediterranean flour moth (*Ephĕs'tia kuehniĕl'la*). The caterpillars spin silken galleries through which they pass, making the flour lumpy and stringy.

The **coccid-eating pyralid** (*Lætil'ia coccidiv'ora*) differs from other members of its family in being predaceous. It feeds upon the eggs and young of several scale insects. The larva spins a silken tube or bag, in which it lives.

The **codling moth** (*Carpocap'sa pomonel'la*) (Fig. 134) is one of the best-known and most cordially hated of moths. It causes an annual loss in the United States of $10,000,000. The adult is small, with finely mottled, ash-gray or rosy fore wings. Near the square ends of these wings is a large brownish spot marked with metallic, bronze bands. The hind wings and abdomen are a lustrous light yellowish brown. This moth lays its eggs singly in the blossom end of an apple, just when the petals fall. When the larva hatches it eats its way into the core. The affected fruit usually falls to the ground before ripening. The full-grown larva burrows out of the apple and pupates in a cocoon under the rough bark of a tree. After two weeks in the pupal stage the adult of the first brood emerges and lays its eggs on later apples. The larvæ are carried into the cellar with the fall and winter apples, pupate in the crevices of the barrels or boxes, and remain till the following apple-blossom time. Spraying the fruit with Paris green soon after the petals fall and again in about two weeks will greatly reduce the loss. At this time the fruit stands with the blossom end up and the poison will then reach the place where the larva hatches."[1] The larva does not remain long in the apple after it falls to the ground. Hence if the apples are burned or fed to hogs at once the larvæ will be destroyed.

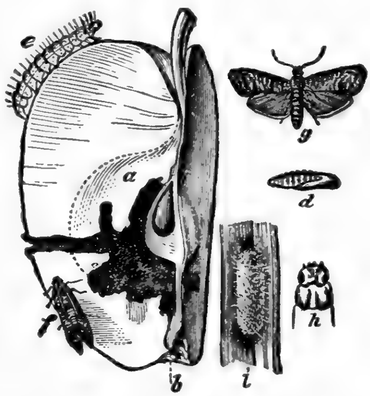



Fig. 134.—The codling moth: *a*, Apple showing burrow; *b*, place where the worm entered; *d*, chrysalis or pupa; *e*, larva or worm; *f*, moth with wings closed; *g*, moth with wings spread; *h*, head end of larva; *i*, cocoon in which the larva changes to a chrysalis. All about life size except *h*. (Riley.)

The **geometrids** are of interest because of the peculiar phase of protective resemblance possessed by their larvæ. They cling by their posterior legs to the branches of trees or other plants, and, holding the body out straight, stiff, and still, look, for all the world, like short, stubby branches. My little daughter searched for fully five minutes within a few inches of a green specimen on a sweet-pea vine before discovering it. When disturbed the caterpillar swings down by a silken cord till it reaches the ground. Most of them are leaf eating and they are sometimes so numerous as to do great injury. Among them are the **canker-worms** (Fig. 135), currant spanworms, two or three species which feed upon the grape, and the raspberry geometrid. They may be poisoned by Paris green, since all insects with biting mouth parts can be killed by poisoning the food with arsenical sprays.

[1] Jackson and Daugherty's "Agriculture," p. 321.

The **owlet moths** (*Noctu'idæ*), of which there are more than twenty-five hundred species in America, fly at night and are familiar visitors around our

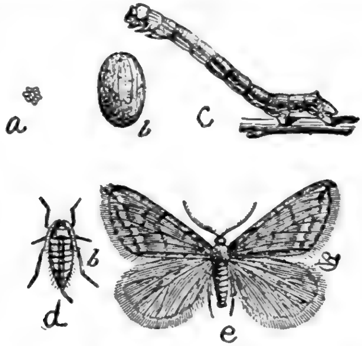



Fig. 135.—The spring canker-worm: *a*, Egg mass, natural size; *b*, egg, magnified; *c*, larva; *d*, female moth; *e*, male moth. (Riley.)

evening lights. To these belong the numerous cut-worm moths and army moths. Most of this large family are inconscipuous and dull colored, but

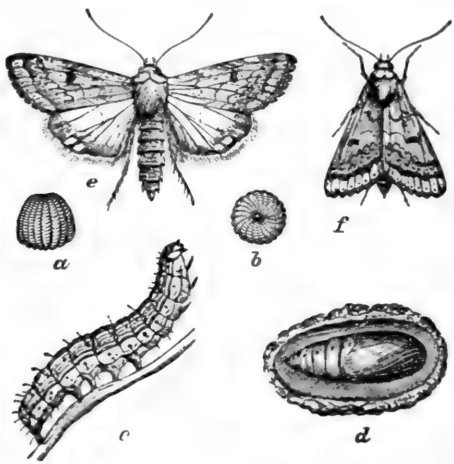



Fig. 136.—The boll-worm or corn-ear-worm. (Riley.)

the group of "underwings," or Catoc'alas, are exceptions to this rule. Strangely enough it is their posterior or under wings which are conspicuously colored and banded. When at rest the inconspicuously marked dull-colored fore wings completely cover the hind wings. During the day the moths rest close against the bark of tree trunks, where it is almost impossible to distinguish them. Collectors smear syrup on the trunks of trees where no sweet-smelling flowers are near, and collect the insects thus enticed on a dark, damp night, with a dark-lantern and wide-mouthed bottles.

The **cotton worm** (*Alĕ'tia argillā'cea*) also belongs to this family. It feeds upon the leaves of the cotton plants. The cotton boll-worm (*Helio'this armĭg'era*) (Fig. 136) feeds upon the pods or bolls. The destruction caused by these two caterpillars causes an annual loss of millions of dollars

Fig. 137.—Corn-worm eating an ear of corn. (Quaintance, F. B. 191, B. Ent. U. S. D. A.)

to the cotton growers. The boll-worm has become a great pest in the north also as the corn-ear-worm (Fig. 137). Just at the roasting ear stage it eats the juicy kernels and leaves a disgusting dark furrow, unfitting the corn for use. It feeds upon the fruit of the tomato also. The naked, greenish-brown caterpillar is marked longitudinally with darker stripes when grown and is about 1¼ inches long. It pupates in the ground through the winter. The moth has dull yellowish fore wings tinged with green. The hind wings are paler. Since it works under cover of the husk, spraying is of no use. Fall plowing practised by all neighbors having infested corn will materially lessen the number of worms. As the moths fly well, it would do comparatively little good for one to plow unless the near neighbors unite in the effort. Rotation of crops is helpful.

The **tussock moths** (*Lymantri'idæ*) (Fig. 138) are of medium size, the antennæ of the males being more broadly pectinated than those of the females. Ocelli are lacking. In some species the females are wingless. The legs are woolly or hairy. The larvæ are more beautiful than the adults. They have several bright colored tufts of hair on the back and long pencils

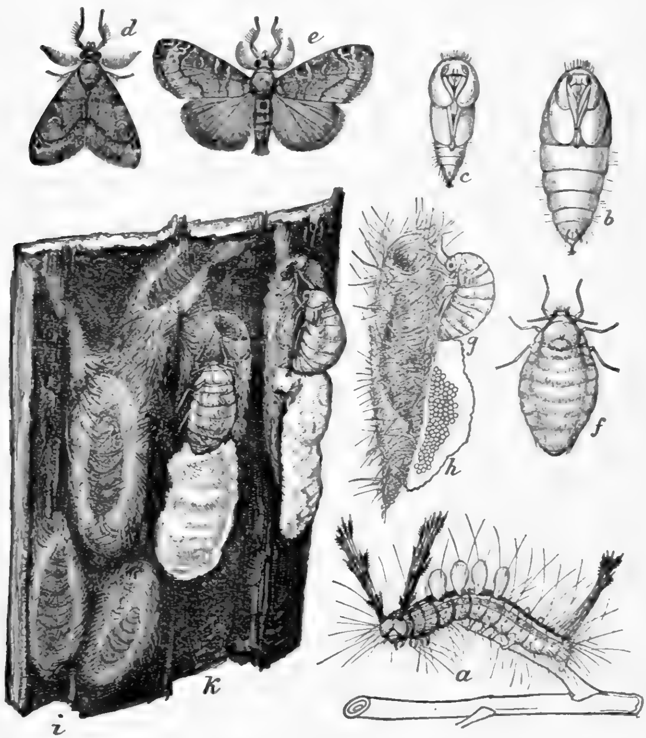



Fig. 138.—*Orgyia leucostig'ma: a*, Larva; *b*, female pupa; *c*, male pupa; *d*, *e*, male moth; *f*, female moth; *g*, same ovipositing; *h*, egg-mass; *i*, male cocoons; *k*, female cocoons with moths carrying eggs. All slightly enlarged. (Howard, Farmers' Bull., U. S. Dept. of Agriculture, 1899.)

of hair on each end of the body. The sixth and seventh segment each bears on the back a coral-red scent gland. It is easy to guess whether these caterpillars are a favorite food of birds. They infest our shade and orchard trees. The eggs are usually deposited upon the cocoon from which the adult female has just emerged, so they may be destroyed by collecting and burning the cocoons in winter.

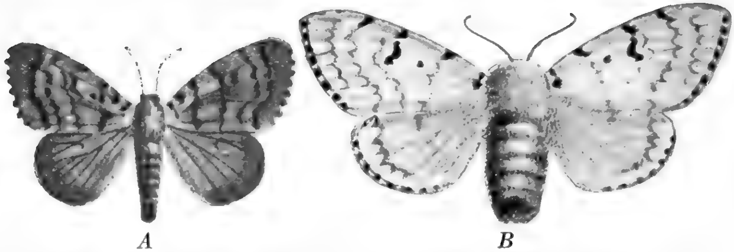



Fig. 139.—*A*, Male, and *B*, female, gypsy moths. Natural size. (Forbush and Fernald.)


Fig. 140.—The life cycle of the gypsy moth. (Figures after Forbush and Fernald.) (Bull. No. 121, New Hampshire State Experiment Station, December, 1905.)

The **gypsy moth** (*Ocne'ria di'spar*) (Fig. 139), imported from Europe in 1868, has become a great pest of forest and shade trees in Massachusetts.

The state fought it in every possible way, employing hundreds of men in spraying, trunk-banding, and egg-collecting. From 1890 to 1900 Massachusetts spent more than a million dollars in keeping this moth in check.

The **hawk moths** (*Sphin'gidæ*), sphynx moths (Fig. 141), or humming-bird moths have a stout, spindle-shaped body and long, narrow, exceedingly strong wings. The sucking tube is very long, sometimes twice as long as the body. When not in use, it is coiled up beneath the head like a watch-spring. Their rich varied tints of olive, tan, black, or yellow, always subdued, save for an occasional dash of bright color on the under parts, mark them as rarely beautiful creatures. As a rule, these moths love the

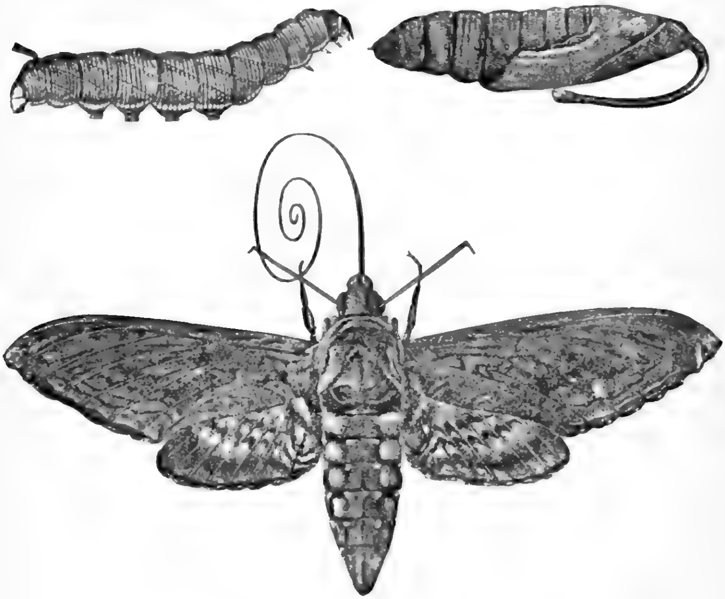


Fig. 141.—Tomato-worm or tobacco-worm: larva, pupa, and adult. (After Walsh and Riley, Am. Ent.)

twilight, and strangely resemble the humming-birds from their habit of rapidly vibrating their wings while poising themselves over a flower and sucking its nectar.

The larva, naked and cylindric, usually has a " horn " on the back of the eighth abdominal segment. These caterpillars are usually green with several oblique light-colored or whitish lines on each side (see Fig. 141). When resting these caterpillars " rear the front of the body up in the air, curl the head down in a most majestic manner, and remain thus rigidly motionless for hours."[1] They are thus supposed to resemble the Egyptian sphynx, hence the name, sphynx moth. They feed upon the leaves of

[1] Kellogg, 331.

various trees or plants, the tomato-worm being perhaps the most familiar example. When full grown this is sometimes 3 inches long. The pupa, which lies buried in the ground, has a firm, naked, dark brown wall, and is distinguished by the peculiar "jug-handle" sheath, in which the sucking tube is developed. Hand picking of the larvæ, fall plowing, and rotation of crops are the best remedies.

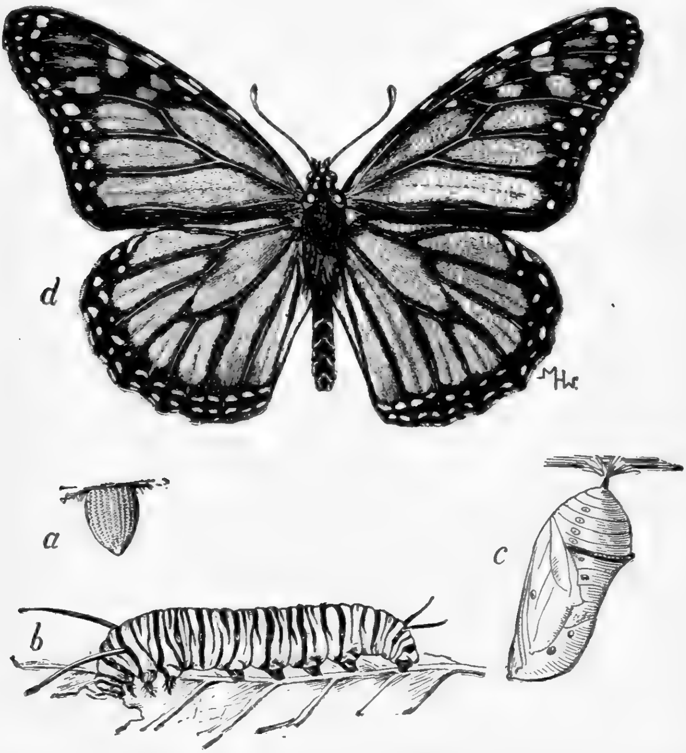



Fig. 142.—Metamorphosis of monarch butterfly (*Anosia plexippus*): *a*, Egg; *b*, larva; *c*, pupa; *d*, imago or adult. (From Jordan and Kellogg, "Animal Life," D. Appleton and Co., Publishers.)

The **monarch** or **milkweed butterfly** (*Ano'sia plexip'pus*) (Fig. 142) is one of our most abundant species. Hundreds or even thousands of these butterflies may sometimes be seen in a swarm, or "roosting" together in trees. Their wings are reddish brown, bordered with black, and the veins are edged with black. There are two rows of white spots on the outer margins.

The larva when grown is a very light green or greenish yellow, and regularly marked with shiny black and yellow bands. On the second thoracic and the eighth abdominal segment there is a pair of slender, fleshy, black filaments. This caterpillar feeds upon the leaves of the milkweed. It attains its growth in two or three weeks, when it pupates from nine to fifteen days in a smooth, bright green chrysalis (Fig. 142), which is about an inch long and beautifully adorned with a few black and gilt spots and bands. In the South there are two generations, but with us but one.

The butterfly is protected from its enemies, the birds, by an ill-tasting acrid fluid, of which its conspicuous color gives warning. The power of flight is strong and these butterflies migrate in winter. The monarch is found all over North and South America and in most of the Pacific islands, and in Australia and Western Europe.

It is closely mimicked by the *viceroy* (see Fig. 92, p. 119), a smaller butterfly which is not distasteful, but is protected from the birds by its resemblance to the odious monarch. The viceroy may be easily distinguished by the transverse band of black on each of the hind wings. Its larvæ feed upon the willow, poplar, and cottonwood. The larva hibernates in a silk-lined nest made of a rolled leaf.

The **swallow-tailed butterflies** (*Papilion'idæ*) are a large and interesting family, having a sort of half-fluttering, half-soaring flight. They are easily distinguished by their large size and their black and yellow—or greenish-white—tiger-like markings. Twenty-one species are found in the United States. The wings are very thickly covered with scales. They are narrow and the posterior wings end in a club-shaped prolongation which is supposed to call the attention of the bird to the less vital part. The larvæ when disturbed project a pair of bright colored fleshy "horns" from a slit in the dorsal wall of the prothorax. The horns exhale an odor which in some species is exceedingly disargeeable.[1]

The **zebra swallow-tail** (*Iphiclī'des a'jax*) differs from all other butterflies of the eastern United States by the black and greenish-white bands on its wings and by its exceedingly long "tails." This butterfly is extremely interesting to the scientist, in that it furnishes an example of *dimorphism* or even of *polymorphism*. All the broods which hatch out the same summer, and there may be several, are of the same form (*ajax*), but many individuals pass the winter in the chrysalis stage, some (*marcellus*) emerging early in the spring, and some (*telamonides*) appearing in late spring. The *marcellus* form has "tails" only about $\frac{3}{5}$ inch long tipped with white, while the *telamonides* is a little larger, with tails nearly an inch in length and bordered on each side of their distal half with white; while *ajax*, the typical form, is still larger and has longer "tails."

The time of emerging seems to be the only influence controlling this variation, since the offspring of each form, when maturing the same season, produces *ajax*, when maturing early the following spring, produces *marcellus*, and late the following spring, *telamonides*.

The larva of this species is light green, "thickest in the thorax," and with transverse markings of black dots and lines and slender yellow stripes, besides a yellow-edged, broad, black, velvety stripe on the thorax. It feeds upon the papaw.

The **tiger swallow-tail** (*Papil'io tur'nus*), another common species, is also dimorphic. In this instance the dimorphism is sexual; at least one of the forms, *glaucus*, is represented only by the female.

[1] Comstock, p. 376.

**The cabbage butterflies** (*Pi'eris*) (Fig. 143), of which there are three species in the different sections of the United States, are the most destructive to agricultural products of any of our butterflies. They have three broods in the North and more in the South.

The wings of *Pieris rapæ* are a dirty white above, tinged with yellowish in the female. The base and apex of the fore wings are blackish and the female has two black dots on the fore wings; the male has but one. There is a black spot on the anterior margin of the hind wing. In the male it is indistinct. The larva is green, with a narrow greenish-yellow band upon the back and a similar narrow broken "stigmatal band." It is covered with fine short hairs. It feeds upon cabbage and other cruciferous plants. It is exceedingly hard to combat, from the facts that there are so many

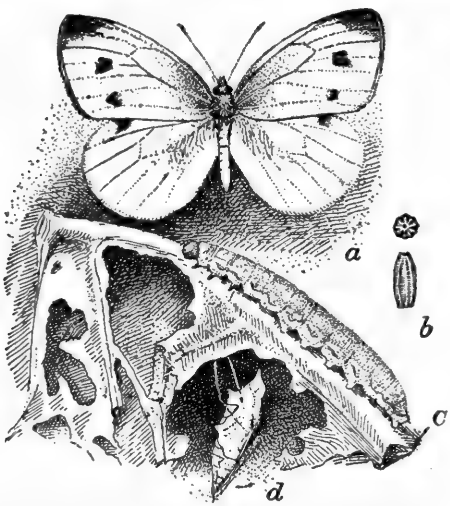



Fig. 143.—Cabbage-worm and butterfly (*Pontia ra'pæ*): *a*, Female; *b*, egg; *c*, worm eating on a cabbage leaf; *d*, suspended chrysalis; *a*, *c*, and *d* slightly enlarged. (Chittenden, Cir. 60, B. Ent., U. S. D. A.)

broods and that the larva bores into the heart of the cabbage. The work of extermination must necessarily be done before the cabbage begins to head. Fresh pyrethrum and kerosene emulsion are helpful. It is hardly safe to use Paris green except with quite young plants.

The **gossamer winged butterflies** (*Lycæni'dæ*) include three well-marked groups which are commonly distinguished by their various colors as the "blues," "the coppers," and the "hair-streaks." They are quite small and delicate. The larvæ are slug-like. The "blues" are often seen flitting about mud-puddles. Several species of the family are carnivorous. One of them, the "harvester" (*Fenis'eca tarquin'ius*), common east of the Mississippi River, is small, with the "upper surface of wings dark brown, with a large irregular yellow patch on the disk of the fore wing and one of the same color next the anal angle of the hind wing." It is a friend to the fruit grower, for its larva feeds upon woolly plant-lice like the apple-tree aphis and the alder blight.

### ORDER XII. HYMENOP'TERA

This order is represented by such familiar insects as the bumble-bees, yellow-jackets, honey-bees, ants, wasps, ichneumon flies, saw-flies, and gall-flies.

The mouth parts (Fig. 144) are adapted for biting or sucking, the mandibles are short and fitted for biting, while the other

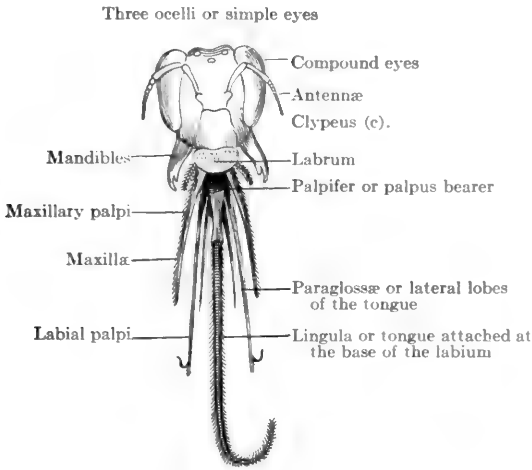



Fig. 144.—Front view of the head of a bee. (Tenney.)

mouth parts, as the *maxillæ*, *labium*, the maxillary and labial *palpi*, are more or less modified into a proboscis for taking up liquid food.

The wings are membranous and four in number. The anterior pair is larger than the posterior. The student will observe that the body and wings of Hymenoptera are shorter than those of the dragon-fly order (Odonata).

The metamorphosis is complete. The larvæ are maggot-like.

*Habits.*—They vary much in habits. Some are herbivorous (saw-flies), some form galls, others are parasitic (ichneumon flies). The stinging Hymenoptera, on account of their efficient means of defense, are often mimicked (Fig. 132, p. 160)—the bumble-bees by the hawk-moths, the hornets by two clear-winged moths of the genus *Sesia*, the bee by the drone-fly (*Eristalis*), the wasp by a common English beetle (*Clytus erictus*), and the hornet by a Nicaraguan Hemiptera.

**Saw-flies and "Horntails."**—Among the boring Hymenoptera are the saw-flies, horntails, and gall-flies.

The saw-flies have a wide head and thorax, with a broad joining of the base of the abdomen and thorax. The ovipositor consists of a pair of saws with which slits are made in leaves or stems where the eggs are laid. The larvæ look much like caterpillars, but may be distinguished by having from twelve to sixteen pro-legs instead of ten. Most of these larvæ have "a curious habit of curling the hind end of the body sidewise" about a branch. The rose-slug and currant-worm are familiar examples.

The currant-worm is the larva of the saw-fly (*Nem'atus ribe'sii*). It is a "criminal emigrant" and has left a large army of descendants. The female deposits her glossy white eggs along the ribs of the first leaves of currant and gooseberry bushes. In ten days the little whitish larvæ hatch. They are voracious feeders and will strip a bush of every leaf if allowed to mature. When mature they are green with a black head and black spots and resemble caterpillars. They pupate in brownish paper-like cocoons, either attached to the bush or hidden in the ground. There are two broods in a season, provided the first is not exterminated by a liberal spraying with Paris green or hellebore. If the spraying is thoroughly done when the worms are quite small, they are easily poisoned, since, like all insects with biting mouth parts, they swallow the poison with their food. If any of the larvæ escape, the spraying must be repeated for the second brood, or the bushes may be killed outright in one season. If the spraying is done soon after the first brood hatches there is no danger of poisoning the fruit.

Fig. 145.—Boring saw-fly or horntail (*Trĕ'mex colŭm'ba*).

The **horntails** (*Siric'idæ*) are so named because the posterior end of the abdomen bears a spine or "horn." They differ from the saw-flies in having an ovipositor "which is composed of five long, slender pieces," adapted for boring instead of for sawing. There are several species in America.

The **pigeon horntail** (*Trĕ'mex colŭm'ba*) (Fig. 145) has a cylindric body about ¼ inch in diameter. It is 1½ inches long, with rusty red thorax and black abdomen, with yellow bands and spots on the sides, a yellow "horntail," and smoky transparent wings. The female pierces holes about ½ inch deep in elm, oak, sycamore, or maple trees, bending the ovipositor at right angles to the body in boring, and deposits her eggs, one in each hole. When the larvæ hatch they do much injury by burrowing into the heart-wood, where they feed, grow, and finally form cocoons of silk and fine bits of wood. The winged adult gnaws its way out through the bark. The ichneumon fly *Thalessa* is parasitic upon *Tremex.*

The **gall-flies** (*Cynip'idæ*) live in closed galls during the larval state, and the full-grown larva either makes a hole and emerges and pupates in the ground, or it pupates in the gall and the adult makes a hole through which it emerges. The adult female pierces a hole in the tissue of the leaf with her sharp-pointed ovipositor which is composed of "several needle-like or awl-like pieces." In the incision thus made she deposits one or more eggs. When the larva hatches an abnormal growth of tissue begins to form about it, caused, perhaps, from some irritating excretions, or from the physical irritation caused by the pressure of the irritating body. The tiny, footless, white, maggot-like larva feeds, probably through the skin, on the sap of the growing gall. When the gall dies, which is usually about the time the larva is grown, it dries and hardens and forms a protecting case in which the larva (or larvæ) pupates, and from which it emerges as a tiny gall-fly in the first or second spring following.

But one of the strange things about these gall-flies is that, in some cases, the successive generations of the same species are not of the same form. The adult flies of one generation, which consists exclusively of females, lay their eggs upon a certain host-plant, but the resulting individuals are not at all like their mothers. This generation includes individuals of both sexes which have developed from "unfertilized eggs," or parthenogenetically. The females of this generation lay their eggs upon a different host-plant, develop very differently shaped galls from those in which they grew up, but, like those of their grandparents, and the resulting individuals are like their own grandparents. Not all gall-flies show this *alternation of generation*, some species appear always in the same form, but, strange to say, they are usually represented only by females. Although there are two hundred species of gall-flies, each species infests a special part, leaf, branch, or root of one or more particular species of plants. The gall produced by each species of insect is of a definite form. This is a remarkable manifestation of instinct. "It is impossible that intelligence or memory can be of any use in guiding the *Cynipidæ;* no Cynips ever sees its young, none ever pricks buds a second season, or lives to know the results that follow the act. Natural selection alone has preserved an impulse which is released by seasonally recurring feelings, sights, or smells and by the simultaneous ripening of the eggs within the fly. These set the whole physiologic apparatus in motion and secure the insertion of eggs at the right time and in the right place."[1]

**The Guest Gall-flies** (*In'quilines*).—There are many gall-flies which do not themselves form galls, but which lay their eggs in the galls formed by others. The larvæ feed and develop here, but do not materially disturb the rightful owners.

**Parasitic hymenoptera** (*Ichneumon'idæ*) are of great economic interest (Fig. 146). Most of them live within the bodies of their victims during the larval stage, the egg being laid either within or upon the body of the host. In the latter case the larva bores its way into the body and feeds upon the blood, so that the host is not killed until the larva is grown. Each species

[1] Stratton.

of ichneumon flies has its special host, the majority of them being caterpillars. The largest insect of this family belongs to genus *Thalessa.*

*Thales'sa luna'tor* has a body $2\frac{1}{2}$ inches long and the insect measures nearly 10 inches from the tips of the antennæ to the end of the ovipositor, and is parasitic upon the larva of *Tremex columba.* The ichneumon fly bores a hole with its flexible ovipositor, which is 6 inches long, into the tree infested by *Tremex,* and deposits its eggs in the burrow of the *Tremex* larva. When the ichneumon larva hatches, it creeps along the burrow until it reaches its victim, the horntail larva, to which it attaches itself and feeds upon its juices. Sometimes the female ichneumon fly gets her ovipositor fast in the wood and it holds her a prisoner until death.

Other important, though usually small, parasitic Hymenoptera are the braconids, the ensign-flies, and the chalcid-flies. While the larvæ of parasitic Hymenoptera are degenerate in the same way as the footless, eyeless, antennæless maggots of house-flies, they are not more so. Their parasitic habit has led to no such extraordinary structural specialization through degenerative loss, or reduction of parts as is the usual condition in other parasites. The adult is active and well developed.

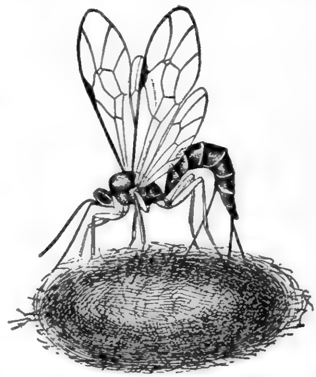


Fig. 146.—*Pimpla* in the act of ovipositing on cocoon of tent caterpillar. Somewhat enlarged. (After Fiske.)

**The Stinging Hymenoptera.**—The females and sterile workers, where there are such, have the ovipositor developed into an organ of defense, the sting. Females may be distinguished from the males by having six segments in the abdomen instead of seven. The group includes ants, wasps, and bees.

**Ants** live in all lands and in very various conditions and occupations. All of the 2500 or more species live in communities, and division of labor among kinds of individuals and, consequently, differentiation of structure, are highly developed. Ants are easily recognized by the form of the body, but they are distinguished from other insects by the character of the first one or two segments of the abdomen. These are expanded dorsally into a "lens-shaped scale or knot," which varies in form and serves as a peduncle to the rest of the abdomen.

The ants' nests or formicaries are composed of irregular rooms and galleries which may be mostly underground, or have a large portion above ground, as a mound or ant-hill, or may be tunnelled out in the wood of decayed trees. "In the tropics," says Comstock, "a greater variety of these structures occur than in our country. . . . One colony of one species has been known to have two hundred mounds covering several hundred square yards. Ants are also very good road makers, sometimes making clean beaten paths or working out covered ways under rubbish."

There are always three classes of ants (Fig. 147) in a community, winged males and females, and wingless workers, sometimes also the soldiers and wingless, but fertile males and females. The winged males and females at maturity issue simultaneously from the nest and from neighboring nests, so that the air will be filled with thousands of ants swarming about in their mating flight. After this the males soon die, and the females which escape from birds and other animals tear off their wings and go in search of a suitable nesting place. Sometimes the queen starts the new colony alone, while in other species the workers find and adopt a queen and form a new colony.

Inside the nest large numbers of very small eggs are laid in "little piles heaped together in various rooms and sometimes moved about by the workers."[1] The larvæ are small, white, footless, helpless grubs, which are fed by the workers with regurgitated food or with chewed insects, or with dry seeds and vegetable matter from the granary where they have been stored. Most species spin cocoons in which to pupate—the white oval bodies seen carried away by the ants when the nest is disturbed. The adults

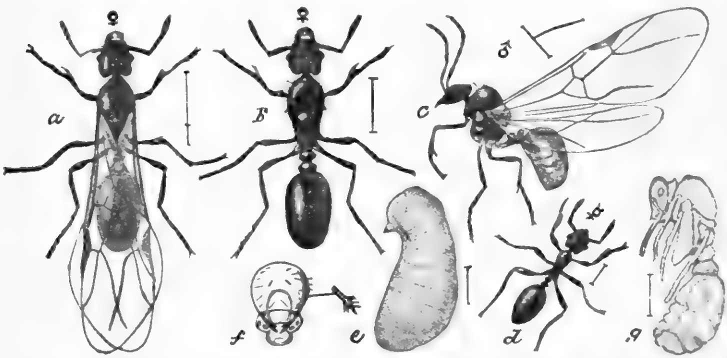



Fig. 147.—The pavement ant (*Tetramorium cæspitum*): *a*, Winged female; *b*, same without wings; *c*, male; *d*, worker; *e*, larva of female; *f*, head of same; *g*, pupa of same; all enlarged. (Marlatt, Bull. U. S. Dept. of Agriculture.)

are unable to escape from these cocoons unaided by the workers. The workers are undeveloped females or females which seldom lay eggs, and if they do, these eggs always develop into males. These workers not only feed the colony, but do all the work, building the nests and defending them against enemies, even by war if necessary.

There may be from one to thirty queens, though in small colonies there is usually but one. As these queens grow old, the workers seek young queens at the swarming period and bring them into the nest. Ants, except the males, which are short lived, are known to live longer than most social insects. Lubbock says he was able to recognize worker ants at least seven years old, and one queen died when over thirteen years old and another lived more than fourteen years.[2]

[1] Comstock.
[2] Lubbock, "Senses, Instincts, and Intelligence of Ants," p. 233.

Although ants are general feeders upon animal substances and fruit juices, they are very fond of sweet substances like the "honey-dew" given off by aphids when stroked by the ants' antennæ. In return for this choice food the ants shelter the aphid eggs in their nests through the winter and carry the young plant-lice to tender plants in the spring. When for any cause these plants become unsafe or unfit for the food of the aphids, the ants will carry them to other plants. If ants are seen running up and down the stem of some favorite plant, one may know, unless there is a sweet substance exuding from bark or flower, that they are "pasturing their cows" upon the juices of tender shoots and newly forming buds. A little close looking will reveal myriads of tiny plant-lice on the under side or in the axles of the leaves. Spraying with a little dilute commercial nicotin will rid the plants of both ants and plant-lice. Arsenic poisons cannot affect aphids or other insects having sucking mouth parts, since their food consists of the internal juices of plants which cannot be reached by the poison.

There are many other *insects which live in the nests of ants.* In 1900 Wasmann recorded 1177 insects living in the nests of ants (myrmecophilous insects), many of which were beetles. Most of these insects live a commensal life with the ants. It is not known of what advantage they are to their hosts. The guests, however, obtain shelter, food, moderate temperature, defense against enemies, and even, in the case of migratory ants, transportation. In the case of some small beetles, however, there is true symbiosis with the ants, the beetles secreting a sweet substance which the ants eat greedily, and in return the ants "clean, care for, and feed by regurgitation" the degenerate little beetles.

The ants furnish an example of a perfect communistic society. There is no special care or favoritism for wife or child or friend, but a common love for the whole community. "Everything is done for the good of the whole and nothing for the individual. The state makes wars, provides food for all, cares for the children, owns all the property, the fate of each one is determined by the accident of birth, and each takes up its work without a murmur. . . . This perfect commune has developed courage, patriotism, loyalty, and never-failing industry, but also war, pillage, slavery, and an utter disregard of the rights of other communities and individuals."[1]

Most of the ants which have been described in this country can be placed in one of three families: (1) **Formic'idæ,** in which is found the interesting **carpenter ant** (*Campon'otus pennsylva'nicus*), one of the largest of our common black ants. It builds its nest in the dead interior wood of living trees and wooden buildings. Here also is the **mound-building ant** (*For'mica exsectoi'des*), with its rust-red head and thorax and black abdomen and legs. Its ant-hills are from 5 to 10 feet in diameter. One of the most interesting of the family is the **slave-making ant** (*For'mica diffic'ilis*). In this species the workers work with the slaves, but *Polyer'gus rufes'cens,* a European species, depends upon the slaves to do all the work for the community. The adults are not taken captive, but in war and pillaging the larvæ and pupæ are some of them eaten and some of them carried home, where, if not eaten, they develop into the adult workers, and instinctively go to work for their hosts, building nests, bringing food, and nursing the young. In some species this is carried on to such an extent that the hosts become unfitted for any work but that of warfare, and are dependent solely upon the slaves for shelter, food, and all the necessary work of the community. Thus their

[1] Comstock, p. 634.

slave making has reacted upon themselves, rendering them unable to help themselves. It is a law in all animal life that dependence upon others renders one more dependent, while dependence upon self develops independent powers.

The **corn-louse ant** (*Las'ius brun'neus*) is the common small brown ant of our pastures, woods, and meadows. It is of especial economic interest on account of the care it bestows on the corn-root plant-louse. The eggs of the plant-louse are laid in the ant's nest, where they are sheltered during the winter. In the spring the ants place the young aphids upon the roots of certain knot-weeds until the corn has germinated and then remove them to the corn-roots. These aphids do great damage in the Middle West. (See p. 144.)

(2) **Poner'idæ** is the smallest family in number of species, there being but about twenty-five known in this country, and the least specialized, that is, the least differentiated into castes. The queen and workers are stingers. Their nests are made under stones or logs.

(3) **Myrmic'idæ**.—This family is characterized by two segments in the peduncle. Usually the queen and workers have stings. The pupæ are naked. To this family belongs the tiny "red ant" (*Monomo'rium pharao'nis*), which is in reality a light yellow, that is the torment of housewives.

The **agricultural ants** (*Pogonomyrmex*) live in the southern and western states. They, with the exception of one species, live in nests partly under ground, covered with conspicuous mounds in open sunny places. They cut away the grass immediately about the nest. It has been popularly believed that they sow the seed for their food, but Wheeler says that they carry out the débris, which consists of chaff and sprouting grain, and deposit it at the edge of the cleared circle. The seeds often grow and do yield a harvest for their next winter's stores, though not intentionally planted.

*Intelligence.*—There is a great diversity of opinion among scientists who have experimented with ants as to the "mentality" of these insects. Bethe[1] and others hold to a purely mechanical or reflex theory, while Loeb, Wheeler, and others attribute to them reflexes, instincts, and animal memory, and Lubbock and Forel give them a considerable degree of intelligence. Comstock says they "think."[2] Whether they are governed by one or all of these attributes, it is surely probably that the mechanical and chemical forces which affect the nervous activities of the ants may also influence those of men, and that if the same rigid experiments and final analyses were applied to the various phases of man's activities, there would result quite as many surprises as have accompanied the experimenting upon insects, indicating that many of his activities are responses to mechanical stimuli, and yet no one doubts that man possesses intelligence. Whether the activities of ants

[1] Kellogg, 544. [2] Comstock, 637.

are governed by reflex action, instincts, or intelligence (in a limited degree, of course), or, what is more probable, by a certain combination of these, they certainly perform many wonderful feats, considering the fact that they have but a single set of tools, the mandibles. They use these to dig and tunnel, to obtain food, and to carry and manipulate their food, to fight, to carry tenderly their eggs and young, or to cut leaves and husks and seeds. Though they have no voice, they are known to communicate by means of touch through the agency of the antennæ. It is believed that they recognize friend or foe by the odor.

The **digger wasps** (*Spheci'na*) are a group of closely allied families of Hymenoptera. They may be distinguished from true wasps by the fact that their wings lie flat above the body, and from bees by the adaptation of their legs for digging and walking. They are all solitary. Each female makes her own nest by burrowing in the ground or in wood, or by constructing a tube of mud, or using one found already made. In this nest she places certain insects which she has paralyzed but not killed, by stinging, lays an egg, and seals up the cavity. When the larva hatches it feeds upon the food thus provided for it by the mother. The parasitic forms lay the eggs upon the paralyzed bodies of their hosts, and the guest-species lay them in the nests of other wasps or bees, where the larvæ feed upon the food prepared by the host for its young.

Familiar examples of the digger wasps are the mud daubers (*Pelopæ'us*) of our attics and eaves. It is thought that these wasps find their nests again, after going in search of insects with which to "provision" their nests, by the memory and recognition of localities, for they go from place to place, back and forth in many curious zigzag or circular routes, but find their way back to their nests readily.

The **"tarantula-killer"** (*Pĕp'sis formō'sa*), of the West and Southwest, is a large solitary wasp which provisions its nest with the choicest of food, such as tarantulas, though many a hard battle is necessary to procure them. Sometimes the tarantula makes a meal of the wasp instead of becoming food for its young.

The **true wasps** (*Vespi'na*) are characterized by the folding of their wings lengthwise like a fan when at rest, by the kidney-shaped eyes, and by the absence of bristles or spines from the legs.

One family (*Eumen'idæ*) of the true wasps leads a solitary life. One of these (*Mono'bia quad'ridens*) tunnels into wood and partitions off the tunnel, making a cell for each larva.

Another species (*Eu'menes frater'nus*) is a thorough mason, making little jug- or vase-shaped nests of clay or mud which it attaches to the stem of a plant. It provisions it with caterpillars, often with canker-worms.

The **social wasps** (*ves'pidæ*) live in communities in spring, summer, and autumn. The males and workers die in the autumn, and the females (queens) hibernate through the winter under logs or stones or in crevices. In the spring each queen starts a colony. She makes a small nest containing a few brood-cells, in each of which she lays an egg. The hatching larvæ are fed by the queen with insects captured, killed, and somewhat masticated by herself. In a few days the larvæ pupate in the cells and soon issue as workers. These enlarge the nest, adding new brood cells, which the queen fills with eggs, which, upon hatching, are fed by the workers. Thus, several broods of workers are reared, and the nest is continually enlarged to make room for the increasing family. Early in autumn a brood is hatched containing males and females, which mate probably with individuals of other communities, and at the approach of winter most of the colony dies, leaving only a few hibernating queens.

The nest of the social wasp may be under ground, in which case it is made of partially decayed wood, or it may be attached to bushes or trees or under

Fig. 148.—A hornet's nest, showing two horizontal sections of comb, one above the other, and the many layers of paper surrounding the nest. (Photographed from object.)

the eaves of buildings. This wood is formed into a pulp by being masticated with saliva and chewed. In the genus *Polis'tes* the nests consist of a single cone and are not inclosed in an envelop, but in the genus *Ves'pa*, including the yellow-jackets and hornets, the nest (Fig. 148) consists of several horizontal cones suspended one above the other, yet separated by a considerable space from each other, and the whole enveloped in a waterproof covering of many thicknesses of wasp-made paper, the whole nest forming a globular or cone-shaped ball. When the nest is to be enlarged the wasps nibble away the inner layers of the enveloping paste and add new layers on the outside.

**Yellow-jackets and Hornets** (*Vespa*).—In this genus the body of the wasp is rather stout and short and the peduncle is very short. The color is black, spotted, and banded with yellow, from which we are all glad to take " warning," for the sting of a hornet is painful and the nest contains thousands of individuals. The queens are larger than the workers. It may be interesting to know that the males have no sting. They may be further distinguished from the other forms by having seven segments in the abdomen instead of six.

The social wasps do not store up food, but continually feed the young throughout the larval stage, which lasts from eight to fifteen days, with partially masticated insects. The adults " feed upon insects or decomposing animal substances (fish especially attracts them) and upon exposed sweet substances, such as syrups and preserved fruits."

**Bees** may be distinguished from all other Hymenoptera by their enlarged and flattened tarsal segments, which, except in the *In'quilines*, are provided with an arrangement for carrying pollen. It is said that the hairs (at least on the head and thorax) are branched or plumose, as revealed by the microscope, while those of all other Hymenoptera are simple.

The nests of bees are always provided with pollen or honey, or both. The larvæ when quite young are fed by a substance called " bee-jelly," regurgitated by the nurse workers; for the bee colony, like those of other Hymenoptera, consists of three forms: the workers, the males or drones, and the female (queen).

The **short-tongued bees** (*Andren'idæ*) are all either solitary or gregarious, none social. Some of the mining bees, genus *Andrena*, are almost as large as the honey-bee workers. In grassy fields they sink a perpendicular shaft into the ground sometimes to the depth of a foot or more, which branches off sidewise to the cells. Though each nest is solitary, the females often build close together.

The smallest of our bees (*Halic'tus*) burrows in sand-banks or cliffs. Several females unite to " make a burrow into the bank, after which each female makes passages extending sidewise from this main burrow or public corridor to her own cells. While *Andre'na* builds villages composed of individual homes, *Halictus* makes cities composed of apartment houses."[1]

The **long-tongued bees** (*A'pidæ*) have the lower lip highly specialized for obtaining nectar from flowers. The basal segment of the labial palpus is also elongated. Some of this family are solitary; others, guest-bees; a few, social.

Among the solitary long-tongued bees is *Megachi'le acu'ta*, a carpenter and leaf-cutter, which, if it does not find a convenient crevice or cavity ready made, tunnels out a tubular cavity in wood and builds a thimble-shaped nest at the bottom out of oblong pieces of leaves which it cuts out for itself, and fills it with a paste of pollen and nectar. The egg is then placed upon this food and the opening tightly plugged up with circular pieces of leaves.

The **little blue carpenter bee** (*Cerat'ina du'pla*) builds its nest in dead twigs of sumach or in the hollows of other plants. The female fills the bottom of the nest with pollen, lays an egg upon it, and makes a partition above the egg out of pith chips made in forming the tunnel. She continues making these cells until the tunnel is nearly full, then she rests in the space above the last cell and waits until the young are grown. When the first one is ready to emerge, it tears down the partition above it and waits till each one has performed the same process, when they are led by the mother into the open air. Comstock says it is the only instance he knows of a solitary

[1] Comstock, p. 666.

bee watching her nest. The old nest is cleaned out by the whole family and used again by one of them.

The **guest-bees** (*In'quilines*) infest the nests of both solitary and social bees, sometimes being unwelcome guests. They have, of course, no worker forms, only males and females, since work is not necessary when they can live off the bounty of others. Those infesting the nests of solitary bees steal into the nest before it is completed and lay their eggs, which hatch before those of the host, and devour the food intended for the young of the rightful owner. Strangely enough, the Inquilines (*Psith'yrus*) seem to be welcome, for if they were not the bumble-bees surely would drive them out, for they certainly could. The female lays her eggs in a bumble-bee's nest, and when the larvæ hatch they are cared for by the bumble-bees as if they belonged to them. Sometimes the guests very closely resemble their hosts in size and color, but in other cases they are marked very differently. The males resemble the bumble-bees so closely in appearance and structure that it is difficult to determine whether they belong to *Psithyrus* or *Bombus*, but the females are easily distinguished, for the pollen-basket of the hind legs has been lost through disuse. There are no workers among the *Psithyrus*, and if for any reason the supply of the host should fail them, the guests would starve, for they are so degenerate as to actually be unable to work. Kellogg says these guest-bees " are like bumble-bees in so many structural details unnecessary for deception (mimicry) that they must be looked on as a degenerate offshoot from the *Bom'bidæ*," that is, as degenerate bumble-bees.

The **social bees**, which are native, belong to the genus *Bombus*. The bumble-bees, like the ants, live in communities having three kinds of individuals: males, females, and workers. In early spring each queen which has survived the winter by hibernating seeks some unoccupied mole's nest or mouse's nest or digs a cavity in the ground for her nest. In this she deposits a ball-shaped mixture of pollen and honey and lays a few eggs, not over twenty, upon it. Then she brings another supply of food and deposits more eggs. When the first larvæ hatch they feed upon the food provided, and when grown each spins a silken cocoon and pupates. These all form worker bees, which enlarge the nest and provide more food. The queen lays more eggs and the workers now enclose the larvæ in waxen cells. A few cells also are filled with pollen or with honey. The nest may become as large as one's head and is covered loosely with bits of vegetation. It usually has two or more openings. " Later in the summer males and females appear, and it can be said to the credit of the bumble-bee queens that they are not jealous, but allow the young queens to live with them in the nest." In early winter all bumble-bees perish except the young queens, which hibernate in some crack or crevice. There are more than fifty species of bumble-bees (*Bombus*) in the United States. They differ in size and in the arrangement of the black and yellow color-patterns.

The **honey bee** is a native of Europe, but has been domesticated the world over. " It has been known and cared for by men for centuries. There are two genera: (1) *Melipona*, which has the sting blunted and apparently never used as a weapon, lives in the tropics and consists of numerous species which have been little studied. (2) *Apis* has but few species, one of which is our common hive bee.

The community consists normally of one queen, from less than a hundred to several hundred males, and from about 10,000 workers in winter to 50,000 in summer. The queen (Fig. 149, *K*) may be known by her long slender abdomen and by the absence of wax plates, planta, and pollen baskets. The queen is hatched from a fertilized egg in a large cylindric, vertical cell (Fig. 149, 6–10), and fed almost wholly upon bee-jelly regurgitated by the nurse workers. Here, at least, is one strong example of the influence of environment during development, for it has been proved that there is no difference between the egg from which the queen is developed and the one which develops into the worker.

The workers (Fig. 149, *A*), which are the bees we commonly see, are smaller than the queens and males. They are hatched in hexagonal, horizontal

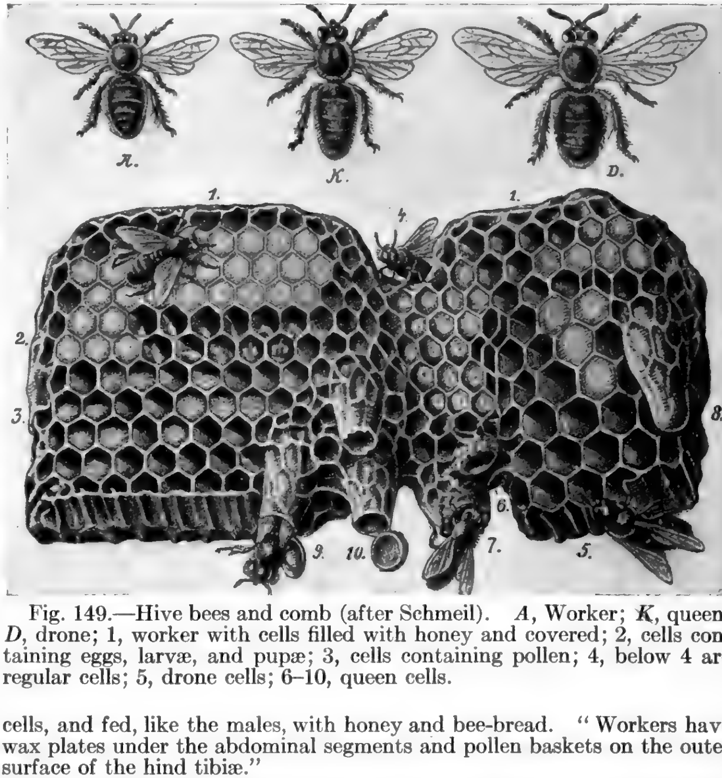



Fig. 149.—Hive bees and comb (after Schmeil). *A*, Worker; *K*, queen; *D*, drone; 1, worker with cells filled with honey and covered; 2, cells containing eggs, larvæ, and pupæ; 3, cells containing pollen; 4, below 4 are regular cells; 5, drone cells; 6–10, queen cells.

cells, and fed, like the males, with honey and bee-bread. " Workers have wax plates under the abdominal segments and pollen baskets on the outer surface of the hind tibiæ."

The males, or drones (Fig. 149, *D*), have a hairy thorax and a heavy, broad, blunt body, and, like the queen, lack the special structures of the workers. They are hatched in the larger, hexagonal, horizontal cells from " unfertilized " eggs. After the swarming season is over, the males are driven out of the hive or stung to death by the workers.

When a community becomes too large, the workers prepare a " queen-cell " and develop a queen by process of special feeding and care, or, it may be, several queens are so developed. When these young queens emerge, the old queens at once enter into battle with them. All new queens are killed but one, which the workers guard. The old queen leaves the hive accompanied by a swarm of workers and founds a new colony. The workers at once begin to secrete wax by gorging themselves with honey and then together "hang quietly in a curtain-like mass, the upper bees clinging to the roof of the hive and the lower ones to the bees above them. After about twenty-four hours there appear little flakes of wax that are forced out from openings between the ventral abdominal segments, called wax-pockets. These wax scales continue to increase in area and soon project beyond the margin, and either fall off or are plucked off by other workers or by the wax-producing worker itself."[1] Other workers construct it into comb, the trowel-like mandibles pressing it into hexagonal cells. Each comb consists of a double layer of cells separated by a common partition. New wax is used in forming cells for storing honey, but old wax or wax mixed with pollen may be used for brood-cells. The workers also carry "*propolis*," a sticky, gummy substance with which they at once stop the chinks of their hive. They carry water also to the thirsty larvæ. By steadily and rapidly vibrating their wings a set of workers stationed at the exit or scattered about the floor form currents of air, thus ventilating the hive. Another set acts as scavengers and carry off all dead and decaying débris from the floor and walls. Still another set guards the entrance from intruders, such as neighboring bees, yellow-jackets, and bee-moths. For guarding against the minute bee-lice and bacterial diseases the help of man, "the bee-keeper," is needed. Kellogg gives an observation hive and how to make it, which would be well worth trying. For after you have studied carefully these, shall I say, intelligent little creatures you will find it, indeed, difficult to decide which of their actions are reflex, instinctive, or intelligent, or which are all of these combined.

**Classification.**—

Class I. *Crusta'cea.*

Sub-class *En'tomos'traca.*

| | | | |
|---|---|---|---|
| Order | I. | Phyllop'oda. | Brine shrimp. Daphnia. |
| Order | II. | Ostrac'oda. | Cypris. |
| Order | III. | Copep'oda. | Cyclops. |
| Order | IV. | Cirripe'dia. | Barnacles. |

Sub-class *Mal'acos'traca.*

| | | | |
|---|---|---|---|
| Order | I. | Phyllocar'ida. | Nebalia. |
| Order | II. | Decap'oda. | Crayfish, lobsters, crabs. |
| Order | III. | Arthros'traca. | Gammarus. Pill-bug. |

Class II. *Arach'nida.*

| | | | |
|---|---|---|---|
| Order | I. | Scorpion'ida. | Scorpions. |
| Order | II. | Phalangi'da. | "Daddy-long-legs." |
| Order | III. | Arane'ida. | Spiders. |
| Order | IV. | Xiphosu'ra. | Limulus or Horshoe Crab. |

[1] Kellogg, p. 526.

| | | | |
|---|---|---|---|
| Class III. *Myriap'oda.* | | | |
| Order | I. | Chilop'oda. | Centipedes. |
| Order | II. | Diplop'oda. | Millipeds. |
| Class IV. *Insec'ta.* | | | |
| Order | I. | Ap'tera, or Thysanu'ra. | "Fish-moth" and "spring tails." |
| Order | II. | Ephemer'ida. | May-flies. |
| Order | III. | Plectop'tera. | Stone-flies. |
| Order | IV. | Odona'ta. | Dragon-flies. |
| Order | V. | Isop'tera. | Termites. |
| Order | VI. | Corroden'ita. | "Book-lice." |
| Order | VII. | Malloph'aga. | "Bird-lice." |
| Order | VIII. | Euplexop'tera. | Earwigs. |
| Order | IX. | Orthop'tera. | Grasshopper, katy-did. |
| Order | X. | Physop'oda. | Thrips. |
| Order | XI. | Hemip'tera. | Chinch-bug, plant lice, and cicada. |
| Order | XII. | Neurop'tera. | Aphis-lion, ant-lion. |
| Order | XIII. | Mecop'tera. | Scorpion-flies. |
| Order | XIV. | Trichop'tera. | Caddice flies. |
| Order | XV. | Lepidop'tera. | Butterflies, moths. |
| Order | XVI. | Coleop'tera. | Beetles. |
| Order | XVII. | Dip'tera. | Flies. |
| Order | XVIII. | Siphonap'tera. | Fleas. |
| Order | XIX. | Hymenop'tera. | Ants, wasps, bees. |

## BRANCH CHORDATA

BRANCH Chordata comprises many of our best-known and valued animals.

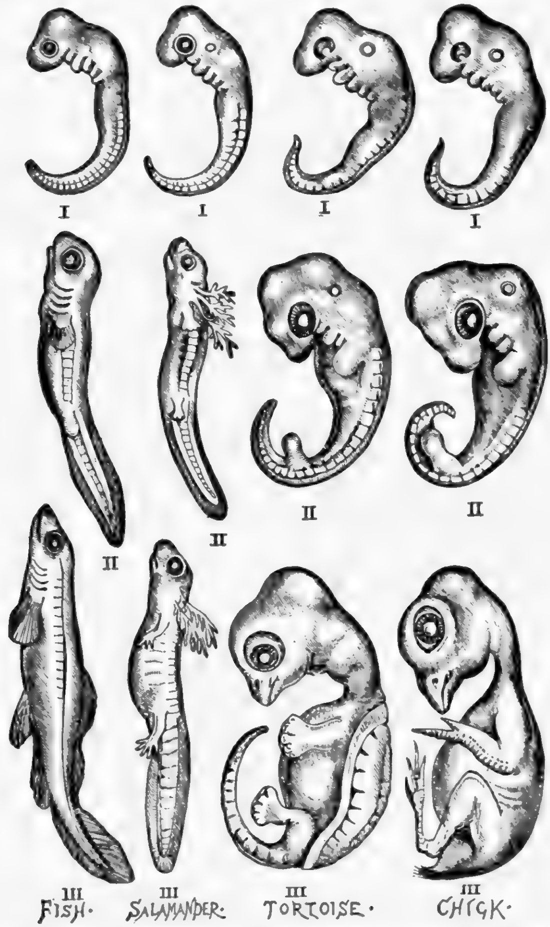



Fig. 150.—A series of embryos at three comparable and progressive stages of development (marked I, II, III), representing each of the classes of vertebrated animals below the Mammalia. (After Häckel.)

**Characteristics.**—They all have (1) Gill-slits in their embry-

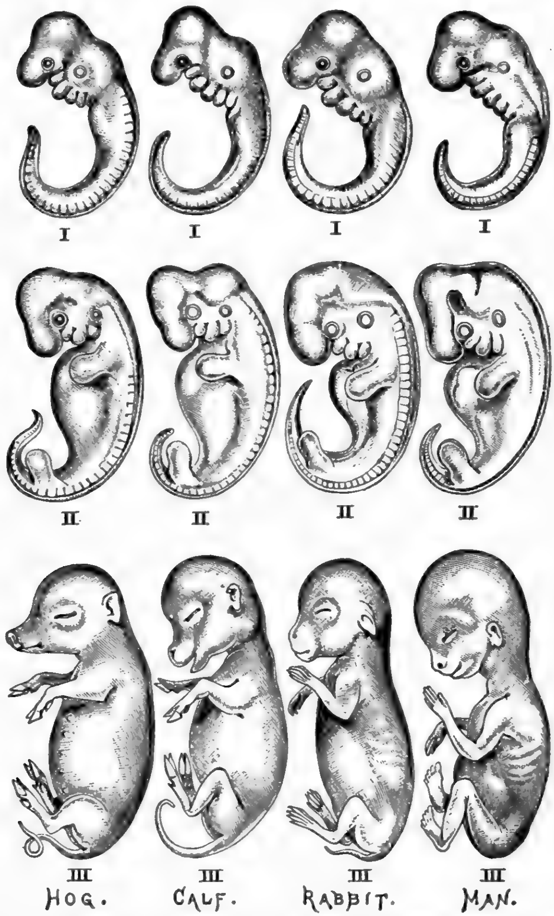



Fig. 151.—A series of embryos at three comparable and progressive stages of development (marked I, II, III), representing four different divisions of the class Mammalia. (After Häckel.)

onic life or they may be permanent; (2) a notochord; (3) a nerve chord or nervous system dorsal to the notochord. The notochord is a smooth, elastic rod typically developed from the endoderm, extending along the median line between the alimentary tube and the central nervous system. It is encased in a tough sheath or membrane and "forms an elastic supporting structure."

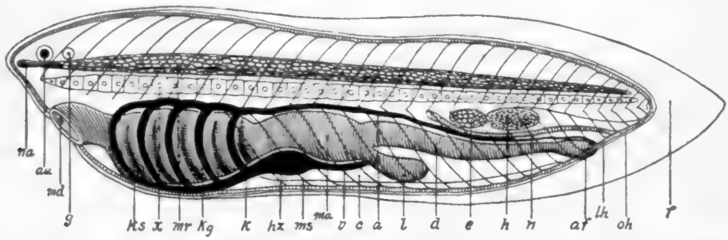



Fig. 152.—Ideal primitive vertebrate, seen from the left side: *na*, Nose; *au*, eye; *md*, mouth; *g*, ear; *ks*, gill openings; *x*, notochord; *mr*, spinal tube; *kg*, gill-vessels; *k*, gill-intestine; *hz*, heart; *ms*, muscles; *ma*, stomach; *v*, intestinal vein; *c*, body cavity; *a*, aorta; *l*, liver; *d*, small intestine; *e*, ovary; *h*, testes; *n*, kidney-canal; *af*, anus; *lh*, true or leather skin; *oh*, outer skin (epidermis); *f*, skin-fold, acting as a fin. (After Häckel.)

In the higher forms the notochord is replaced by a segmented cartilaginous or bony vertebral column.

These three characteristics may not be easily recognized by the beginner as he looks at the worm-like *Bal'anoglos'sus*, the

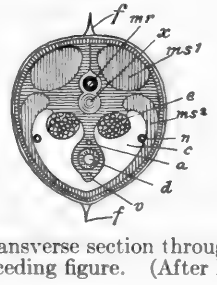



Fig. 153.—The same in transverse section through the ovaries; lettering as in the preceding figure. (After Häckel.)

sac-like sea-squirt, or the small fish-like or worm-like *Am'phiox'us* or *Lance'let*, but, passing by these low forms to the fishes, frogs, reptiles, birds, and mammals, one readily finds that the body has two cavities instead of one, as in the invertebrates.

**Neural Cavity.**—The upper or neural cavity contains the brain and the spinal cord.

**Hemal Cavity.**—Below the vertebral column with its neural cavity is the large cavity of the body, the *hemal cavity*, which contains the heart, lungs, digestive organs, and other viscera.

**Skeleton.**—Most of these higher forms have an internal bony skeleton or a cartilaginous one, as in some fishes. The vertebral column, or backbone, is composed of a varying number of bones, each called a vertebra, hence the branch is named Vertebrata, or, if named from the notochord, Chordata.

Divisions of the branch are usually made to distinguish the primitive groups (Fig. 152) or *Protovertebrates*, from the true *Vertebrates*.

The Protovertebrates consist of three separate groups or sub-phyla, not closely related to each other, but each, in a primitive way, is entitled to relationship with the Chordata or Vertebrata.

## SUB-PHYLUM AND CLASS I. ADELOCHORDA

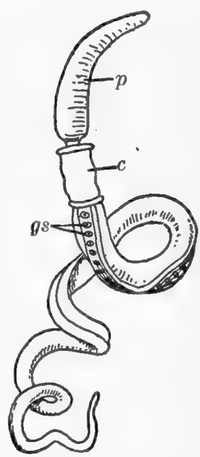



Fig. 154.—*Balanoglossus: p*, Proboscis; *c*, "collar"; *gs*, gill-slits; enlarged. (From Dodge's "General Zoology," American Book Co., Publishers.)

The **Balanoglossus** is the principal genus of this group, though two deep-sea forms (*Rhabdopleu'ra* and *Ceph'alodis'cus*) have a notochord, and the latter has a pair of gill-slits, but in other ways they are like the polyzoans. The Balanoglossus (Fig. 154) is a small marine chordate. Its surface is ciliated. It is from 1 to 4 or 5 inches in length, and, by means of its proboscis, burrows in the mud along the seashore. A study of the animal or of a good figure will show that it has (1) a dorsal nerve cord, (2) a notochord, and (3) gill-slits.

*Body Regions.*—The Balanoglossus is divided into three body regions: the proboscis, a club-shaped hollow anterior portion opening exteriorly by a single pore; back of the proboscis is the collar, opening by two spores into the first gill-slit; the remainder constitutes the flattened but nearly cylindric trunk. There is no segmentation of the body. By alternately contracting and dilating the proboscis and the collar the Balanoglossus can burrow in the mud.

*Gill-slits.*—On the dorsal surface of the anterior portion (the *branchial region*) of the trunk is a double row of gill-slits which increase in number throughout life.

*Digestive System.*—The mouth is situated ventrally at the base of the proboscis just within the collar, and from it the alimentary canal extends to the posterior extremity of the body. "Into the dorsal half of the anterior portion of the alimentary canal open the internal gill openings." The *hepatic cæca* bulge out in external prominences in the middle part of the canal. The anal opening is at the posterior end of the body.

The *notochord*, "a blind tube surrounded by a tough membrane, extends from the pharynx into the proboscis." There are dorsal and ventral nerve strands connected by nerves in the collar.

A *dorsal blood-vessel* lies above the notochord.

The larvæ of some species so much resembles certain echinoderms that the Balanoglossus was formerly placed with that branch.

## SUB-PHYLUM AND CLASS II. UROCHOR'DA OR TUNICATA

This degenerate group is represented by minute animals a few centimeters long and by some measuring several feet in length. They are found singly or in string-like colonies which have been developed from a solitary individual by budding, the two forms thus giving rise to alternation of generations. Multiplication is both sexual and asexual. They are hermaphroditic, but cross-fertilization occurs. They are marine and most of them are pelagic.

The most common forms, the **"sea-squirts"** or **ascidians** (Fig. 155), are surrounded by a tough elastic bag, one end of which is attached to stones. At the other end is a large round *oral* aperture, for the inlet of water carrying food and air, and near it, on one side, is the *atrial* aperture, for the exit of the current. Sea-squirts are destitute of head and limbs. The ventral heart enclosed in a pericardium is situated between the gill region and the stomach. This heart has the peculiarity of changing the direction of its contractions. When the blood has been driven to the gills for a while it rests a little, and then forces the blood in the opposite direction.

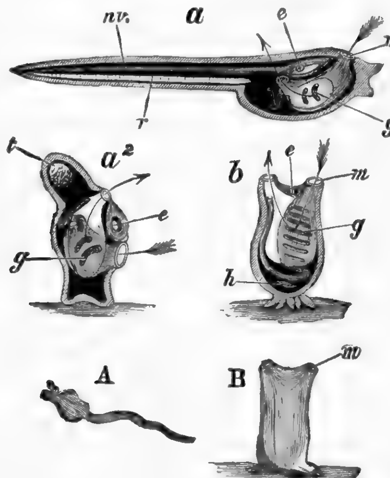
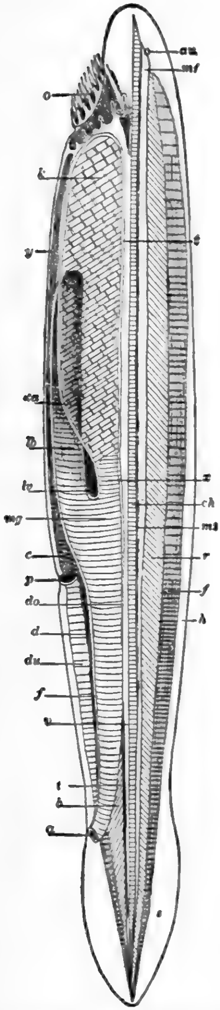



Fig. 155.—Diagram of the growth of a sea-squirt or ascidian: A, *a*, young free-swimming stage; $a^2$, intermediate stage just before becoming fixed. B, *b*, Full-grown sea-squirt, rooted to the sea bottom and incapable of movement: *m*, mouth; *e*, hollow brain with eye; *g*, gill-slits; *h*, heart; *r*, rod of gristle in free-swimming form; *nv*, nerve cord in same; *t*, tail in process of absorption in intermediate form. (After Haddon.) (From Baskett, "The Story of the Fishes," D. Appleton and Co., Publishers.)

The "sea-squirts" were formerly called "Tunicates," until a study of their larval stage showed them to have vertebrate characteristics. The larva has a slender finned tail containing a notochord and a nerve cord. They furnish an example of retrograde development. They are free for a few hours, then become fixed and lose the notochord and nearly all traces of their vertebrate characteristics which promised a higher development.

## SUB-PHYLUM AND CLASS III. ACRA'NIA OR AMPHIOXUS



This is a small fish-like chordate 2 or 3 inches in length.

Its shape is one found for the first time, that of narrow ventral and dorsal surfaces and deep lateral surfaces. It is pointed at both ends. It falls on its side when not in motion.

It is marine and lies buried in the clean sand along warm seacoasts, with its ciliated lips protruding. The currents produced by the cilia bring fresh water with its oxygen to the gills. Small organisms are also thus furnished for food.

The **Am'phiox'us** (Fig. 156) has no limbs, no skull, no well-differentiated brain, and no heart, but it has a *notochord* (a smooth cylindric rod lying above the alimentary tube), a *nerve cord* dorsal to the notochord, numerous *gill-slits*, and an *alimentary tube*. The sexes are separate.

The *alimentary tube* is a straight tube consisting of mouth, pharynx, and intestine. On the right side of the pharynx is a blind pouch, the so-called liver.

The *circulatory system* consists of a dorsal arterial trunk and a ventral venous trunk connected by lateral arches. The blood is colorless.

Fig. 156.—*Amphiox'us lanceola'tus*: *a*, Anus; *au*, eye; *b*, ventral muscles; *c*, body cavity; *ch*, notochord; *d*, intestine; *do* and *du*, dorsal and ventral walls of intestine; *f*, fin-seam; *h*, skin; *k*, gills; *ka*, gill-artery; *lb*, liver; *lv*, liver-vein; $m^1$, brain vesicle; $m^2$, spinal marrow; *mg*, stomach; *o*, mouth; *p*, ventral pore; *r*, dorsal muscle; *s*, tail fin; *t*, *t*, aorta; *v*, intestinal vein; *x*, boundary between gill intestine and stomach intestine; *y*, hypobranchial groove. (After Häckel.)

*Locomotion.*—The Amphioxus has a median dorsal fin which extends over the tail both dorsally and ventrally. The tail, that portion of the body posterior to the alimentary tube and filled with muscle, is the chief organ of locomotion. It is nocturnal, swimming about at night, but quickly returns to its burrow if disturbed. It can burrow in the sand with either head or tail.

*Nervous System.*—A simple dorsal nerve lies above the notochord. It does not reach entirely to the front of the body. Its anterior tip is called the *cerebral vesicle,* in which there is an *eye-spot.* There is also possibly an olfactory organ consisting of a simple pit reaching from the skin down into the anterior tip of the nerve cord.

## SUB-PHYLUM IV. CRANIA'TA OR VERTEBRA'TA

These are chordates having a brain or skull. The group includes fishes, amphibians, reptiles, birds, and mammals. The body is usually elongated and more or less cylindric. The mouth is situated anteriorly. Ventrally and near it, except in *Cyclostom'ata,* are the paired nostrils. Situated in the head there are also a pair of eyes and a pair of ears, though the ears are not always external. Gill-slits are never more than *seven* in number, and partially or altogether disappear in the adult air-breathing forms. There are one or two pairs of jointed limbs, but in some cases they are rudimentary or wanting.

### CLASS I. CY'CLOSTOM'ATA

The animals of this class inhabit both fresh and salt water. They have no lower jaw. The mouth is suctorial, the skull cartilaginous, the notochord persistent, and the teeth horny. The neural arches are rudimentary. There are no limbs or scales and no paired fins; but unpaired dorsal and caudal ones are present. The class includes the lampreys (Fig. 157) or "lamprey-eels" and the hag-fishes. The skin is slimy and very smooth. The gills of the lampreys open into a respiratory tube lying below the gullet.

Fig. 157.—Lamprey (*Petromy'zon mari'nus*). (After Goode.)

They are parasitic on fishes and also devour crustaceans. The slimy eels bore into fishes and eat the flesh.

## CLASS II. PIS'CES

To this class belong the true fishes, common examples of which are the sunfish, perch, salmon, catfish, carp, and trout. They are aquatic, gill-bearing, poikilothermal, usually scaly, bilaterally symmetric finned chordates.

**Shape.**—The typical fish is wedge shaped (Fig. 158) at both ends, so that it can pass rapidly through the water. The head is large and pointed, with the viscera situated near it, while the trunk is long and tapering, for the attachment of muscles to flex the tail in locomotion. Usually the body is more or less flattened from side to side, though it may be quite cylindric, as in the eel, or flattened dorsoventrally, as in the adult flounder, or the body may be long and slender, as in the pipe-fish and ribbon-fish. The shape conforms largely to the habits and habitat. The fishes having the under side flattened usually swim near or rest upon the bottom at some time, as our catfish, but the broad forms, flattened above and below, like the skates and flounders, live upon the bottom and are not built for speed. The "flat fishes" in early life have the position common to most fishes, but in adult life the dorsoventral plane becomes horizontal instead of vertical, the eye lies upon the upper side, and the color of the upper side becomes dark like the dorsal side of most fishes, and the under side light like the ventral side.

**Size and Number.**—Fishes vary in length from an inch or less to 30 or 40 feet. Kellogg says there are about "15,000 species of fishes known, of which 3000 species live in North America." Is it any wonder they vary in size, color, and habits? They are the best adapted of all vertebrates for an aquatic life.

**Covering.**—The epidermis consists of many layers of protoplasmic cells with a very thin cuticle. The secretion of mucus by the great numbers of "slime-cells" of the epidermis gives to fishes their slippery skin. The epidermis contains also pigment cells. The dermis consists of numerous layers of connective

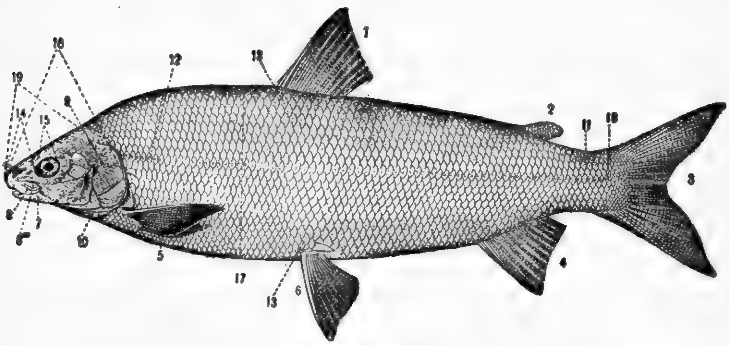


Fig. 158.—Figure of a whitefish, showing the location of parts usually referred to in descriptions: 1, Dorsal fin; 2, adipose fin; 3, caudal fin; 4, anal fin; 5, pectoral fin; 6, ventral fin; 7, lower jaw, or mandible; 8, upper jaw, or maxillary; 8*a*, supplemental maxillary; 9, opercle; 10, branchiostegals; 11, caudal peduncle; 12, lateral line; 13, series of crosswise scales usually counted; 14, snout; 15, eye; 16, head; 17, depth; 18, base of caudal; 19, distance from snout to nape or occiput. (Report U. S. F. C., 1894.)

tissue and furnishes the dermal or exoskeleton or scales which are usually embedded in pockets of the dermis.

In many fishes the scales overlap each other. In the brown trout, for example, the greater portion of each scale lies under the one anterior to it, and the remainder, a small triangular portion, is covered by the epidermis only. The scales sometimes receive a layer of enamel or vitrodentin from the epidermis. (1) The *placoid* scales are rhombic, plate-like bodies often bearing a spine covered with vitrodentin. These scales are placed close together, but do not overlap. (2) The *ganoid* scales also are generally "rhomboid and arranged like parquetry." They are covered with a thick coating of vitrodentin which gives an iridescent effect, and are often closely articulated into a coat of armor. (3) The cycloid scales are closely related. They are placed loosely in the pockets and arranged in rows. In overlapping, one scale covers parts of two scales posterior to it. The middle part of the scale is surrounded by concentric lines from which proceed radiating lines. (4) The ctenoid scales (see Fig. 174) have the posterior edges truncate and the free margin toothed. The scales are often striated or polished, and this gives rise to various colors, especially the iridescent gleam on the sides of the fish.

**Color.**—The color in general harmonizes with its environment. Most of the fresh-water fishes are dark colored (olive or greenish) above and whitish below, so that to the enemies from above, as fish-eating birds, the form appears indistinct in the water, and to the enemies below they look white like the light. Many are variously dotted or striped with lighter or darker colors, thus simulating the lights and shadows among the weeds and grasses. The scales reflect all the hues and tints of the rainbow, causing the fishes to rival the birds in beauty. The males of some species put on brighter colors at the spawning season. Some species have the power of changing color at once to meet the surroundings, as the pipe-fishes, some sticklebacks, the plaice, and the little *Oligocottus snyderi*, of Monterey Bay, California. Many others change the colors more gradually. Recent experiments upon fishes in aquaria have shown that if the light be thrown from below and cut off from above, the upper part grows light colored and the lower part dark colored. This would seem to show that the colors are due to the action of light, but while many fishes in caves are colorless, it is said that those in the black depths of the ocean may be either pearly white or black; so the question is yet unsolved. Many deep-sea forms are phosphorescent.

Some fishes have special protective resemblance, as the leaf-finned sea-horse, the pipe-fish, and some angler-fishes, the posterior fins of which are bedecked with fringes "that exactly mimic seaweed." The mouse-fish, or *Sargassum*, is colored to harmonize with the gulf weed, *Sargassum*, among which plants it lives.

"The color of fishes is of threefold origin. The silvery luster is due to crystals of guanin which occur in the skin. The other colors are due partly to numerous strongly pigmented fat-cells and partly to the chromatophores in the derma, which under the control of the nervous system can alter their forms and extent and thus produce color changes in the fish, thus adapting it to its surroundings. It is of interest to note that destruction of the eyes results in loss of power to change color."[1]

**Locomotion and Appendages.**—The appendages of fishes, except in rare instances, are the unpaired dorsal, anal, and caudal fins, and the paired pectoral and ventral fins. "Fishes are the only vertebrates having median fins supported by fin-rays." The fin-rays supporting all the fins are of dermal origin. The locomotion is mainly produced by the flexing of the body and tail, so as to propel the usually spindle-shaped animal through the water. The fins aid in directing the movements of the fish, as does also the air-bladder, which regulates the specific gravity of the fish.

The **skeleton** is cartilaginous or bony. The notochord of the protovertebrate becomes surrounded by a mesodermic sheath which produces the centra of the vertebræ, consisting of cartilage or bone. From the centra are outgrowths dorsally which give rise to the neural tube, "an inverted tunnel of cartilage" enclosing the cerebrospinal cavity, and ventral (hemal) outgrowths protecting the viscera. Thelvertebræ are usually amphicelous, and the notochord persists in the cavities between the centra. The neural arches extend throughout the spinal column, while the hemal are complete only in the tail. In the trunk the hemal spines are absent and the hemal processes are divided into basal processes and ribs which surround the viscera. There is no sternum.

The **skull** (Fig. 159) encloses the brain which does not fill the cavity. The lower jaw is movable and usually bears teeth. Some fishes have many teeth; others, few or none. They have no other prehensile organs.

The *pectoral* and *ventral fins* are homologous with the paired limbs of the higher vertebrates, but lack many of the bones of the higher forms, as a comparison of the bones of man's arm with those of the pectoral fins will show.

[1] Hertwig's "Manual of Zoölogy," Kingsley, p. 559.

**Digestive System.**—The food is principally animal. Food securing is, of course, by the mouth. The mouths of fishes vary in size, shape, and position, according to the food and feeding habits. The digestive tract is large, near the region of the pharynx, but narrows into a tube in which there is little distinction

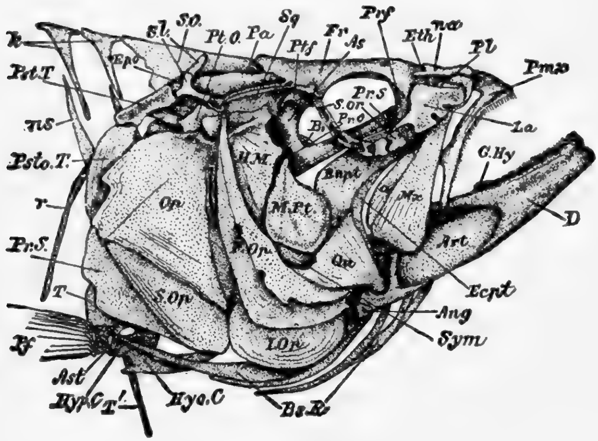



Fig. 159.—Right lateral view of skull of *M. dolomieu*, with other bones; natural size: *Pmx*, premaxillary; *Pl.*, palatine; *na.*, nasal; *Eth.*, ethmoid; *Prf.*, prefrontal; *As.*, alisphenoid; *Fr.*, frontal; *Ptf.*, postfrontal; *Sq.*, squamosal; *Pa.*, parietal; *Pt.o.*, pterotic; *S.O.*, supra-occipital; *s.l.*, supralinear; *Ep.o.*, epiotic; *k*, interneural spines; *La.*, lacrymal; *Pr.s.*, parasphenoid; *S.or.*, suborbital; *Pr.o.*, proötic; *Bs.*, basisphenoid; *G.Hy.*, glossohyal; *D*,. dentary; *Art.*, articular; *Mx.*, maxillary; *a*, admaxillary; *Enpt.*, entopterygoid; *Ecpt.*, ectopterygoid; *M.Pt.*, metapterygoid; *Pst.T.*, posttemporal; *Pr.s.*, proscapula; *Pf.*, pectoral fin; *Hyo.C.*, hypocoracoid; *Op.*, operculum; *S.Op.*, suboperculum; *Ang.*, angular; *Sym.*, symplectic; *n.s.*, neural spine; *Psto.T.*, posterotemporal; *T*, teleotemporal; *T′*, lower teleotemporal; *Bs.R.*, branchiostegal rays; *P.Op*, preoperculum; *I.Op.*, interoperculum; *H.M.*, hyomandibular; *Qu.*, quadrate; *r.*, rib; *Ast.*, actinosts; *Hyp.C.*, hypercoracoid. (Shufeldt.)

between the parts. Many fishes have pyloric ceca at the junction of the stomach and intestine. Others have a spiral valve, a fold of mucous membrane increasing the digestive surface. There is a large liver and a spleen and usually a pancreas and gall-bladder.

**Excretion.**—The nephridea unite in a pair of large kidneys. The ureter may or may not empty into a urinary bladder.

**Circulation** (Fig. 160).—The heart is surrounded by a pericardium. It consists of *sinus venosus*, auricle, ventricle, and *conus arteriosus*. The blood, which is red, goes from the gills over the body. The veins collect it and return it to the *sinus venosus*, from which it passes through the parts of the heart in the order named, and the circulation begins anew.

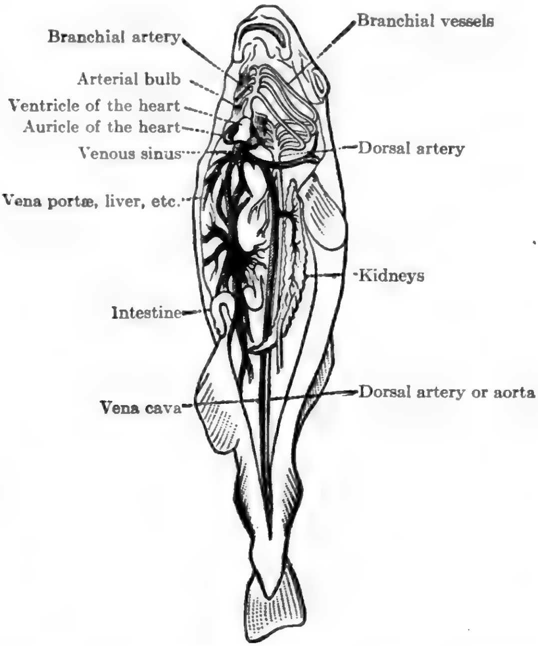



Fig. 160.—The circulatory apparatus of a fish. (Tenney.)

**Respiration** is by gills except in the lung fishes, which take the mechanically dissolved air from the water and give off waste matter. The gills arise as paired pouches of the pharynx and open on the exterior by gill-slits. They are attached to the branchial arches and are persistent through life.

The **brain** is of the vertebral type, but small, and occupies but a small portion of the cranium. The cerebrum is comparatively small. The cerebellum is sometimes large. The optic and olfactory lobes are conspicuous (Fig. 161). The medulla is also present, all the parts being distinct and visible from above. The brain sends off at least ten pairs of nerves.

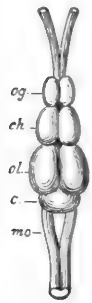



Fig. 161.—Brain of a cod: *og*, Olfactory ganglia; *ch*, cerebral hemispheres; *ol*, optic lobes; *c*, cerebellum; *mo*, medulla oblongata. (Tenney.)

**The Senses.**—Of all the sense organs, the most noticeable are those along the lateral line. The lateral line on either side of the fish from tail to head is "marked by a groove in the scales which opens to the exterior by numerous canals through the scales." (Examine several scales along the lateral line.) The function of the lateral line is possibly to ascertain the water pressure at different depths.

The *skin* and especially the lips are the seat of the sense of touch.

The *eye* has several peculiarities. The lens is very convex, owing to the slight refraction from the light in passing from the water into the cornea. The eye is short sighted, since light is so absorbed by water as to render objects a short distance away invisible. Lids are wanting or very poorly developed. Only

Fig. 162.—*Lucifu'ga.* A blind fish containing unborn young with well-developed eyes. (Eigenmann, Bulletin 526, U. S. F. C., 1902.)

a few fishes have a nictitating membrane. There are no tears. Through disuse for generations the cave fishes have lost their sight (Fig. 162).

The ear[1] has a relative size found in no other vertebrate. There are no external ears. Many *teleosts* have two otoliths. Experiments show that the ear is principally for a balancing organ.

Fig. 163.—Stickleback and nest. (From Baskett, "The Story of the Fishes," D. Appleton and Co., Publishers.)

[1] "The maigre is said to produce a flute-like note audible in twenty fathoms. Many fishes utter sounds, but perhaps the grunt (*Hæmulon*) on the outer Florida reef is most remarkable for the variation of the sound. . . . The dog-fish utters a croak or bark. The gizard-shad (*Hippocampus*), eels, catfish, porcupine-fish, sunfish, carp, gurnards, etc., utter sounds either accidental or intentional. The sound, a single note, frequently uttered by the eel is, according to Abbott, more distinctly musical than those made by other fishes." (Holder.)

The function of the nostrils is smelling and not breathing. For none of them, except those in the hag-fish and lung fish, open into the mouth. The odors must come through the water. All fishes proper have two nostrils. Experimental proof of smell is lacking, but the well-developed olfactory lobes and nerves argue that the sense cannot be entirely wanting.

**Emotions.**—If you have ever tried the sport of fishing with hook and line, you know that fishes have emotions of fear and curiosity. Romanes says they have also those of play, anger, pugnacity, and jealousy. In some species parental affection is proved by the building of nests (Fig. 163) and the care of the young; sexual feelings, by courtship; social or gregarious instincts, by their "schools."[1]

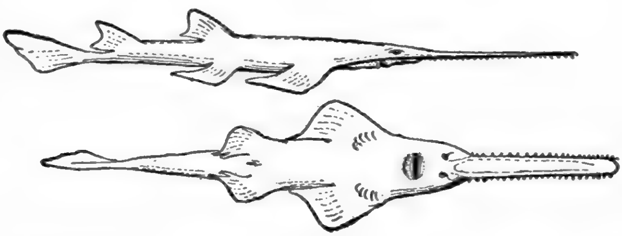


Fig. 164.—Sawfish. Upper, profile view. Lower, view of under part. (*Pristis pectinatus.*)

**Means of Defense.**—Fishes most often protect themselves from their enemies by their close resemblance to the surroundings, or by their swift movements, darting away at the least intimation of danger. But many are also armed with weapons of defense, such as the spines connected with the fins of the dogfish and the catfish. The mucus which flows over the spines is somewhat poisonous, making the wound painful. The "*Scorpanoids*" have a little poison sac on each side near the tip from which the poison flows down a groove of the spine into the wound. The *Thallassophryne* has, besides the dorsal hollow poisonous spines, in which the poison sac is situated at the base, non-poisonous spines on the gill-covers. The porcupine-fish (*Di'odon macula'ta*) and the globe-fish (*Chylomyc'terus geome'tricus*) have spines all over the body. The "surgeons" and rays

[1] Baskett.

have spines on the tail. The thresher-shark (*Alo'pias vulpes*) has its pliable tail prolonged into a terrible weapon, with which, it is said, it can kill a whale. This lashing tail serves a second purpose by so frightening the small fishes that they crowd together and are thus easily obtained for food. The "devil-fish" strikes terrible blows with its broad pectoral fins. The saw-fish

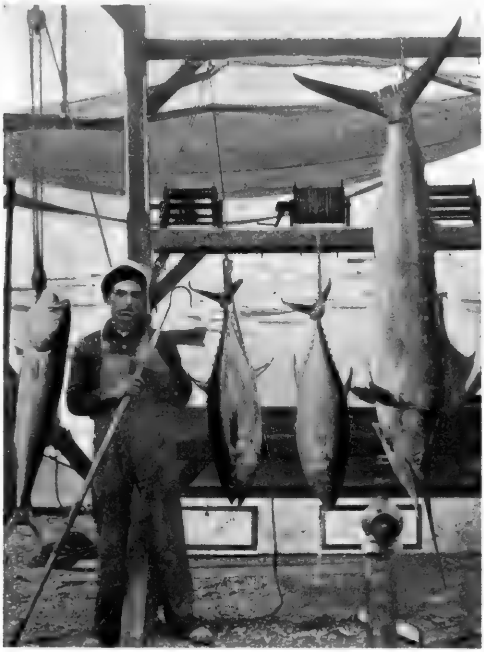


Fig. 165.—Sword-fish (*Tetraptu'rus*), yellow-fin tuna, and yellow tail, caught with rod and reel at Santa Catalina Island. (Bulletin of B. of F., vol. xxviii, 1908.)

(Fig. 164), sword-fish (Fig. 165), and the like use their long strong jaws as frightful weapons. The torpedo and other electrical fishes surprise and stun their victims by an electric shock.

**Influence of Temperature.**—Species differ in their ability to endure cold or heat. The brook trout loves the cool water of the mountain streams, while the catfish can live in exceedingly warm water. "Fishes have been found in hot springs of 120° F." The *Protop'terus* of Africa and Asia "so completely slimes a ball of mud around it that it may live thus for more than one season."[1] Other fishes bury themselves in the mud and *æstivate* through the dry season. The little "mud-skippers" move from pond to pond by the use of their pectoral fins. Other fishes migrate to cooler waters as necessity requires. In winter some of the fishes of our small streams hibernate in the mud, while some, as the carp, may have the water frozen into ice about them and live when thawed out.

**Development.**—The sexes are separate. Multiplication is by eggs, which are numerous. The cod is said to lay one million eggs. In the bony fishes the eggs are naked and numerous, and fertilization usually takes place in the water.

In sharks the eggs are few and are protected by a horny shell. In most sharks and in a few bony fishes the eggs are fertilized and hatched within the body of the mother fish. Mating takes place in a few viviparous forms only. Most fishes do not care for their young "fry," but the stickleback builds a nest and defends it with great courage. There is usually no metamorphosis, but some ocean species change almost as much as frogs.

### SUB-CLASS I. ELASMOBRAN'CHII

The **rays** and **sharks** represent the *Sela'chiī*, in which are found all the living elasmobranchs. They have no *operculum* (gill-cover) and no air-bladder. The skeleton is cartilaginous. The mouth and nostrils are ventral and the tail heterocercal.[2] The scales are small. "The cloaca is the common outlet for the rectum, renal and reproductive ducts." Some are viviparous, others lay a few eggs, each enclosed in a chitinous case.

Sharks vary in length from 2 to 60 feet, the majority being under 8 feet in length. Some are large and voracious, a few dangerous even to man. Hornaday says the only loss of life from sharks on our coast occurred in 1830. They feed mostly upon fishes.

The rays (*Rai'idæ*) have the body disk shaped, broad, and flat,

[1] Baskett. [2] Glossary.

the pectoral fins being much expanded. The skin is roughened by spines or prickles. Rays most generally live on the bottom of the sea, feeding upon fishes, mollusks, crabs, and other bottom-frequenting animals.

To the order *Sela'chii* belong the skates (Fig. 166), sting-rays, and torpedoes or electric-rays. The saw-fish ray also belongs to this order. Its formidable, sharp-toothed snout, several feet in length, makes it a dreaded enemy. It disables its prey by dashing into a school of fishes, striking right and left. Then it eats its disabled prey at leisure.

Fig. 166.—Common skate (*Ra'ia erinacea.*)

### SUB-CLASS II. HOLOCEPH'ALI

This group is represented on our Atlantic coast by the *Chimæ'ra monstro'sa* (Fig. 167). The *Holoceph'ali* were formerly abundant, but are now represented by only a few genera. The skeleton is cartilaginous and the skin is smooth. These are very peculiar looking fishes, as a glance at Fig. 167 will show. The nostrils and mouth are ventral. In general they resemble the sharks in their compressed form, but differ from them by the large head and small mouth. "Fossil remains are found from the lower Jurassic rocks upward."

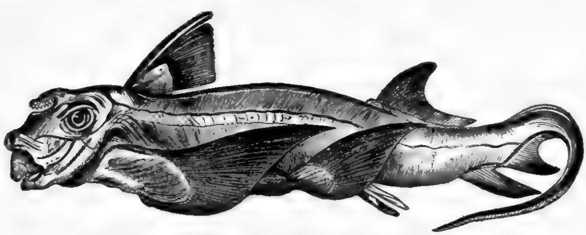


Fig. 167.—*Chimæ'ra monstro'sa.* (Claus.)

### SUB-CLASS III. DIP'NOI

The "lung fishes" are snake-like or eel-like (Fig. 168), and bear small, soft, cycloid scales, small paired fins, and a diphycer-

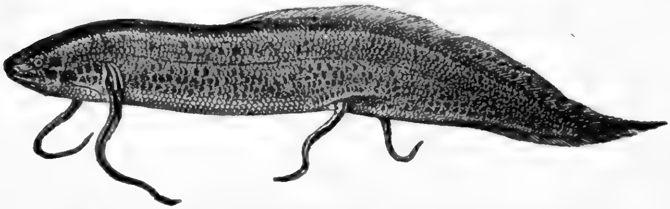


Fig. 168.—Lung fish (*Protop'terus annecteris*). (Boas.)

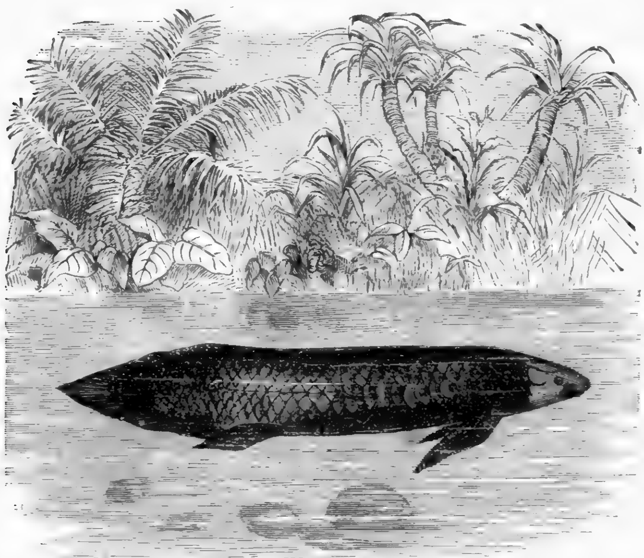


Fig. 169.—The *Cer'atodus* of Queensland, an air-breathing and water-breathing mudfish of the ancient type, with paddle fins. (From Baskett, "The Story of the Fishes," D. Appleton and Co., Publishers.)

cal caudal fin. The skeleton is largely cartilage and the notochord persistent. They live in fresh water, and usually breathe by gills, but when the water gives out or becomes unfit for use the swim-bladder, which may be single or double, is used for lungs. It opens into the ventral side of the gullet and contains air-cells. In this case the air enters through the nose.

They are interesting as showing how land forms may have originated from aquatic forms. There are only three existing genera: the Lepidosi′ren, of the Amazon; the Cer′atodus (Fig. 169), of Australia, and the Protop′terus, of Africa. The Protopterus (see Fig. 168) "can live out of water, it burrows in the mud at the dry season and builds a cocoon lined with mucus in which it remains quiescent until the wet season."[1]

### SUB-CLASS IV. TELEOS′TOMI

To this extensive sub-class belong our bony fishes, including most of the living fishes. It contains thousands of species.

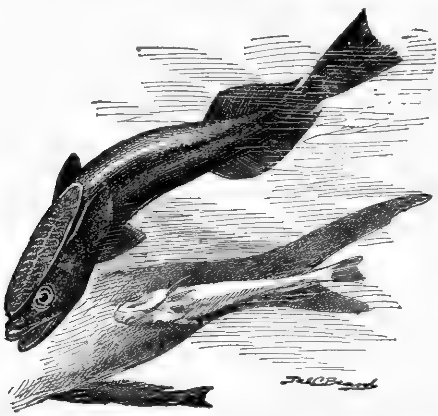


Fig. 170.—Remoras and shark, showing dorsal fins modified into sucking disks, by which the remora attaches itself to the shark in its commensal life, thus securing free transportation. (From Baskett, "The Story of the Fishes," D. Appleton and Co., Publishers.)

Familiar examples are the perch, sunfish, catfish, trout, carp, pike, cod, and salmon. The mouth is terminal. The nostrils are on the upper surface of the snout. The tail is homocercal

[1] Hertwig.

(see Fig. 170, Rem'ora), the scales are either ctenoid or cycloid. These fishes vary in shape. They vary in size from our little darter, $1\frac{1}{2}$ inches in length, to the "horse-mackerel," which may weigh as much as a cow. They differ in habits from the predaceous, swift pikes and pickerels to the peculiar flounder on the bottom of the sea.

The **Remora** (Fig. 170) is a lazy fish. It has a sucker on top of its head, by which it holds fast to sharks or larger fishes, and thus saves itself the effort of locomotion.

**Order I. Crossopteryg'ii.**—There are only two existing genera, *Polyp'terus* and *Calamoichthys*, of Africa.

**Order II. Chondros'tei** (Sturgeons) (Fig. 171).—They have paired fins with no basal lobe, supported by dermal rays. The pelvic fins are abdominal. The vertebral column consists of the notochord with cartilaginous arches. The tail is heterocercal.

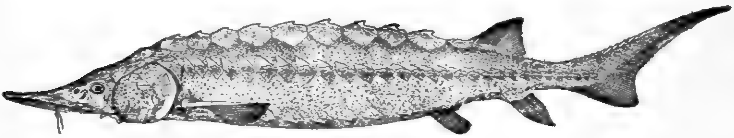


Fig. 171.—Common sturgeon (*Acipen'ser stu'rio*). (Report U. S. F. C., 1899.)

The mouth is ventral, projectile, and toothless, and sucks up worms and larvæ from the muddy bottom. The surface is roughened by separate scales and by five rows of bony plates.

Sturgeons are found in streams and lakes of the Northern Hemisphere and are the largest fresh-water fishes. Those of the lower Columbia River sometimes weigh from 800 to a 1000 pounds.

From the swim-bladder of the sturgeon, glue, cement, court-plaster, and isinglass are made. The egg-masses, called roe, furnish caviare.

**Order III. Holos'tei.**—Familiar examples of this order are the gar-pike and the mud-fish, often called dog-fish, of the streams of the central states.

The skull is ossified. The scales are ganoid or cycloid; the tail, diphycercal or homocercal. The pelvic fins are abdominal.

The spiral valve is present. The double air-bladder aids in breathing.

The **gar-pike** (Fig. 172) has a cylindric body covered by rhomboid, bony scales, which are coated with enamel. The snout is long and bony and armed with sharp teeth. This fish is voracious. There are three species found in the fresh water of North and Central America, including Cuba. They are from 5 to 10 feet in length.

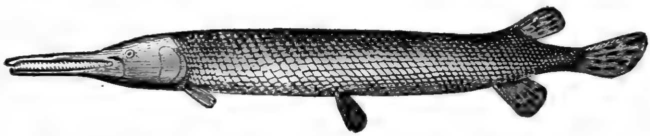


Fig. 172.—Gar-pike (*Lepidos'teus os'seus*). (After Tenney.)

The **mud-fish** or **bow-fin** is abundant in the shallow waters of the Mississippi Valley. It has a somewhat bony skeleton and a soft flesh, which is not generally used as food.

Both the gar-pike and the bow-fin come to the surface to emit gases and to take in a fresh supply of air. They can live some time out of water, when they use the air-bladder as a sort of lung.

Fig. 173.—Cycloid scale.

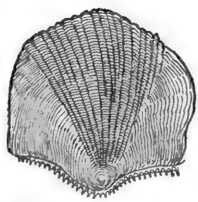


Fig. 174.—Ctenoid scale.

The three foregoing orders are often spoken of as Ganoids. Though now insignificant, they were abundant in the Paleozoic and Mesozoic Epochs.

**Order IV. Teleos'tei.**—The skeleton is well ossified. The tail is usually homocercal. There is no spiral valve save in one genus. The scales are cycloid or ctenoid (Figs. 173, 174), or, in rare instances, the body is naked. The operculum is always present. The swim-bladder is usually present, but its duct is often closed. Eyes are usually conspicuous and without lids.

Reproduction is by eggs. They are small and numerous, and are fertilized in the water by the *milt* deposited by the male at the same time. This accounts for the enormous schools of some fishes in certain places at the breeding season each year. They sometimes go thousands of miles to reach these spawning places. The salmon come from the salt water up into the rivers to deposit their eggs, which are about the size of peas, in depressions or nests. When very small the young salmon are banded and called *parr*, and later become silvery *smolt*. The perches form nests or hollows in the ground near the shore. In a form allied to the perch both male and female form these depressions and guard the eggs. The male *Chromis* of Lake Tiberias carries the eggs and young in its mouth. The stickleback (see Fig. 163), a small fresh-water fish, builds a nest and the male cares for the young. The male *Loph'obranch* carries the eggs in a ventral pouch, forcing the young out by pressing the pouch against a stone. An Indian ocean form carries the eggs in a pouch formed by the ventral fins of the mother.

**Sub-order Physos'tomi** includes the catfishes, buffalo, carp, salmon, trout, herring, eels, etc.

The **catfishes** (*Silu'ridæ*) are devoid of scales. The majority live in fresh water. The head is flat and the wide mouth is provided with long thread-like feelers or barbels. They have, for a weapon of defense, a strong stiff spine for the first ray of dorsal and pectoral fins. They are sluggish and abound in the muddy streams of the Mississippi Valley. The flesh is quite free from bones and is much used for food. Some catfishes weigh 150 pounds.

The common catfish guards its young. The South American catfish carries its eggs and young in its mouth. Other South American species build nests of leaves in which they place their young. An electric catfish inhabits the Nile, and blind catfishes live in subterranean streams of Pennsylvania.

**Carps, buffalo fishes,** and **suckers** have a naked head and usually scaly body. The flesh is bony and not of much food value, yet quite largely used because inexpensive on account of the immense number seined. They have a toothless sucking mouth and are vegetable feeders, hence the intestine is long. The air-bladder consists of two or three links. . . . The shiners, minnows, and dace (Fig. 175) belong to this group. The black-nosed dace (*Rhĭnich'thys atronasus*) is a nest builder. Both male and female form a depression in which the eggs are deposited. Both parents then cover them by a heap of stones placed layer upon layer to a height of about 10 inches.

The **salmon** (*Salmon'idæ*) are found in Europe and North America. They live in salt water, but often go thousands of miles to their fresh-water

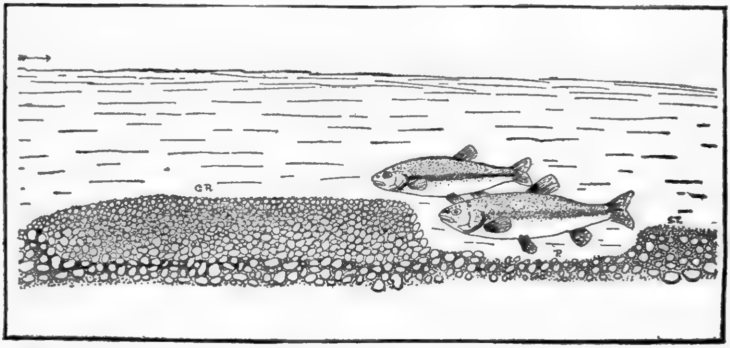


Fig. 175.—Showing longitudinal section of the nest of a dace with the male and female fish in the nest. The stream flows in the direction indicated by the arrow at the upper left-hand corner of the figure. (Bull. Bureau of Fisheries, 1908.)

breeding places. The white fish and the various species of fresh-water trout belong to this group and are delicious food fishes. The red-spotted brook trout is most widely known, and is found from Maine to Dakota. On account of its great cunning the trout is much sought by sportsmen, and is fast becoming exterminated in its natural haunts.

Fig. 176.—Eel (*Anguil'la chrysypa*). (Bull. U. S. F. C., 1895.)

**Eels** (*Anguil'lidæ*) have the body greatly elongated, having many vertebræ, and being almost cylindric (Fig. 176). They have no ventral fins and the "pharyngeal and opercular bones are more or less deficient." The scales are minute or entirely wanting and the skin is very slimy. They are mostly tropical and marine. The true eels, genus *Anguilla*, which crawl " in the mud and ooze of brackish and fresh waters of most regions, are absent on the Pacific Coast of America."[1] They are very voracious and are especially fond of shrimp and crayfish, which they find by overturning stones. They will also devour dead fish. They sometimes go considerable distances in the damp vegetation on land, thus avoiding waterfalls and other obstructions. The females are larger and lighter colored than the males and have smaller eyes and higher fins. In the spring the eggs are deposited in the sea. It is said the young ascend rivers and after two or three years return to the sea to spawn. A Brazilian eel (*Gymno'tus*) is electric, having two pairs of batteries in the ventral portion of its long tail. " A metamorphosis is known only in the eel-like fishes, the larvæ of which are flat, transparent forms, with colorless blood, enormous tails, and very small trunks. The larvæ normally occur in the sea at a depth of several hundred fathoms."[2]

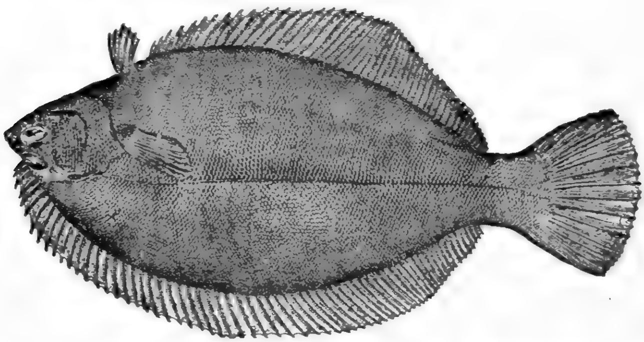


Fig. 177.—Winter flounder (*Pseu'dopleuronec'tes america'nus*). (After Goode.)

The **blind fishes** (*Amblyop'sidæ*) of Mammoth Cave are colorless and translucent. They have rudimentary eyes, but have lost their sight through disuse for many generations. They have no lateral line. Their knowledge of danger comes through the hearing, which is very acute. The head is very flat and the mouth is directed upward, as food is scarce near the bottom. They come to the surface to feed, but at the slightest noise dart beneath stones at the bottom.

**Sub-order Anacan'thini** includes the cod, haddock, whiting, as well as the flat fishes—soles, turbots, flounders, halibuts, etc. There are nearly a hundred species of **codfish.** Some reach a length of 4 or 5 feet and weigh 100 pounds. The female lays nine or ten millions of eggs in a single season. They rise to the surface of the sea and hatch in about twenty days. There is one fresh-water codfish.

The **haddock** resembles the cod in appearance and habits.

[1] Jordan.
[2] Kingsley's translation of Hertwig's "Zoölogy."

Many kinds of **flounders** lie upon the left side upon the sea bottom. The young flounder is somewhat cylindric, has an eye on each side, and swims vertically like other fishes. The eye moves over by successive stages until both eyes are upon the upper or right side (Fig. 177). The mouth also becomes crooked and the under side of the fish becomes white. The upper side is colored and its color may be changed to suit the surroundings. "The blind flounder does not adapt its color to its surroundings."

The **halibut** sometimes attains a weight of 400 pounds and a length of 6 feet. It is found on both sides of the Atlantic Ocean.

**Sub-order Acanthop'teri.**—The spiny-rayed fishes constitute a large group, including the greater number of the marine fishes and many fresh-water species. The stickleback, perch, mullet, mackerel, our river bass and sea bass, and our common sunfish belong here.

The **perch** is a carnivorous fish found both in fresh water and along the seacoast and is widely distributed. These fishes spawn in winter, forming nests in the gravel near the shore.

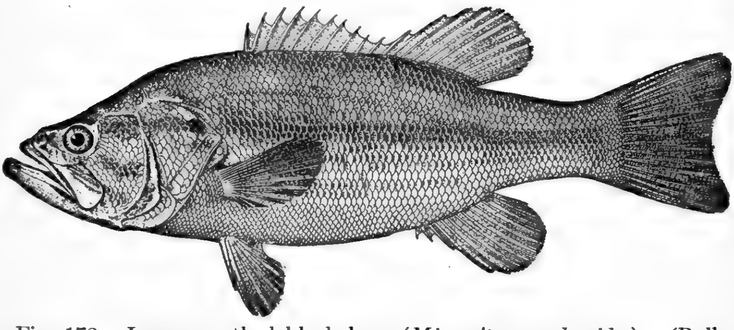


Fig. 178.—Large-mouthed black bass (*Microp'terus salmoides*). (Bull. U. S. F. C., 1900.)

The **bass** and **sunfish** are common in our streams. The black bass is found in clear running water from the St. Lawrence to Dakota and south to Arkansas (Figs. 178, 179). Its length is 1 to 2 feet and it weighs from 2 to 7 pounds. It varies in color, the adult being olive green. It is a great game fish. The sunfishes have short compressed bodies. They are carnivorous, gamy, and usually brightly colored.

The green sunfish (*Lepo'mis cyanell'us*), common in streams east of the Mississippi, makes a nest of gravel in the shallow water and deposits several thousand eggs, which the male guards.

The seventy species of **mackerel** (*Scom'bridæ*) are all marine. In early summer great schools appear on the shores from Greenland south to Cape Hatteras. The young from one female number from 500,000 to 600,000.

As they go north after spawning vast numbers are caught, whole fleets being engaged in catching them. The mackerel is phosphorescent and the light from these enormous schools is so great that they can be seined at night. They are sold either fresh or salted. One of the largest and swiftest of the mackerel tribe is the **sword-fish,** in which the upper jaw is developed into a long, bony, sword-like projection (see p. 205). This forms a strong weapon, as the fish dashes into schools of fishes, cutting and slashing and devouring them. It has been known to pierce the wooden and copper bottoms of vessels. It does not breed in North America. The young are not like the adult.

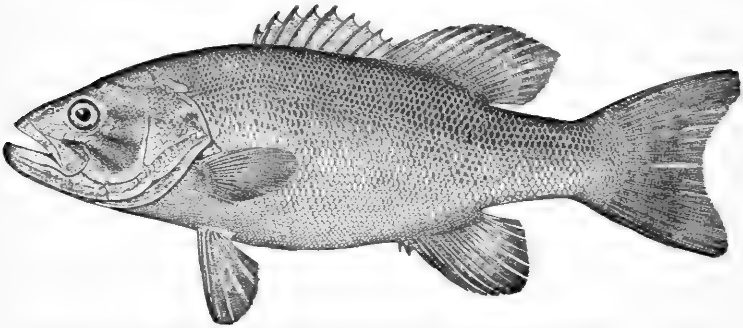


Fig. 179.—Small-mouthed black bass (*Microp'terus dolomieu*). (Bull. U. S. F. C., 1900.)

The **sticklebacks** are found in both North America and Europe. They derive their name from their formidable dorsal spines. They are small marine or fresh-water fishes.

**Sub-order Pharyngog'nathi** includes the Wrasses and "flying-fishes." The pectoral fins of flying-fishes (Fig. 180) are large, and serve as parachutes when the fishes leap from the water.

**Sub-order Plectog'nathi.**—To this group belong the file-fishes, which are often protected by plates or spines, and in shape are very deep and thin. They are common from Cape Cod to Cuba.

Here also belong the *trunk-fishes*, which are enclosed in a "box" made up of bony plates or scales, the tail, mouth, and fins being movable.

The *porcupine fishes* are covered with sharp spines. The *Gymnodon'ta* or "swell-fishes" can inflate their bodies into spheric sacs. Their flesh is poisonous.

**Sub-order Lophobran'chii.**—These fishes are covered with rings of large plates. They have club-shaped tufted gills, no pelvic fins, and a rudimentary tail fin. The mouth is at the end of a long muzzle.

The *pipe-fish* resembles the seaweed and has the power of changing color to suit its environment. It feeds upon small crustacea and mollusca. It is found on both European and American shores.

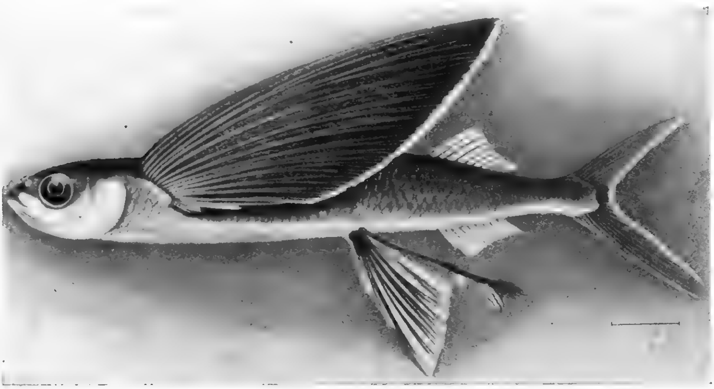


Fig. 180.—*Exonautes gilberti.* Type. (Bulletin 546, U. S. Fish Commission.)

The *sea-horse* (Fig. 181) has the muzzle at nearly a right angle with the rest of the trunk, giving it a fanciful resemblance to the head of a horse. It swims slowly by means of its dorsal fins. It wraps its slender curling tail about seaweeds and roots, and thus avoids being transported, unless perchance the seaweed is floating, when the fish is carried far away from its birthplace. It resembles the seaweeds among which it lives—an Australian species having reddish streaming filaments resembling plants.

**Economic Importance.**—Fishes have been of great value since primitive times, but the various methods of preserving them by drying and canning has greatly added to their importance, for they can now be shipped to any part of the world. Probably salmon, cod, and herring are of the greatest value. The lake and river trout, the white fish, catfish, the black, white, and rock bass, and the perches are important fresh-water fishes, though there are scores of others. The value of the annual output of our streams and coasts is at least $50,000,000.

Each nation reserves all fishing rights within three miles of its coasts. Outside of this the sea fishes are open to the world. The largest sea fisheries are those of the Atlantic coast of the United States, Canada, and Newfoundland, and next in importance are those of northern Europe. Thousands of fishermen from the United States, Canada, and France are engaged in the cod-fishing on the foggy banks of Newfoundland, whose shallow waters furnish an abundance of food for the cod, and make these the greatest cod-fisheries in the world. The fisheries along our New England coast supply most of the fresh cod-fish for our home use. Gloucester is the largest fishing port of the United States and supplies a large part of the salted cod-fish for our use. "The Columbia and other rivers of our northwest coast, including Alaska, furnish our largest salmon fisheries. The salmon canning industry of Alaska is said to be the largest of the world."

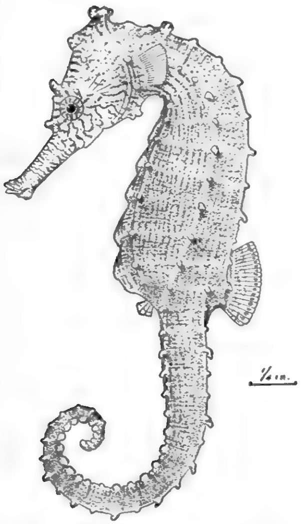


Fig. 181.—Sea-horse (*Hippocam'pus barbouri*). (Bull. U. S. F. C., 1907.)

The demand for this wholesome food product, together with recklessness, has caused the destruction of certain species in many waters. To prevent their extermination the United States Government has a Bureau of Fisheries which has established fish-hatcheries in almost all the states. In these the spawn are cared for until they hatch, and when old enough the young fishes are shipped to various localities for stocking ponds and streams; or, the eggs themselves may be distributed. The food supply of these fishes is also protected or introduced, and their enemies, diseases, and life histories are studied. The annual distribution of eggs and young fishes numbers more than a billion and a half. Efforts are made to rid the streams of voracious fishes, such as the pike, pickerel, and muscalonge, which feed upon our food fishes.

Besides being used for food, fishes furnish other useful products. The skin of the "dog-fish" (shark) is used as leather, and shagreen. The bodies are used as guano or fertilizer. Oil is obtained from the menhaden, cod, and other forms. Caviare is a preparation of the salted roe of sturgeons, the preparation of which constitutes an important industry on the Black and Caspian Seas. Scales of some species are used in ornamental work, and the teeth of sharks are used as weapons by Pacific Islanders. The swim-bladders of cod-fishes are used in making isinglass. They are also pickled and eaten under the name of "sounds."

**Geologic Distribution.**—Teeth of the true fishes have been found in the Ordovician of Europe. The remains of sharks prove their existence in the Silurian. Fishes are found in great variety and abundance in the Devonian Period, the sharks, lung-fishes, Crossopterygii and the Ganoids, the most advanced, are represented. The bony fishes (Teleosts) are entirely absent in the Devonian. These, according to Scott, are approximated by some of the Jurassic fishes. In the Cretaceous Period, Ganoids become rare and Teleosts take the dominant place among fishes. Marine and fresh-water fishes assume the modern forms in the Eocene Epoch.

**Important Biologic Facts.**—The skull is a continuation of the vertebral column, and contains, but is not filled, by a genuine brain. The vertebræ are amphicœlous, that is, concave at each end. The true fishes have true jaws.

They have a closed, though an incomplete circulation. The blood-corpuscles are red.

The multiplication is sexual, but the eggs, or roe, are fertilized in the water.

The skin of vertebrates is distinguished from that of invertebrates by the many layered condition of the epidermis and the thickness of the dermis. The scales of fishes are of dermal origin and different from the epidermal scales of reptiles. It is from the dermal scales that the bony plates of turtles and armadillos have arisen, as well as the secondary or membrane bones.

The strange development or change of the flounder from a symmetric to a "flat" fish demonstrates the principle that special habits of life result in special modifications of structure which fit the animal for those habits.

The lung-fishes (Dipnoi) show many advancements toward the air-breathing conditions, such as the swim-bladder used as a lung and the partly separated auricle, and the flipper with a central axis rather than a fin, so that zoölogists are led to believe that they may represent the division of fishes from which the amphibians sprang.

**Classification.**—

Sub-phylum Vertebrata or Craniata.

| | |
|---|---|
| Class I. Cyclostōm′ata. | Lamprey, hag-fishes. |
| Order I. Petromyzon′tes. | Lamprey. |
| Order II. Myxinoi′dei. | Hag-fishes. |
| Class II. Pis′ces. | |
| Sub-class I. Elasmobran′chii. | |
| Order I. Cladosela′chea. | Extinct shark-like forms. Cladoselache. |
| Order II. Pleuracan′thea. | Extinct Pleuracanths. |
| Order III. Sela′chii. | Extinct forms and all the living Elasmobranchs, as sharks and rays. |
| Sub-class II. Holoceph′ali. | Three genera of *Chimæridæ.* |
| Sub-class III. Dip′noi. | |
| Order I. Monopneu′mona. | *Ceratodus.* |
| Order II. Dipneu′mona. | *Protopterus* and *Lepidosiren.* |
| Sub-class IV. Tēleos′tomi. | |
| Order I. Crossopteryg′ii. | |
| Order II. Chondros′tei. | |
| Order III. Holos′tei. | |
| Order IV. Teleos′tei. | |

## CLASS III. AMPHIBIA

To this class belong the toads, frogs, salamanders, and newts. The skin is smooth, as in the frog, or warty, as in the toad, with a glandular secretion. It is often highly colored owing to the pigment cells in the deep layers. In the common "tree-toad," as well as in some of the terrestrial frogs, the color may be changed to harmonize with the environment. No amphibians are marine. Most of them are aquatic or semi-aquatic. In the adult stage some are terrestrial, some arboreal. They are usually carnivorous in the adult stage, but the larvæ may be herbivorous. They hibernate in the mud at

Fig. 182.—Bullfrog. (Skeleton cleaned and mounted by students.)

Fig. 183.—*Necturus*. (Skeleton cleaned and mounted by students.)

the bottom of a stream and may live a long time without food. They make fine specimens for study in a tank or tub, since many of them will endure captivity a good while.

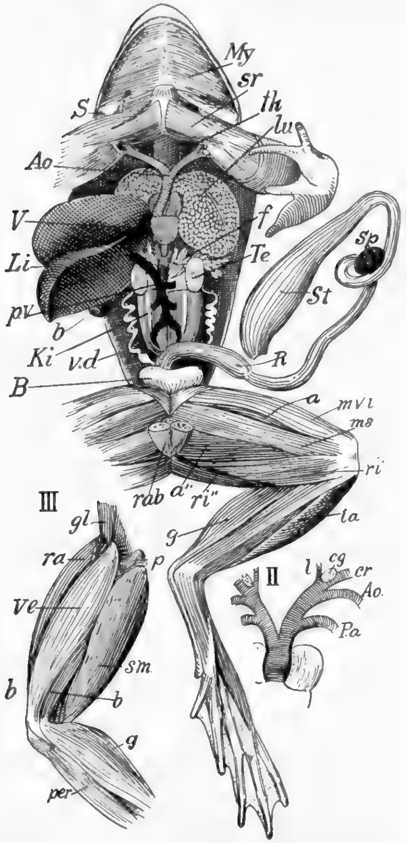



Fig. 184.—Anatomy of common frog: *My*, mylohyoid; *sr*, sternoradials; *th*, thyroid; *lu*, lungs; *f*, fat-body; *Te*, testis; *St*, stomach; *Sp*, spleen; *R*, rectum; *a*, adductor longus; *mvi*, vastus internus; *ms*, sartorius; *ri'*, rectus internus major; *ta*, tibialis anticus; *g*, gastrocnemius; *ri''*, rectus internus minor; *a''*, adductor magnus; *rab*, rectus abdominalis; *B*, bladder; *vd*, vas deferens; *b*, gall-bladder; *Ki*, kidney; *pv*, portal vein; *Li*, liver; *V*, vena cava inferior; *Ao*, aorta; *S*, vocal sac or croaking-bag. II. Origin of the arterial trunks: *l*, Arteria ingualis; *cg*, carotid gland, which is merely a *rete mirabile; cr*, carotid artery; *Ao*, aortic arch; *Pa*, pulmonary artery. III. Dorsal view of muscles of hind leg: *gl*, Gluteus; *ra*, rectus anterior; *p*, pyriformis; *ve*, vastus externus; *sm*, semimembranosus; *b*, *b*, biceps; *g*, gastrocnemius; *per*, peroneus. (From drawing by C. S. Minot.) (From Packard's "Zoölogy," Henry Holt & Co., Publishers.)

**The Skeleton.**—There are two occipital condyles. The vertebræ of the lower forms are like those of fishes, biconcave; those of higher Amphibia are usually concavoconvex. A sternum first appears in this class, as well as a typical vertebrate limb-skeleton. The pelvic girdle is united with the spinal column. There may be four, two, or no limbs, that take the place of fins. They have digits which are generally without claws.[1] The tail is temporary in frogs and toads and permanent in other amphibians. Teeth are present in most amphibians, but lacking in the toad. They are small, sharp, and point backward.

**Respiration.**—Amphibians breathe by gills in the larval or tadpole stage, and in the adult forms by persistent gills or by persistent gills and lungs, as in *Necturus*, or by lungs, as in the salamander. The skin is also an important organ for taking in oxygen and giving off impurities. The frog breathes with the mouth shut, by lowering the tongue and taking in air through the nostrils, then raising the tongue, closing the nostrils, and forcing the air into the lungs.

**Circulation** (Fig. 184).—Amphibians are poikilothermal. The heart has one ventricle and two auricles. The arteries carry the blood to all parts of the body. The veins from the lungs return the pure blood to the left auricle, and those from the body return the impure blood to the right auricle. The auricles contract and force both pure and impure blood into the ventricle, which forces it out in such a manner that the venous blood goes to the body and the pure blood to the head.[2]

**The Nervous System** (Fig. 185).—The brain of a frog has advanced above that of the fish in the development of the cerebrum, but the cerebellum, which is very small, being, in fact, but a thin lamella, is inferior to that of the fish.

The **skin** on the whole surface of the body is provided with tactile nerve-endings. Special taste organs are located on the tongue and mouth. In adult amphibians the nostrils open into the mouth, and Baskett says, "there is much in the arrangement of the mucous membrane of the frog's nose which implies that it smells." The strong odors of some of their ex-

[1] See "Amphibia and Reptiles," Gadow, p. 146.
[2] Linville and Kelly's "General Zoölogy," p. 330.

cretions would also imply a sense of smell, but these may be wholly for defense. The nostrils[1] of toads and frogs can be closed by special muscles.

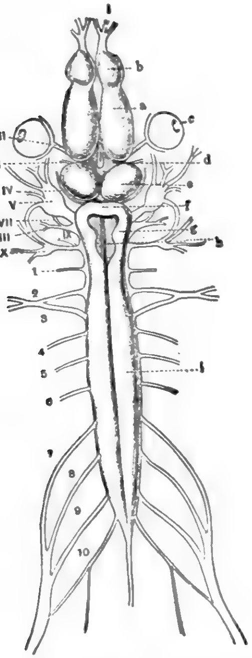


Fig. 185.—Brain and spinal cord of frog (x about 2): a, Cerebral hemisphere; b, olfactory lobe; c, eye; d, thalamencephalon; e, optic lobes; f, cerebellum; g, medulla oblongata; h, fourth ventricle; i, spinal cord; I, Olfactory nerves; II, optic nerve; III, oculomotor nerve; IV, patheticus; V, fifth nerve; VII, facial nerve; VIII, auditory nerve; IX, glossopharyngeal nerve; X, vagus nerve; 1–10, first to tenth spinal nerves; 2 and 3 unite to form the brachial, and 7, 8, and 9, to form the sciatic plexus. (Shipley and McBride.)

The lateral line of the tadpole disappears in the adult. It seems that whatever senses may be located in the lateral line, they are ineffectual outside of water.

In most amphibians there is an **internal ear** which opens by one or two openings into the mouth, back of the openings from the nostrils. None of them have any outside opening to the ear, but most of the higher forms (*Anura*) have a drum-cavity and a tympanic membrane over it, lying at the surface. A single bone, the *columella*, lies across the middle ear and has one end against the tympanum. There is no *cochlea*, or at least a very rudimentary one; hence it does not seem possible that the frog can detect differences in pitch. Perhaps this accounts for his monotonous song. Yerkes found that frogs "straightened up and raised the head as if listening when other frogs croaked or splashed into the water," but found it impossible to make them respond in any way to any noise he himself made so long as he remained invisible.[2] He thinks they depend on sight for the

[1] "There seems to be no experimental proof of specific taste or smell among amphibians or reptiles."—Washburn.

[2] Linville and Kelly.

knowledge of danger. Romanes records an instance of a pet frog which would come when his name, "Tommy," was called, no matter at what time of day, though fed only at morning, and another instance of a toad kept as a pet for thirty-six years, which knew all of his friends. In either case, the knowledge might have been gained, at least in part, by sight.

The **eye** has no lids in the lower forms, and is degenerate in the *Pro'teus*, which lives in caves (see Fig. 189), and in some *Gymnophi'ona*. Most of the *Anura* have an upper lid, but no lower one. There are no tears. The "flying tree-toad" has large owl-like eyes (see Fig. 195), so that it can see as far as it leaps. Frogs are able to project the eyes upward to give greater range of vision. When the mouth is inflated the eyes are pushed forward, since there is no partition between the eyes and mouth. It is well known by boys that frogs recognize bright colors, and it has been proved by experiment that they can distinguish red from white.

**Development.**—The eggs of Anura, which consist of the yolk enclosed in a mass of jelly-like matter, are not surrounded by a shell. They are usualy deposited in masses (frogs) or in strings (toads), and then left to hatch by the heat of the sun. The little tadpole has a small sucking mouth and a slender active tail. The branched gills soon grow out on the sides of the neck, but are later replaced by internal gills, when the water passes in through an opening on each side of the neck. The tail is gradually absorbed, the legs develop, the holes on the sides of the neck close, and the limbs develop underneath the skin, the hind legs coming out first in the frog forms, but in all others it is the fore limb that first shows.[1] Meanwhile "the tadpole ceases to feed, the whole intestinal canal is voided of its contents, and, by histolysis, is entirely rebuilt, becoming wider and shrinking to about one-sixth of its original length, undoing thereby the spiral, preparatory for the coarser food, which consists of insects, worms,"[2] and any live animals it can capture.

**Care of the Young.**—Usually the parents take no care of the young, but there are some interesting exceptions. The little South American frog (*Rhinoder'ma dar'wini*) carries the eggs in

[1] Baskett, "Story of the Amphibians and Reptiles," p. 34.
[2] Gadow, p. 61.

the immense vocal sacs of the male until they are hatched. A tree frog (*Hylo'des linia'tus*) of Dutch Guiana carries its young, which cling by sucking disks, upon its back. The "Surinam toad" (Fig. 186) places the eggs upon the back of the female, where the skin is soft and spongy, during the breeding season. Each egg sinks down and is covered by a jelly-like film. They remain embedded here until the tadpole stage is passed. The pouched frog (*Nototre'ma marsupia'tum*) has the eggs stored in a pouch on the back, where they hatch and the larvæ develop. The male of the European species (*A'lytes obstet'ricans*) winds the

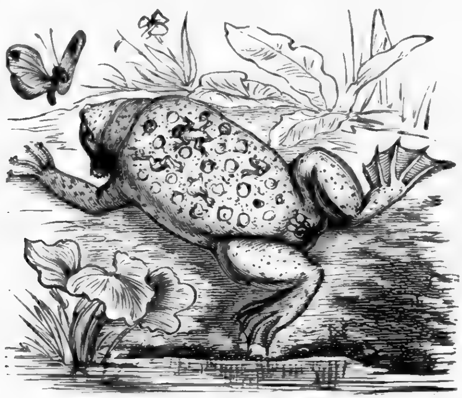


Fig. 186.—Surinam toad, showing young escaping. (From Holder's "Elements of Zoölogy," American Book Co., Publishers.)

string of eggs about the thighs and body. A Japanese frog makes a nest on the ground. One in Brazil makes circular nests in shallow water, smoothing and shaping rings of mud and laying the eggs in these cup-like depressions. Many amphibians are viviparous.[1]

**Defense.**—Almost all amphibians are more or less poisonous, says Gadow. It has been proved that if a quantity proportionate to the size of the animal be injected, that the poison secreted by toads, salamanders, and newts will kill mammals, birds, reptiles, and fishes. The poison acts upon the heart and central

[1] Baskett, see "Viviparous Amphibians."

nervous system.[1] The Indians of Columbia, it is said, use the secretion of *Dendrob'ates tincto'rius* for poisoning arrows to shoot monkeys. That this secretion protects these amphibians from their enemies (the "glass snake" is an exception) is evident from the fact that "a dog that has once been induced to bite a toad suffers so severely that it will not repeat the experiment." The handling of the tree-frogs irritates both nose and eyes. Many of the most poisonous amphibians (as *Salaman'dra maculo'sa, Bom'binator*, and *Dendrob'ates*) are conspicuously marked with yellow and black. The horned frog of South America, which fights and poisons its antagonist, is brilliant in green and gold. Many assume a threatening attitude. "Toads normally have the sections of the breast-bones overlapping, so that they can swell themselves enormously when angry."[2]

**Ec'dysis.**—All amphibians shed the epidermis. The first ecdysis occurs at the time the metamorphosis is completed, preparatory to terrestrial life. The *Anu'ra* roll up the cast-off skin and swallow it. The *Urode'la* also eat it. The skin of the *Anura* generally splits down the back, but that of the *Urodela* breaks loose around the mouth, and the animal slips out, turning its hide wrong side out. So long as growth continues, the skin must be shed often, as this outside layer will not "give" to make room for growth. The adult *Urodela* do not molt often, but usually at the breeding season, when they go to the water to deposit their eggs. The *Anura* molt frequently, at least every few months, probably to keep the skin moist.

**Voice.**—Most of the *Anura* and some of the *Urodela* have a voice produced by the larynx, which is often provided with a complicated cartilaginous and muscular apparatus and with vocal cords. The female of the *Anura* is mute or utters only a grunt. The sound made by the male is called a croak. The voice of *Urodela* is a feeble squeak. The song of frogs and toads is usually of the nature of a serenade to its would-be mate, for they do not, as a rule, cry out in fright nor in rage. A notable exception is that of the vicious horned frog of South America, which is said to defy its foes with a sort of bark, but which has a clear bell-like tone for its friends. Our common green frog is

[1] Gadow, "Amphibia and Reptiles," p. 38.
[2] Baskett, p. 29.

also an exception. That cloudy or damp weather has some effect in making certain species, as the tree-frogs, sing, is perhaps explained by the fact that the skin of amphibians is used as a breathing organ as well as for a body covering, and it must be kept moist to be serviceable.

**Influence of Temperature.**—Amphibians living in the water assume its temperature, which varies much from noon to midnight, and from the stream in open sunshine to the cool, shady spring. According to Gadow, "most *Anura* die when their temperature rises to 40° C.," but those outside of water in open air endure greater heat than aquatic ones, since the evaporation of the moisture from their skin lowers their temperature. Most of them, and especially the drier skinned toads, seek the cool shade or even estivate during the hottest part of the summer. Many of them, unless they are used to tropical climates, can endure a very great amount of cold, their temperature sometimes falling to the freezing-point during hibernation. Our spotted salamander, in a jar of water out-doors, was forgotten one severely cold night, when the water about it froze solid. It was put into a cool room and allowed to thaw gradually as the weather moderated, after which the salamander seemed to be as active as ever. Of course, the animal was not sawed into parts to find out if it was frozen solid, but it surely looked solid enough. It does not seem possible that the heart was absolutely frozen, for the heart "must not itself be frozen if the animal is to have a chance of recovery."[1]

## CLASSIFICATION OF AMPHIBIA

**Order I. Stegoceph′ala.**—This is an extinct order of amphibians, described by Scott as animals, which have a skull "well covered with a roof of sculptured bones and which are of moderate or small size, not exceeding 7 or 8 feet in length and mostly much smaller. The backbone is not ossified, the limbs are weak, the tail short and broad, and in many forms the belly is protected by an armor of bony scutes."[2] Most of them were like salamanders in shape, but some were long and snake-like.

**Order II. Ap′oda or Gymnophi′ona.**—This group comprises one family of limbless, tailless, vermiform, subterranean am-

[1] Gadow, p. 68.
[2] Scott, "Introduction to Geology," p. 427.

phibians of the tropical regions. They have from two hundred to three hundred vertebræ. There are no gills or gill-slits in the adult stage. Their mode of locomotion is much like that of the earthworm. It is produced by the peristaltic motion of the skin, aided by the numerous ring-shaped constrictions. The eyes are vestigial and concealed beneath the skin.

The only family is *Cæcili'idæ*, with some forty species. Some genera, as *Ichthyophis*, have small scales embedded in the skin. Others, as the *Typhlonectes* of Guiana and Venezuela, are scaleless. *T. compressicauda* is 18 inches long and $\frac{3}{4}$ inch in diameter. Its color is from an olive brown to black, which is the general color of most species. Some, as *Ichthyophis*, are oviparous; others, as *Dermophis*, are viviparous.

**Order III. Urode'la or Cauda'ta.**—These are the tailed and limbed amphibians. They have four limbs, as in the toads and

Fig. 187.—Siren (*Si'ren lacerti'na*). (Chapin and Rettger, Englehard & Co., Publishers.)

frogs; or two, as in the Siren. The skin is smooth and slimy. Locomotion is accomplished mostly by body motion, aided by the weak limbs, in strong contrast with the limb-motion of the frogs and toads. They are not very common as compared with frogs and toads. Newts and salamanders are examples.

*Siren'idæ* is a small family of two genera of one species each. The **"mud-eel"** (*Siren lacertina*) (Fig. 187) of the southern United States is 2 or 3 feet long. Posterior limbs are wanting, and the weak anterior limbs have four digits. The tail is long, compressed, and thin. There are three pairs of gills, but they atrophy in the young and are redeveloped subsequently.[1] The mud-eel is a harmless creature, burrowing in the mud of ponds and ditches. Dorsally it is dark colored, but lighter ventrally. Sometimes

[1] Gadow, p. 136.

it is spotted with small white specks. When swimming, the limbs are folded back.

The other species (*Pseudobran'chus stria'tus*) is only about 7 inches in length and has three digits to each fore foot.

Fig. 188.—Mud-puppy. (Chapin and Rettger, Englehard & Co., Publishers.)

The family *Prote'idæ* consists of amphibians having three pairs of persistent gills, two pairs of weak limbs with four digits to each one, or the

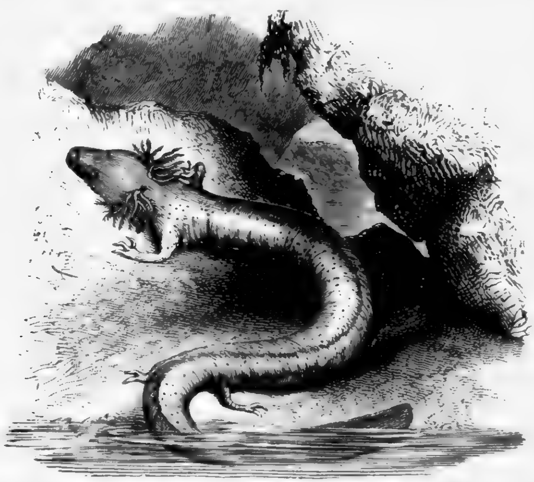


Fig. 189.—*Pro'teus angui'nus.* Europe. (From Dodge's "General Zoölogy," American Book Co., Publishers.)

anterior pair with two, and the posterior with three digits. The eyes are without lids and covered by a transparent skin, but are functional. They have teeth on the vomer, mandible, and premaxillaries.

The **water-dog** or **mud-puppy** (Fig. 188) (*Nectu'rus macula'tus*) is a rather common, clumsy form found in the Mississippi Valley and the region of the Great Lakes and east to the Alleghenies. They are nocturnal, but voracious, feeding on insects, worms, small fish, and crustaceans. Those in our laboratory were 15 inches long with dark brown spots.

The blind *Pro'teus angui'nus* of Europe (Fig. 189) belongs to this family. It is white and lives in total darkness in a temperature of about 50° F. If brought to the light the skin will ultimately change to a dark color. There is a similar species (*Typhlomol'ge rath'buni*) in Texas.

**Family Amphi'ūmidæ.**—These animals are without gills in the adult stage. They have teeth in both jaws. They have four small, weak limbs.

The **hellbender** (*Cryptobran'chus alleghanien'sis*) is a stout-bodied, four-footed, ugly, but harmless amphibian, which is sometimes 2 feet in length. It is brown or gray above and lighter below. It feeds on worms, crayfish, fish, and such other creatures as it can obtain in its aquatic habitat. It is restricted in its distribution to the streams of the mountainous regions of the eastern United States.

Fig. 190.—Congo snake (*Amphiu'ma me'ans*). (From Holder's "Elements of Zoölogy," American Book Co., Publishers.)

The **giant salamander** of Japan (*C. japon'icus*) reaches a length of 4 to 5 feet. It lives in small streams and mountain meadows of Japan and China, from 600 to 4500 feet above sea-level. Sasaki reports that it lives singly, lying concealed under rocks, in swift, thickly shaded, small, clear, cold streams. It feeds on animals which it can capture in the water and may be caught with a fish-hook. It is used for food by the Japanese.

The **"Congo snake"** (*Amphiu'ma me'ans*) (Fig. 190) is eel-like, with four weak limbs, having two or three toes each. Its general color is black, with lighter under parts. It attains a length of 3 feet. It lives in the swamps and rice fields of the southeastern United States. It feeds on crayfish, mollusks, and fishes. It is quite harmless.

Family *Salaman'dridæ*, or salamanders and newts, are our most common *Urodela*. All are harmless, and are generally but erroneously called lizards. They have no persistent gills. They have two pairs of weak limbs. Nearly all have movable eyelids and teeth in both jaws. There are twelve or fifteen species in the United States.

The **spotted salamander** (*Amblys'toma puncta'tum*) is our common species in the Mississippi Valley (Fig. 191). It is dark brown or blackish above, marked with about thirty irregular yellow spots. It is found in wells and cellars. It is oviparous.

One species (*Amblys'toma tigri'num*), which is found in Mexico and California and even in New York and Minnesota, affords a striking example of *neoteny*,[1] or the " more or less complete retardation of development, or the retention of partially larval conditions."[2] If the pond in which this *axolotl*, or larva (Fig. 192), lives begins to dry up, its gills, fins, and tail shrink, and finally disappear, the animal begins to breathe air, and gradually becomes a terrestrial salamander.[3] But if it is reared in deep water or forced by deep walls to remain in aquatic conditions, the larval or aquatic gills and tail are retained, even after sexual maturity has been reached. One would think this was a forcible proof of the influence of environment on the development of the individual, but the strangest part of it is that it is said

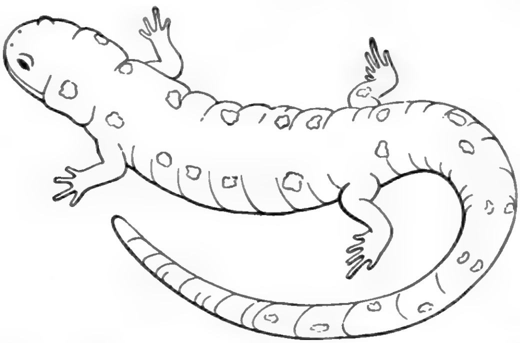


Fig. 191.—Common yellow spotted salamander. (Morse.)

there have sometimes been found, side by side with these prolonged larval individuals, others apparently of the same species which have completed their metamorphosis.[4]

The **newts** or **tritons** all prefer moisture without heat. In the mating season they take to the water, undergo various changes, and become aquatic. After the breeding season is over, they become terrestrial, hiding in cracks or in the sand. Some estivate in the hot dry season. They hibernate usually in the ground, but sometimes in ponds. The food consists of insects, centipedes, and snails. " They do not drink, but soak themselves in water."[5]

[1] Baskett and Ditmars.
[2] Parker and Haswell.
[3] Linville and Kelly.
[4] Hertwig (p. 587, Kingsley's translation) says adults of true axolotl are unknown.
[5] Gadow, p. 123.

The **crimson-spotted newt** (*Tri'ton virides'cens*) is abundant in northern and eastern states. Above, it is greenish brown, with two rows of crimson spots. Below, it is orange, with black dots. It lives in deeper water than is usual for salamanders and "swims freely, often in an upright position, with hind legs hanging motionless, while the tail does all the work."

**Order IV. Anu'ra or Ecauda'ta.**—"The Anura are a very specialized group. Their development (see p. 225) indicates their

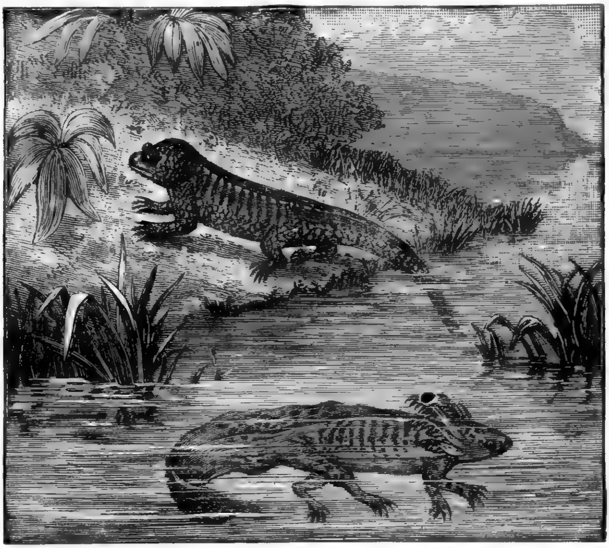


Fig. 192.—Axolotl, a creature living and breeding for generations in the water. Amblystoma coming out of the water. Amblystoma breathes by lungs, having lost its gills. (From Holder's "Elements of Zoölogy," American Book Co., Publishers.)

derivation from branchiate, tailed forms, but there is no paleontologic evidence on this point."[1]

**Aglos'sa.**—This group is characterized by the absence of a tongue and by a common opening for the Eustachian tubes. It is represented by the *Pipa* or "Surinam toad" of South America (see Fig. 186) and by the *Dactyl'ethra* (Fig. 193) of Africa.

[1] Parker and Haswell, p. 291.

**Phaneroglos′sa.**—This group is characterized by the presence of a tongue and by distinct Eustachian tubes. It includes the toads and frogs. Gadow estimates 900 species in the world. Frogs and toads have tails in the larval or tadpole (Fig. 194) condition, but are tailless in the adult stage. The body is short and stout. They have a small number of trunk vertebræ and the caudal vertebræ are replaced by one long bone, the urostyle. They have four limbs, the posterior ones, long, strong, and adapted for leaping or hopping. Toads are crepuscular and nocturnal. They hibernate in the mud at the bottom of the water. The tadpole or "pollywog" is fish-like and aquatic. It has a long tail and breathes by gills. Its intestine is very long, adapting it to its vegetable food.

Fig. 193.—*Dactyl′ethra capen′sis.* (Claus.)

**Family Bufon′idæ.** — Toads are clumsy, stout-bodied, nocturnal insect-feeders. The tongue is fixed by the anterior end and can be thrust out to catch its food. They have no teeth. The skin is warty or glandular and secretes a fluid for protection. The toes are webbed, but not dilated at the tips. Toads resemble the ground very closely.

The *American toad* (*Bu′fo lentigino′sus*) is familiar to all. The young are nearly smooth, the adults warty. They are brownish-olive, with a yellowish median line and brown spots. There is a bony ridge behind and above the eye and two black patches below the eye. The tympanum is large.

**Family Hy′lidæ or Tree Frogs.**—These are arboreal frogs with an opposing thumb and with adhering disks on the end of each toe, by which they cling to the trees in which they live.

Our most common example is the northern tree-frog (*Hy′la ver′sicolor*) of the eastern United States and Canada. It is about 2 inches long and delicately colored. "Its color passes within a short time from dark brown or olive gray to pale gray or white, occasionally retaining a few large dark patches on the back and delicate cross-bars on the limbs." It has small warts, which produce an acrid secretion. It is found not over 20 feet from the ground in trees or on lichen-covered stone fences. Its color renders it almost perfect in protective resemblance. One may be within a foot of it and not be able to distinguish it. It croaks noisily in the evening or just before a rain. In croaking its vocal sacs swell to enormous proportions. It remains quiet in the shade during the day, but is lively in

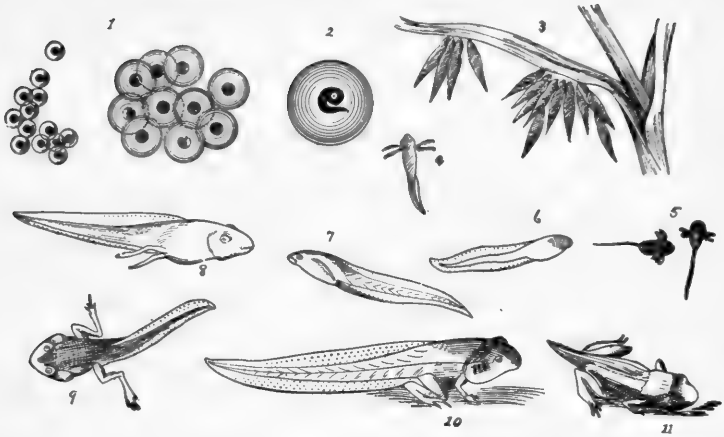



Fig. 194.—The metamorphosis of the frog. The numbers indicate the sequence. (Galloway after Brehm.)

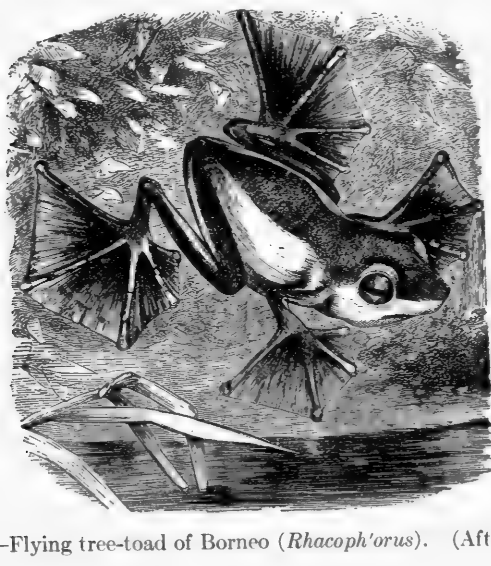


Fig. 195.—Flying tree-toad of Borneo (*Rhacoph'orus*). (After Wallace.)

the evening, feeding on insects. Gadow mentions a tree-frog which lived twenty-one years.

**Family Răn′idæ.**—**Frogs** (*Raninæ*) have teeth in the upper jaw. The toes, four to five, are more or less webbed. The tongue is like the toad's.

Our largest species is the **bullfrog** (*Ra′na catesbia′na*), which measures from 5 to 8 inches. It is known by its deep bass voice. It has two large internal vocal sacs. Its toes are broadly webbed. In color it is varying shades of green above, with faint dark spots, the head is bright green, the legs blotched. The tympanum is large. Its hind limbs are much prized for food. Bullfrogs are solitary except in the breeding season, when hundreds collect in the same small pond. They are commonly found sitting half immersed in water, or waiting for their prey upon the banks of a pond. The bullfrog is voracious, devouring mollusks, fishes, and frogs, as well as ducklings and young water fowls. It is eaten by fishes, birds, otters, snakes, and alligators.

The **green frog** (*R. clamata*) is a brownish-green color, brighter in front, with irregular small black spots, and blotched limbs. Below, the color is yellowish white. The tympanum is large. It is common in the eastern United States. The vocal sacs are small and internal.

Wallace describes a species of *Ranidæ* which was brought to him in Borneo. The body was about 4 inches in length and the webs of both fore and hind feet were enlarged and used as parachutes by these "flying frogs" (Fig. 195).

**Classification.**—

| | *Order.* | *Examples.* |
|---|---|---|
| I. | Stegoceph′al′ia. | Extinct forms. |
| II. | Ap′oda or Gymnophi′ona. | Cœciliidæ. |
| III. | Urode′la or Cauda′ta. | Necturus, Salamanders. |
| IV. | Anu′ra or Ecauda′ta. | Frogs, Toads. |

## CLASS IV. REPTILIA

This class of Chordates consists of snakes, lizards, turtles, crocodiles, and alligators, together with a number of extinct orders.

Reptiles are scaly. They are aquatic or terrestrial; a few are arboreal. There is one occipital condyle, and the lower jaw is united to the base of the skull by a quadrate bone.

The limbs are four, two (the Python and some kindred forms have the vestiges of the hind limbs only), or none, as in the "glass snake" and our common snakes.

Reptiles are poikilothermal. The heart has one ventricle and two auricles, except in order Cro′codilia, where the heart has two auricles and two ventricles.

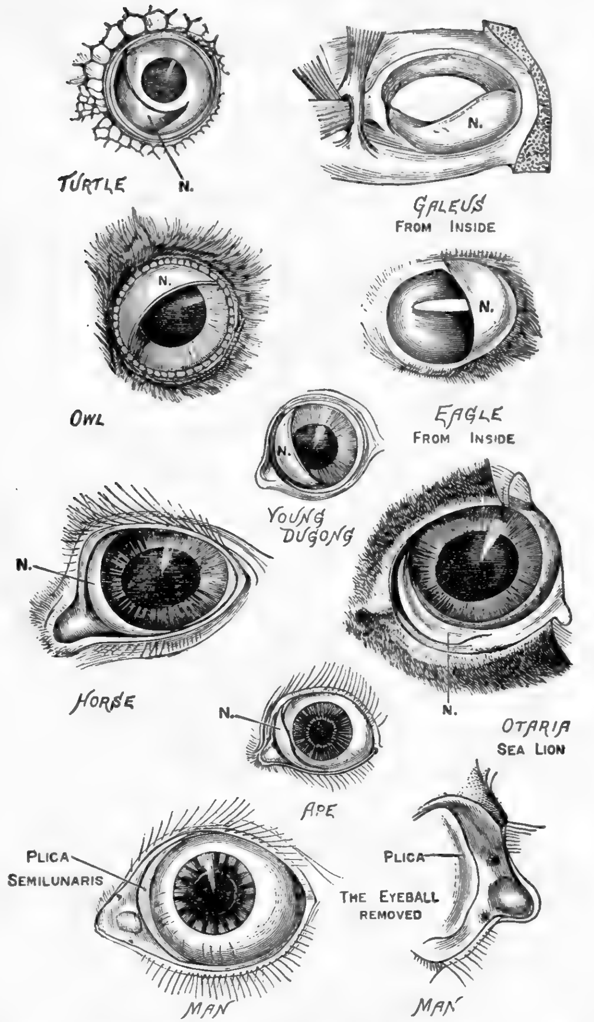



Fig. 196.—Illustrations of the nictitating membrane in the various animals named, drawn from nature. The letter N. indicates the membrane in each case. In man it is called the *plica semilunaris*, and is represented in the two lower drawings under this name. In the case of the shark (*Galeus*) the muscular mechanism is shown as dissected. (Romanes.)

Reptiles always breathe by lungs. "The air is drawn into the lungs of snakes, lizards, and crocodiles by the play of the ribs."[1]

The **nervous system** is somewhat more highly developed than in the amphibians. There is a middle and an inner ear. The eye has an upper and a lower movable eyelid and also a nictitating membrane (Fig. 196). True nostrils and salivary glands appear first among the reptiles.

Reptiles are oviparous, ovoviviparous, or viviparous. There is no metamorphosis.

In ecdysis the skin may be cast in one piece, as in all snakes save sea-snakes and in most lizards; in strips, as in some lizards; in little pieces, as in the western horned toads; or in flakes, as in the geckos. Some tortoises shed the whole outer layer of epidermal shields periodically.

Gadow briefly defines Reptilia as "monocondylia with a scaly skin."

Reptiles live longer than most warm-blooded animals. A turtle in the Zoölogical Park, New York, says Ditmars, is estimated to be over three hundred and fifty years old.

### ORDER I. RHYNCHOCEPHALIA

Rhynchocephali is represented by *Sphen'don puncta'tum* (*Hatte'ria*) of New Zealand. It is a lizard-like, four-limbed, pentadactyle, nocturnal, carnivorous reptile.

Its color is dark olive green, with small white or yellowish specks on the sides. Its length is from 15 to 30 inches, while fossil forms were sometimes 6 feet long. A row of spines extends along the back. Its means of defense are biting and scratching. It burrows. It lays about ten hard-shelled white eggs in the sand.

Gadow has "come to the conclusion that they are dull, not companionable creatures." Their sound is a grunt or croak.

For an interesting description of this living fossil read Gadow, "Amphibia and Reptiles," pp. 294–300. Look at the picture of the skeleton and state the branch, class, and ordinal characteristics you see.

[1] Dodge.

## ORDER II. OPHIDIA

**Snakes** are considered degenerate lizards, and by some zoologists are classed with the lizards, and the group together called Order Squamata.

The Ophidians are reptiles with no fore limbs, no pectoral girdle, no sternum or sternal ribs, but the ends of the dorsal ribs are connected with the ventral scales, or scutes, and both

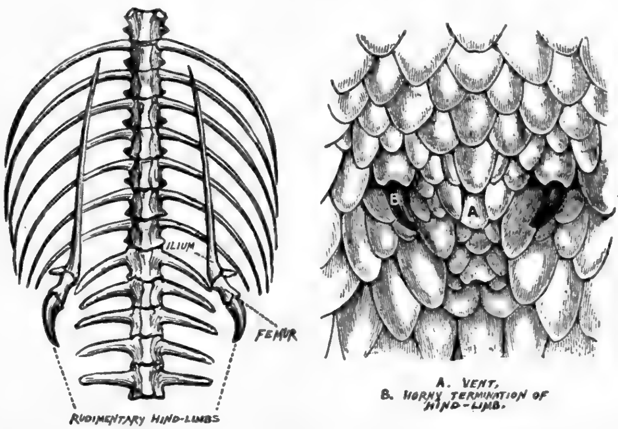



Fig. 197.—Rudimentary or vestigial hind limbs of python as exhibited in the skeleton and on the external surface of the animal ($\frac{1}{4}$ natural size). (Romanes.)

scales and ribs aid in the body motion. "A snake literally walks on the ends of its ribs."

Vestiges of the hind limbs (Fig. 197) sometimes appear as little spurs on either side of the vent. The ribs, which begin with the second vertebra and continue to the end of the body, aid in respiration. They aid in locomotion also, their ventral ends fitting into the "connective tissue of the sides of the ventral transverse scales (scutes)." The body is long and the vertebræ very numerous.

They vary in *size* from the enormous ones of the tropics to our little green grass snakes. Some are aquatic, some terrestrial or subterranean, while still others are arboreal in their habits and habitat.

The *color* of snakes is usually brownish or green, which affords a good protective resemblance to the ground or grass upon which they creep.

The *skin* is scaly. The horny epidermis is shed from one to several times yearly, the whole outer skin, from lips to tail, being turned wrong-side out, even to the transparent covering of the eyes. The first molting takes place "within forty-eight hours after birth" before the young snake begins to feed. In the rattlesnake, at each time the skin is shed, "there is left a ridge or rim of it at the tail, which forms the rattle."

**Food.**—Since there are no limbs for prehension, snakes must depend upon the mouth to secure the prey, which is swallowed whole. The constrictors, like our common blue racer and the boa constrictor, wind their bodies about their victims and literally squeeze them to death. The teeth point toward the throat, thus preventing the escape of the prey from the mouth. The snake has also a distensible lower jaw, enabling it to swallow an animal as large or larger than the diameter of the snake's own body. The bones and palatal apparatus are united by ligaments only, thus allowing them to spread apart in the process of swallowing. An abundant supply of saliva (which appears first in reptiles) renders swallowing the more easy.

Snakes are carnivorous, feeding upon mice, birds, frogs, and insects. Poisonous snakes should be killed, of course, but the non-poisonous ones are quite useful in the fields in destroying vegetable-feeding animals, especially rodents and insects.

**Respiration** is mainly by one lung, the other one being rudimentary. The trachea may be slightly protruded between the halves of the lower jaw during the process of swallowing, to prevent suffocation.

**Senses and Intelligence.**—The eyes are not movable nor have they a movable eyelid, hence their glassy stare. The lacrimal fluid passes internally into the nasal cavities. No external ear is visible, though the hearing is good. The sense of smell is well developed, some snakes being greatly aided by it in their search for prey. The tongue, which is slender, forked, and sheathed, is protractile, moist, and very sensitive to touch.

Snakes, while showing considerable intelligence, are seldom much attached to their keepers, being more often reticent and surly.

**Multiplication.**—The eggs of snakes are not hard shelled, but are covered with a tough membrane. Generally the snake loosely buries the eggs or deposits them half-hidden in cracks and crevices. Many snakes are ovoviviparous.[1] The young are precocial. Male snakes are smaller than the females.

As in reptiles generally, the number of young at a litter is large, but the number varies with the species. That of the poisonous snakes is said to seldom exceed fifteen, except those of some of the tropical ones. Ditmars mentions a boa constrictor in captivity which "gave birth to sixty-four fully developed young, while a huge python deposited seventy-nine eggs, which she gathered in her coils and guarded jealously" until hatched. During this period of incubation the body temperature is raised. Our little garter snake has a litter of about thirty-five, while that of the common water snake has been known to number sixty. The copperhead has about eight or nine young.

The **length of life** may be said to be considerably shorter than that of the chelonians and crocodilians, as growth is more rapid. Adult snakes received in the Zoölogical Garden, New York, says Ditmars, have been kept for ten years without showing signs of age, and pythons even fifteen years. The snakes of this latitude hibernate in caves and dens or in deep crevices between the rocks. In the tropical regions some species estivate in summer.

**Defense.**—Besides their protective coloration, snakes are further provided with several means of defense. Some are protected from their enemies by a characteristic odor, while others have the deadly poison fangs. Another, and by far the most common means, is by noiseless flight. A few species burrow or slip into holes to escape, while the boa constrictors squeeze their enemies to death. Most snakes will not attack man if unmolested, and they are generally as much frightened as the person is. They charm birds, probably by paralyzing them with fear, until they can creep up to and catch them.

[1] See Glossary.

The author attracted the attention of a charmed bird from its gaze upon the snake and the bird immediately flew away.

The poison gland is an especially modified salivary gland, and the poison fangs are maxillary teeth which have a furrow on the


Fig. 198.—A case of mimicry, where a non-venomous species of snake resembles a venomous one. (Romanes.)

anterior side, or the furrow is changed into a canal for the passage of the poison to the end of the fang, and hence to the deepest portion of the wound, where it poisons the blood of the victim. Colton gives, as an antidote, a 10 per cent. solution of ammonium carbonate taken internally.

There are many enemies of snakes. Prominent among them are kites, hawks, shrikes, and other birds of prey, hogs, and man.

**Family Colu′bridæ** includes all our common harmless snakes, as the garter snake, " hoop snake," water snake, green snake, black snake or blue racer, blowing viper, and others. They are all perfectly harmless, though they make great pretensions with their terrifying appearance or bluff as to what they might do if you came too close.

**Family Crotal′idæ** includes the rattlesnake, copperhead, and water moccasin. All of these are poisonous and to be feared. The rattlesnake gives warning, not so the deadly copperhead and water moccasin. Happily for man, civilization is driving out these dangerous reptiles.

**Family Elap′idæ** is another family of venomous, chiefly East Indian, snakes. There is one species (Fig. 198), the "bead snake" (*E′laps ful′vius*), found from Virginia to Arkansas and south. Jordan describes it as " jet black with about seventeen broad crimson rings, each bordered with yellow and spotted below with black, a yellow occipital band, tail with yellow rings." It is surely an example of warning colors which one will do well to heed. A non-venomous species closely resembles it.

**Library References.**—Gadow's "Amphibia and Reptiles"—Ophidia. Read of snakes of other lands. Baskett and Ditmar's " Story of Amphibians and Reptiles "; Parker and Haswell on " Reptilia."

## ORDER III. LACERTILIA

**Lizards** are reptiles with a distinct head, a snake-like body, a tail generally longer than the body, and four short, nearly

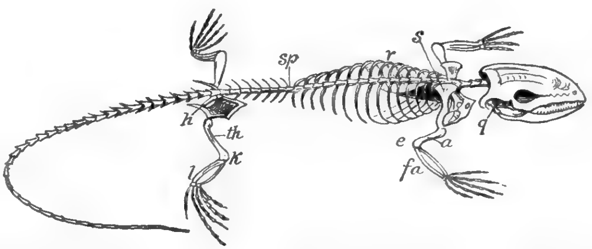



Fig. 199.—Skeleton of a lizard: *sp*, Spinous processes, which in the tortoise are flattened into plates; *r*, ribs; *s*, shoulder-bone; *a*, upper arm; *e*, elbow; *fa*, forearm; *h*, hip-bone; *th*, thigh-bone; *k*, knee; *l*, bones of the leg; *q*, quadrate bone between upper and lower jaw. (From Holder.)

equal limbs, or no functional limbs, as in the so-called " glass snake " or " joint snake." Their locomotion is aided by a wriggling body motion. "Two aortic branches, a left and a right, survive in lizards."[1]

Lizards are very various in size, shape, color, and habitat. Most of them are terrestrial, some burrow, some are semi-aquatic, and still others are arboreal. They are generally covered with horny epidermal plates. Lizards shed their skin entire.

The shoulder girdle and sternum are present. The "flying dragons" of the Indo-Malayan countries have "a pair of wing-

Fig. 200.—*Heloder'ma*, a poisonous lizard. (From Holder's "Zoölogy," American Book Co., Publishers.)

like membranes supported by five or six elongated posterior ribs, which they use as a parachute or fold up like a fan."

**Food.**—Most lizards are insectivorous, eating small animals also, but some are herbivorous, living upon buds, blossoms, and tender leaves of plants.

**Special Senses.**—The eyes are usually provided with an upper and a lower movable eyelid and with a transparent nictitating membrane. The tympanic membrane is situated in a slight depression behind the eye. The tongue is free and both jaws are armed with teeth. The mouth is not distensible.

[1] Packard.

**Multiplication.**—The egg-laying lizards deposit their eggs in the sand or soil, except the Iguanidæ, which lay them in hollow trees. Many lizards are viviparous. The male is larger and more brightly colored than the female.

Lizards, as well as amphibians and snakes, find the ocean a barrier to their progress, but lizard's eggs have in some way been carried to oceanic islands.

All are harmless except the *Gila monster* (Fig. 200), of the Gila River region, which is the only poisonous lizard known. The specimen in our laboratory is about 17 inches long, black, and mottled with orange. Its only sound was a hiss, which it gave when disturbed.

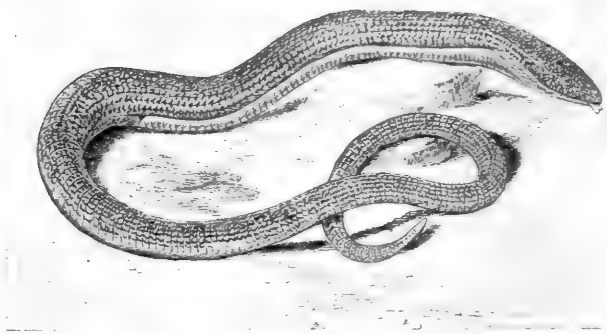


Fig. 201.—Glass snake (*Opheosau'rus ventral'is*). The tail is twice the length of the body, and breaks off at the slightest blow. When broken off it grows again. (From Baskett and Ditmars, "The Story of the Amphibians and Reptiles," D. Appleton and Co., Publishers.)

**The Skinks.**—This family (*Scin'cidæ*) is represented by the cosmopolitan blue-tailed lizard common east of the Rockies as far north as northern Indiana, and by the ground lizard of the Southern States.

**Cnēmidŏph'orus,** a very little active brown lizard streaked with yellow and black, is found from Connecticut to Virginia and from Wisconsin to Mexico. In this family (*Tē'idæ*) there are over one hundred species distributed throughout South and Central America and the warmer parts of North America.

The **"glass snake"** (Fig. 201), our representative of the family *An'guidæ*, has a long brittle tail. Its brittleness is due to the fact that not only are the caudal vertebræ loosely joined together, but each vertebra is provided with a middle cartilaginous partition, so that it is easily separated. The caudal vertebræ of the Geckones and of most Lacertæ break in the same manner. It is one means of self defense, as the animal escapes with only the loss of its tail. The popular notion of the pieces being collected again is without foundation. When " the tail is broken off," and this is always at this cartilaginous partition, " the cells of the remaining half reproduce a

Fig. 202.—*An'olis* or American chameleon (*Anolis principalis*). Although the general color of the animal beneath is white, the upper parts may quickly assume hues varying from a vivid emerald green to a dark iridescent bronze color. (From Baskett and Ditmars, " The Story of the Amphibians and Reptiles," D. Appleton and Co., Publishers.)

new tail." This new tail, says Gadow, is only a " sham tail," since it does not consist of a series of vertebræ, but of " a non-segmented rod or tube of fibrocartilage."

This lizard cannot climb, and does not like the water, so it may be said to be entirely terrestrial. Its food consists of " snails, insects, worms, mice, small lizards, birds, and vipers." It shakes its prey until the victim is stunned, then chews and swallows it. It does not bite when caught, but winds about the wrist and emits a stinking discharge. It hides among the leaves and in the sand under bushes. This species lays eggs, though some of its family are viviparous. It hides its eggs under moss and leaves and the young mature very slowly, taking several years to reach maturity.

**The American Chameleon and its Relatives.**—Our very interesting little lizard (*An'olis*) (Fig. 202) of Florida and the Carolinas is commonly called a "chameleon," but the real chameleon is a native of Africa. The "green chameleon" (*Anolis*) has the power of suddenly and voluntarily changing its color to adapt itself to its environment. Experiments upon this animal in our laboratory proved that it changes color more rapidly when placed upon objects with natural colors than it does upon artificially colored ones. It is arboreal and insectivorous. The males have "large gular sacs which can be distended by the hyoid bones." These sacs are white, with occasional red lines and spots, but when inflated they become crimson. The *Anolis* is 5 or 6 inches long.

Another member of this family is our little **Swift,** common in the forests and fence corners of the United States as far north as Michigan. It delights to lie basking in the sun, but disappears quickly when disturbed.

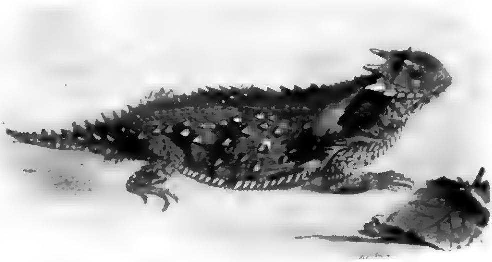


Fig. 203.—The "horned toad" (*Phrynoso'ma blainvillei*). The spiny covering repels many enemies. (From Jordan and Kellogg, "Animal Life," D. Appleton and Co., Publishers.)

Another member is the very interesting little lizard called the **"horned toad"** (Fig. 203), Phrynoso'ma, found in the dry regions of the Southwestern States. The body is oval in form, rather flat and broad, with a short conical tail. It is covered with irregularly shaped keeled or spiny scales, the head being "bordered posteriorly with osseous spines." The small eyes are each protected by a ridge running backward above them. The ventral side of the author's pet "horned toad," a specimen from southeast Kansas, is yellowish in color, with a number of brown spots dotted over it. The scales are small and regular. The general color of the animal, dorsally, is grayish or yellowish brown, affording, together with its irregular and roughened surface, an excellent protective resemblance to the sand in the desert regions, in which it likes to sink until the spines of the head alone stick out. Thus some species, at any rate, lie concealed through the night and on cloudy days. They are liveliest in the middle of the day and delight in the hot sun. When alarmed they shut their eyes and lie flat on the sand. Their food is insects, which they catch as toads do with their tongues, which are smooth, short, and scarcely at all notched, and can be thrust out a short distance only, perhaps not over ½ inch. " Horned toads " will endure long fasts. They hibernate in winter. All species are viviparous and the young at one litter number seven or eight.

Another **Iguana** (*tuberculata*), of South and Central America and the West Indies, is sometimes 5 or 6 feet long and weighs nearly 30 pounds. It spends much of its time in trees, but when alarmed plunges into the water below it. It lays about two dozen eggs in a hole in the side of the bank. The flesh of these animals is much prized for food by the natives.

**The Monitors.**—The one genus (*Var'anus*) of this family (*Varan'idæ*) consists of about thirty species. They are found in Africa, but not in Madagascar, in Australia, and in Southern Asia. They have long forked extensible tongues. They are large, attaining the length of 4 or 5, or even 6 feet. Some are found in desert or dry regions, while others are semi-aquatic. The natives of some regions use the flesh of the monitors for food. The monitors are rapacious, devouring any animals which they can get. The monitor of the Nile is a great enemy of the crocodile, devouring great numbers of its eggs.

**Library Work.**—See Gadow or other large works on reptiles for an extended description of Lacertilia of the tropical regions. The " Flying Dragon " and other interesting forms are well worth your study. Baskett and Ditmar's " Story of Amphibians and Reptiles " relates many interesting facts in a simple, yet instructive manner, also, Hornaday's " American Natural History." Do not fail to read the larger works. Get beyond mere text-book study of these wonderful forms in this and other lands. *Broaden your own horizon.*

### ORDER IV. CHELONIA

**Turtles** vary in size from a few inches in length to 6 or more feet in some marine forms. The turtles of to-day are small as compared with some extinct forms. They vary in weight from a few ounces to over 1000 pounds. There are marine, fresh-water, and land forms, while the " gophers " of the South burrow in the ground.

**Skeleton.**—Turtles are easily recognized by their shell or exoskeleton. The dorsal portion of the shell is called the carapace, and the ventral portion the plastron. The covering of this shell consists of horny epidermal plates. These are thin, and when pulled off reveal the bony shields beneath.

The *bony carapace* (Figs. 204, 205) is composed of the spines of the dorsal vertebræ, flattened, the ribs broadened out and joined to each other by sutures, also to the outer marginal row of

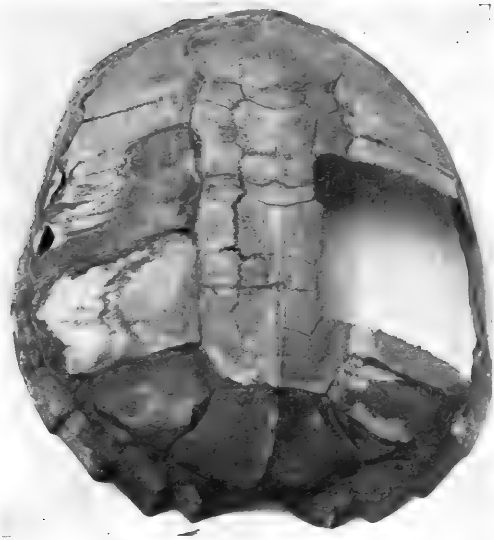


Fig. 204.—Bony carapace of turtle with epidermal plates removed to reveal bony shield with portion missing. Dorsal view.

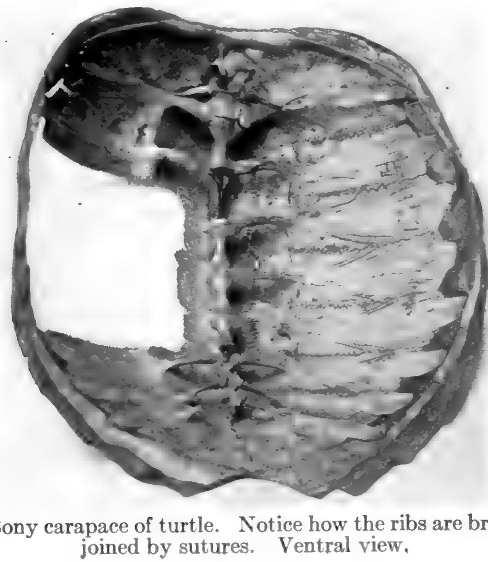


Fig. 205.—Bony carapace of turtle. Notice how the ribs are broadened and joined by sutures. Ventral view.

dermal bones, all fused into one bony carapace which is covered by epidermal plates. The plastron consists of epidermal plates underlaid with bony shields. The head, limbs, and tail may be more or less withdrawn under the carapace for protection; in some forms so completely that there is no part of the turtle visible outside of the shell.

They have four short, strong, clawed, pentadactyle limbs, or, in the case of some marine forms, flippers. The marine paddle-limbed forms are usually designated as turtles, and those with walking limbs as tortoises.

The *bones* of the head are firmly united. The jaws are toothless, but are inclosed in sharp horny beaks, with which they seize and crush their prey and then swallow it whole. The pectoral arch is a "triradiate structure, of which the

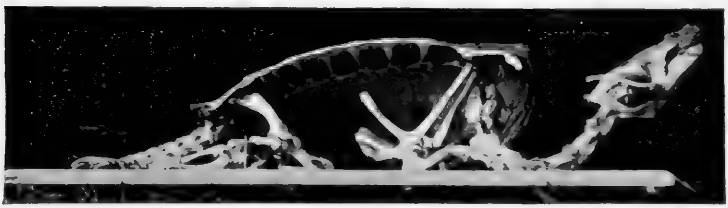


Fig. 206.—Skeleton of snapping-turtle with portion of carapace sawed off to show interior. Cleaned and mounted by students; (much reduced.)

most ventral and posterior ray ending in a free extremity is the coracoid, while the other two are the procoracoid and the scapula with the suprascapula, which are fused at their glenoid ends."[1] The pelvis is strong, consisting on each side of the pubis, the ischium, and the ilium. These meet at the articular surface of the hind limb. The vertebræ are few as compared with those of the snake. Those of the neck fit into one another with ball-and-socket-joint. There is no trace of a sternum or of sternal ribs.

**Digestive System.**—The tongue is usually soft and wide and not extensible. The esophagus is covered with "conical projections pointing toward the stomach." There is no cecum.

**Food.**—Some species are carnivorous, some are herbivorous,

[1] Parker and Haswell, vol. ii, p. 329.

while others are omnivorous. Predacious species probably lie in wait for their prey.

The **respiration** is unique. The large spongy lungs reach to the pelvis. In breathing the neck and limbs act like pistons in being drawn in and out. The throat is alternately inflated and emptied by the hyoidean apparatus when the neck is stretched out, thus the air is swallowed or pumped into the lungs. Since the lungs are so roomy and the animals poikilothermal, most turtles can live for a long time without breathing, sometimes remaining under water for hours or even days.

**Special Senses.**—Their eyes, though comparatively small, are their most highly developed sense organ. They are situated far forward on the head and protected by two lids and a nictitating membrane. The nostrils are terminal; thus by exposing a minimum portion of the head above water they are able to breathe and see what is going on about them, comparatively free from danger. The sense of smell is well developed, many species showing a choice of certain kinds of food which they distinguish by smell. The sense of hearing is not well developed. That they distinguish sounds is evident from their voice, which Gadow declares is very tiny and piping during the pairing season. Some species, at least, snap their jaws together when angry, and when the head and limbs are withdrawn they make a hissing sound. Holder says the male "elephant turtle" of the Galapagos Islands "utters a hoarse croak or bellow during the breeding season." They are frightened by noise. The tympanic membrane in most water forms is thin and quite exposed. In land tortoises it is often thick and covered with the skin. Turtles, contrary to the notion of small boys, are very sensitive to the touch, both upon the shell and upon the soft parts.

**Multiplication.**—Turtles lay their eggs at night in the sand, cover them carefully, and leave them for the heat of the sun-warmed sand to hatch.

The young are like the adult in general, but differ somewhat in color.

**Enemies and Defense.**—They are preyed upon by carnivorous birds, fishes, alligators, and by men. They defend themselves by closing up their shell, as the box turtle; by snapping and scratching, as the snapping turtle; by swimming away or by hiding in the mud, and thus escaping by the protective resemblance. They hibernate in winter in this latitude.

The **leathery shelled sea-turtle** (*Sphar'gis coriacea*) is the largest of all recent turtles. It is from 6 to 8 feet long, and of a dark brown color, and may weigh 500 pounds or more. It is widely distributed in the tropical seas, but it is abundant nowhere. The dorsal and ventral portions of the weak bony shell are continuous. It is buried under a layer of fat which yields "about a pint of oil to each square foot."[1] The sea-turtles have long flat triangular flippers without toes or claws. The front flippers are long. Its flesh is not edible.

**Hard-shelled Sea-turtles** (*Chelon'idæ*).—In this group is found the green turtle, one of the most widely distributed of the Atlantic turtles. It is found from Long Island to Cuba and south to Brazil and also in the Indian Ocean. Its flesh is prized for food. It varies in weight from 50 to 500 pounds.

The **tortoise-shell turtle,** from which is obtained the valuable tortoise shell, has its upper jaw terminated in a strongly hooked beak. Until the animal is very old the shields overlap one another from before backward. The scales are clear yellowish horn beautifully mottled with black and brown. These turtles do not reach the size of the green turtle; the largest one on record, says Gadow, is 34 inches long. They range over all the tropical and subtropical seas, being found occasionally around the Bahama Islands.

The **soft-shelled turtles** (*Trionych'idæ*) are of wide distribution both in time and space. The shell is very flat and almost circular. It is imperfectly ossified both above and below, and terminates at the edges in thin plates of leathery skin. When properly cooked the shell is tasty.[2] These turtles are brown, mottled with black above and clear white below, and weigh from 20 to 30 pounds.

**The Snapping Terrapins** (*Chelyd'ridæ*).—This family includes the alligator snapper, the largest North American terrapin of the Gulf States, and our common "snapping turtle" found everywhere in fresh-water ponds and streams. The snapping terrapin has very powerful strongly hooked jaws, a long tail with a crest of bony compressed tubercles, and a small cross-shaped plastron. It seldom leaves the water. It is carnivorous, very voracious, and savage. It is destructive to fishes and water birds.

**The Smooth-shelled Terrapins** (*Emyd'idæ*).—The diamond-back terrapin is found (or was until so much hunted for food) in salt marshes from New York to Teaxs. It varies in color from greenish to dark olive or black (rarely). It is small, one weighing a pound is considered large. It is regarded as the choicest variety for a terrapin stew. It is said that there are several "terrapin farms" in the South in which this turtle is being reared for the market. Unless some such provision is made they will soon be exterminated.

The **painted terrapin** (*Chry'semys pic'ta*) is common in most regions east of the Mississippi. The shell is much depressed. The plates of the carapace in *Chrysemys picta* are greenish black edged with yellow, those about

[1] Hornaday, p. 331.
[2] Ibid.

the margin being conspicuously marked with red. The plastron is yellow, blotched with brown. There are markings of yellow and red upon the sides, neck, limbs, and tail, a pair of bright yellow patches behind the eyes, and a smaller pair on the back of the head. The toes are strong and broadly webbed. They are especially fond of insects and worms. They are very shy and active. *Chrysemys marginata* is a western form.

The **common box-turtle** (*Cistu'do*), a terrestrial member of this group, is built for life on land. Its carapace is high and it can withdraw its head, legs, and tail within it. Across the center of the plastron is a double hinge, so that when disturbed it completely shuts itself in the box, and nothing short of injuring the shell can harm it. One was once subjected to a strong dose of chloroform in our tight-covered " killing jar " for two hours with little or no effect, so tightly was it shut up in its box. It is surely a good illustration of special adaptation to environment. Since it cannot run, like the rabbit, nor swim, like its relatives of the streams, it closes up its house and remains motionless. It is found from New York to Missouri and southward.

The **musk terrapin** (*Aromoch'elys odora'tus*), a representative of the family *Kinosternidæ*, is a small fresh-water specimen which has a strong, musky characteristic odor. Its food consists of aquatic insects, small fishes, and worms.

**The Land Tortoises** (*Testudin'idæ*).—The giant tortoise, which inhabits the Galapagos Islands and two islands of the Indian Ocean, is the only survivor of a race of giant tortoises of the Reptilian Age. A specimen once in the New York Zoölogical Garden weighed 310 pounds, and was estimated to be four hundred years old.

Almost every island of the Galapagos group has had or has its own peculiar form of tortoise. How they got to these islands or where they came from it is impossible to say definitely. They could not have migrated, since land tortoises are easily drowned, and anyway, " there are now none of their kind on the continents of Asia, Africa, or South America."[1] So it is assumed that they are descendants of tortoises once populating the land which, except these islands, now lies below the Indian Ocean.

Our native species of this family is the Gopher tortoise, found in the pine barrens of the Southern States.

## ORDER V. CROCODILIA

**Crocodiles** and **alligators** are the largest of living reptiles, some of the largest crocodiles attaining a length of 30 feet. They are covered with horny plates or scales.

The **head** is remarkable for its powerful jaws, whose enormous gape enables the animal to seize and crush its prey.

[1] Gadow.

The eyes, nostrils, and ears are on top of the head. While exposing only a small part of its body, it can see and hear well the approach of an enemy. "Crocodiles are the only reptiles whose nostrils open in the throat behind the palate instead of directly into the mouth cavity. This enables the crocodile to drown its victim without drowning itself, for by keeping its snout above water it can breathe with its mouth wide open."[1] When under water the nostrils are closed by a valve.

**Limbs and Tail.**—Their four limbs are stout, short, and powerful. The tail is strong and compressed. It aids the animal in locomotion, in self-defense, and in knocking its prey off the bank into the water, where it is seized and held under water until strangled to death.

**Habits.**—They are aquatic and nocturnal in activity, feeding at night upon fishes, birds, mammals, and whatever they can capture. Hornaday describes how an alligator dismembered its victim. It seized the prey by one leg, whirled itself round and round till the leg was twisted off. He saw another shake a companion until the skin of its back was torn in two.

They hibernate in temperate regions, and estivate or migrate in tropical regions when drought overtakes them.

The Florida crocodile digs burrows in the sandy banks. The entrances are wholly or partly under water. At the farther end the burrow is wide enough for the crocodile to turn round in.

They lay their large white eggs in the sand away from the water, or build rude nests or mounds in which they deposit their eggs in layers and watch and defend them until the young are hatched.

The **ga'vial of India** (Fig. 207) is long, and slender snouted. The animal may reach a length of 20 feet, but is harmless to man, being a fish-eater.

**Alligators.**—The male alligator may reach a length of 12 feet and the female that of 8. The male has a heavier and more powerful head and is the more brilliantly colored during the breeding season. The large nest is built by the female on the bank of a stream or pool. The young are active and shift for themselves. The alligator finds its northern limit in North Carolina, about 35° North Latitude. From here south they abound near the mouths of creeks and rivers as far south as the Rio Grande. They ascend the Mississippi to 33° 50″ North Latitude, or to the mouth of the Red River.

There is a small species of alligator in China. It is about 6 feet long, of a greenish black color dotted with yellow.

[1] Dodge, p. 476.

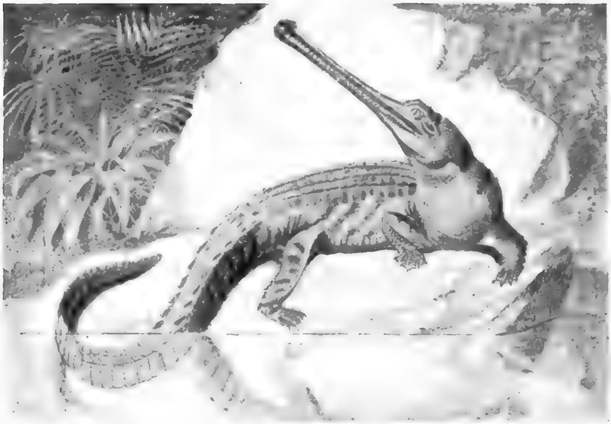


Fig. 207.—Gavial (*Gavia'lis gange'tica*). (From Baskett and Ditmars, "The Story of the Amphibians and Reptiles," D. Appleton and Co., Publishers.)

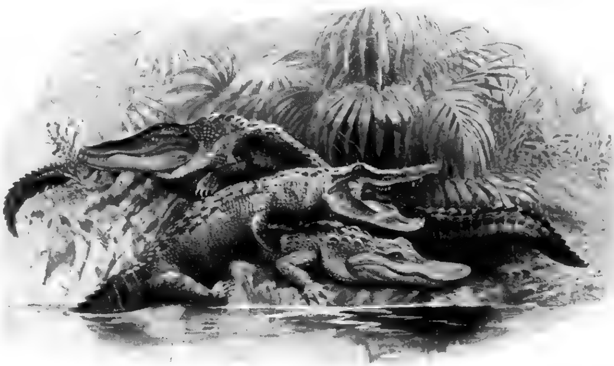


Fig. 208.—Crocodiles. (From Baskett and Ditmars, "The Story of the Amphibians and Reptiles," D. Appleton and Co., Publishers.)

The **caiman,** of Central and South America and the West Indies, is something like our alligators and may reach a length of from 6 to 20 feet.

The **crocodile** (Fig. 208) of the Nile and Madagascar and Asia is the largest of the order, sometimes reaching a length of over 20 feet. Hornaday says four species of crocodiles are found in America, and that only three of the nineteen species of crocodiles are dangerous to man, the most dangerous of these being the "salt-water crocodile" of the Malay Peninsula. The American crocodile and the alligator are not dangerous to man.

"The Florida crocodile is the only crocodile which inhabits a country that is visited by killing frosts."[1] It is most abundant in low wet lands and shallow water, where the mainland sinks into the gulf. There is a Cuban crocodile and two South American species.

**Distribution of Reptiles.**—The animals of this class are generally tropical and subtropical. Snakes are said to extend farther north in America than do lizards. In Europe snakes are not found north of 60°, while lizards are sometimes found farther north or at an elevation of ten thousand feet.

Lizards are the most numerous of reptiles at the present time, and are found in all except the circumpolar regions.

Chelonia are also widely distributed in the tropical and temperate regions.

The alligators occur only in North America and in China, and the Caimans are found only in Central and South America. Crocodiles are distributed over Africa, southern Asia, northern Australia, and tropical America, there being one species in Florida.

True reptiles are known to have existed in the Permian Period. Indeed, there was such a "variegated reptilian fauna" that it is believed their ancestors must have lived in the Carboniferous Period. One of the Permian orders (*Theromor'pha*) exhibits certain strong points of resemblance to the earliest amphibians and other points of resemblance to the lower animals. They have been found in rocks of the Permian and Triassic Periods, but in none of the more recent formations. These fossils have been found in Texas, South America, Europe, Africa, and India.

Lizard-like forms (*Sauroptery'gia*) existed in the Cretaceous and Triassic and possibly in the Permian periods. They varied from small forms up to those of 40 feet in length. A fish-like form (*Ichthyoptery'gia*), varying from 30 to 40 feet in length, existed from the upper Triassic to the upper Cretaceous periods. In the Triassic were also forms allied to the crocodile.

One of the most characteristic of the Mesozoic orders of reptiles was the Dinosauria, many of which existed in the Triassic Period. Some were herbivorous, others carnivorous. Some

[1] Hornaday.

walked on all fours, others occasionally or habitually walked upright, after the manner of birds, with which they had many structural features in common. Their size was so great that the footprints measured from 14 to 18 inches. The length was sometimes 60 to 70 feet and the height nearly 20 feet.

The earliest turtles were found in the Triassic of Europe. True lizards appeared and turtles abounded in the Jurassic. The *Pterosau'ria* appeared in the Jurassic. They had toothed jaws and were winged like a bat. The spread of wings did not exceed 3 feet. In the Cretaceous Period the spread of wings was 20 feet. Gigantic carnivorous marine lizards swarmed on the Atlantic and Gulf coasts and in the interior seas of that time.

In the tertiary period reptilian life shows a great change, the animals being neither so large nor so varied.

All the fossil snakes, except one found in the cretaceous, have been found in the tertiary period.[1]

It is plain to be seen why the Mesozoic Era is called the "age of reptiles," and how closely related the reptiles are to both amphibians and birds. They differ from amphibians in having bodies covered with scales, in having but one occipital condyle, in having the embryonic membranes, the amnion and allantois; in Crocodilia, in having a four-chambered heart; in never having gills, and in never having a tadpole stage. They differ from birds in having scales, but never feathers, and in the circulation (being poikilothermal). If we include the extinct forms, there will be found many points of similarity between reptiles and birds. Hence it is believed that amphibians, reptiles, and birds have a common ancestry.

**Economic Importance.**—As has been mentioned, many reptiles are used for food. The skins of rattlesnakes and boas are made into bags, cases, boots, saddle cloth, etc. The oil of the rattlesnake and boas is valuable, and that of the copperhead is used in medicine. The scales of the tortoise-shell turtle are valued for combs and ornaments, and the oil from its eggs is used in dressing leather. From alligators we get valuable leather, oil, and musk. The teeth, flesh, hide, and oil of crocodiles are valued.

Most of our common forms are not dangerous to man, and,

[1] Parker and Haswell.

17

any way, will not attack him if unmolested. A few forms of snakes and crocodiles are dangerous to man.

**Important Biologic Facts.**—The embryonic membranes, the amnion and the allantois, first appear in this class. Respiration is by lungs. True nostrils appear. The heart is four chambered in Crocodilia.

**Classification.**—

| *Order.* | *Examples.* |
|---|---|
| I. Rhy̆nchocepha′lia. | Sphenodon punctatum. |
| II. Ophĭd′ia. | Snakes. |
| III. Lăcertĭl′ia. | Lizards. |
| IV. Chēlō′nia. | Turtles. |
| V. Crŏcodĭl′ia. | Crocodiles, alligators. |

## CLASS V. AVES

"I have considered the birds,
And I find their life good,
And better, the better understood."
(McDonald.)

In existing forms, birds are feathered chordates having no teeth, but from paleontology we learn that some of the fossil birds (Figs. 209–212), as the *Archæop′teryx* (Fig. 212), of the Jurassic Period, had teeth and a long vertebrated tail.

Birds have several characteristics in common with reptiles, among which are the large eggs, the lack of a complete diaphragm, the quadrate bone connecting the lower jaw with the skull, and the single occipital condyle. It is believed that in the early stages of their development birds floated in the air by means of a *patagium*, or wing membrane, and that even "feathers were used at first as a means of sailing down" after having crawled up to some height by the use of claws on the "fingers," vestiges of which are yet shown by many birds, such as the turkey, the vulture, certain ostriches, swans, thrushes, and young gallinules, which have claws variously located on the wing tips.

**Covering.**—The lower part of the legs is covered with hard, reptile-like scales, or epidermal shields, for protection. The beak and claws are also horny epidermal structures.

The skin of a bird is thin and the body is not uniformly covered with feathers (Fig. 213). There are many bare spots, as may be readily seen by turning back the feathers on the neck or breast. The bare spaces, *apteria*, are concealed by the overlapping feathers. Note where the feathers grow. These spaces are called *pterylæ*, from two Greek words meaning "feather forest."

Feathers are homologous with scales, as "the feather may be regarded as a cornified outgrowth from the skin, which has arisen

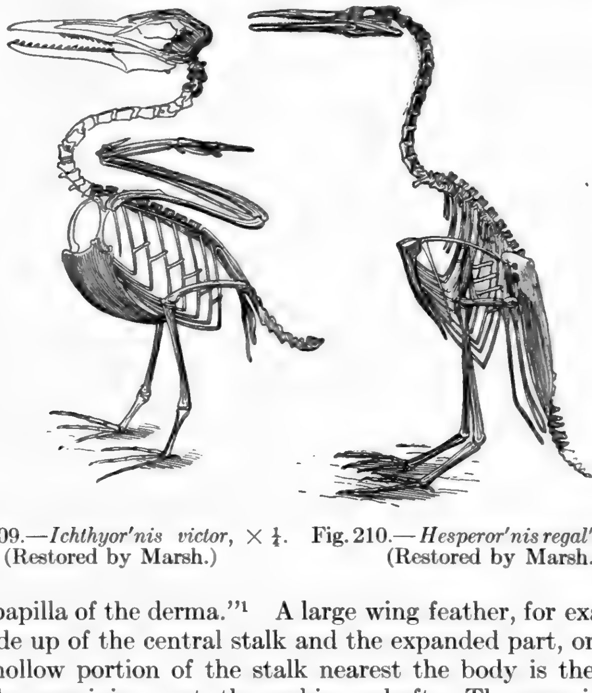


Fig. 209.—*Ichthyor'nis victor*, $\times \frac{1}{4}$. (Restored by Marsh.) Fig. 210.—*Hesperor'nis regal'is*, $\times \frac{1}{16}$. (Restored by Marsh.)

on a papilla of the derma."[1] A large wing feather, for example, is made up of the central stalk and the expanded part, or vane. The hollow portion of the stalk nearest the body is the quill, and the remaining part, the rachis or shaft. The vane is composed of side branches or barbs, the barbs of side branchlets or barbules, which are provided with hooks. The hooks of one barbule interlock with those of the next and thus hold the parts of the vane together. In down feathers the hooks are lacking.

[1] Hertwig.

The large feathers on the wing and tail are called quills; the similar but smaller ones on the body, the contour or outline feathers; those without barbs, down; and the hair-like ones, the filoplumes or pin-feathers. These different kinds have various

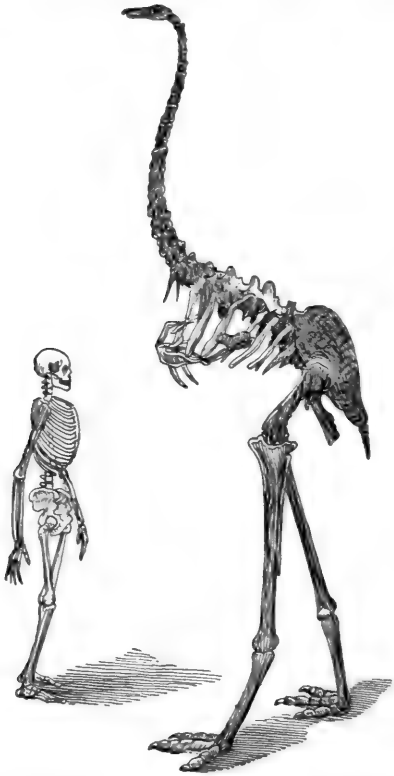


Fig. 211.—*Dinor'nis giganteus*, $\times \frac{1}{36}$. (From a photograph of a skeleton in Christchurch Museum, New Zealand.)

uses. Can the student see the advantage to the bird of each kind of feather? What use does man make of the different kinds of feathers?

"Since the feathers are not only for protection, but give to most birds the power of prolonged flight, they predict a special mode of life. The character of the skeleton, the respiratory organs, and, in part, the sense organs and brain are connected with the powers of flight."[1]

**Variation in Plumage.**—The changing of the feathers and the colors of birds is very little understood. The nestling plumage may be so meager that we speak of the young as naked, but the precocial forms, as the grouse, snipes, and ducks, have a thick covering of down. This is followed by what is known as the


Fig. 212.—*A*, *Archæopteryx macura*, restored (Fowler). *B*, Section of the tail (after Owen). (Romanes.)

first plumage, which appears more quickly upon the naked than upon the down-covered young and which may be unlike that of either parent. In most land birds this is soon followed by the immature plumage to be worn during the winter. This plumage may be like that of the adult parent of the same sex, or it may be that both immature males and females may resemble the adult female, or they may be unlike either parent. In the

[1] Hertwig, p. 604.

first, second, or even the third spring the plumage becomes like that of the adult.

The time of molting varies not only among different species, but often among different individuals of the same species, according to sex, age, and physical conditions. All birds molt after the nesting season. Some birds lose a few of the body feathers in the next spring before the nesting season, while many lose the body feathers, but not those of the wing and tail. Some change

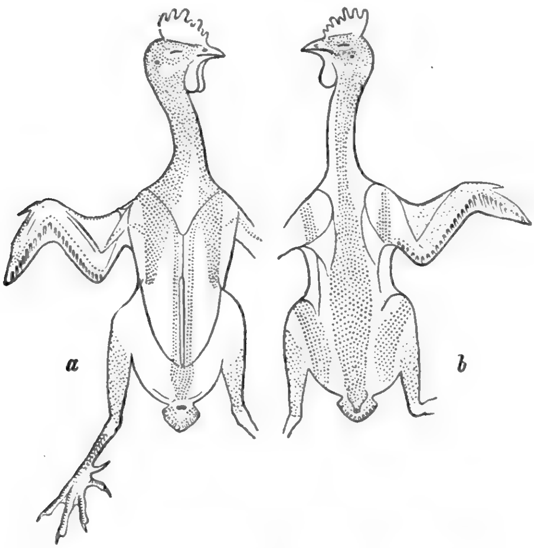



Fig. 213.—Pterylæ and apteria of *Gallus bankiva* (Nitzsch): *a*, Ventral side; *b*, dorsal side.

color by wearing off the fringes of the feather tips, and others at this season are adorned with special nuptial plumes,[1] such as the aigrette of the heron, for which these birds have been so slaughtered.

There are no periodic molts of the skin, as in reptiles, but the horny layer of the integument undergoes a constant renewal, as in mammals. Some penguins, it is said, "exhibit the old rep-

[1] Chapman, " Bird Life," p. 38.

tilian habit of shedding theirs in great flakes, with feathers attached."[1]

**General Structure.**—The skull (Fig. 214) is thin; the bill or horny beak varies much according to its use; and there is, as in reptiles, only one occipital condyle. The neck is long and flexible. In different kinds of birds, the number of neck vertebræ varies from eight to twenty-four.

The *wings* are adapted for flight in our birds. While the ostrich cannot fly, its rudimentary wings are compensated for by its very strong legs, which are adapted for rapid running. No other animal has wings of the same structure as a bird's. The characteristic structure of the wing-bones is the hand. It is comparable with the human hand.

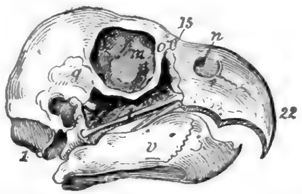



Fig. 214.—Skull of parrot: 22, Premaxillary bone ensheathed in horn; 15, nasal bones; *v*, mandible, the end sheathed with horn; *l*, malosquamosal zygomatic style or maxillojugal bar; *g*, postfrontal bone; *o*, lacrimal bone; *n*, nostril, showing also the articulation of the nasopremaxillary bone; *e*, quadrate bone; *m*, orbit; 1, occipital bone. (After Owen.)

The legs and feet (Fig. 215) of birds are adapted for running, scratching, swimming, or perching. Note the position of the thigh (femur) on the side of a bird. Do you see any advantage of such a position? Distally the femur or thigh is joined to the *tibiotarsus* and the *fibula,* which is found partially united with the tibiotarsus. The proximal row of tarsal bones unites with the distal end of the tibia, hence the name *tibiotarsus* or "drumstick" in the chicken. The distal row of tarsal bones unites with the metatarsal bones to form the *tarsometatarsus* or simply the tarsus, which bears the usually four-clawed toes. One toe is generally directed backward and three forward.

Where is the knee in the bird? The ankle? Do you see any

[1] Baskett, "Story of the Birds," p. 33.

advantage in this arrangement? Why do they differ from the structure and arrangement in the leg of man?

The *body skeleton* (Fig. 216) is strong, light, and flexible, as it must be for flight. Note how firmly the vertebræ are joined in

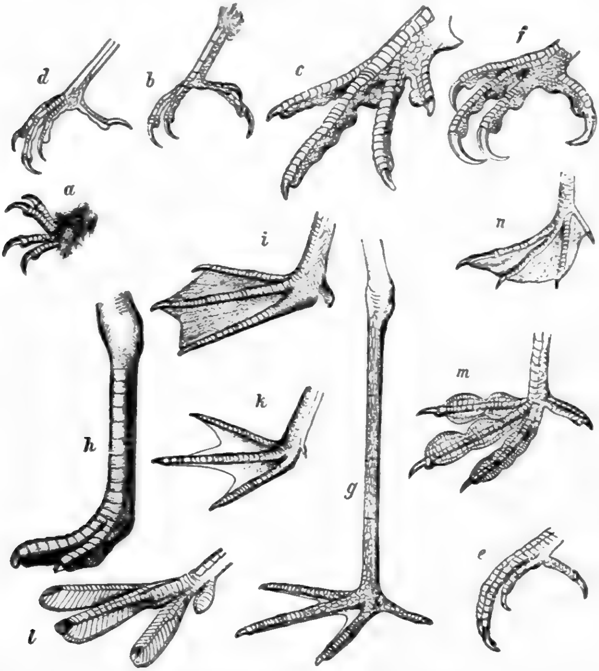



Fig. 215.—The most important forms of birds' feet (*b, c, d, f, n*, from the règne animal): *a*, Pes adhamans of *Cypselus apus; b*, P. scansorius of *Picus capensis; c*, P. ambulatorius of *Phasianus colchicus; d*, P. fissus of *Turdus torquatus; e*, P. gressorius of *Alcedo ispida; f*, P. insidens of *Falco biarmicus; g*, P. colligatus of *Mycteria senegalensis; h*, P. cursorius of *Struthio camelus; i*, P. palmatus of *Mergus merganser; k*, P. semipalmatus of *Recurvirostra avocetta; l*, P. fissipalmatus of *Podiceps cristatus; m*, P. lobatus of *Fulica atra; n*, P. steganus of *Phaëton æthereus*. (After Claus.)

the back. Note also the very short bony tail, consisting of a few vertebræ fused into the pygostyle, which supports the tail feathers. The oil gland is situated near the pygostyle and from it birds get the oil for their feathers. Note also that the sternum is keeled in our birds, while the keel is lacking in the ostrich. The keel or carina is a basis of classification. Birds with the keel poorly or not at all developed are called *Ratī'tæ*, or raft-like birds, while the keeled birds are called *Carinā'tæ*, which group contains our native American birds.

The shoulder-girdle is a peculiar device of flying creatures. It consists of the scapula, coracoid process, and the V-shaped

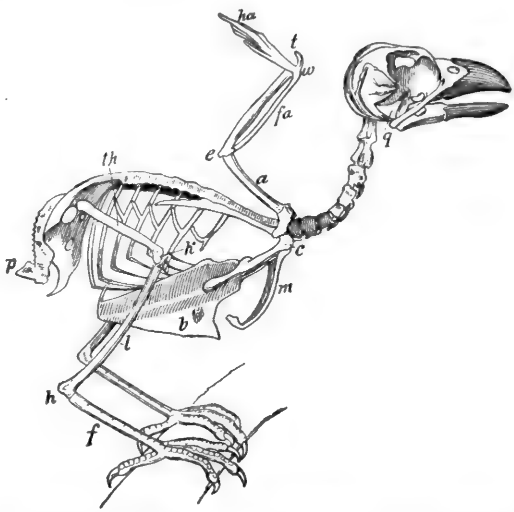



Fig. 216.—Skeleton of a sparrow: *q*, Quadrate bone, peculiar to reptiles and birds and some *amphibia; b*, breast-bone; *m*, merry-thought or collar-bone; *c*, coracoid bone, over which the tendon works to pull up the wing; *p*, plowshare-bone, on which the tail grows. Wing-bones: *a*, Upper-arm; *e*, elbow; *fa*, fore-arm; *w*, wrist; *t*, thumb; *ha*, hand. Leg-bones: *th*, Thigh-bone; *k*, knee; *l*, lower part of leg; *h*, heel; *f*, foot. (From Holder, American Book Co., Publishers.)

clavicle, or "wish-bone." The pelvic girdle consists of three paired bones, *ilium*, *ischium*, and *os pubis*, which unite at the cup or *acetabulum*, which holds the head of the femur.

A careful study of the skeleton of a bird shows its marvelous adaptation to its uses. It must be strong to support the great muscles of flight and to protect the viscera, while it must be light and flexible for the purpose of aërial locomotion.

**The Digestive System.**—The mouth is devoid of teeth in existing birds. Extinct birds (see Figs. 209 and 210) had teeth (see Geology). Can the student see any reason why birds have lost their teeth? The beak (Fig. 217) is very strong in birds of prey, such as the eagle and hawk. The mouth opens into the

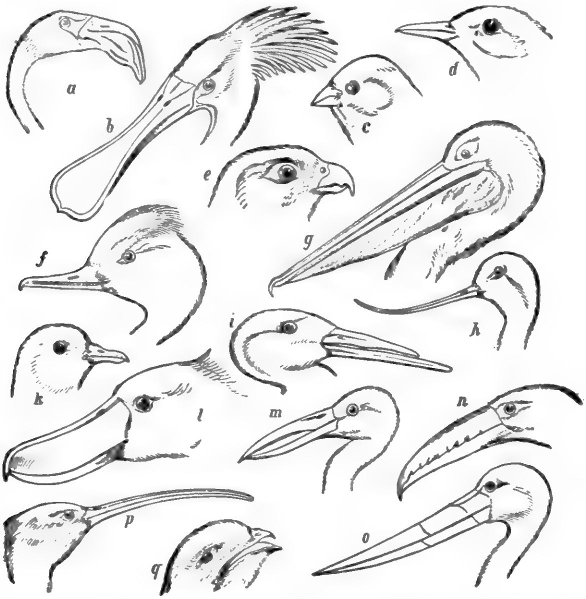



Fig. 217.—Forms of beaks (*a, b, c, d, k*, after Naumann; *g, i, m, o*, règne animal; *l*, from Brehm): *a, Phœnicopterus antiquorum; b, Platalea leucorodia; c, Emberiza citrinella; d, Turdus cyanus; e, Falco candicans; f, Mergus merganser; g, Pelecanus perspicillatus; h, Recurvirostra avocetta; i, Rhynchops nigra; k, Columba livia; l, Balæniceps rex; m, Anastomos coromandelianus; n, Pteroglossus discolor; o, Mycteria senegalensis; p, Falcinellies igneus; q, Cypselus apus.* (After Claus.)

esophagus, which opens into the large crop, in which the bird rapidly stores its food, which is passed on to the glandular stomach or *proventriculus*. It is then passed to the muscular gizzard, where with the aid of gravel and other hard substances, the food is ground fine. The spleen is a small, red ovoid body at the right of the *proventriculus*. Following the gizzard is the duodenum. The pancreas is in a loop of the duodenum and pours its secretion into it. The large liver pours its bile into the duodenum. The ileum continues from the duodenum to the large, straight intestine, the rectum. The junction is marked by long, blind pouches or ceca. The large intestine ends in an enlargement called the cloaca, or sewer, because it receives the undigested food, the excretions of various organs, and the eggs, all of which pass out by one external opening.

**Circulatory System.**—Circulation is complete. The heart is large and composed of two auricles and two ventricles. The right aortic arch persists in birds, while the left persists in man. The circulation is double, pulmonary and systemic. The septum is complete between the ventricles, thus keeping the impure blood (venous) from the pure blood (arterial).

**The Respiratory System.**—The pharynx opens by the glottis into the trachea, which divides and sends ramifying branches into the lungs. The lungs connect with the system of air-sacs which aid the bird in flight. "Usually five pairs of these sacs are present, largely in the cœlom, but extending in between the muscles (breast and axillary region) and also into the bones."[1] The syrinx or voice-box is at the junction of the bronchial tubes and the trachea, where they enlarge to form it. This syrinx is especially well-developed in singing birds.

Many of the bones are hollow and filled with air. Thus is the inspired air distributed over the body, so that the aëration of the blood is not confined to the limited area of an ordinary organ of respiration. The bird is a very warm-blooded animal, and to keep up its heat it must use oxygen rapidly. This it does by its rapid breathing, which may be at the rate of sixty per minute. The temperature of birds is from 100° to 110° F., while in man the temperature is 98.6° F. The temperature is also kept up by the non-conducting feathers and by the absence of skin glands, with the exception of the oil gland at the base of the tail.

In the absence of a diaphragm, expiration is effected by the drawing of the sternum toward the spinal column and the bending of the hinged ribs. Inspiration is effected by the straightening of the ribs brought about by relaxing the muscles. Thus the

[1] Hertwig.

lungs, which are attached to the ribs, are alternately enlarged and contracted.

**The Excretory System.**—With each expiration the lungs excrete carbon dioxid and other waste products. The kidneys are dark-colored, paired organs lying in the pelvic region close against the back. They open into the cloaca by the ureters.

**The Reproductive System.**—Anterior to the kidneys are the reproductive organs, which open into the cloaca. Multiplication is by eggs, which are noted for their very large size. The egg begins in the left ovary, the right ovary not being developed.

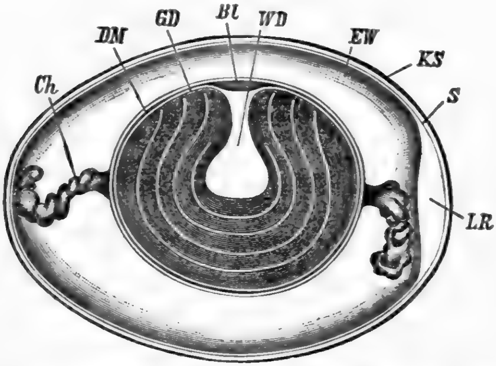



Fig. 218.—Diagrammatic longitudinal section through an undeveloped hen's egg: *Bl*, Germinal disk; *GD*, yellow yolk; *WD*, white yolk; *DM*, vitelline membrane; *EW*, albumen; *Ch*, chalazæ; *S*, shell membrane; *KS*, calcareous shell; *LR*, air-chamber. (After Allen Thompson.)

It passes into the oviduct, where it is fertilized. As it passes on down this duct it acquires the yolk, the white, the linings, and the shell from glands that secrete these essential parts of the egg (Fig. 218). The birds are developed by the large amount of food within the shell.

Incubation, or sitting upon the eggs for a definite period of time, is peculiar to birds, though the python is said to coil upon its eggs. The number of eggs in a clutch varies from one to a score or more. Some birds, like the pigeon, are monogamous, choosing one mate for life, but many are polygamous, like the barnyard fowls. It is said that most pretty birds are flirts.

The young of some birds are altricial (Fig. 219) and must be cared for and fed by the parent or parents; while others, like


Fig. 219.—The altricial nestlings of the blue jay (*Cyanocit'ta crista'ta*). (From Jordan and Kellogg, "Animal Life," D. Appleton and Co., Publishers.)

the quail, are precocial and are able to feed and care for themselves as soon as hatched.

The nests of birds vary much according to the habitat of the bird and the material available (Fig. 220). Birds, like men, use the material they find about them. Ground birds use the material they find on the ground, while the arboreal forms more often use small twigs for their nests, which they sometimes line with finer material, such as strings and hairs. The woodpecker uses no material but the tiny chips he has made in digging the hole. The swift glues together the twigs of its nest by a sticky saliva. According to the manner in which they construct their nests, birds have been variously styled weavers, tailors (Fig. 221), carpenters, or masons, and their tools vary according to

Fig. 220.—Brown pelican and nest in young cabbage palmetto. (Photograph by Frank M. Chapman.) (Y. B. U. S. Dept. of Agricul.)

the work to be done, or vice versa. Sometimes both sexes build the nest, or one collects the material and the other arranges it. In other cases the male sits by and sings, leaving the building to his mate. The position of the nest varies. It may be placed upon the ground, like that of the quail, or on a rock, like the penguin's, or suspended far out on the swaying branches, like the delicate hanging nest of the oriole (Fig. 222). The object of the position, of course, is for protection. One must observe how well birds are protected by their colors, especially the female birds at nesting time.

**The Nervous System and Special Senses.**—The *brain* (Fig. 223) of birds is larger and more highly developed than that of reptiles. The cerebrum and cerebellum are larger. The cerebrum is smooth, but the cerebellum is convoluted transversely.

Fig. 221.—Tailor-bird (*Orthot'omus suto'rius*) and nest. (From Jordan and Kellogg, "Animal Life," D. Appleton & Co., publishers.)

The *eyes* of the bird are large, to meet the demands of far vision in flight. There are two movable eyelids and a third membrane called the nictitating membrane, which the bird can draw over the eye by a peculiar muscular arrangement. This membrane protects the eye from too bright light (Fig. 196). The *pecten*, "a comb-shaped growth of the coroid into the vitreous body," is a peculiar avian characteristic. The avian eye is characterized not only by the sharpness of vision consequent upon the

Fig. 222.—Baltimore orioles and nest; the male in upper left-hand corner of figure. (From Jordan and Kellogg, "Animal Life," D. Appleton & Co., publishers.)

large size and complicated structure of the retina, but also by the highly developed power of accommodation, and by the great mobility of the muscular iris in the dilation and contraction of the pupil.

The *ear* is well developed. There is no external ear, but the opening to the tympanum is concealed by feathers posterior to the eye. The ear has three semicircular canals, the dilated cochlea, and a Eustachian tube extending to the mouth from each ear.

Of the other senses it may be stated that touch is common in all parts of the body; that taste is poorly developed; that smell is apparently not very acute, except in vultures or turkey buzzards and other carrion-eating birds.

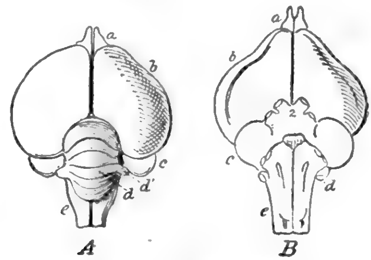



Fig. 223.—Brain of the hen (*A*, from above; *B*, from below): *a*, Olfactory bulbs; *b*, cerebral hemispheres; *c*, optic lobes; *d*, cerebellum; *d'*, its lateral parts; *e*, medulla. (After Carus, from Gegenbaur.)

**Behavior and Intelligence.**—As has been said of other animals, it is exceedingly difficult to judge what goes on in the mind of a bird without ever having been a bird. It is very probable that many writers upon animal intelligence give birds credit for

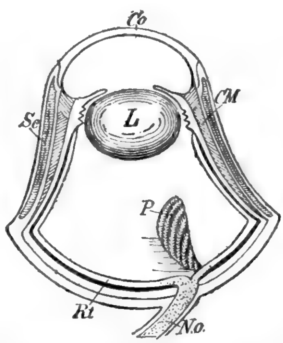



Fig. 224.—Eye of a nocturnal bird of prey: *Co*, Cornea; *L*, lens; *Rt*, retina; *P*, pecten; *N.o.*, optic nerve; *Sc*, ossifications of the sclerotic; *CM*, ciliary muscle. (After Wiedersheim.)

a higher intelligence than they possess because they draw mistaken conclusions from bird activities, or, more often, because observations have been inaccurate or incomplete. When a child performs a certain action, we ascribe to him certain sensations, emotions, or phases of intelligence. When a bird does the same thing, it is only fair to believe that these same activities are accompanied by similar, though perhaps less distinguishable, psychologic processes. If we deal fairly, and our *observations* are *complete*, much may be learned to add to the meager information given in our scientific books upon this fascinating subject. Always ask these questions: Exactly what did the bird do? Under precisely what circumstances? Possible causes? Most probable cause? Does the result of the bird's action prove that your conclusion is correct?

Scientists differ widely in their opinions on bird mind, but it is thought that there is abundant proof that, in intelligence, birds stand next to mammals, if they do not surpass some of them. All will surely agree that birds feel pleasure and pain; that they exhibit surprise, fear, sexual feeling, sexual selection, parental affection, curiosity, industry, pugnacity, anger, jealousy, play, grief, and a wonderful homing instinct.[1] Many examples are recorded which seem to show sympathy, revenge, recognition of persons, and affection for, or, at least, attachment to, their human friends. Birds recognize their offspring, they have memory, association of ideas, and communication of ideas. Examples are given by some of recognition of pictures. It is hoped that this will be further experimented with. Bower birds (Fig. 225) and others show an appreciation of beautiful surroundings, while many birds seem to appreciate the brilliant colors and songs of their mates. By experimenting with different colored foods it has been proved that birds can distinguish colors in objects and that they learn by experience and make intelligent choice. The best possible treatise on the psychology of birds is the living, acting bird which every student can have almost every day in the year. Study the birds. Make accurate observations and record them. Weigh your conclusions.

**The Migration of Birds.**—There is no theory which satisfactorily accounts for the periodic coming and going of the birds. One theory attributes it to the varying temperature. Another theory attributes it to a lack of food, but many of our birds come in March, when food is still scarce and the temperature low, and

[1] Romanes, "Animal Intelligence." Also Darwin, "Origin of Species."

leave in August or September, when there is still an abundance of food. Another theory is that of securing better and more protected breeding grounds. Nest concealing is possibly a factor. Chapman believes that the origin of this great pilgrimage "is found in the existence of an annual nesting season," and that it is exactly paralleled by the annual migration of certain fishes to their spawning grounds, and the regular return of seals to their breeding-rookeries. But what seems to us most strange is that the

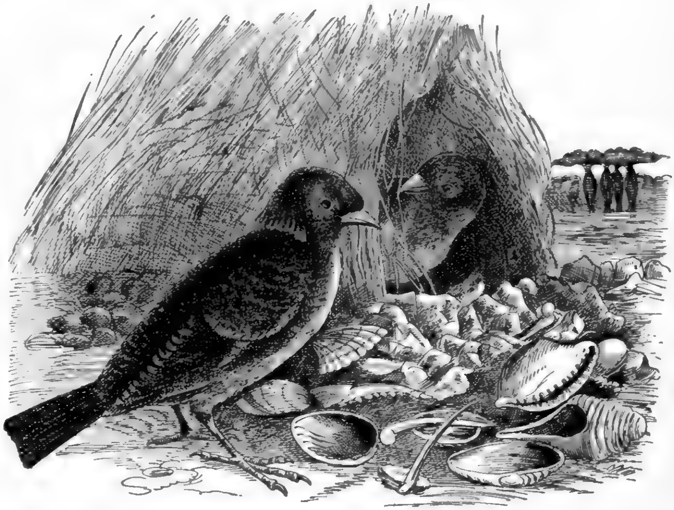


Fig. 225.—Bower bird (*Chlamydera maculata*) with bower. (From Brehm.)

same species of birds takes the same definite route of migration for generations, except that its range is gradually lessened or extended. Chapman gives as an illustration of the stability of routes of migration the bobolinks, which are Eastern birds, now spread westward to Utah, yet, instead of migrating directly south through Texas and Mexico, they, "true to their inherited habit, retrace their steps and leave the United States by the round-a-bout way of Florida, crossing thence to Cuba, Jamaica, and Yucatan, and wintering south of the Amazon."[1] The extent

[1] Chapman's "Bird Life," p. 60.

of these migrations varies. Some birds do not migrate, but stay all winter in the same locality, often changing from an insectivorous to a seed-eating life. Others migrate but short distances. The snipes and plovers make extended migrations, going from the arctic regions to the tropics, some species travelling from Alaska to Patagonia.

**Parasitism.**—The American cow-bird and European cuckoo lay their eggs in the nests of other birds, where the young are cared for by the foster parents, often at the loss of their own offspring.

**Rivalry** among birds may be by means of ornament, color, antics, battle, or song. The male is usually more brightly colored than the female and puts on his most brilliant attire at the courting season. Rarely the female is more brilliantly colored than the male (see p. 291). In this case she does the courting, but as a rule the female is much more inconspicuously colored, since she is generally the one which sits upon the nest, and it is to the interest of the family that she be protectively colored. Darwin believes[1] in the choice of the female in mating, and that the attractiveness of the male may lie in the tinted or lengthened beak, or the striped or brightly colored feet, or the bright wattles or other appendages about the head; but the most common and the most brilliant display of colors is in the plumage. Some think that the health and vigor generally may be the cause of this brilliancy, but Darwin believes that it has been intensified from generation to generation by the choice of the females, thus perpetuating these characteristic pleasing colors and color-patterns in the offspring. Mr. Wallace, strangely enough, denies the female any part in the matter of mating, while he "ascribes to natural selection any secondary sexual character which is of practical use to the male in conflict with a rival."[2] Some birds seem to be more easily pleased by antics and pranks which are sometimes connected with the display of ornament and sometimes not, as if he who made the biggest clown of himself was the favored suitor.[3] A familiar example of the display of beauty-spots is afforded by the flicker which sits upon a twig facing his

[1] See Darwin's "Selection in Relation to Sex," "Descent of Man."
[2] Wallace's "Darwinism."
[3] Baskett, "Story of the Birds."

sweetheart, "lifts his wings, spreads his tail, and begins to nod right and left as he exhibits his moustache to his charmer and sets his jet locket first on one side of the twig and then on the other, and she plays back at him in a similar peek-a-boo fashion." The drumming of the grouse and the bill tattoo of the woodpecker are efforts to charm. Odor has no part to play in the art of pleasing among birds, for the musk duck is said to be the only bird which secretes an especially odorous substance.

Battle among birds may be for self-defense or for defense of young, but it is most commonly for rivalry, as both Wallace and Darwin believe. For bird battles there are various kinds of weapons. The cassowary has the elongated inner toe armed with a long straight claw and the short wing quills modified into spines. During the nesting season many males have wing spurs which subside into something like knobs when the season for their use is over. Unlike the bony wing-spur, the leg-spur is developed from the skin. Some birds fight fiercely, while others merely run a bluff by some terrifying attitude, wherein they display their wing-spurs.

**Song.**—There is much reason to think that the song of the male bird is a means of pleasing or courting the favor of his wished-for mate, though he afterward sings to cheer her during the period of incubation. The song often ceases when the young are hatched; there is something else to be done then. But the song is heard again during the preparation for the second brood.

There are many call-notes for other purposes than rivalry. Chapman says that "call-notes form the language of every day life, while song is the outburst of special emotion." The call of the mother to her young in warning, in fear, in reassurance when danger is over, the cry of hunger or distress in the young, the thankful little chirp when feeding or when cuddling under the mother's wing, the scolding of both parent birds when an enemy approaches the nest; all these and others have their significance in bird language. One would find this study far more interesting than that of a dead language and the opportunity for its pursuance is present everywhere. Try to imitate the various call-notes of the birds with which you are familiar and make a list.

**Classification.**—The classification of birds seems to be chaotic, no two zoölogists agreeing. Some claim birds are of too recent origin geologically to have differentiated as yet into well-marked orders. They might be grouped as land birds and water birds, or as runners and flyers, but such classification would not be scientific. If there were a geologic series showing the natural affinities, a natural classification would be a comparatively easy task, as all classification should be based on development and structure.

## Division A. Rati'tæ

Living birds are divided into two groups, the *Rati'tæ* and the *Carina'tæ*. Ratitæ are birds with a raft-like or keelless breast bone, wings rudimentary or too small for flight, legs large, strong, and fitted for rapid running. As examples may be

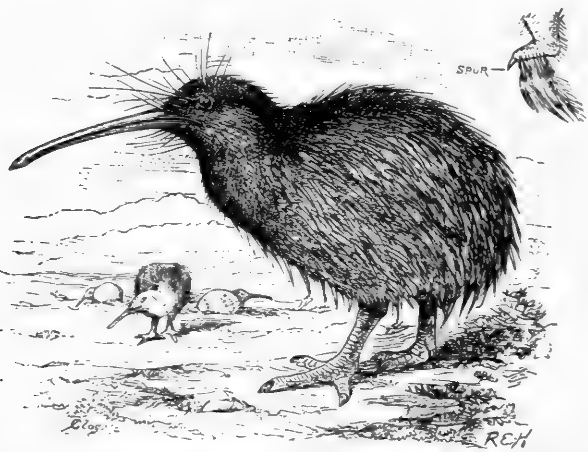



Fig. 226.—*Ap'teryx austral'is*, a nocturnal flightless bird with nostrils near the end of the bill. The external wing is shown in the upper part of the cut. (Romanes.)

named the ostrich, emu, rhea, cassowary, kiwi (Fig. 226), and the extinct moa and other ostrich-like birds. None of these birds is native to the United States, but in recent years they have been imported into some parts of the west, as Pasadena, California, Salt River Valley, Arizona, and some other dry, warm localities, where they are breeding and becoming of much value for their plumes.

The **ostrich** is the largest of living birds (Fig. 227). It may attain to a height of 6 or 8 feet, and may easily reach, with outstretched neck, a height of 10 feet. It weighs from 375 to 450 pounds. It is a rapid runner, a single stride is said to

Fig. 227.—Ostrich twenty-six months old. (Year-book U. S. Dept. Agricul., 1905.)

cover 25 feet or more.[1] It uses its two-toed feet in defense and its kick is dangerous. "The cry is said to be hoarse and mournful, resembling the roar of a lion or the lowing of an ox." The eggs are 5 or 6 inches in length, and one ostrich egg equals a score of common hen eggs. They are laid in a hollow nest in

[1] Evans, " Birds," p. 28.

the soil or sand and one nest may contain as many as twenty-five or thirty eggs, several hens laying in one nest. The male does most of the incubating, the eggs hatching in from forty to forty-five days. The ostrich is a native of Africa. It is found from Barbary to Arabia and even into Mesopotamia, where it has long been domesticated. "The plumes are plucked or, preferably, cut twice a year." The flesh is coarse and little

Fig. 228.—Ostriches five days old. (Year-book U. S. Dept. Agricul., 1905.)

used. The yearly sales in South Africa amount to nearly five million dollars.

The **three-toed rhea,** or so-called ostrich, is a South American bird. Rheas are shorter than the ostrich and the feathers are rounded and very soft. Their favorite haunts are the "treeless flats of the Argentine Pampas, the scrub-covered plains of Patagonia, or the dry open sertoes of Brazil."[1]

The **cassowaries** and **emus** have rudimentary wings, and they lack the ornamental wing and tail plumes. The hair-like coat is characteristic. The female cassowary is larger than the male, and both sexes are black. The plumage is made into rugs, mats, and head ornaments.

[1] Evans, " Birds."

## Division B. Carinatæ

This group contains the birds with a keeled breast-bone. It is usually divided into seventeen orders by American ornithologists. The orders of birds are not well differentiated as compared with the reptilian orders. The classification followed for Carinatæ is that of Reed and Chapman in their "Color Key to North American Birds."

### WATER BIRDS

**Order I. Pygop'odes.**—Auks, grebes, and loons are examples of this order of marine birds. Their legs are situated far back on the body, the feet are broadly webbed, and the bills are narrow. They are good swimmers and divers, and some are good flyers.

Fig. 229.—Great penguin (*Aptenody'tes patagon'ica.*) (After Tenney.)

The **penguins,** of which there are about twenty-eight species, are found in the Antarctic region and on the South American coast (Fig. 229). When on land these birds rest on the whole metatarsus and assume an erect attitude, their legs being situated very far back. They are famous swimmers and divers, but they cannot fly. Their wings are degenerate, being really feathered flippers. These feathers in some species look more like scales.[1] When under water the wings act as paddles and the feet as rudders. Penguins are gregarious, swimming in schools, and are seldom seen on land except at the breeding season, when they go in great numbers to their rookeries. The nests of grass and leaves may be under stones or in caves or burrows. The male assists in incubating the two white or greenish eggs, which require six weeks to hatch. The young are blind and altricial, and are fed by the parents, which insert their bills in those of the young. The food of the penguin consists of crustaceans, mollusks, and fishes with a small amount of vegetable matter. The voice may be a hoarse bark, " croak or scream, or a murmuring sound, or, in the young, it may be a whistle."

**Order II. Longipen'nes.**—These are mostly sea birds, with long wings and webbed feet. Gulls and terns may be named as ex-

Fig. 230.—Franklin gull; 15 inches. (Photographed from specimen.)

amples of this order (Fig. 230). *Gulls* feed chiefly on fish, but one may observe hundreds of them about an ocean liner as it comes into port. They seek what is thrown overboard. They

[1] Hornaday.

are the scavengers of the water, feeding from the surface. Gulls are at home in the open seas.

**Terns** are littoral (Fig. 231). They are more slender and active than the gulls, and have long forked tails and pointed bills. They nest in colonies, coming from the South in May and remaining until September. When in search of food the terns fly with the bill downward, while gulls carry the bill in a line with the body. Terns nest in colonies on islands. The nest

Fig. 231.—Terns in Southwest Harbor Key in Breton Island Reservation. (Year-book U. S. Dept. Agricul., 1905. Photo by Frank M. Miller.)

is made of a few wisps of grass. The eggs, two or three in number, are laid in a depression in the sand or pebbles. The young of both gulls and terns are precocial. When frightened, both gulls and terns squat low near the ground and remain motionless until actually touched.

**Order III. Tubina'res** are so called because the nostrils are carried well forward through the two round tubes that lie either along the top or the sides of the bill. The opening of the nostril is about half-way between the base and the tip of the bill. The bill is hooked like that of a bird of prey. "All are deep-water birds, strong of wing, and brave spirited beyond all other birds. The range of the order is worldwide. The most of them are found in the southern oceans."

To this order belong the *petrels*, "Mother Carey's chickens," which one sees hundreds of miles out on the ocean. The stormy petrels are the smallest of web-footed birds, being no larger than catbirds. Their note is shrill, and their flight butterfly-like.

The wandering albatross, with an expanse of wing from 10 to 14 feet, is also a member of this order. It is a wonderful flyer, sailing for hours without resting, always with rigid, motionless wings, rising, descending, or turning without a visible movement of them. It has been made immortal by Coleridge's "Rime of the Ancient Mariner."

Fig. 232.—A little corner of Pelican Island. (Year-book U. S. Dept. Agricul., 1905.)

**Order IV. Steganop'odes.**—The members of this order have the four toes connected by a web. The bill has no *lamellæ*. The nostrils are small or wanting and the throat is usually pouched. Here belong such large aquatic birds as the frigate or man-of-war bird, the cormorant, and the pelican.

The **frigate** or **man-of-war bird** is a very long-winged, long-tailed bird of the ocean. Its legs are very weak, but it is a remarkable flyer. It is found hundreds of miles from shore on the ocean. These birds live in the southern waters of both hemispheres. In the Cocos-Keeling Islands, Mr. H. O. Forbes says, they gain their living by forcing other fishing birds, like the gannets and noddy terns, to disgorge the fishes they have caught.

The **cormorants** are large, green-eyed, marine blackbirds. They are common along the seashore. They feed chiefly on fish and are gregarious. Their gular pouch is rudimentary as compared with that of the pelican. The Chinese tame the cormorant and use it in catching fish. The pelican is used for a like purpose in the East Indies.

The **pelicans** are large birds, with very large bills and immense gular pouches in which they catch the fish upon which they feed. The brown pelican (*Peleca'nus fus'cus*) of Florida is a sociable bird, about 4 feet in height. It does not acquire its full colors until its third year. The neck of the adult bird is in two colors, white and a rich blackish brown. The back is a beautiful silvery gray-brown effect composed of many tints. The top of the head is white or yellowish, the pouch a bluish purple or greenish. The bill is a foot long and demands and supplies four pounds of fish each day. Pelican Island, Florida, is the government reservation for these birds (Fig. 232).

The California brown pelican (*Peleca'nus califor'nicus*) is found along the Pacific coast from Galapagos to British Columbia. The beautiful great white pelican (*P. erythrorhyn'chos*) is now rare. It is found in large western inland lakes and in the Yellowstone National Park. The male has a peculiar knob on the bill during the breeding season only.

**Order V. An'seres.**—These birds have flat, lamellated bills (Fig. 233). The body is rather flat. The legs are far back on the body, causing them to waddle when they walk and making them good swimmers. Their toes are webbed. The feathers are well oiled so they can go into the water. Geese spend less time in the water than ducks do. The food is largely vegetable. The swans, geese, and eider duck do not dive in feeding, but thrust the head and neck under water, sometimes tipping up the body. Marine ducks are expert divers. The wild geese, ducks, and brant are migratory, but they are not so numerous as formerly, since so many have been slaughtered for market and sport

The **swan** belongs to this order and is the largest of the *Anseres*. In fact, it is one of our largest birds. Hornaday says it is pugnacious and quarrelsome. The plumage of the trumpeter swan is white; the bill and feet are black. The young are a dirty gray. The " voice is like a blast from a French horn," but is musical when given by a large flock in chorus. The range is from the Gulf to the fur countries. They breed from Iowa north and west to the Pacific coast.

**Order VI. Odontoglos'sæ.**—The *American flamingo,* of the warm parts of the Atlantic coast, is our representative of this order. It is a large, web-footed, long-necked, wading bird. The color varies from rose to vermilion. It has a heavy, bent, lamellated bill, with which it scoops up and crushes small mollusks and crustaceans, on which it feeds. Its webbed feet are used more for support in walking on the soft mud than for swimming.

Fig. 233.—Ring-necked duck (*Aythya collaris*); 17 inches. (From specimen.)

Flamingoes nest in colonies. A colony visited by Mr. Chapman contained upward of two thousand nests. One or two eggs make up a clutch. The voice is a vibrant honking, like that of a wild goose.

**Order VII. Hero'diones.**—This order is represented by such birds as the storks, herons, ibises, and spoon-bills. They are long-billed, long-necked, long-legged, wading birds, with short tails and broad, rounded wings. They frequent the water and seize their prey, be it fish or frog, with their long sharp bills. The young are altricial.

There are probably twenty species of *storks*, all but two of which are found in the Old World. The migratory stork of Europe is the most famous. Their clumsy nests are known over the world.

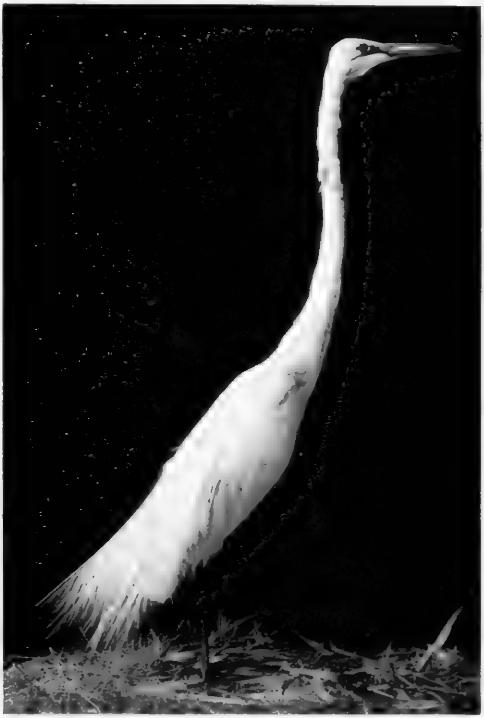


Fig. 234.—American egret (*Ard'ea egret'ta*). Length, 41 inches. (Photograph from specimen with neck extended.)

The **herons** are variously called the bittern, the great blue heron, the green heron, the great white egret, and the "squawk." Many have ornamental crests and plumes. Some herons stand in waiting, while others run rapidly and noisily through the water, depending on their agility in capturing their prey. Some stalk slowly and silently along in shallow water, the head carried in front in a line with the shoulders, and the large eyes scrutinizing every object in the water. Herons and ibises are gregarious, nesting and roosting in flocks, but feeding individually.

The heronry or rookery is located in low trees on a small island or marsh. Bitterns are found singly or in pairs.

The herons, egrets,[1] and ibises have been so persistently hunted for their plumes that some species are now quite rare. The snowy heron (*Ard'ea candidis'sima*) and the American egret (*Ard'ea egret'ta*) (Fig. 234) are the most beautiful of these. Their black legs and bills only intensify the

Fig. 235.—Sand-hill crane (*Grus mexica'na*). Length, 44 inches. (From specimen.)

snowy whiteness of their plumage. The filmy aigrettes are like spun glass. These number about fifty and are worn by the mother during the breeding season only. To obtain these plumes the mother must be shot, and the nestlings are left to perish simply to gratify the vanity of thoughtless women. The sale of these aigrettes in the United States is now forbidden by law.

[1] Apgar's "Birds of the United States."

**Order VIII. Paludic'olæ**, as the name indicates, are marsh-inhabiting birds. The crane is a familiar example.

The **coot, or mud-hen,** is abundant in reedy swamps, near small creeks and shallow lakes. It is an excellent swimmer. Its foot is scalloped or only half-webbed. It is omnivorous.

The **rails** and cranes resemble large or overgrown *Limicolæ*. The young are precocial. These birds usually feed on surface materials rather than

Fig. 236.—A valuable bird in danger of extinction—field plover. (Yearbook, U. S. Dept. of Agricul., 1907.)

by probing in the mud, as the plovers and snipes do. The rails are chiefly marsh or swamp birds of medium or small size. The Virginia rail is a little smaller than a quail. "He is an odd-looking bird, with a half-quizzical, half-cynical expression. His eyes are blood red and deeply sunk in the long, narrow head."

The **cranes** (Fig. 235), of which there are but three species in North America, are easily distinguished by the long bill, long head, very long neck, short, broad wings, short tail, and very long legs. They fly in single file with legs and neck outstretched. The cranes resemble the rails in general structure, but the herons in external form.

The **whooping or white crane** is now very rare. A full-grown one is 4¼ feet high. Hornaday says its trumpet call will carry as far as the roar of a lion. The sand-hill or brown crane ranges from the Gulf to Manitoba. The nests, of roots, rushes, and weeds, are made on the ground and usually contain two eggs. Goss says "during courtship and the early breeding season their actions and antics at times are ludicrous in the extreme, bowing and leaping high in the air, hopping, skipping, and circling about with drooping wings and croaking whoop, an almost indescribable dance and

Fig. 237.—Long-billed curlew (*Nume'nius longirŏs'tris*); 23 inches. (Photograph from specimen.)

din, in which the females (an exception to the rule) join, all working themselves up into a fever of excitement only equalled by an Indian war dance, and, like the same, it only stops when the last one is exhausted."

**Order IX. Limic'olæ.**—These are small or medium-sized birds, usually brown or gray, with some white in their plumage. The bill is long and slender and the legs spindling. Except in a few species the tibia is bare of feathers, sometimes almost to the knee. With a single exception, the hind toe is short and elevated or lacking. There are about 125 species of these shore birds, or, as their original name suggests, mud-dwellers, of which 75 live in America, north of Mexico.

The **Phal'aropes** are small in size and in number of species, of which there are but three. These lobe-toed birds have this peculiar characteristic: the female, which is larger and more brightly colored than the male, does the courting. The male does the incubating and cares for the young, which are soon able to swim and to hunt their own food.

**Snipes** and **plovers** (Fig. 236) are much sought for game birds in some regions. The young are precocial. They afford some fine examples of protective resemblance. One may be very near a snipe and not see it if it only keeps still, so perfect is its resemblance to its surroundings.

The **Jack snipe** (*Gallina'go delica'ta*) and the American woodcock (*Philohe'la minor*) have shorter legs and the eyes are farther back on the heads than in any other birds. Their long, straight bills have sensitive tips, with which they probe down into the mud for earthworms. Hornaday describes the shrill cry of the Jack snipe when it rises as a half-scream, half-squawk. Its range is large, extending all through the United States, except in arid regions.

The **avocet** or **stilt** (*Recurviro'stra americana*) is like a snipe, but the legs and bill are much longer than those of a snipe.

The **curlews** (Fig. 237), sandpipers, and oyster-catchers also belong to this order.

A **plover** (*Ægiali'tis vocif'era*), commonly called killdeer, is found throughout the temperate portion of North America. They are quite common birds in the Mississippi Valley. Though scattered when feeding, they fly in flocks.

## LAND BIRDS

**Order X. Galli'næ.**—This order includes many birds valuable to man, as pheasants, pea-fowls, guineas, chickens, turkeys, quails (Fig. 238), and prairie-chickens. The birds of this order are chiefly ground birds, living largely on seeds and grains, hence the crop and gizzard are well developed. Their bodies are robust, their wings rather short, the legs stout, and the feet clawed. The bills are short and stout. They are poor flyers, often going with a " whirr." In the wild forms the protective resemblance is almost perfect, their colors blending with the grass, brush, and weeds in which they live. The ptarmigan (Fig. 239) changes color with the season to suit its environment, being white in winter. The males of this order usually have conspicuous markings on the head, as the rooster's comb and wattle, and the red head of the turkey gobblers, or conspicuous plumage, as the peacock. They are polygamous. The rivalry is keen and the males fight fierce battles.

The only native bird of the pheasants is the **wild turkey,** now almost exterminated by the sportmen, being found in a few regions of the Eastern and Southern States, and in Oklahoma and Texas. Several pheasants have been introduced into this country from China. The common chickens are descendants of the jungle fowl of India (*Gallus bankivus*).

The grouse family all nest on the ground. Their colors are chiefly brown and gray, so they rely on concealment for protection. The "whirr" accompanying flight is caused by the beating of their small concave wings.

Fig. 238.—Quail (*Coli'nus virginia'nus*); 10 inches. (Photograph from specimen.)

To this family belong the **bob-white** or "quail," the sage grouse of the West, and the once common prairie-hen of the Mississippi Valley. The male prairie-chicken has peculiar salmon-colored air-sacs on the sides of his neck which he inflates in making his "bum-bum-boo" as he struts and bows to his prospective mate in the courting season.

**Order XI. Colum'bæ.**—This order is represented in the United States by the pigeons and doves. There are about 300 species in the world, but only ten or eleven in the United States. The head is small and round, the bill and legs short, the body plump, and the plumage has a peculiar iridescence. Some live on the ground, others in trees, and still others in open places.

The **turtle dove,** or mourning dove, is one of our commonest species and its plaintive cooing is quite familiar to all. It breeds throughout the United States, and one often meets it in the country roads. It is one of the farmer's useful, as well as beautiful, friends. Three stomachs, examined at Washington, were found to contain 23,100 weed seeds.

Darwin says our **domestic pigeons** originated from the blue-rock pigeon (*Colum'ba liv'ia*). The nest of the pigeon is a flimsy one of twigs, on which it lays two white eggs, from which hatch the naked, altricial "squabs."

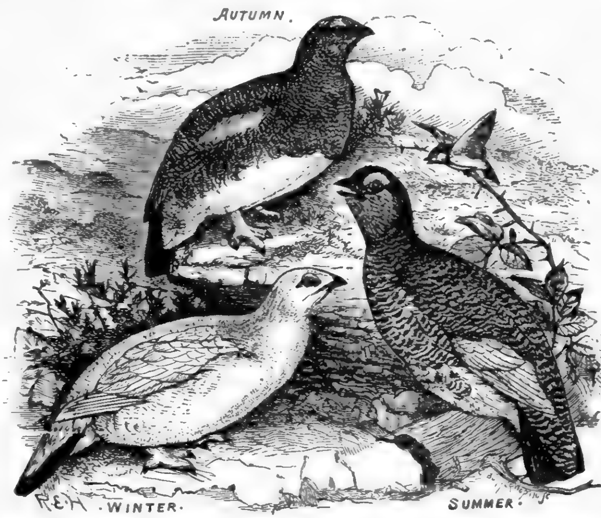



Fig. 239.—Seasonal changes of color in ptarmigan (*Lago'pus mu'tus*); $\frac{1}{6}$ natural size. (Romanes.)

Both sexes incubate. The young are fed on "pigeon's milk," the parent thrusting its bill into the mouth of the young and discharging therein food which has been softened in its own crop. Chapman and Reed say also that some species of pigeons nest in isolated pairs and other species in large colonies. If you have ever watched a pigeon drink, you know that it holds the bill in the water till it has finished drinking. The passenger pigeon is a noted bird for sending messages. It was formerly very abundant. In 1808 Wilson estimated one flock at over 2,000,000,000 pigeons. They are now almost extinct, another result of the hunter and his gun.

Allied to the pigeons was the extinct **dodo** of Madagascar. It was a giant compared to our pigeons. Look up a picture of it[1] and see what a strange looking bird it was. It could not fly.

[1] Evans, "Birds," p. 329.

**Order XII. Rapto'res.**—These are usually large, strong birds, with hooked bill and strong claws for seizing and holding their prey, which consists of fish, birds, rats, mice, and other small mammals. To this order belong hawks, eagles, condors, buzzards, vultures, and owls.

Fig. 240.—Bald eagle (*Haliæe'tus leucoceph'alus*) (drawn by R. Ridgway); 34 inches. (Bulletin 27, Biological Survey, U. S. Dept. of Agricul., 1906.)

The **hawks** and **eagles** (*Falcon'idæ*) (Fig. 240) comprise about three hundred and fifty species and include such birds as the kites, hawks, buzzards, and the osprey or fish-hawk. These are almost exclusively carnivorous. *Raptores* are easily distinguished by their hooked bills and sharp talons. They feed chiefly on rats and mice. Occasionally some of the hawks will attack chickens, but there are more friends than foes among them. Hawks build large nests of sticks in tall trees. They lay four whitish eggs with brown blotches.

The **sharp-shinned hawk** is small (length, 11½ inches), with a long square tail marked by widely separated dark bands across it, the widest one nearest the end. The principal food is song birds, so this hawk should be destroyed wherever found. Cooper's hawk is dark brown with grayish and brownish spotted under parts. Its tail is round. In food habits it is much like the sharp-shinned hawk, and it should be destroyed.

The **red-tailed hawk** (Fig. 241), more often called the chicken-hawk, is a great destroyer of injurious mammals. Poultry and other birds do not constitute 10 per cent. of this hawk's food, and all other beneficial animals which it eats added do not make 15 per cent. So its record is 85 per cent. as a friend, against 15 per cent. as an enemy, of the farmer.

Fig. 241.—Red-tailed hawk (much reduced). Length, 21 inches. (Bulletin 17, Biological Survey, 1902.)

**Owls** in America north of Mexico number eighteen species. "They vary in size from the tiny elf-owl of Arizona (only 6 inches long) to the great gray owl of the Arctic regions (30 inches long). The owls (Fig. 242) (*Bubon'idæ* and *Strig'idæ*) have a soft plumage, hence their silent flight. Their eyes are large and dilatable, enabling them to see well at night. The face is so broad that both eyes look forward. They are immovable, so that to look in another direction the head must be turned. They have a peculiar voice, a screech in our little screech owl and a "who-hoo-whoo" in the great horned owl. When one is camping in the woods the sound of this bird gives one queer creepy feelings until one knows what is making it. Owls live chiefly on rats, mice, frogs, snakes, and rabbits. Some of the smaller ones devour many grasshoppers and other insects. They regurgitate the indigestible portions of their prey in little oblong balls or pellets, which may be found on the ground under the trees in which they nest. Owls nest in holes in trees or banks, and lay from three to five pure white eggs. They feed at night when the rats and mice are about. Thus they are of more benefit than the day-feeding hawks.

The **great horned owl** is the only species which is harmful to man, and even it pays something for its chickens with the mice and rats it kills. "Mr. O. E. Niles, of Ohio, once found in a nest of this bird several full-grown

Fig. 242.—Barn owl (*Strix pratin'cola*). (Photograph from specimen.)

Norway rats, and on the ground under the tree containing the nest he found the bodies of 113 rats."[1] Now how many chickens would that number of rats eat in a year? Probably more than one great horned owl would eat, and a lot of corn besides. The investigations at Washington prove, however, that, although many rats and mice are eaten, so many small birds and domestic fowls are destroyed by it, that one is justified in shooting the great horned owl.

**Burrowing owls** (see Prairie dogs) nest in the abandoned nests of prairie dogs, but do not live in the same nest with them.

[1] Hornaday, p. 223.

**Order XIII. Psit′taci.**—Parrots or paroquets are usually highly colored, harsh-voiced tropical birds, with thick, stout bills. The upper half of the bill extends down over the lower one. The toes, which are used as hands, or with which they walk or climb, are arranged two in front and two behind. There are about 500 species of these birds. They live on fruits and seeds. They are of considerable commercial importance. The parrot is quite a common pet. The Carolina paroquet is the only species found native in the United States. Its range formerly

Fig. 243.—Belted kingfisher (*Cer′yle alcyon*); 13 inches. (Photographed from specimen.)

extended to the Great Lakes, but now it is found only "rarely in Florida and along the Gulf coast to Indian Territory."

**Order XIV. Coc′cyges.**—This is an Old World order of tropical birds, "classified together in one miscellaneous group only because they belong to no other order."

**Kingfishers** are a large family of about two hundred species, chiefly of tropical birds, represented in the United States by three species. The belted kingfisher (Fig. 243) is our common species, described by Apgar as "a noisy, short-tailed, large, straight-billed, crested, blue-backed bird, with white lower parts and a bluish band across the breast."

The **trogons** (fifty species) are brilliantly colored tropical birds. The coppery tailed trogon of Texas is our representative. It is said to be the most beautiful of North American birds.

**Cuckoos** (two hundred species) are tropical birds represented in the United States by several species. The rain crow, or yellow-billed cuckoo (Fig. 244), is an example. It feeds on the tent caterpillar which infests our trees. It is the Old World cuckoo which lays its eggs in the nests of other birds, not our American bird. With the species *Anis*, one nest serves for several females and it sometimes contains thirty eggs. The joint owners share in the care of the young.

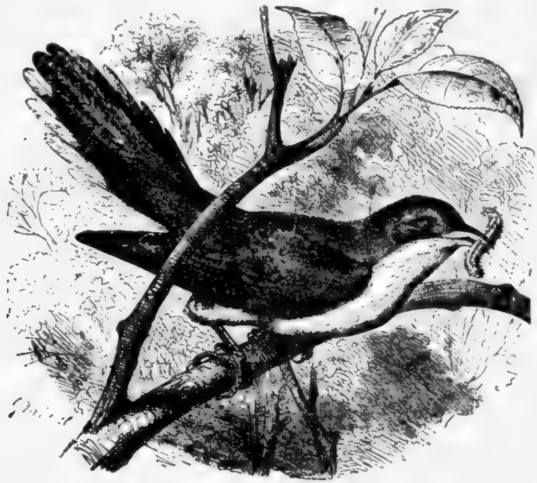


Fig. 244.—Yellow-billed cuckoo which feeds upon hairy tent caterpillars. (After Brehm.)

**Order XV. Pi′ci.**—In our latitude this order includes woodpeckers of various kinds and under various common names, such as red-headed and downy woodpeckers (Fig. 245), sap-suckers, and flickers or yellow-hammers. All are arboreal, and all, except the sap-suckers, are insectivorous. Their toes are arranged two in front and two behind, except in a few American three-toed woodpeckers. The tail feathers are stiff and help to brace the bird as it clings to the trunk of a tree and pecks for food. The bill is strong and fitted for drilling holes into trees for nests or to procure food. The tongue is long, flexible, and spear-tipped, so as to enable the bird to reach a long distance and to spear the larvæ of insects, on which it delights to feed. The birds of this order are poor singers, but good drummers. Everyone has heard the tattoo of the woodpecker on the trunk of an old dead tree. The four to nine eggs are white, and the nest is placed in a hole high up in the tree away from enemies. The young are naked and are reared in the nest (altricial). There are 350 species distributed

Fig. 245.—The hairy woodpecker at breakfast. (Biological Survey, U. S. Dept. of Agriculture.)

throughout the wooded districts of the world, except in Madagascar and Australia. The North American species are not highly migratory, but are represented in the northern parts of their range throughout the year, since they feed largely on the eggs and larvæ of boring insects, which they can find all the year. They are of great value. Two-thirds or more of the food of the downy and hairy woodpeckers consists of noxious insects.

**Order XVI. Machrochi′res.**—To this order belongs a group of remarkable flyers, such as the humming-bird, chimney-swifts, whip-poor-wills, and night-hawks. These birds have long, pointed wings. Most of them fly at dusk or at night and feed chiefly on insects.

The **humming-birds** are tropical or semitropical birds of the New World, there being some 400 or 500 species. The hawk or sphynx-moths which feed at dusk may be mistaken for humming-birds. Apgar says several species are found west of the Rocky Mountains in the United States. The ruby throated humming-bird is the one we see about our trumpet-creepers, honeysuckle, and salvia, seeking both insects and nectar. Chapman says " the young are fed by regurgitation, the parent bird inserting its bill into the mouth of its offspring and injecting food as though from a syringe." Its note is a mere squeak or prolonged twitter. A humming-bird's nest is about the size of a lady's watch, and the two frail, pearly white eggs, like large peas, hatch in fourteen days.

The **swifts** are widely distributed. They have strong wings. They can fly straight up or down and feed on the wing. The legs are so weak that some species cling to a vertical surface, using the tail to help support them, instead of perching. The tip of each tail feather ends in a sharp point, the shaft extending beyond the vane. They nest in hollow trees or chimneys. " The nest of our chimney-swift is a bracket-like basket of small twigs gathered while the bird is on the wing, and glued together and to tree or chimney by a glutinous saliva."

The **night-hawk** resembles the whip-poor-will, and is usually compared with it, but it is a bird of the sky, and " its note is a loud nasal peënt uttered as it flies." It has an enormous mouth fringed above with bristles. It eats insects which it catches on the wing. When it alights it chooses a nearly horizontal limb on which it sits lengthwise, looking like a big knot. It migrates to South America in winter

The **whip-poor-will** is well known by its peculiar cry. It feeds on insects which it catches at night as it flies. During the day it rests quietly on the ground in the woods.

**Order XVII. Pas′seres.**—This vast order comprises at least half of the birds. They have four toes, three in front and one behind, on a level with the front toes. The legs are rather slender, and so placed on the body as to give it a horizontal position when it rests. These are our most common birds. They vary in size from the little house wren to the crow. Thrushes, bluebirds, kinglets, chickadees, creepers, wrens, wag-tails, warblers, vireos, shrikes, wax-wings, swallows, tanagers, sparrows, orioles, crows, larks, and fly-catchers are representatives of this order. They include some of our finest songsters. Most of them are plainly clad, inconspicuous birds, working and singing, often unseen. Not all of them, however, are unattractive in appearance, for think of the bobolink, the magpie, the jay, the grosbeak, the tanager, the cardinal, the oriole, and the modest little wax-wing. Each brings to one's mind a different type of beauty. The temperate zone contains the sweetest singers in all the bird world. The great majority of this order live upon insect food, wherein lies their greatest value. Others live on weed seeds and waste grain, and, lastly, on fruit in its season.

The **fly-catchers** (*Tyran'nidæ*) (Fig. 246) are found only in America, being especially abundant in the tropics. They number over 350 species.

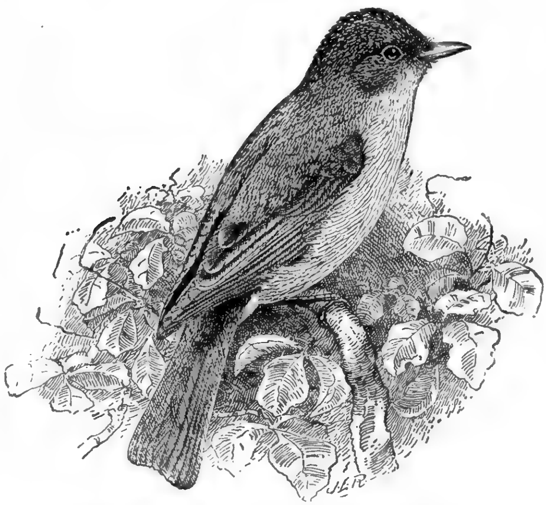


Fig. 246.—Phœbe. (Bulletin 17, U. S. Biological Survey, 1902.)

Of the thirty species that breed here, not more than a half dozen are permanent residents of the temperate region. They feed on insects, mostly injurious ones, which they catch while on the wing.

The **true larks** (*Alau'didæ*) are chiefly Old World birds, there being about 100 species in Europe, most notably the skylark. We have only about a dozen of this family, the horned and shore larks. The "meadow-lark" belongs not in this family, but with the blackbirds.

Of the **crows** and **jays** (*Cor'vidæ*) we have about twenty-five of the two hundred species. They are migratory only to a certain extent, being winter residents except in the North. They are omnivorous, eating fruits, seeds, insects, and, in some cases, the eggs and young of other birds. This last habit is by far their worst one. They have unusual intelligence.

The orange and black **Baltimore oriole** (Fig. 247), one of the most beautiful, as well as useful, of our summer birds, destroys many tent caterpillars and other hairy larvæ which few birds will eat. If one has ever known his rich, clear whistle, one can never forget it or fail to recognize it when the bird arrives about the first week of May. The delicate hanging nest, which the female weaves of grass and hair and strings, is a marvelous accomplishment. It is suspended far out near the end of a small flexible twig, where cats and boys cannot come. The elm is a favorite nesting tree.

Fig. 247.—Baltimore oriole attacking nest of American tent caterpillar. (Bulletin 75, 1900, New Hampshire Coll. Exp. Station.)

**Grackles or blackbirds** are common summer residents. They are said to have the same bad habit as the jays and crows, of eating the eggs and young of other birds, though they eat also many injurious insects.

The **cowbird** lays its eggs in the nests of other birds. It should be killed and its eggs destroyed.

The largest family (*Fringill'idæ*) of birds (about 500 species), containing the finches, sparrows, and grosbeaks, is represented everywhere except in the Australian region. They are chiefly seed-eating (Fig. 248) and so are less migratory than insect-eating birds. The sparrows are plain-inhabiting and are protectively colored, while the more arboreal grosbeaks and finches are rather brilliant.

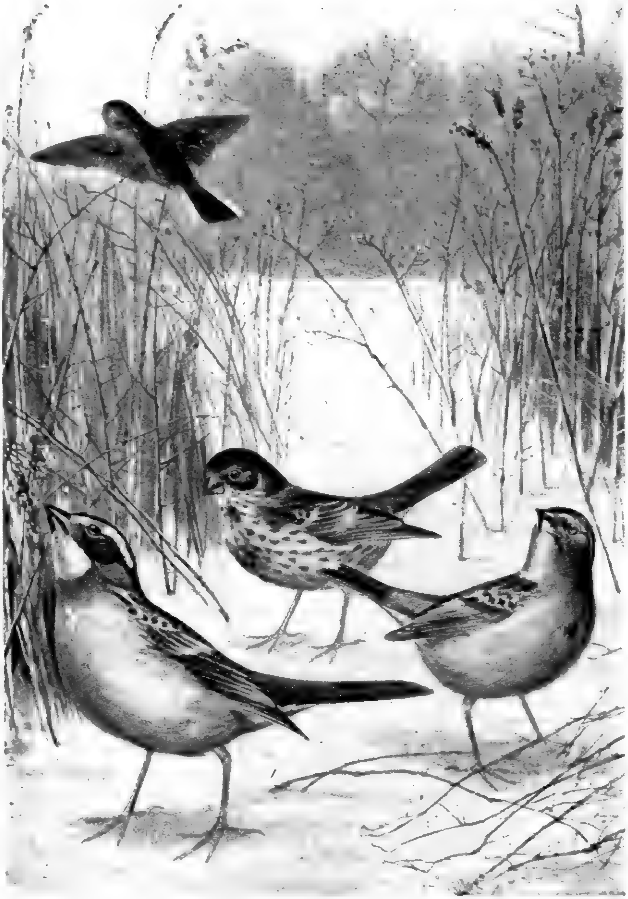



Fig. 248.—Four common seed-destroying sparrows: 1, Junco; 2, white-throated sparrow; 3, fox sparrow; 4, true sparrow. (Bulletin 17, Biological Survey, U. S. Dept. of Agriculture.)

Although the **tanagers** are distinctively American, only five of them come so far north as the United States. They are remarkable for their brilliant plumage. When one sees the tanager in his royal or "court costume" one feels that this beautiful bird of summer has indeed put brightness into that day. Tanagers are arboreal, loving the woods. They feed on flowers, fruit, and insects.

**Swallows** (*Hi'rundin'idæ*) have a remarkable power of flight. In summer they are found throughout North America. Our barn swallow in winter goes as far south as Brazil. The number of injurious and annoying insects which they catch on the wing is almost beyond imagination.

The **wax-wings** (*Ampel'idæ*) (Fig. 249) are found in the northern parts of both the Old and New Worlds, though there are but three species. They feed chiefly on wild fruits and insects, including the elm beetle. They are

Fig. 249.—Cedar wax-wing. (Biological Survey, U. S. Dept. Agricul.)

usually found in small flocks. Their common notes are a few unmusical calls, which our cedar wax-wing usually utters when about to fly.[1] The quiet beauty of these birds is beyond all description.

The **warblers** (*Mniotil'tidæ*) are characteristic North American birds and number more than 100 species, of which 70 visit the United States. The others are tropical. With us in the temperate region they are only birds of passage, making us brief but regular visits in May as they go to their northern breeding ground, and again in September as they return to the southland. Most of them are woodland birds. Some are terrestrial, some arboreal, and others are lovers of the thickets. They migrate by night. Insects constitute nearly their entire food, and they are among our best friends.

[1] Reed and Chapman.

The **black-masked Maryland yellow throat** is one of the tiny warblers often seen in the Mississippi Valley. He haunts the thicket. His song, "witchery, witchery, witchery," is characteristic of his active, nervous energy.

The **little black and white warbler,** often called the black and white creeper, is about 5 inches long. It is a more active climber than even the true creepers, hanging from the under surface of branches and twigs or flitting from tree to tree. It is usually silent. Its occasional "see-see-see" is thin and wiry.

The **wrens, thrashers,** and the **mocking-bird** (Fig. 250) (*Troglodyt'idæ*) include many fine singers. They are inconspicuously colored birds, feeding near the ground. Many of them like the low scrubby tangled growth so dear to the catbird, which cheers us all the summer day, rain or shine. This bird does valiant service as a caterpillar hunter, especially when feeding the young.

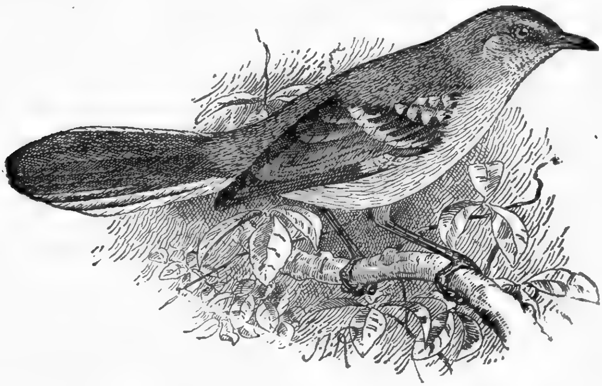


Fig. 250.—Mocking-bird. (Biological Survey, U. S. Dept. Agricul.)

The **creepers** (*Certhi'idæ*) do good work in keeping down the pests of the tree trunks all the year around.

The **nuthatches** (*Par'idæ*) also help in tree keeping, as do our little chickadees, which stay the winter through.

The **thrushes** (*Tur'didæ*) are usually fine singers. The best known are the much-loved robin and bluebird (Fig. 251).

There are several other families of *Passeres*, but lack of space forbids us to dwell longer on this fascinating subject.

**Economic Importance.**—Millions of dollars' worth of farm products are destroyed annually by insect pests, but if these great hordes of marauders were not held in check by their natural enemies, the birds, the devastation would be so great in a few years as to cause actual famine.

Where man has not interfered, nature has a well-balanced arrangement for the protection of his crops. The grasses and low-growing herbs are protected from such enemies as the cutworm, caterpillar, and grasshopper by the chipping sparrow, robin, and bluebird, and, farther afield, by the quail, meadowlark, blackbird, and field sparrow. In the edge of the woods are

Fig. 251.—Bluebird at edge of nest with grasshopper in mouth. (From photograph by Rev. P. B. Peabody.) (Bulletin 17, Biological Survey, U. S. Dept. of Agriculture.)

the chewinks and brown thrashers; and in the deep woods, the ruffed grouse; while along the fresh-water streams and ponds may be seen the woodcocks, sandpipers, and snipes. In the trees "the woodpeckers, assisted by the nuthatches and creepers, look after insects on and beneath the bark of both the trunk and the branches."[1] The chickadees, bluebirds, thrushes, warblers,

[1] Weed and Dearborn, "Birds in Their Relation to Man."

vireos, kinglets, and many more guard the leaves. The insects of the air are preyed upon in the daytime by the diurnal birds, such as the swallows, swifts, kingbirds, and fly-catchers. Crepuscular insects are caught by such birds as the whip-poor-will, night-hawk, and small owls.

Hawks and owls destroy many rats and mice and other young rodents, while the vultures are very useful as scavangers, since they subsist largely on carrion. The South African secretary bird (Fig. 252) belongs in the list of friends.

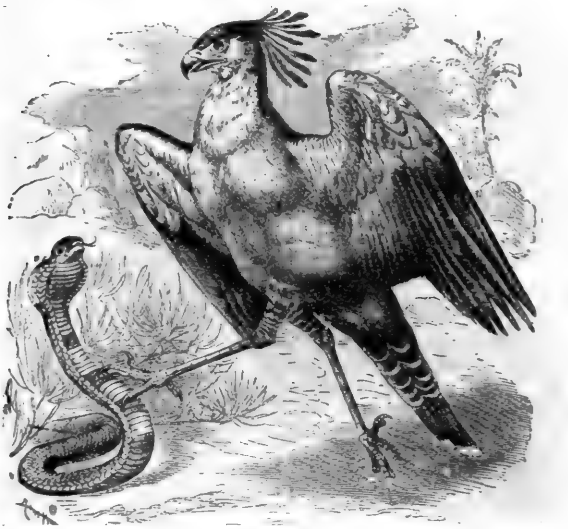


Fig. 252.—Secretary bird (*Gypoger'anus reptiliv'orus*). A South African snake-killer protected by law. (After Houssay.)

Certain kinds of birds are of especially great value on account of their specific food, insect pests which are making such havoc with particular crops or with certain trees. Thus, the swallows, which eat almost nothing of value to man, prey upon the cotton-boll weevil, which they catch upon the wing. Forty-seven adult weevils have been found in the stomach of a single swallow. It should be remembered that the swallows, which are such indefatigable insect destroyers here in the breeding season, migrate to the South and are of great specific value there by reason of their raids upon the cotton-boll weevil, so they should be encouraged and protected from the English sparrow. Orioles do royal service in catching weevils on the bolls. Blackbirds, wrens, and fly-catchers do good work.


Fig. 253.—Weed seeds commonly eaten by birds: *a*, Birdweed; *b*, lambs' quarter; *c*, purslane; *d*, amaranth; *e*, spotted spurge; *f*, ragweed; *g*, pigeon grass; *h*, dandelion. (Biological Survey, U. S. Dept. Agricul.)

Sparrows prey upon the green wheat aphid of North Carolina.

During an outbreak of cankerworm in a central Illinois apple orchard the investigations of Prof. S. A. Forbes showed that the food of robins, catbirds, brown thrashers, and bluebirds consisted of 96 per cent. insects, of which 16 per cent. was cankerworms, while the food of the house wrens he examined was 50 per cent. cankerworms; 25 per cent. of the food of the hairy and downy woodpeckers consists of boring larvæ.

It is true that birds eat a certain percentage of fruit and seeds, but the entire amount of vegetable matter is usually much less than the animal matter consumed. A large proportion of the seeds eaten are weed seeds (Fig. 253), such as dandelion, dock, knot-weed, purslane, pigeon-grass, and rag-weed.[1] The grain which birds eat is, much of it, picked up from the waste matter about the farm-yard.

Doctor Judd[2] says the great horned owl, the sharp-shinned and Cooper hawk, and the English sparrow are injurious birds

[1] Jackson and Daugherty, "Agriculture through the Laboratory and School Garden."

[2] Linville and Kelly.

and should be killed. The cowbird should be added to this list, since it lays its eggs in the nests of smaller birds. When this hatches, it deprives their young of room and care, often pushing them out of the nest, or taking their food and allowing them to starve. The blackbirds and jaybirds are questionable characters, since they are so mean about robbing nests and driving away other birds. The protection of all but the few birds named should be emphasized, especially by all farmers and fruit growers.

The useless destruction of bird life every year is alarming. Besides the thousands on thousands killed for food, there are thousands of others killed by the plume-hunters to gratify the foolish pride of thoughtless, silly women. Much as this is to be deprecated, it slaughters but one-fifth as many birds as those killed by men and boys for the mere sport of killing. Surely the killing for the love of it, many times leaving the birds to decay where they have been shot, perhaps only wounded and left to die by a slow torture of starvation, is a cruel and senseless practice, yet fully one-half of all the birds killed in the United States are killed merely for sport.[1]

Surely it is time to stop and think; time to teach the coming generation the value of birds to human life; time to teach the boys and girls to love the birds and to study their habits, so as to learn which are friends and which foes. Girls should learn that a dead bird upon the hat, no matter how beautiful, is a mark of the heartlessness of the wearer. Boys should be taught to shoot birds with a camera, not with a gun. It takes far more intelligence and skill and will be found a more fascinating sport.

Laws are being made in many states for bird protection. The United States Government is making bird reservations, such as Pelican Island, off the coast of Florida; Breton Island, Louisiana; Stump Lake, North Dakota, and Yellowstone Lake in the National Park.

**Geographic Distribution.**—Birds as a class are the most widely distributed of all animals. They are at home in the frozen regions of the North or in the dense shades of the tropics, upon the rocky steeps of the mountains, or out on the ocean far from sight of land. Their wide range of variation in structure and habits renders them, as a class, able to adapt themselves to

[1] Hornaday, p. 172.

all climates, and their mode of locomotion makes them less restricted by barriers.

**Important Biologic Facts.**—Birds have, in common with reptiles, the quadrate bone, and but one occipital condyle. They are wonderfully adapted to their aërial mode of life by their feathers, by the modifications of the fore limbs into wings, and by the air-filled cavity of the bones. Birds are warm-blooded (homoiothermal), the heart being completely divided into right and left halves. The fusion of the bones of the hand and the tibiotarsus and the tarsometatarsus are peculiar to birds. Nest building, as well as incubation, is peculiar to this class, though, in rare instances, fishes build nests and reptiles practice incubation.

**Classification.**—

Division

A. Rati′tæ. Ostrich, Rhea, etc.

B. Carina′tæ.

| | | | |
|---|---|---|---|
| Order | I. | Pygop′odes. | Grebes, Auks, and Loons. |
| Order | II. | Longipen′nes. | Gulls, Terns. |
| Order | III. | Tubina′res. | Albatross, Petrel. |
| Order | IV. | Steganop′odes. | Cormorants, Pelicans. |
| Order | V. | An′seres. | Ducks, Geese, and Swans. |
| Order | VI. | Odontoglos′sæ. | Flamingoes. |
| Order | VII. | Hero′diones. | Herons, Storks, Ibises. |
| Order | VIII. | Paludic′olæ. | Cranes, Rails. |
| Order | IX. | Limic′olæ. | Snipes, Plovers. |
| Order | X. | Galli′næ. | Quails, Grouse, and Chickens. |
| Order | XI. | Colum′bæ. | Doves, Pigeons. |
| Order | XII. | Rapto′res. | Hawks, Owls. |
| Order | XIII. | Psit′taci. | Parrots. |
| Order | XIV. | Coc′cyges. | Cuckoos, Kingfishers. |
| Order | XV. | Pi′ci. | Woodpeckers. |
| Order | XVI. | Macrochi′res. | Swifts, Humming-birds. |
| Order | XVII. | Pas′seres (Perching birds). | All our most common small birds. |

## CLASS VI. MAMMALIA

Mammals are homoiothermal, bilaterally symmetric, air-breathing, usually hairy chordates. They are, as a rule, viviparous and suckle their young. They vary in size from the tiny little harvest mouse, probably less than 5 inches long, to the great sulphur whale, weighing many tons. Not all of them, however, are widely distributed, but everywhere, save in a few of the South Sea Islands, some of the several thousand species are found.

**Covering.**—No other characteristic is more rightfully called a distinguishing characteristic than the hair of mammals. True hair is found on no other vertebrate. It is general to find a hairy covering among mammals. Even among the *Cetacea* hairs are sometimes found upon the muzzle, and traces of hair are sometimes found in the embryo. The skin of the whale is underlaid by a layer of fat or blubber, while that of those ungulates that are sparsely covered with hair, as the rhinoceros, is very thick. The hair may differ greatly both in length and texture. It may be soft and kinky "wool" or very fine fur. The coarse hairs may become long, hard bristles, like those of the hog, or be differentiated into stiff "spines," like those of the porcupine, or into a scale armor, like that of the armadillo.

Sweat glands in the skin are also characteristic of mammals.

The **skeleton** is the most nearly perfect of any of the chordates. The skull (Fig. 254) is composed of fewer bones more firmly united than in the lower chordates. The lower jaw is composed of a single bone on each side, the dentary, and is articulated directly with the squamosal. The skull is connected with the first vertebra, the atlas, by two occipital condyles instead of one, as in the birds and reptiles.

The spinal column (Fig. 255) consists of a varying number of vertebræ, the first two, the atlas and axis, being somewhat modified to support the head and to permit its various movements. The vertebræ do not articulate with one another by cup and ball (except in some ungulates), as in amphibians, reptiles, and birds, since the intervertebral disks of fibrocartilage permit lateral bending of the spine. The vertebræ are classified, according to their location, as cervical, dorsal, lumbar, sacral, and caudal. The cervical or neck vertebræ are nearly always seven (there are six in the manatee, and six, eight, or nine in some of the sloths). So the length of the neck depends upon the length, not the number, of the vertebræ. The dorsal vertebræ carry ribs and vary in number (from nine in *Hypero'ödon*[1] to

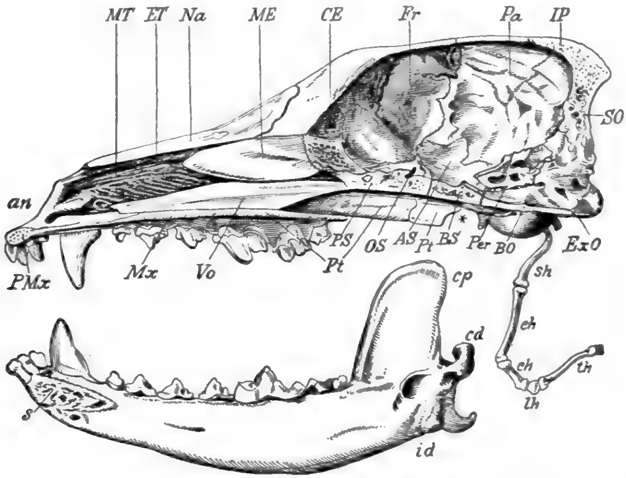



Fig. 254.—Skull of a dog, side view, with the right half of the mandible or lower jaw and hyoid arch, the lower jaw displaced downward to show its whole form. (Reduced). *an*, Anterior narial aperture; *MT*, maxilloturbinal bone; *ET*, ethmoturbinal; *Na*, nasal; *ME*, ossified portion of the mesethmoid; *CE*, cribriform plate of the ethmoturbinal; *Fr*, frontal; *Pa*, parietal; *IP*, interparietal; *SO*, supra-occipital; *ExO*, exoccipital; *BO*, basi-occipital; *Per*, periotic; *BS*, basisphenoid; *Pt*, pterygoid; *AS*, alisphenoid; *OS*, orbitosphenoid; *PS*, presphenoid; *Pl*, palatine; *Vo*, vomer; *Mx*, maxilla; *PMx*, premaxilla (*sh*, stylohyal; *eh*, epihyal; *ch*, ceratohyal; *bh*, basihyal; *th*, thyrohyal) equal the right half of the hyoidean apparatus; *s*, symphysis of the mandible; *cp*, coronoid process; *cd*, condyle; *a*, angle; *id*, inferior dental canal; *, the part of the cranium to which the condyle is articulated. (After Tenney.)

twenty-two in *Hyrax*). The lumbar vertebræ also vary in number, usually inversely, as the dorsal, their sum being rather constant. The sacral vertebræ are fused together. They are absent in *Ceta'cea* and *Sire'nia*, where there are no functional hind limbs. The caudal vertebræ vary from three to fifty.

[1] Beddard's "Mammalia," p. 23.

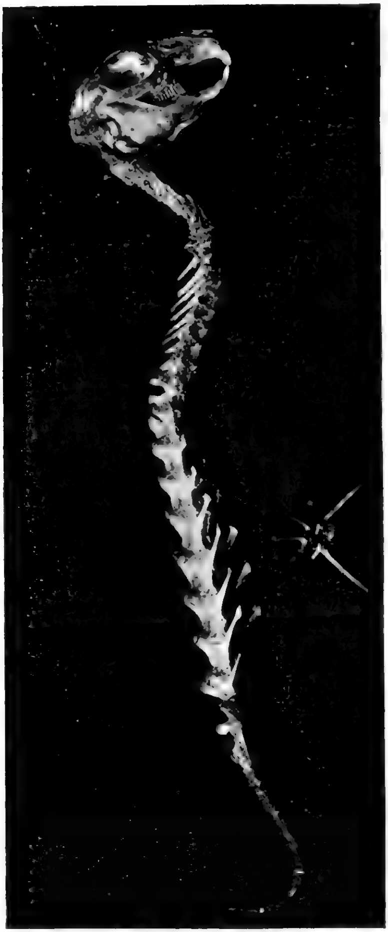


Fig. 255.—Skull and spinal column and single vertebra of a common cotton-tail rabbit (*Le'pus sylvat'icus*). (Cleaned and mounted by students.)

Fig. 256.—Pelvic girdle of Jack-rabbit. (From dissection.)

All mammals have ribs. They vary in number in different groups, or, it may be, in different species. The greater number of them are attached anteriorly to the sternum, which is always present, and posteriorly to the vertebræ, but there are also a number of floating ribs or those attached posteriorly only.

The pectoral girdle consists of two bones on each side, the scapula (Fig. 257) and the clavicle. The clavicle is absent in ungulates, which use their fore limbs mainly for support and in walking, but it is well developed in "flying," digging, or burrowing mammals.

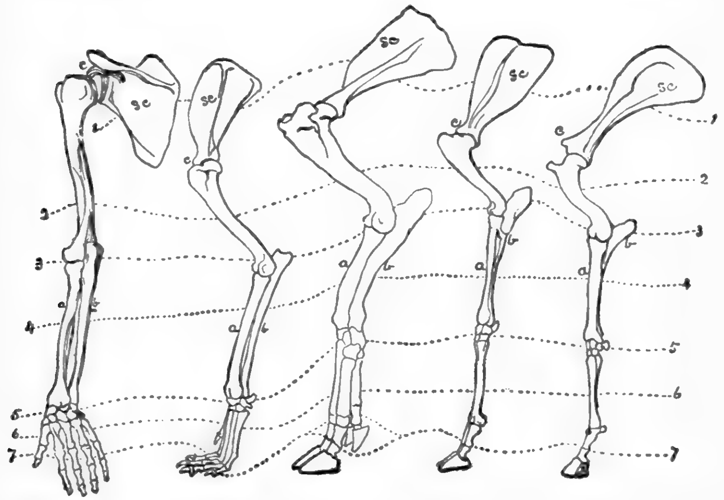



Fig. 257.—Anterior limb of man, dog, hog, sheep, and horse: *Sc*, Shoulder-blade; *c*, coracoid; *a*, *b*, bones of forearm; 5, bones of the wrist; 6, bones of the hand; 7, bones of the fingers. (Le Conte's "Geology," American Book Co., Publishers.)

The pelvic girdle (Fig. 256) consists, normally, of the *os innominatum* on each side. There are "four distinct elements in each one: the ischium, the ilium, the pubis, and the cotyloid."[1]

The limbs which raise the body from the ground and are the principal organs of locomotion are four in number, except in *Sĭre'nia* and *Cetacea*, where there are no externally visible hind limbs. Rudiments of the pelvis are found in both of these orders, and in some of the *Cetacea* rudiments of the femur and of the tibia. The bones of both anterior and posterior limbs (Figs. 257,

[1] Beddard, "Mammalia," p. 41.

258) vary in size, shape, and number, depending on the environmental habits. In all but the *Cetacea* the ends of the digits are protected by horny epidermal coverings, variously termed hoofs, nails, or claws. Rudiments of these are found in the embryos of the *Cetacea*, thus suggesting their terrestrial origin.

**The Digestive Organs.**—One of the peculiarities of the digestive organs in mammals is the development of the salivary glands. The teeth are "heterodont" (Fig. 254) instead of "homodont," as in some of the lower classes of chordates.

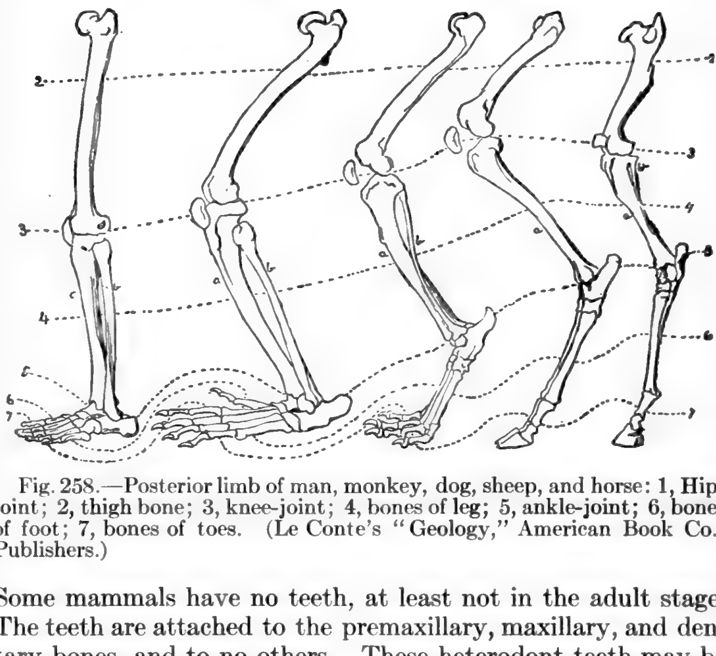


Fig. 258.—Posterior limb of man, monkey, dog, sheep, and horse: 1, Hip-joint; 2, thigh bone; 3, knee-joint; 4, bones of leg; 5, ankle-joint; 6, bones of foot; 7, bones of toes. (Le Conte's "Geology," American Book Co., Publishers.)

Some mammals have no teeth, at least not in the adult stage. The teeth are attached to the premaxillary, maxillary, and dentary bones, and to no others. These heterodont teeth may be classed as incisors, canines, premolars, and molars. The teeth would indicate an omnivorous feeding habit, but this is not true for all mammals. Some are omnivorous, some carnivorous, and many herbivorous. The teeth often give a hint as to the feeding habits, as well as proving an important element in classification.

The *mouth* is generally characterized by thick and fleshy lips, which serve as organs of prehension to grasp the food, as does also the tongue, the latter being also the seat of the sense of taste.

Owing also to the varying feeding habits, the different organs of digestion vary in size; for example, the intestine, which is longer in mammals than in any other chordate, is, in the ruminants, ten times the length of the animal, while in the carnivora it is only three or four times as long. At the junction of the small with the large intestine there is a blind tube or cecum, which is especially developed in most of the vegetable feeders.

**The Circulatory System.**—The heart is composed of four parts: two ventricles and two auricles. The circulation is double, closed, and complete. The left aortic arch is present instead of the right aortic arch, as in birds. "There are two features in the venous system which distinguish all mammals (except *Echidna*) from the lower chordates. The hepatic portal system is limited to a vein which conveys to the liver blood derived from the alimentary tract; in no mammal (except in *Echidna*) is there any representative of the anterior abdominal vein of the lower vertebrates. . . . In no mammal is there any trace of a renal portal system. The kidneys derive their blood from the renal arteries only."[1]

The red corpuscles of the blood of mammals differ from those of other chordates in being much smaller, non-nucleated, circular, and biconcave, except in the camel, in which they are elliptic.

**The Respiratory System.**—No mammals have external gills, but all breathe by means of lungs throughout life. Respiration is aided by a diaphragm or muscular partition, which completely divides the body cavity, separating the heart and lungs from the abdominal viscera. When this muscular diaphragm contracts its upper surface becomes more concave, increasing the lung cavity and allowing the lungs to expand under the pressure of the air. When the muscles relax the upper surface again becomes convex and the lung cavity is reduced, thus forcing out the air of the lungs.

The soft palate and the epiglottis are structures peculiar to

[1] Beddard, p. 88.

mammals. The vocal organs are in the upper part of the trachea instead of the lower, as in birds.

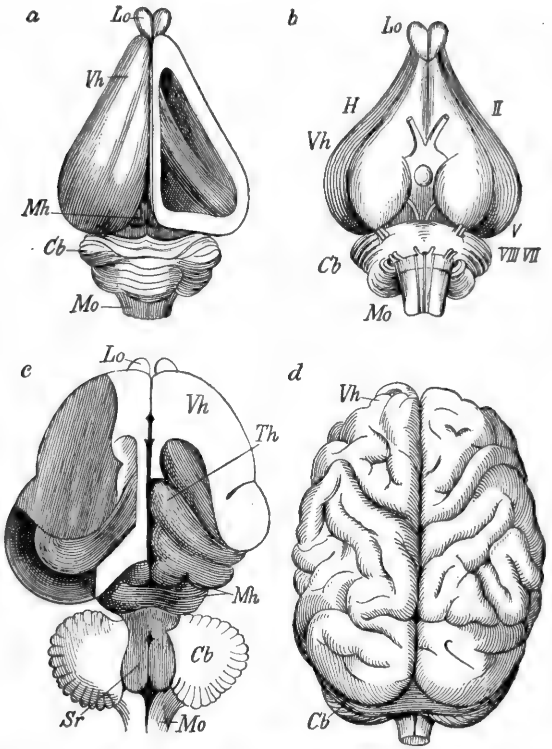



Fig. 259.—*a*, Brain of rabbit, from above; the roof of the right hemisphere is removed so as to expose the lateral ventricle; *b*, the same from below; *c*, brain of cat; on the right side the lateral and posterior part of the hemisphere is removed, and almost as much on the left side, and the greater part of the hemispheres of the cerebellum have been removed; *d*, brain of orang (*a*, *b*, *c*, after Gegenbaur; *d*, from the règne animal): *Vh*, Cerebral hemispheres; *Mh*, corpus quadrigeminum; *Cb*, cerebellum; *Mo*, medulla oblongata; *Lo*, olfactory lobe; *II*, optic nerve; *V*, trigeminal; *VII*, *VIII*, facial and auditory nerves; *H*, hypophosis cerebri; *Th*, optic thalamus; *Sr*, sinus rhomboidalis. (After Claus.)

**The Nervous System.**—The brain is relatively larger in mammals than in other chordates. The cerebral hemispheres are especially developed and are connected by the *corpus callosum,* which is not present in birds. The brain (Fig. 259), with a few exceptions, is convoluted.

The special senses are all present except in some *Cetacea,* where the olfactory membrane is degenerate and the sense of smell is lacking. The organs of sight and hearing (Fig. 260) vary most, owing to the different environments and consequent habits and needs of the various species. The sense of touch, while distributed over the surface of the body, is especially

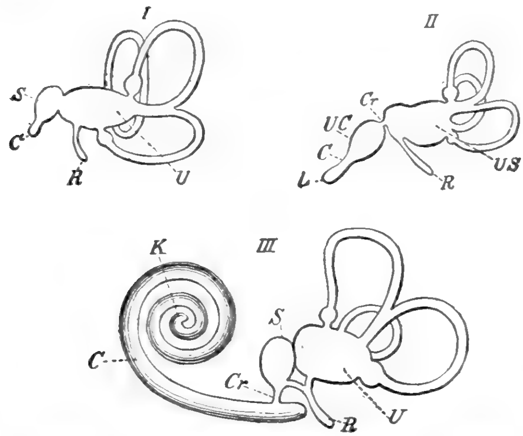



Fig. 260.—Diagram of the labyrinth of the ear in *I,* the fish; *II,* the bird; and *III,* a mammal: *U,* Utriculus; *D,* sacculus; *US,* utriculus and sacculus; *Cr,* canalis reuniens; *R,* recessus labyrinthi; *UC,* commencement of the cochlea, *C, L,* lagena; *K,* cecal sac at the apex; *C,* cecal sac of the vestibulum of the cochlear canal. (After Waldeyer, from Gegenbaur.)

sensitive at the ends of the fingers, on the lips, tongue or snout, and, in some monkeys, upon the under surface of the tail. The cat has long sensitive hairs (*vibrissæ*) connected with nerve-endings, which are tactile in function. The sense of taste, situated on the base and tip of the tongue and on the soft palate, is more highly developed than in any other class.

The sense of scent or smell is highly developed. Correlated with the development of smell is the presence of odoriferous glands in many mammals. The odors may serve for recognition, for warning, or for protection by mimicking the odors of a more formidable foe; as the odor of the musk deer may suggest that of a crocodile.

It is readily seen that the nervous system is the highest and most complicated of any chordate's, thus giving mammals highest rank in the scale of intelligence.

**Order I. Mŏnōtrĕm'ata.**—The animals of this order are primitive mammals, but that they are mammals is proved by the fact that they are covered with hair and nourish their young with milk. The heart has an incomplete auriculoventricular valve. The temperature is lower and more variable than in the higher mammals.[1] The brain has no *corpus callosum.* Like birds and reptiles, they are oviparous, and the intestines open into a cloaca. These animals are characterized by a temporary

Fig. 261.—A spiny ant-eater. (From Claus.)

"mammary pouch," in which they are hatched or to which they are transferred after hatching, and into which open the ducts of the mammary gland.

The **spiny ant-eater** (*Echid'na aculea'ta*) (Fig. 261) is a small nocturnal animal about the size of a duck-bill. It is covered with spines mingled with hairs. When danger threatens it curls up like a hedge-hog. Its legs are short and stout, and its feet are armed with strong claws for tearing open ant-hills. Its tail is vestigial. It has a long, pointed, toothless snout and a long, extensible tongue for licking up ants, other insects, and worms. The salivary glands are very highly developed, and when the tongue, covered with sticky saliva, is thrust into an ant-hill, it is soon covered with the insects. The tongue is then drawn back into the mouth and the adhering insects swallowed. It seems that the mother places the egg in the mammary pouch with her mouth. When the young is hatched it is nourished with milk. When it attains sufficient growth she removes it from the pouch, replacing it from time to time for nourishment. She shows further intelligence by digging a burrow and concealing her young in it when she goes out

[1] Beddard, p. 112.

at night for food. An allied form, the nodiak, is eaten by the aborigines of the Papuan region.

The **duck-bill** (*Ornithoryn'chus*) (Fig. 262) is found in southern and eastern Australia and Tasmania. It has a small, round head, and a broad, flattened, sensitive bill. Its eyes are small and somewhat hidden, but well developed. Its great paddling feet are five toed and webbed, the webs of the anterior feet being longer than the claws. It is about the size of our common rabbit and has short legs and a flattened tail. Its body is covered with loose skin, protected by thick, glossy hair, with an under layer of fine waterproof fur. The duck-bill is aquatic, digging burrows 30 or 40 feet long in the banks of streams. One opening of this burrow is below the water. It dives, enters this opening, and is safe from its enemies. It has teeth when young, but soon sheds them, and the gums harden into horny plates for crushing insects, worms, snails, and mussels, which it digs out of the mud with its snout and stores away in its cheek pouches to be eaten as

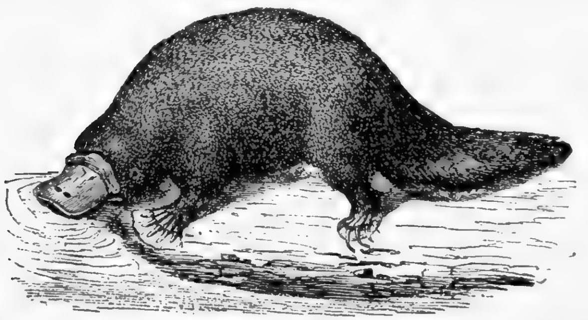


Fig. 262.—Duck-bill (*Ornithorhynchus paradoxus*). (From Lütken.)

it drifts upon the water. Sight and hearing are acute, but it has no external ears. The male is armed with a strong horny spur on each hind foot, which is connected with a poison gland. The duck-bill is as shy as a beaver. Its voice is like the growl of a puppy. The young are blind and naked.

**Order II. Marsupia'lia.**—Marsupials are fur-covered, terrestrial (rarely aquatic), or arboreal, or subterranean mammals, which carry the young, born immature, naked, and blind, attached to the mammary gland in an abdominal integumentary pouch. The milk is forced down the throat of the young by the muscular action of the mother. The young are able to breathe at the same time by the wrapping of the soft palate around the upper end of the trachea in such a manner that the air may pass from the nose down the trachea while the milk passes down the throat. The clavicle is present. The cloaca is reduced. The *corpus callosum,* if present, is rudimenatry. *Parameles* possess a true allantoic placenta. Many thousand skins of the opossums are used yearly. The hair is used in making hats and felt. The fur and leather of the kangaroo are also used.

The **opossum family** (*Didel'phidæ*) consists of pendactylous, plantigrade marsupials. The pouch is present or absent according to the species. The great toe is large and separable from the others, making the foot prehensile. The tail is long, prehensile, and usually covered by a scaly skin and a few scattered hairs. There are two distinct genera. The first has been divided into several by some authors.

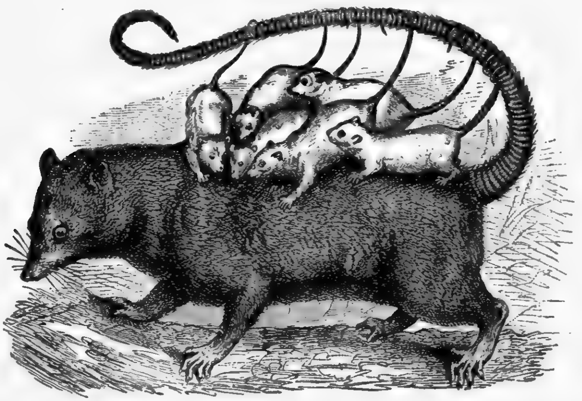


Fig. 263.—The female of *Didel'phys dorsig'era*, one of the South American opossums, carrying its young upon its back. (After Nicholson.)

Genus *Didelphys* comprises twenty-three species, most of which are tropical, being found in Mexico, Central America, and Brazil, but never in Australia. It is represented in the United States by the common opossum (*Didel'phus virginia'na*). Its habit of feigning death or "playing 'possum" when confronted by an enemy is well known. It is about the size of a large cat. Its nose is pointed, its eyes and ears large. It is arboreal and nocturnal. It eats anything from insects to small reptiles and birds, and also devours muskmelons and certain mushrooms; indeed, it is almost omnivorous. It does not hibernate. Its young are about ½ inch in length and are carried in the pouch for about eight weeks. After this, in some species, they are carried on the back (Fig. 263), their tails interlocking with that of the mother.

**Tasmanian marsupials** (family *Dasyur'idæ*) are distinguished from the American opossum by fewer incisor teeth, a rudimentary first digit on the fore and hind feet, by the absence of a cecum, and by a non-prehensile tail.

The Tasmanian wolf has a skull like a dog's, and is like the ordinary wolf in size, build, and habits. It is of a dusky hue and marked upon the hind parts with blackish bands. The hallux is wanting. The "Tasmanian devil" is black with white patches on the body. It is the size of a badger and its voice is a yelling growl.

The **Australian ant-eater** is of a bright reddish color, banded posteriorly and dorsally with white, and looks much like a large red squirrel. It feeds upon ants, which it captures with its tongue. Its habitat is both terrestrial and arboreal. The young are nourished as in other marsupials, but the pouch is lacking, and they are concealed only by the long hair of the mother.

The **Australian mole** has somewhat the appearance and habits of our common mole. It is pale golden red, in harmony with the arid soil in which it lives. The claws of the third and fourth front toes are enlarged. "It is not only blind, but its eyes have been more completely lost by degeneration than in any other known case. Its anatomy abounds in curious adaptations to an underground existence, evidently antique."

**The Wombats.**—There are three species, one Tasmanian and two Australian. Cheek pouches and tail are rudimentary. They are heavily built animals, like the badger or marmot, with a shuffling gait. They are gregarious, live in burrows, and feed upon roots. They are gentle, but stupid. Over a hundred thousand skins are sold in London yearly.

Several of the smaller species of family *Phalanger'idæ* are called "flying phalangers." They cannot fly upward, of course, but are supported by a parachute-like membrane from fore to hind limb, as they descend with a sort of skimming or sailing movement. The tail is usually long and prehensile, and the thumb opposable and nailless.

The **Kangaroos** (*Macropod'idæ*) are herbivorous marsupials of Australia and the surrounding islands (Fig. 264). They have three incisors on each side of the upper jaw and one on each side of the lower. The lower pair of incisors are sharp on the inner edge, and to some extent may be moved toward and from each other, cutting grass like shears. The fourth toe of the hind foot is exceedingly long and strong, and the fifth nearly as strong, but shorter, while the third digits are syndactylous,[1] but so slender that they are of no use in supporting the body. The fore limbs are short and small and are used only for grasping. With the exception of *Dendrol'agus*, which is arboreal and has less difference in the length of fore and hind limbs, this family is terrestrial. Locomotion consists of a series of leaps, effected by the long limbs and the long and powerful tail.[2] They vary in size from that of a rabbit to giant forms 5 or 6 feet in height. The larva[3] of a large kangaroo is not over 3 inches in length. They are gregarious, the droves numbering from 50 to 150. They are crepuscular, nocturnal, and herbivorous. They are timid, shy, and harmless if unmolested, but they can rip open a dog with their strong hind claw when necessary to defend themselves. When wounded they take to water, and if they get hold of a dog, they undertake to drown it.

Genus *Mac'ropus* includes kangaroos and wallabies, making together twenty-three species. *Macropus rufus* attains the height of 5 feet, 5

[1] See Glossary.

[2] Some authorities state that the tail is not used in rapid locomotion, but we know from observation of the kangaroo in the Zoölogical Gardens that it does rest upon the tail between successive leaps in slow locomotion.

[3] Beddard, p. 124.

inches, not including the tail. *M. gigantius* is reported by Sir Joseph Banks as good for food. It is said that a large kangaroo in rapid flight leaps 20 to 30 feet at a bound. The female will weigh 120 pounds, some old males weigh 200 pounds. The smaller species of kangaroos furnish the most fur and leather and the best venison. About 350,000 are sold in London annually.

**Rock wallabies** (genus *Petrog'ale*) have a shorter claw on the hind foot and a more slender tail, which is thickly covered with hair and never used in locomotion (Fig. 264). The tail is used as a balancer, as they leap from

Fig. 264.—*Petrogale xanthopus.* The rock wallaby, with young in pouch. (After Vogt and Specht.)

rock to rock. They are found in Australia only. The nocturnal genus (*Bettongia*) and others have sometimes been inaccurately called "rat kangaroos." The four species are subterranean, with prehensile tails, with which they carry their food, grass, roots, and leaves. One species burrows to a depth of 10 feet. It is found in Tasmania and Australia.

**Order III. Edenta'ta.**—The five families of this order are arboreal, terrestrial, or subterranean, with clawed limbs. They are chiefly tropical. The name, *Edentata*, is somewhat misleading, as teeth are not wholly lacking, except in the family *Myrmecophag'idæ* and the African genus *Manis*, which, having no use for teeth, have lost them. Front teeth are always lacking in this order. None of the teeth in the adult have enamel. They are said to be stupid and sluggish creatures, and, except in the ant-eaters, the brain is devoid of convolutions.

**Ant-eaters** (*Myrmecophag'idæ*).—This family consists of three South American genera, all without teeth and with long protrusible, viscid tongues, the salivary glands being highly developed. The snout is long and the body covered with long hair, while the tail is long and bushy. The claws are long and powerful, enabling them to tear open the ant-hills, or, in the arboreal forms (*Taman'dua* and *Cyclotu'rus*), to tear the bark from trees and search for insects or to defend themselves.

The great ant-eater (*Myrmecophagidæ jubata*) is said not to "fear the presence of the serpent's fold or the teeth of the jaguar," and will rip open a big dog with its claws before the dog's teeth can make an impression through the shaggy hair. Including the tail, this species may reach a length of 6 or 7 feet. The tail is 2 feet long and said to be the largest of that of any mammal. The great ant-eater sleeps through the day in a kind of "lair" in the tall grass, where it lies "on one side with its head buried in the long fur of the chest, the legs folded together, and the huge tail curled around the exposed side of the body."[1] They are numerous in their region, although the mother produces but one each year. The young stays with the mother a year, riding on her back when little.

The **sloths** (*Bradypod'idæ*), of South America, are arboreal forms, with very long anterior limbs, short tails, and round heads. Instead of the usual seven cervical vertebræ, the three-toed sloth (*Brad'ypus*) or "Ai," so called from its plaintive cry, has the unusual number of nine, while the two-toed genus (*Cholæ'pus*) has the exceptional number of six. The toes have long, recurved, non-retractile claws for clinging to the branches of trees. The feet are like hooks with the fingers bent under them, hence they walk slowly and clumsily on the ground, but climb about with ease in the trees, where they live continually day and night, hanging back downward, even in sleep, from the lower side of the limb. They never descend to the ground unless compelled to do so, but spring from tree to tree in search of food, which consists of leaves and green shoots. They are nocturnal. Their hair is long and shaggy and covered with minute green algæ, giving the animal an almost perfect resemblance to a lichen-covered branch. This may be taken as an example of commensalism between animals and plants.

**Armadillos** (*Dasypod'idæ*).—There are several genera of armadillos (Fig. 265), and they are found chiefly in South America. They are also known in Central America, and one species is said to occur in Texas. They are the only mammals in which the dermis develops into hard bony plates like those of the turtle, while the hair on the dorsal part of the body is replaced by horny scales covering the bony plate.

"Traces of dermal armature exist in one or two genera of the whales."[2]

[1] Ingersoll, p. 471.
[2] Beddard, p. 173.

The different forms are distinguished chiefly by the number of the movable bands of "scutes" between the anterior and posterior shields. The little *Chlamydoph'orus*, of about 5 inches in length, has no movable bands at all, the series of plates being uniform and continuous even to the neck. The conspicuous external ears so prevalent among the armadillos are also absent. *Tolypeu'tes* can roll itself up into a ball and be protected by its armor, or roll away from its enemies. Its walking is digitigrade and it is called "pig-footed." Armadillos are omnivorous, and one species (*Das'ypus sexcinc'tus*) is especially fond of carrion, burrowing up to a carcass like beetles. The limbs of armadillos are short, powerful, and clawed, enabling them to dig rapidly in the ground.

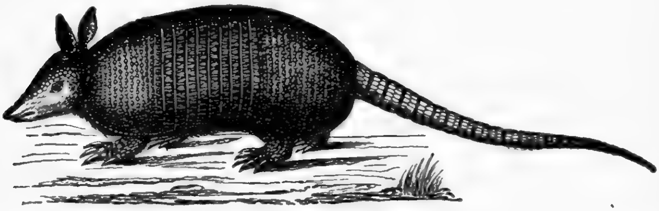


Fig. 265.—Nine-banded armadillo (*Das'ypus novemcinc'tus*). (Lütken.)

**Order IV. Sire'nia.**—These are dark-colored, sparsely haired or bristly, toothed, herbivorous mammals. The elongated snout of the whale is replaced by large movable lips for grasping the food, which consists of seaweed and other aquatic plants. External ears and hind limbs are absent. The anterior limbs are flipper-like, but more flexible than those of the whale, and the mother sometimes holds the young under her arm. The tail is horizontal. *Sirenia* grow to a length of 9 or 10 feet. They have two sets of heterodont teeth.

The *dugong* (Fig. 266) is sparsely covered with stout hairs. The thick skin is underlaid with blubber. It is found on the east coast of Africa, in the Indian Ocean, and the north coast of Australia, and in the Red Sea.

The *manatee* is found on the Atlantic coast of South America and of Africa, and in the mouths of the large rivers of these countries. The blubber in the manatee differs from that of the whale in that it has no free oil.

*Steller's sea-cow*, the recently extinct *Rhyti'na*, was found in herds in Behring Sea. It reached a length of 20 to 30 feet. The flesh was good for food, and the hide and oil of value.

**Order V. Ceta′cea.**—The whales must be regarded as true mammals, since they nourish their young with milk. They are, however, hairless, with the exception of a small number of hairs about the muzzle in some species. They are perfectly aquatic, never leaving the water. Their form is fish-like, with a large and powerful tail horizontally flattened, with a fluke on each side. The tail is the chief organ of locomotion, moving up and down in a sort of rotary motion, and thus propelling the animal from place to place.[1]

Fig. 266.—The dugong. (From Brehm.)

The fore limbs are fin-like paddles or flippers and are used as balancers. Whales have lost all external trace of hind limbs, but a pair of small vestigial bones is found embedded in the body. A fleshy dorsal fin is generally present.

**Whales** (Fig. 267) are distinguished by a great rounded cranium, the elongation of jaws and face, and by a prow-like snout of fat for the defense of the skull. The mouth is very large and the throat extremely small. The nostrils are represented by a single or double blow-hole far back on the snout, nearly on top of the head. "When the whale breathes the expired air rushes out through the nostrils. The vapor in this expired breath,

[1] Beddard, p. 173.

together with mucus from the nostrils, is condensed into drops of water in the cold regions, but the water taken into the mouth does not pass out through the blow-hole. The nose is directly connected with the windpipe, so that a whale can breathe while swimming through the water with its mouth open. The eyes are relatively very small, and there are usually no external ears." (Traces of external ears in the porpoise are recorded by Professor Howell.)[1] The opening of the ear is minute. The cervical vertebræ are very short and more or less fused.

The skin is smooth and shiny, like coach leather, and a thick coating of fat immediately underlies the skin. The blubber or fat from whales yielded much profit from its oil until the modern

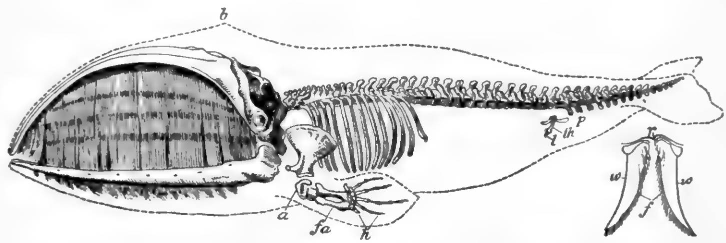



Fig. 267.—Skeleton of a whalebone whale, and section of the mouth, with whalebone: *b*, Blow-hole; *a*, upper arm; *fa*, forearm; *h*, hand; *p, th, l*, small remains of pelvic or hip-bone, thigh, and leg; *r*, roof of the palate; *w, w*, plates of whalebone; *f*, whalebone-fringe. (Holder's "Zoölogy," American Book Co., Publishers.)

method of getting oil from deep oil wells, and the scarcity of whales has almost excluded the whale industry from the oil trade. The toothed whales feed upon fish and larger marine animals, while the whalebone whales feed upon minute *Mollusca*, jelly-fish, and *Crustacea*.

The toothless whales are those in which the teeth, present in the embryo only, are replaced in the adult by baleen or whalebone (Fig. 267), a horny product of the epithelium of the mouth, which consists of a large number (from 330 to 370) of horny plates hanging down like curtains in pairs, one on each side of the mouth, nearly meeting each other in the middle, each pair immediately behind another. The lower edges of these horny

[1] Beddard, p. 346.

plates are "frayed out" and form a strainer, through which the water taken into the mouth trickles out, leaving the small animals from the water in the mouth. This baleen or whalebone is worth several dollars a pound, and from 800 pounds to several tons are derived from a single whale. One whale has been reported as furnishing $12,230 worth of whalebone, and oil valued at $3490.

Whales vary from 6 to 60 or 80 feet in length, and some have been found 100 feet long. The voice of some species has been described as similar to the lowing of a cow, and others like the bellowing of a bull. The young whale is called a calf.

The great *Ror'qual whales* may measure from 60 to 85 or even 100 feet. A species of whale, probably of genus *Balænop'tera*, is described as having a mouth so wide that "divers men might have stood up in it, yet the throat so narrow as would not have admitted the least of fishes." The blue whale (*Balænopter'idæ sibbal'dii*) is the giant of the rorquals. The California gray whale is said to be a cunning, courageous enemy.

The "*right whales*" are from 50 to 60 feet long, the head about one-fourth the length of the entire animal, and with no dorsal fins. The whalebone is valuable and the oil is of excellent quality and large quantity. In toothed whales, which have no whalebone, the orifice of the blow-hole is single.

The *sperm whales* (*Physeter'idæ*) have teeth in the lower jaw only. *Physe'ter macroceph'alus*) is from 55 to 80 feet long. The head is enormous, ending in a great blunt snout. The mouth is ventral and "it has been asserted that the sperm whale turns over on its back to bite."[1] The single blow-hole is not in the median line, but on one side. Inside of the great "square head" is a cavity lying above the skull, which during life is filled with oil or fluid fat, of which the spermaceti of commerce is the product. This oil is also found in other whales. Ambergris, an expensive substance used in connection with perfumery (which is at first a greasy mass and then hardens), is a product from the intestinal canal of the sperm whale. This whale is tropical. The females are found in herds or schools. Their food is chiefly cuttle-fishes. The throat is said to be large enough[2] to have swallowed Jonah. It has great strength, being able to throw itself entirely out of the water.

*Dolphins* and *porpoises* have many teeth which are present in both upper and lower jaw. The size of these animals is small to medium. The *Be-lu'ga*, or "white whale," is a northern species. It has a distinct neck and free vertebræ. The young are blackish, growing white as they mature. This porpoise ascends rivers in search of food, which is preferably salmon. One (*Delphin'idæ elphineraptus*) is fairly common in the Gulf of St. Lawrence.[3]

[1] Beddard, p. 362.
[2] Ibid., p. 365.
[3] Shipley and McBride.

*Distribution.—Cetacea* are cosmopolitan, mostly marine. A few ascend rivers, some being exclusively river forms of South America and southeastern Asia.

*Use to Man.*—A good quality of ivory is obtained from norwhal's tusks (the left upper incisor which sometimes reaches a length of 8 to 10 feet). Whalebone, oil, and spermaceti have already been mentioned.

*Geologic Distribution.*—The cetaceans are represented in the Eocene and Miocene of Europe, Egypt, and North America. Both whalebone whales and toothed forms have been found in the Pliocene deposits. The toothed whales are represented in the Miocene, Pliocene, and Pleistocene of Europe, North America, New Zealand, and Australia by the extinct heterodont family *Squalodon'tidæ.*

**Order VI. Ungula'ta.**—This is a large order of diverse forms. A large proportion of these forms are extinct, and existing forms are connected to some extent by fossil forms. Many of these animals are very large. They are chiefly herbivorous. The molar teeth are adapted for grinding by having broad crowns, with tuberculated or ridged surfaces. Canines are absent or small, or, in a few cases, tusk-like in the upper jaw. Although the older types were plantigrade, the existing forms, excepting such as Hyrax, are digitigrade, walking on the tips of their toes. The one-four terminal phalanges are nearly always encased in solid horny hoofs, which are, in reality, enlarged and thickened claws. The weight of the body usually rests upon these hoofs. The limbs have no power of grasping or climbing, but are simply organs of locomotion. Clavicles are absent. This is the only order of mammals in which horns appear. They are surely a needed and effective means of defense in those forms which are too heavy to be swift, as they cannot defend themselves with teeth nor claws, as do the rodents and carnivores. The order contains many domesticated animals indispensable to man as beasts of burden or as food. It is the most beneficial to man of any order of mammals.

**The Hyrax** (*Hyracoi'dea*).—This and the following family are often placed in a sub-order. They are the survivors of those great animals of the past that had their wrist-bones placed in a longitudinal series and had toes which were nearly equal in length. The hyrax (Fig. 268) is a small animal found in Ethiopia, Africa, and Arabia, including Palestine.[1] It is sometimes called the "rock-rabbit," since the most species live among rocks and mountains, and their squatty attitude, short tail, and split muffle, as well as a pair of rodent-like incisors in the upper jaw, remind one of the rabbit. They have no canine teeth. Some species are found upon the trunks and large branches of trees, and sleep in the hollows of trees. The skull shows affinity with the Perissodactyles and also with the rodents. The ears are short and the body fur covered. The clavicle is absent, the radius and ulna complete, but often ankylosed. The hyrax has a greater number of trunk vertebræ than any other mammal, twenty-one or twenty-two of them bearing ribs. The hyrax differs from all other mammals in having, in addition to the ordinary cecum, a pair of supplementary ceca situated some distance down the large intestine.

**The Elephant** (*Proboscid'ea*).—The skin is greatly thickened and scantily covered with hair. There is a tuft of hair on the end of the tail. The massive, stiff limbs are quite free from the body. The nose and upper lip[2] are produced into a long, flexible, muscular, prehensile trunk or proboscis (Fig. 269), at the end of which the nares are situated. There are five complete digits on both fore and hind limbs, and though they are bound together in

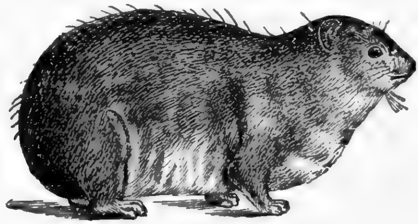


Fig. 268.—*Hyrax syriacus.*

the integument, each is encased in a separate hoof. The skull is very large, but the bones are rendered light by their numerous air cavities. The brain-case is small in comparison with the size of the skull, as the bones are enormously thickened. In some specimens the bony skull wall is greater in diameter than the cranial cavity, the frontal bones in older animals sometimes reaching the thickness of one foot. In existing forms there is a single pair of upper incisors, which develop into long tusks of solid ivory. A single tusk sold in London in 1874 weighed 188 pounds. There is no trace of any canines. Molars are so large that there is never but a single functional one on each side of each jaw at a time. They are transversely ridged. Elephants are herbivorous. The stomach is simple and the cecum

[1] This is supposed to be the cony of the Bible, where it is spoken of as a "wise, though a feeble folk." It is said to be too wise to be caught in traps, at least, but the further reference that it "cheweth the cud, but divideth not the hoof" throws some doubt upon its identity. However, Bruce kept one in captivity and found that it did chew the cud. (See Beddard, p. 234.)

[2] Beddard's "Mammalia."

wide. The cerebral hemispheres are much convoluted, but the cerebellum has no convolutions. There are but two living species: one (*El'ephas africanus*) is found in the forests of tropical Africa, the other (*E. indicus*) is found in India, Ceylon, and the Malayan Islands. The African species has not the two rounded bosses which give the wise countenance to the Indian species, and its head slopes back more and the ears are much larger. It is digitigrade, though a thick pad of fat makes it appear plantigrade. It reaches the height of about 12 feet. "Jumbo" was 11 feet to the shoulder and weighed 6½ tons. There are tusks in both sexes, but in this species they are larger in the female. The tusks are used not only as a means of defense, but especially the right one is used also for grubbing roots for food. The *Africa'nus* is more active and savage than *In'dicus*, but it has been tamed. It is not used in Africa now save for food and ivory. It is long lived, maturing at forty and living one hundred and fifty or more

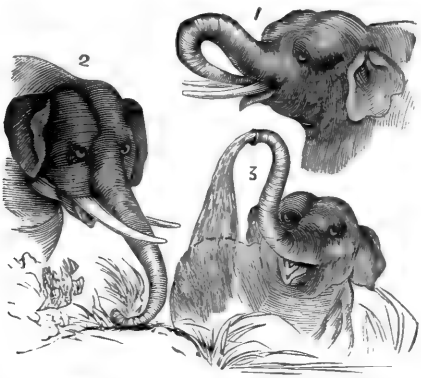



Fig. 269.—Various uses of the trunk of the elephant: 1, Drinking; 2, pulling grass; 3, washing. (From Holder's "Elements of Zoölogy," American Book Co., Publishers.)

years. *Elephas indicus* is invaluable as a beast of burden on account of its great strength, though not all are to be depended upon. One may be perfectly docile and obedient, and another furious, vicious, and unmanageable, but, stranger yet, they are sometimes exceedingly timid. Baker tells of one he was riding fairly bolting at the sight of a hare. The elephant rushes into the nearest jungles, when bolting, tearing through the underbrush, while the rider is swept off or torn by the thorns. Its obedience to the slightest sign of the Indian mahout shows that it has considerable intelligence. Baker asserts that the locality and time of ripening of particular kinds of fruit are remembered by it. The power of remembering and recognizing individuals is proved by their revenge of particular treatment of certain keepers. This group of ungulates appeared in the Miocene.

The **Mammoth** is an extinct form which once was found about the north pole in Siberia, Europe, and America. It was covered with long, woolly fur.

Fossil remains of another extinct form, the Mastodon, are constantly being found in the gravel pits of Europe, Asia, and North America. Some species have tusks in both jaws and tuberculated molars like the pig.

The remainder of this order is included in the two great divisions of *Perissodac'tyla* (odd toed) and *Artiodac'tyla* (even toed).

**Perissodactyla.**—The odd-toed group has the molars and premolars of the same size and the middle toe predominantly developed. "The other toes in the three living families are reduced to different degrees."

The **tapirs** (*Tapir'idæ*) are among the oldest mammals represented to-day, the family being as old as that of *Equidæ*, though the specialization of the toes has never advanced so far. The fore feet are four toed, and the hind feet three toed. The nose and the upper lip are lengthened into a short proboscis.

An American species (*Tapiridæ terrestris*) is a solitary, dull, and gloomy, timid and defenseless animal, hiding away near the streams in the marshy, tropical woods in the daytime, and feeding at night. When alarmed or pursued it always takes to the water for safety. The jaguar is its most formidable enemy.

The Malayan forms haunt the most retired spots among the wooded hills, thus escaping its enemy, the tiger.

The tapirs (genus *Tap'irus*) are now found only in South and Central America, the Malay Peninsula, Java, and Sumatra. They are small or moderate sized, ungainly creatures, covered with brownish-black hair. The young is spotted and striped with white, as is the rule among quadrupeds of the forest.[1] The tapir's quick senses enable it to slip away, which it can do with great rapidity, when disturbed. When at rest in the daytime a Malayan form "exactly resembles a grayish boulder, and as it often lives near the rocky streams of the hill jungles, it is not easily detected." Tapirs are browsers, seizing and drawing the succulent leaves and shoots into the mouth with the proboscis. "They are extremely fond of the leaves of the low-growing cocoa plant, and they often in one night destroy a cocoa field which has cost a poor Indian the hard labor of a year."

South American tapirs are said to make interesting pets. They are kept in the National Zoölogical Park at Washington. In Costa Rica the tapir is much hunted, for its flesh is good, both fresh and salted, and its thick hide is made into twisted whips (rawhides).

The primitive forms were distributed all over the world, "but as the later tertiary conditions changed from torrid to temperate outside the tropics, they became extinct everywhere save in the hot, moist climate under the equator, where they have continued to the present time." Although now structurally very different from the horse of to-day, they probably represent something of the character of the ancestral horse.

The **rhinoceros** (*Rhinocerot'idæ*) is a relic of nature's early attempts to formulate the solid-hoofed type of quadruped. It is recognized in fossils toward the close of the Eocene in both Europe and North America, and the

[1] Ingersoll, p. 372.

skeletons of those of the Miocene differ little from those of to-day. These once numerous and widely scattered animals are represented by two African and three East Indian species.

They have three short toes on each foot, each toe encased in a hoof-like nail. The central or third toe is the largest, but the weight is sustained by a sole pad. The East Indian forms (Fig. 270) have but one nose horn. The small Sumatran form and the African forms have two horns. These horns are simply outgrowths of the skin based upon a thickening of the nasal bone, and are composed of a number of tapering whalebone-like fibers, which sprout from papillæ. They are finely cemented together, growing at the base as fast as they wear away at the tips. The usually naked skin is very thick, deposited in folds, making it look like plates of armor. In fact, the dried skin is used as shields by the oriental soldiers. The rhinoceros feeds upon leaves, twigs, and grass. It occasionally fights a tiger or leopard. It wallows in the mud. There is but a single calf at birth. The young are easily tamed. Selous says the white rhinocerous puts her nose close to the

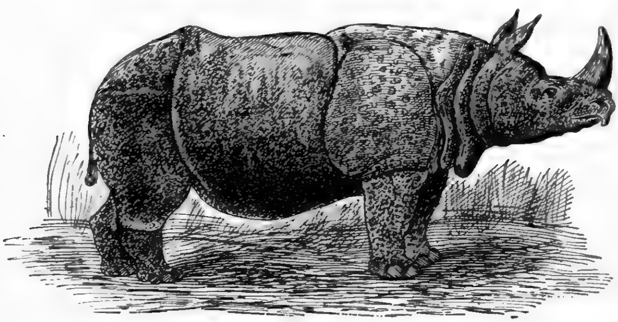


Fig. 270.—Indian rhinoceros (*R. indicus*).

ground and guides the little one (which precedes her) by keeping the point of her horn close against the rump. In disposition he says they are sluggish, inoffensive animals, lying asleep in daytime, and coming to the water to drink in the evening. The African species are bluish gray when clean.[1]

The long-lipped species of Africa (*Rhinocerot'idæ bicor'nis*) has an overhanging extensible upper lip with which it grasps and tears off the leaves and twigs upon which it feeds exclusively. The calf follows alongside of its mother. So sharp is the horn of a rhinocerous and so strong the head and neck that it can "disembowel and toss over its back any smaller animal, and it could rip open an elephant if it got at his side, though some African explorers say that the rhinocerous usually runs from a man; but some are vicious."

The horns are used as knife-handles and as weapons. The horn of the white rhinocerous (*R. simus*) has been known to measure 56 inches long, while that of *R. bicornis* is not known to exceed 40 inches. The Chinese

[1] Ingersoll, p. 382.

and Burmese "pay high prices for the horns, tongues, and other efficacious parts of the eastern rhinocerous, to be ground into medicinal powders."[1]

The **horse** (*Eq'uidæ*) has the most complete geologic record of any living animal. Fossil remains were found in the Eocene Epoch, on which there were four front toes and three hind ones. Then in the Miocene were found ancestors having three toes both before and behind, while at present this family is distinguished by a single functional toe on each foot, the second and fourth toes forming splint bones on either side of the toe. The tibia also is vestigial.

In the Eocene times Europe and Asia were joined in the arctic latitudes by way of North America. The horse inhabited all continents except Australia, but it disappeared entirely from America in the later geologic ages, for which no adequate explanation has been made.[2] At first it was adapted to a forest life, but it has come to be more and more adapted to living upon the high, dry plains, and it is one of the most highly specialized animals in its adaptation to its environment. The remains of man and the horse are first found together in the interglacial or postglacial period. "There is abundant proof that men first hunted and ate, then drove, and finally rode the horse."

The horse industry stands second only to the cattle industry among stock men. Horsehide leather is used for razor straps, gloves, and shoe uppers. The hair is used for upholstery and the bones for fertilizing, and the flesh for cheap meat. The mare's milk is used by the nomadic peoples of inner Asia. Koumiss, often used as a beverage, is fermented mare's milk.

All our breeds of horses have been introduced from the Old World, as there have been no native wild horses in America. The ass, the zebra, and the recently extinct African quagga are also members of this family. The ass is wild in both Asia and Africa, and the zebra in Africa. The breeding of the hybrid mule is confined chiefly to the southern and some of the western states.

**Artiodactyla.**—The even-toed ungulates, in which the third and fourth digits form a symmetric pair, have the three or four premolars smaller than the molars, and have a complicated stomach.

The *non-ruminants* comprise the hippopotamus, hog, and peccary. They are omnivorous. The canine teeth are frequently developed into tusks.

The **hippopot'amus** (*Hippopotam'idæ*) is at present confined to Africa. It formerly inhabited Europe and there were also Indian species in the lower Pliocene. The common hippopotamus (Fig. 271) is thick skinned and almost hairless. The two strong incisors on each side of each jaw and the canine teeth continue growing throughout life. The stomach is divided into two parts. The cecum is lacking. This huge animal, 14 feet long, has very short limbs and tail. The feet have four-hoofed toes. The hippopotamus is nocturnal and aquatic, and not only walks rapidly along the

[1] Ingersoll, p. 378.
[2] Ibid., pp. 354–360.

bottom of the river, but swims. It is thought that it swam from the Continent across to Madagascar, thus populating that island with the genus, fossils of which are found in the swamps. The gap of the mouth is wide and the large teeth are used in cutting the bark from trees, which is a prominent feature of the food. They produce a strange carmine-colored secretion, "sweat," containing small crystals and corpuscles, from the skin. "Like other aquatic animals the nostrils are on the surface of the head and can be closed when under water," where it can remain not over ten minutes, and, after reaching the surface again, it spouts like a whale. It is a dangerous animal to meet, as it cannot only capsize a boat, but even bite out large portions of it and will attack man.

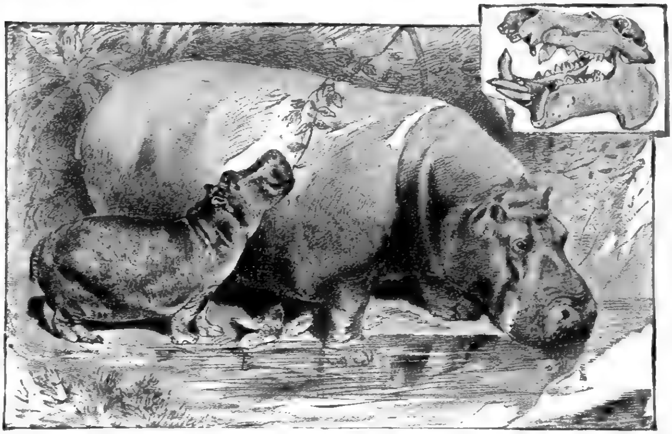


Fig. 271.—Hippopotamus and young. (Holder's "Zoölogy," American Book Co., Publishers.)

The **hog** (*Suidæ*) (Fig. 272) has four toes, but only two touch the ground, except in miry places. The nostril is situated at the end of the tough, proboscis-like snout. Hogs are generally covered with coarse hair or bristles. The stomach is simple and the cecum present. The typical genus *Sus* is found in Europe, northern Africa, Asia, and in the Malay Archipelago. The wild boar is *Sus scrofa* of Europe.

The wild hog loves to wallow in the wet ground, but sees to it that "cover is handy." The male is usually solitary, while the female and young go about in groups of about a dozen. In India it makes huts of leaves, grass, and twigs, so interwoven as to be practically rainproof, in which the young are housed for several weeks. The domestic pig has been developed from the wild hog by artificial selection and intercrossing. The African wart-hog, the ugliest of land animals, and *Babiru'sa* are allied.

The hog industry in the United States represents hundreds of millions of dollars. One-third of the hogs of the world are produced here. Besides the pork used at home, large quantities are exported to Europe. It is said that at the large packing-houses everything about the hog is used, except the squeals. The hair is sold for mixing mortar or for making brushes. The skin is used for making foot-balls. The bones and teeth are carbonized and sold to sugar refiners or ground into a fertilizer. The sinews and hoofs are used in making glue, the intestines for sausage-casings, and the blood for making buttons, or, together with the refuse, for making fertilizer.

*American Hogs.*—The collared peccary is our best representative of the wild hog. It is grayish black, with a white collar or streak about the withers. It ranges from the Rio Grande in Texas southward to Patagonia. It prefers moist, bushy, upland jungles, but it has been found in regions surprisingly dry, hot, and bare of vegetation. Peccaries go in small droves,

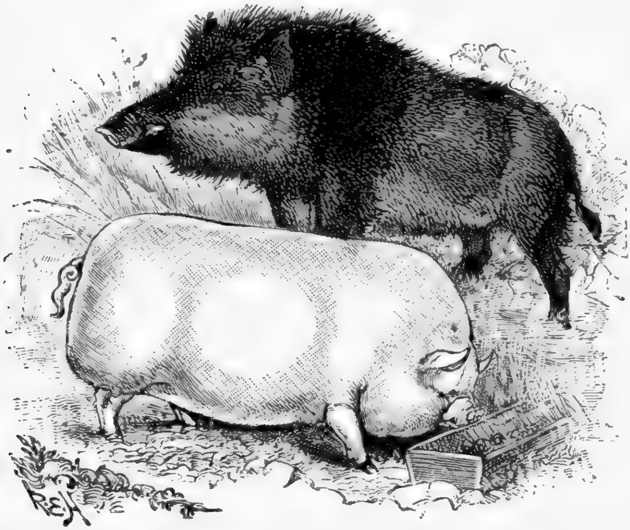


Fig. 272.—Wild boar contrasted with a modern domesticated pig. (Romanes.)

and feed at night on roots, mushrooms, farm products, and small animals. "When pursued, they run in open ground with great fleetness, and in cover will squat and dodge like a jack-rabbit." When cornered they are courageous and pugnacious, fighting viciously, so that the boldest hunter "does not hesitate to climb the best tree that happens to be available." Only their courage and the use of their tusks have protected them from annihilation in forests infested with jaguars, pumas, wolves, and ocelots. If the musk gland is cut out as soon as the animal is killed the flesh is palatable.

The **ruminants,** or cud-chewers, include the giraffe, deer, ox, sheep, and antelope. Teeth and stomach are both adapted to an herbivorous diet. In the upper jaw the canines are usually degenerate. There are generally no incisors, never more than a single pair, and in their place is a thickened calloused pad. The canines of the lower jaw have taken the form of incisors. The molars are selenodont, with crescent-shaped cusps; the stomach is usually divided into four compartments (Fig. 273), the *rumen* or paunch, which receives the food when it is eaten; from here it is regurgitated and chewed again as cud. It is then passed into the second division of the stomach, the *reticulum*, from which it passes into the third division, the *omasum;* and from there to the true stomach or *abomasum.* These animals

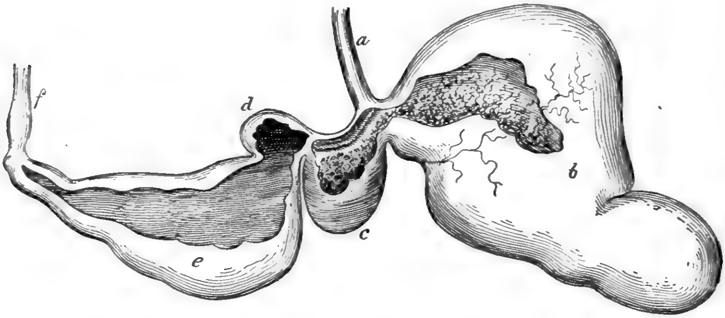



Fig. 273.—Stomach of a ruminant (sheep), showing the four compartments: *a*, Esophagus; *b*, paunch; *c*, honeycomb or reticulum; *d*, liber psalterium or manyplies; *e*, true digestive stomach; *f*, beginning of the intestine. (After Owen.)

are usually large and many of them bear horns, which are larger (or exclusively) on the males.

The **Chev'rotain** belongs to the primitive Asiatic and African family *Tragu'lidæ.* It is the smallest ungulate living to-day. It has both deer-like and pig-like characteristics. It is hornless and the stomach has but three divisions.

The **camels** and **llamas** (*Camel'idæ*) have long limbs, with no trace of second and fifth toes. The *rumen* has smooth walls, and from it are developed the water cells (Fig. 274). Camels are wonderfully adapted to their desert home by the sole pads on their feet; by their sandy color; by their long necks, which give long range of vision and enable them to reach the desert shrubs on each side of their path; by their cartilaginous mouth, which enables them to eat the hard and thorny plants of the deserts on which no other animal could subsist; by their small ears; by the valve-like folds by which the large nostrils may be closed against the simoons of the desert; and by their prominent eyes and heavy, overhanging eyelids. The hump is a real and acknowledged reservoir of nutriment stored up during moist seasons, as well as nature's pack saddle for the commerce of the ages.[1] For centuries the camel has been the means of transportation over the desert. Papyrus records show it was well known in Egypt at least thirty-two centuries ago. Yet in all these centuries "little of sympathetic association has been gained between beast and master." Owing to its viciousness and stupidity it has been subjugated rather than domesticated. However, it has been developed into many serviceable forms, some swift and elegant, others strong and ugly.

There are two distinct species of camels, the Bactrian or two-humped camel (*Came'lus bactrianus*) and the one-humped species (*C. dromedarius*) (Fig. 275). The two species will interbreed it is said, and it is not probable that either is now found in a genuinely wild state. The camel is a thickly built, ungainly pack horse. The dromedary is the finer-haired, light-step-

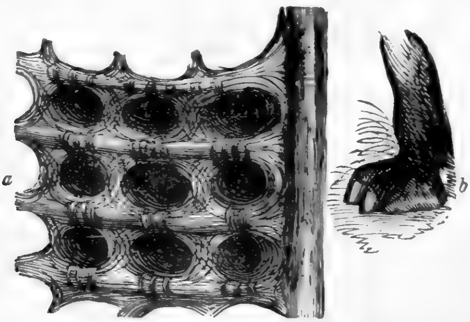



Fig. 274.—*a*, Water-cells in the paunch of the camel; *b*, foot, showing the pad. (From Holder's "Elements of Zoölogy," American Book Co., Publishers.)

ping race horse. The former travels three miles in an hour and six hours in a day, while the latter can run seventy miles a day. The latter is several times the value of the former. The single calf is weaned when about a year old, but it is not fitted for service until five years old. We are accustomed to think of camels as associated with heated countries alone, but the Bactrian camel can endure much cold, and carry on the overland trade between China and Russia across the plains of Mongolia or Turkestan amid the snows of winter and the dust of summer. Every spring the camel loses every fragment of its hair and for about twenty days it is as naked as if clean shaven, and is then sensitive to cold and rain. When the hair, which is at first fine and beautiful, becomes long and thick it can brave the severest frost. Its strong, elastic, lustrous hair is woven into warm cloth. The Andean vicunia has finer, soft, curly wool. The Arabian depends upon the camel for many things: "fuel, milk, hair for tents, ropes, shawls, and coarser fabrics; and flesh, leather, and bones from the dead animal. Camel's milk, though

[1] Ingersoll, p. 337.

bitter from the wormwood pasturage, is the staple diet of thousands in Africa."[1]

The genus **Llama** includes the llama, alpaca, huanaco, and vicunia. They differ from the camel in their smaller size and the absence of the hump.

The llama was used in Peru as a beast of burden for centuries before the Spanish Conquest, and is still the only trustworthy carrier in the higher Andes. Its flesh is coarse and unpalatable, and its hair is coarser and inferior to that of the alpaca. It defends itself by "spitting," that is, forcibly ejecting not only the saliva, but the contents of the stomach at any offender. The discharge is injurious to man's eyes. The llama can also kick and bite. The alpaca is a smaller variety, bred in Peru and Chile for its thick growth of black to gray or yellowish woolly hair.

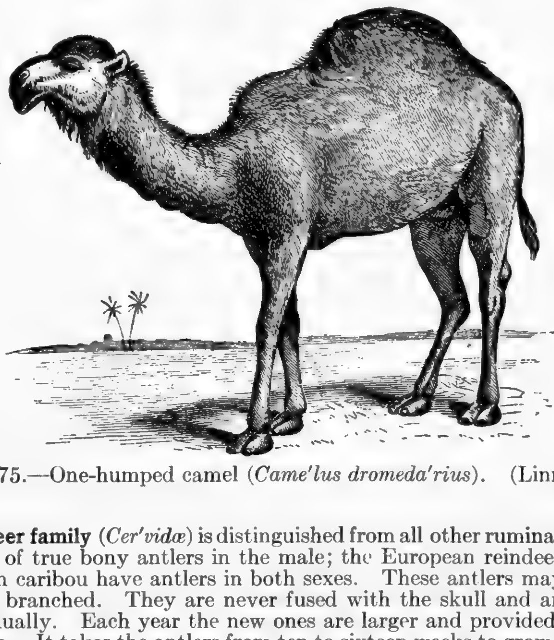


Fig. 275.—One-humped camel (*Came'lus dromeda'rius*). (Linnaeus.)

The **deer family** (*Cer'vidæ*) is distinguished from all other ruminants by the presence of true bony antlers in the male; the European reindeer and the American caribou have antlers in both sexes. These antlers may be little or much branched. They are never fused with the skull and are usually shed annually. Each year the new ones are larger and provided with one more tine. It takes the antlers from ten to sixteen weeks to grow to maturity. During the greater portion of this time the males are weak and inoffensive. At this time the does are rearing the young (fawns). When the new antlers are fully developed (about October) (Fig. 276) the males are as savage as tigers.

The **white-tailed Virginia deer** (*Odocoi'leus virginia'nus*) is our most widely distributed deer. It weighs about 250 pounds, is light brown in summer and reddish brown in winter, with the under parts of throat and tail pure white. It crouches and carries its head low, and saves itself by clinging

[1] Zwemer.

to the cover of brush or timber, in which it is not easily perceived until it starts to run, when it raises its tail and waves its "white flag" right and left in utter defiance of the rifle. If this white tail is not used as a recognition[1] mark, it is surely unexplainable.

The **American elk** or **wapiti** (*Cer'vus canaden'sis*) is the largest of the round-horned deer, handsome and tall as a horse, with a luxuriant mane and imposing antlers. The wild elks are nearly exterminated except in Yellowstone Park, though formerly abounding from the Adirondacks and southern Alleghenies to California and even Alaska. An effort is being made to restock the Adirondacks, but reckless hunters make it almost impossible. The elk is both a browsing and a grazing animal. In winter those in Yellowstone Park migrate southward to the sheltering valleys of Jackson Hole. In summer they love to ascend the high mountains. They

Fig. 276.—"Pushing match." (From life.)

are kept in many city parks, as they breed freely in captivity. The red deer of Europe is a close ally.

The **reindeer** (*Ran'gifer taran'dus*) of arctic Europe is unique in that both sexes bear horns. These are used not only for defense, but to shovel snow in search for food. Their fur is of a lighter color in winter. In Spitzbergen they migrate "in the summer to the inland region of the island, and in the autumn back again to the seacoast to browse upon the seaweed."[2] Reindeer are annually imported into Alaska from Siberia for food and burden bearers for the natives. The multiplication of these reindeer has proved a source of food supply. The young develop into larger and stronger animals than their parents.

Very closely allied is the **American caribou,** which ranges from the east coast of Greenland to the west coast of Alaska. Next to the musk-ox it is

[1] Glossary.
[2] Beddard, p. 299.

the most northerly of the ungulates. The caribou is an odd-looking animal, with thick long legs and with hoofs so expanded and flattened as to make good snow-shoes. Its covering is warm and consists of a "coat of fine wool-like hair, through which grows the coarse hair of the rain coat." It feels like a thick felt mat. The food is moss and lichen. These animals migrate southward in great herds, though they are not known beyond the Churchill River. In spring they return to the most northern headlands, where they bear their young. Upon these migrations the savages who live in these

Fig. 277.—Rocky Mountain elk. (Farmer's Bulletin No. 330, U. S. Dept. of Agriculture.)

arctic deserts of rock and snow depend for subsistence. Every part of the animal is used. The flesh, stomach, and intestines are eaten, as are the points of the antlers when soft, and the marrow of the leg bones. Soup is made from the blood and meat mixed together. The hair forms the warmest clothing; also tents, cords, and shoe-strings. Knives and needles are made from the bones; fish-hooks, spears, and knife-handles from the horns; while certain tendons serve as fine strong sewing thread for use with the bone needles.[1]

[1] Ingersoll, p. 323.

The **American moose** (*Al'ces america'nus*) is the largest member of the family (Fig. 278), living or extinct, and the male has the heaviest and widest spreading antlers.[1] These are much flattened and expanded. The moose has a long, thick, and rather prehensile upper lip, and browses upon the bark, leaves, and twigs of certain trees, and upon moss and lichens. It is as fond of wading and swimming as a schoolboy. It is very fleet, and can pass over large fallen tree trunks or a 5-foot fence with ease. Its cry is a long, resonant bawl. The calf is not spotted. The male has a long, ornamental strip of hair-covered skin, "the bell," which in the adult is sometimes a foot long. The cow has neither antlers nor bell. The moose is easily

Fig. 278.—The Alaska moose (*Alces americanus gigas*). (Yearbook, U. S. Dept. of Agriculture, 1907.)

handled and may be trained to drive in harness, but it does not live long in captivity except in forest preserves. During the stormy winter "they herd together in sheltered spots in the forest, and, through moving about in a small area, the snow is trodden down until they form a moose-yard" of several miles in extent. The animals browse upon the twigs of adjacent trees and bushes, and with their antlers keep their enemies, the wolves, at bay.

The so-called **"musk-deer"** differs from other *Cervidæ* in the absence of horns and in the presence of a gall-bladder, tusks, and the musk gland of the

[1] A pair of antlers from Alaska in the Field Columbian Museum has a spread of $78\frac{1}{2}$ inches, and, together with the skull, weighs $93\frac{1}{4}$ pounds.

male. These glands, or "pads," as they are commercially called, form the basis for many manufactured perfumes, and command a high price, hence these deer are rapidly diminishing in numbers.

Besides furnishing fine venison and the many other articles already mentioned, the deer family supplies "hartshorn," or ammonia. It is made from

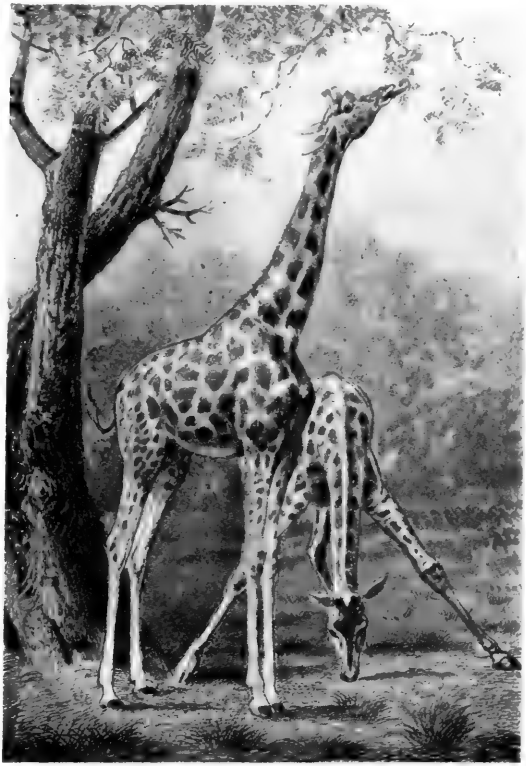


Fig. 279.—Giraffes feeding. (From Jordan and Kellogg's "Animal Life," D. Appleton and Co., Publishers.)

the shavings and refuse left from antlers in the manufacture of handles for cutlery.

The **giraffes** (*Giraf'fidæ*) have many deer-like characteristics, but neither sex bears antlers. In their stead they have horny projections covered with hairy skin. The giraffe is the tallest of all animals, the top of its head being 18 or 19 feet from the ground. Its neck, though so long, contains only the same number of vertebræ (seven) as that of man. Each vertebra is lengthened, still the neck is not long enough to reach the ground, so that in drinking or in reaching a tuft of grass the animal has to straddle out his legs and lower his position (Fig. 279). The giraffe's eyes are large, dark, and liquid, and its face has a gentle expression, but it is sometimes vicious and fights by kicking either with fore or hind feet. It has chocolate-colored spots separated by pale tawny markings or spaces, but these vary in both pattern and shade, proving a source of protective resemblance in the lights and shadows of the leafy trees, while the long neck may be mistaken for a weather-beaten tree-trunk. The under parts, shins, and feet are whitish. The long neck is useful in reaching the twigs of the trees upon which the giraffe browses, and also in allowing a wide range of vision, that it may look out for lions and leopards in which the long grass abounds. In locomotion

Fig. 280.—Head of young prong-horn antelope. (After Hays.)

the giraffe moves both the fore and hind limb of each side simultaneously, giving it a rocking motion. Giraffes are natives of Africa, there being a northern and a southern form.

The **North American prong-horn** (*Antiloca'pra america'na*) (Fig. 280) seems to occupy, like the giraffe, an intermediate stage between the deer and the true antelope on account of the structure of its horns. The horns are branched in the male, like those of the deer, though having but two or three prongs. The horns of the female are not branched. These horns—that is, the external portion, corresponding to the "velvet" of the deer, but which is here a true horn—are shed annually. The prong-horn has no "false hoofs." The male is "about 38 inches high and of a varying yellowish brown above, darker on the face, dull white on chin and cheeks, in two crescent patches across the throat, on the under surfaces, and in a broad heart-shaped patch around the brown scut of a tail." This whiteness of stern belongs in a greater or less degree to nearly all the ruminants and to other gregarious animals. It is thought to be a recognition mark by which the young and other members of a herd follow the leader or one another. The prong-horns are gregarious. The prong-horn is, or used to be, a creature of the plains, living on the dry bush grass, and avoiding these wolf- and wildcat-inhabited thickets, but now frequently seeks their cover. The young fawns (usually two) cling close upon the heels of the mother, which defends them with lowered horns and sharp, striking feet. The fur is useless, but the flesh is delicious.

The **cattle** family (*Bo'vidæ*) contains the wild cattle, the bison or buffalo, sheep, goats, and antelopes. They are distinguished by divided hoofs and unbranched horns, which consist of a hollow sheath growing over a horny core, which are never shed. As a rule they are present in both sexes. They have no upper canine teeth. They are heribvorous, preferring grass and herbage. Only a few examples can be mentioned here.

The **antelopes,** so far as we know, are the oldest of all bovine animals. They date from the Miocene. They differ from true cattle in their more graceful form, in that the horns, when curved, curve backward toward the neck. Their skin is usually smooth and sleek. They are now limited to Europe, Asia, and Africa, predominating in tropical Africa. The sable antelope (*Hippot'ragus nī'ger*), says Cumming, "is the rarest and most beautiful animal in Africa. It is large and strong, looking much like the ibex. Its back and sides are glossy black and the under parts pure white. The horns are upward of 3 feet in length and bend strongly back with a bold sweep, reaching nearly to the haunches." The mane is erect, the hide satin-like, and the whole attitude fearless and noble. Like all the antelopes, it has an equine form and gait. It is readily tamed and seems able to breed in captivity. These antelopes love to pasture on the open plain, a few together, mostly chestnut cows, says Ingersoll, and "the horns are used with undaunted courage even when attacked by lions."

We cannot refrain from mentioning the small, active, beautiful *gazelle*. "The skin is as sleek as satin, of a color difficult to describe, as it varies between the lightest mauve and yellowish brown," the belly and legs from the knee down are white, the hoof tapers to a sharp point. "The head of the buck is ornamented by gracefully curved, annulated horns, perfectly black, and generally from 9 to 12 inches long on the bend. The eye is the well-known perfection, the full, large, soft, and jet-black eye of the gazelle." The Dorcas gazelles are found in twos and threes all over Egypt. They feed upon juicy plants and shrubs, and visit the crops at night. They may stand motionless until the hunter is within rifle shot and then fairly skim the groud in their flight.

Associated with the antelopes are the ugly **gnus** of South Africa.

**Sheep** and **goats** are very closely allied, the goats differing from the sheep in their slight build, in the beard of the male, and in the horns, which are arched over the back instead of spirally curved, as is the rule with sheep.

True goats (*Ca'pra*) are almost exclusively Palæarctic. They are represented by the Spanish ibex (*C. pyrenaica*), the steinbock (*C. ibex*) of the Alps and Tyrol, and the Persian wild goat (*C. ægagrus*). The Persian wild goat is probably the principal species from which the tame goats are derived. According to Mr. Blanford, the "bezoar stones," the concretions of various lime salts found in the stomach, were supposed to be of great virtue as an antidote for poison. One stone of 4 ounces once sold in Europe for £200.

Geologically, goats are traced back to the Pliocene. Their distribution is limited and varied, owing chiefly to their mountain-loving nature. Their different environments and tendency to vary have given rise to many and very various breeds of the domestic goat.

The goats of central Asia, living in a climate of great extremes of temperature, furnish the fine wool of Cashmere and Thibet, which is their under coat. The Angora goat of Asia Minor furnishes millions of pounds annually of long silky hair. The cashmeres and mohairs of our stores are from goat hair and wool. The leather from goat hide is always valuable, especially that of morocco, while the skin of the kid is valued for gloves. The goat has for many centuries been used as a domestic animal. It supplies an abundance of good milk, rich in cheese-making casein, and requires much less food than the cow. In southern Europe herds of goats are driven from house to house and milked at the door of each customer, and then driven

Fig. 281.—Rocky Mountain goat (*Haploc'eros monta'nus*).

back to pasture. The goat readily cleaves to the household and exhibits more intelligence than other members of our flocks and herds.

The **chamois** of the European Alps and the Rocky Mountain goat (Fig. 281) are described as goat antelopes. The Rocky Mountain goat is the nearest we have to the goat, for this is not a true goat nor a true antelope. It is twice as large as a goat and looks much like a miniature buffalo, only its pelage is pure white, soft, and fine. Its hoofs, horns, and nose are black. "It has high shoulders, low hind-quarters, thick legs, and neck. It carries its head low. Its face is long." The small, angular hoofs consist of a pad inside and a knife-edge outside, equally adapted to snow or bare rock. It "inhabits the grassy belt of high mountains just above timber line, and loves the dangerous ice-covered slopes," being able to ascend almost perpendicular precipices. It is exceedingly difficult to capture and does not live long in captivity. "It is now found in only Idaho, Washington, and northwest Montana. It is scattered at long intervals through British Columbia and Alaska, as far as the head of Cook's inlet."[1]

The **sheep** (*Ovis*) are almost entirely palæarctic and nearctic, barely getting into the oriental region. They, like the goats, are often limited to islands and small stretches of country, owing in part to their mountain-

Fig. 282.—The White Mountain sheep of Alaska (*Ovis dalli*). (Osgood, Yearbook, 1907, U. S. Dept. of Agriculture.)

loving habits (Fig. 282). There are six North American species. The Rocky Mountain big-horn (*Ovis montana*) ranges from the far north to New Mexico. The mountain sheep is a fine, sturdy animal, bold, keen-eyed, active, and strong. It fears no storm and defies all enemies, save man with his gun and domestic sheep with their diseases. It delights in the highest

[1] Hornaday.

crags of the mountains, the boldest rim-rock of the plateau, or the most rugged "bad lands," for which it is adapted by its round firm hoofs, its warm winter under coat, its ability to subsist on scant herbage, and its keen senses. It is hunted by mountain lions and by man for its savory flesh. It has a handsome head and massive horns curved into the half or three-fourths of a circle, as are the horns of no other wild animal. It needs to be seen in its native cloudland to be fully appreciated.

There are many breeds of the domestic sheep. The original of this perhaps most useful and least educated of animals is not known. The variation of external characters, such as horns, ears, and tail, and in the color, length, texture, and quality of the fleece, is exceedingly great. The existence of these numerous breeds is probably due to their tendency to vary and to effect fertile crosses, and to long-continued selection, combined with the obstinacy with which these variations are transmitted and retained. Sheep are used to an enormous extent both for the production of their wholesome flesh and for their wool. Thousands of Persian lamb skins are used in the fur trade annually, and hundreds of thousands of Astrakans, which is the same breed taken when exceedingly young, it is said, before their natural birth. This breed is also greatly valued for its fat, which accumulates on the haunches in two great protuberances. In the fat-tailed sheep of Asia the tail of pure fat sometimes weighs 30 to 50 pounds, and trails upon the ground if not suspended upon wheels or carried upon a truck. This fat is regarded as a great luxury. The Spanish Merino sheep has been introduced into South Africa, Australia, and the United States. It is celebrated for the fine quality of its wool.

The **musk-ox** (*O'vibos moscha'tus*) is a strange, long-haired, short-legged creature of the frozen North. It belongs between the sheep and ox, partaking of the characters of each.

**Oxen** are distinguished from other hollow-horned ruminants by their stouter build, and by their smooth curved (not twisted) horns, which stand out from the sides of the head. The wild ox of Europe (*Bos primigenius*), believed to be surviving in the herds of Chillingham and Chartley,[1] is supposed to be the progenitor of our cattle. The original, called the auroch, or, by the Romans, Urus, was of more gigantic size.

One of the largest of the family to-day is the **European bison** (*Bos bonasus*). It looks much like our American bison or buffalo, but is taller. Bisons differ from oxen in having a hump over the shoulder formed by spinous processes for the attachment of the great muscles used in holding up the massive head and in the great pushing matches of the bulls. The American "buffalo" is more shaggy and robust than the European "wisent" (Fig. 283). The latter was forest inhabiting, while our "buffaloes" loved the plains, where they congregated formerly in great herds in spring and fall, but usually formed only scattered bands which traveled over the plains in single file. The true buffalo of Africa and India has no hump and is almost hairless. No animal is more dangerous than an infuriated bull buffalo, and none more easily provoked. Pugnacity and revenge are its ruling impulses. It has been domesticated in India, and is very useful, but not lovable. Africa has two species, which are sometimes accompanied by starlings. In the East starlings and herons "perch on their backs and hunt for ticks and other parasites"—a strange, but mutually beneficial commensalism.

The **yak** (*Bos grunniens*), of the mountains of Thibet, has short legs, goat-like feet, humped shoulders, smooth, spreading horns, and carries its

[1] Beddard, p. 321.

head low. From the chin, throat, and lower parts of the sides the hair grows long and forms a fringe, a wonderful adaptation to the climate. This long hair serves as a mat beneath it when it lies down upon the ice and snow, as well as a warm cover under which it curls its legs. The tail is thick and silky, sometimes 6 feet long. It is often beautifully mounted on antelope-horn handles and used for fly-whisks in the East. The cry is much like the grunt of a pig, but louder and longer.[1] Tame yaks have long been used as strong, sure-footed beasts of burden. The flesh, milk, and butter are excellent. From its hide, clothing, tent covers, and harness are made, and the hair is twisted into ropes.

Fig. 283.—A group of buffaloes, "American bison" (*Bos americanus*) in Yellowstone National Park. (From life.)

The numerous breeds of domestic cattle form an enormous industry. The exports of the United States alone, such as cheese, butter, hides, tallow, and beef, amount to many million dollars annually.

*Geologic Distribution of Ungulates.*—The camel is represented in the Oligocene. The Miocene forms in America had horns something like deer antlers. The *Procamelus*, the probable ancestor of both camels and llamas, flourished in the Miocene. In the Pliocene, Europe had deer, antelopes, oxen, and the first

[1] Ingersoll, p. 247.

Old World camels, as well as giraffe-like forms. "That the camel got the pads on his feet, the water-pockets in his stomach, and the other drought and sand resisting arrangements from an ancestor that began in the United States a million or more years years ago" has been proved by Cope, Doctor Wirtman, and his assistants. The oldest fossil deer types are Miocene. They were small, hornless creatures. The first horned deer were in the middle Miocene, when the horns were bifid. The giraffe, or its close allies, existed in the Miocene. The bison existed in the Miocene, as shown in fossil *Bos sivalensis* from India. The Pliocene life included a variety of oxen and two North American bisons.

**Order VII. Rodentia or Gli'res.**—Rodents are exceedingly numerous and well-known mammals, covered with fur or spines. They are generally small, varying in size from the porcupine, of about 3 feet in length, to some of our small mice, not over 4 or 5 inches long.

The one distinguishing characteristic of rodents is their teeth. (See Fig. 288, p. 355.) These have enamel on their front surfaces only. Thus, their incisors, which grow continuously from persistant pulps, are always chisel shaped and kept sharp by the wearing away of the posterior surfaces. There are never more than two incisor teeth in the lower jaw, and only two in the upper, except in *Lepor'idæ,* where there are four. The lack of canine teeth in all rodents leaves a space or *diastema* between the incisors and the molars. The molars vary in number from two to six on each side of each jaw. There is a hairy ingrowth in the mouth back of the incisors, which serves to catch the particles when the animals are gnawing. They are usually vegetable feeders, but some are carnivorous or omnivorous. The intestine is long and the cecum large (except in dormice) and often complicated.

As a rule the clavicle is present. Most rodents are five toed. The toes have claw-like nails. They are usually plantigrade or semiplantigrade. The cerebrum is small and nearly or quite smooth, but in some of the larger forms (the beaver excepted) it is well convoluted. The ears and eyes are well developed. The voice is a squeak or squeal. Their defense is by spines, as in the porcupine; by biting, as in the rat; and by flight or concealment, as in the rabbit, though the rabbit will fight viciously by biting and by striking with its hind feet if cornered, or if the nest or "form" containing the young is attacked.

Some hibernate in winter, others migrate in flocks. They live almost everywhere, but are chiefly terrestrial; some are aquatic, some subterranean, and still others arboreal. They are very

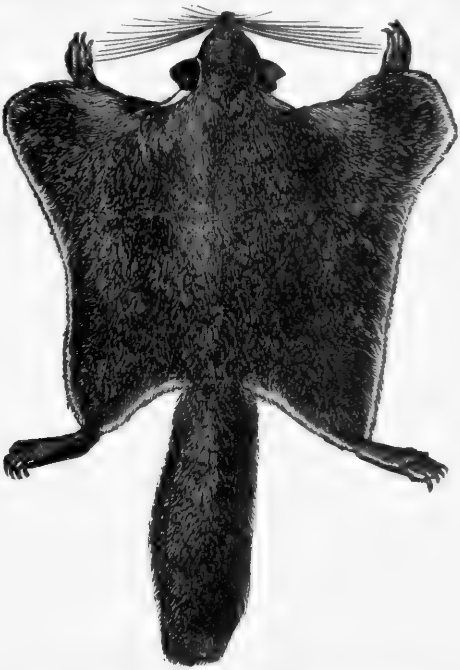


Fig. 284.—American flying squirrel (*Sciurop'terus volucella*). (From Packard's "Zoölogy," Henry Holt & Co., Publishers.)

prolific, the young being numerous, and, in some families, four to six litters a year. Since they are hardy, often nocturnal, and not very particular as to the character of their food or lodging, they have become worldwide in distribution.

**Squirrels** (*Sciu'ridæ*) are worldwide, excepting Australia and Madagascar. The eyes and ears are large, the tail long and bushy, the thumbs on the fore feet inconspicuous. There are four toes on the hind feet and the tibia and fibula are distinct. They feed upon nuts and grain, as well as eggs and young birds. They are chiefly arboreal, building their nests in tree-tops. They lay up a store of food in hollow trees, where they pass the severe winter weather. Four species of this genus (*Sciurus*) are found in the United States and Canada. *S. vulgaris*, the common squirrel of Great Britain, is found from Ireland to Japan.

**Flying squirrels** (genus *Sciurop'terus*) (Fig. 284) of the palæarctic region (which includes Europe, northern Asia and Japan, North America, and India) have a furry membrane connecting the anterior and posterior limbs. This, together with the broad tail, acts as a sort of parachute, enabling these squirrels to take enormous downward leaps from limb to limb or tree to tree. They cannot "fly" upward, but ascend the tree by climbing. The Asiatic flying squirrel is 16 to 18 inches long without the tail, and, it is said, 80 yards have been covered in their longest leaps.

The little striped **ground squirrel** (*Tamias striatus*) burrows and carries its food in its cheek pouches to its nest in the ground.

The **prairie-dog** (genus *Cy'nomys*), of the great western plains, is also subterranean, digging a burrow and throwing up a mound at its entrance. There are whole villages of these mounds, sometimes covering acres. The prairie-dog hibernates in winter, at least comes out only occasionally. One kept in a cage by the author comes out of his "straw burrow" at night or just before dawn, only at long intervals, for food. They sit up on their hind feet and look all around like sentinels, but dart back into their burrows again at the least approach of danger, uttering a shrill cry as a warning to the rest of the community. They are so quick of movement that it is difficult to shoot or trap them. Their ears are small. Their legs are so short that in running they "hug the ground," of which, in sandy regions, they are very nearly the color. They grasp their food with their paws like true squirrels.

The **marmots** of the arctic regions are closely allied to these. The Alpine marmot (*Arcto'mys marmotta*) lives far up in the Alps. Its danger signal is a shrill whistle. These marmots hibernate, ten to fifteen being packed together in a well-lined burrow.

The **North American beaver** (family *Castor'idæ*) is an aquatic rodent with a stout body, flat, scaly tail, and webbed hind feet. It fells trees by means of its strong incisors, damming the stream so as to raise the level of water above the entrance to its burrow. The beaver (*Castor canadensis*) is fast becoming exterminated on account of the demand for its fur.

**Rats** and **mice** (*Muridæ*) have naked tails which are scaly underneath. The soles of the feet are naked and the tibia and fibula are united below. Some of the numerous genera are found in all parts of the world. The muskrat is the largest member of this family. Some of the species are among the smallest quadrupeds known.

The **North American muskrat** (genus *Fiber*) is a genus of two species of dark brown aquatic animals. They dig burrows in the banks of streams, the entrances to which are beneath the surface of the water. The hind feet are slightly webbed, the tail flattened and scaly, with scattered hairs. The shortened thumb has a fully developed claw, and they grasp their food, which consists of roots and water plants, with their paws, like the squirrels. A Rocky Mountain species (*Fiber osoyoosensis*) is said to construct a dome-shaped house of "bulrushes" in the water. It feeds largely upon water-fowls and fish.

The **common mouse** (*Mus mus'culus*) and **rat** (*M. decumanus*) have been introduced into America from the Old World. *M. minutus* is said to be the smallest British quadruped, except the lesser shrews. It is $2\frac{1}{2}$ inches long without the tail, which is the same length. The water rats, or voles, represent another genus, also the meadow mice or "field mice" (*Microtus*) (Fig. 285). The typical field mouse is a "short-eared, short-tailed, thick-set" little creature $4\frac{1}{3}$ inches long, with a tail $1\frac{1}{2}$ inches long. It is brown above and white or grayish below. It is found from the Atlantic to the Dakotas. It feeds on grass, roots, and grain. In severe winters they sometimes do much damage by eating the bark of young trees (Fig. 286).

**Dormice.**—The common dormouse of the Old World (*Muscardi'nus avellanarius*) has a long bushy tail and looks much like a tiny squirrel. Its body is "3 inches long with a tail $2\frac{1}{2}$ inches long."

Fig. 285.—Carson field or meadow mouse (*Microt'us montanus*). (Yearbook U. S. Dept. of Agriculture, 1908.)

The **American porcupines** are chiefly arboreal. The quills, which are but an inch or two long and are somewhat hidden among the intermingled hairs, are loosely attached, so that when an animal comes in contact with them they stick into it, and, being barbed, they pull out of the porcupine and remain in the enemy. Hence porcupines are considered a nuisance by cattlemen of the West. They are also annoying to the lumbermen of the North, as they gnaw the wooden handles of their tools. These animals are so well protected by their spines that they need little intelligence to escape their enemies, and are rather stupid. The Old World porcupines, by some authorities placed in another family, have spines a foot in length. On the tail are hollow quills, which make a rattling noise somewhat like that of the rattlesnake to warn the enemy. The South American genus has a prehensile tail. The little guinea-pigs are South American relatives.

**Jumping-mice** (*Dipod'idæ*) (Fig. 287) are represented by the American jumping mice and the Palæarctic Jerboas. They have long tails and the hind legs are greatly elongated and adapted for taking enormous leaps.

Fig. 286.—Lombardy poplar killed by field mice. (Farmer's Bulletin No. 335, U. S. Dept. of Agriculture, October, 1908.)

Fig. 287.—Jumping mouse. (After Tenney.)

The **pouched gophers** (*Geomy'idæ*) have large cheek pouches opening externally (Fig. 288, *a*, *b*, *c*). These burrowing rodents are restricted to Central America and the central plains of North America. They have small ears and eyes. The claws of the anterior limbs are strong.

The family *Leporidæ* is represented by **hares** and **rabbits.** Formula for the teeth: Incisors, $\frac{4}{2}$; molars, $\frac{6-6}{5-5}$, or 28 in all. One pair of upper incisors is much smaller and immediately behind the other. This arrangement of

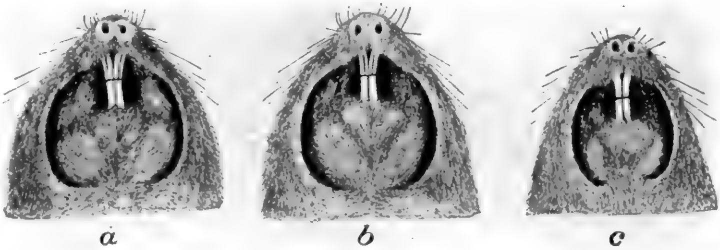


Fig. 288.—Faces of pocket gophers, showing pouches and incisors: *a, Geomys; b, Cratogeomys; c, Thomomys.* (Yearbook U. S. Dept. of Agriculture, 1909.)

the incisors has given rise to the term *Duplicidenta'ta.* The soles are furred, the tail short and recurved, the eyes large, and the ears long. The hind limbs (Fig. 289) are longer than the fore limbs (Fig. 290), and they "run" by

Fig. 289.—Posterior limb of Jack-rabbit. (Mounted by students.)

prodigious leaps. Genus *Lepus* contains thirty or forty species. Our common forms in the United States are the "cotton-tail" (*L. sylvaticus*); the marsh hare (*L. palustris*); the water rabbit (*L. aquaticus*), also a southern form; the Jack-rabbit (*L. campestris*) of the West and Southwest; and *L. americanus*, a northern variable species, whose fur turns white in winter. They are not gregarious, though it is said they often play together on moonlight nights. They are crepuscular and somewhat nocturnal.

*Geologic Distribution.*—Rodents appeared first in America in the Wasatch stage of the Eocene. Almost all the principal groups of existing forms appeared within the tertiary.[1]

*Use to Man.*—Great numbers of rabbits are used for food in the cities during the winter season. Their fur is used for making

Fig. 290.—Scapula and anterior limb of Jack-rabbit. (Mounted by students.)

felt hats. "Nine-tenths of the felt hats worn in the United States are made from rabbit-fur." Where they are numerous or food is scarce they gnaw the bark of young fruit trees. In many localities the orchard is enclosed in rabbit-proof fence. Beaver skins are also much used for furs.

**Order VIII. Carniv'ora** ("Mammals of Prey").—These flesh-eating mammals may be small or large. They may be terrestrial, arboreal, or aquatic. They feed upon the flesh and blood

[1] Parker and Haswell, p. 574.

of other animals, which they catch by cunning, by chasing, or by stealthily creeping up upon them and pouncing on them, whereupon they bite and tear them in pieces. Here we find another striking illustration of the adaptation of structure to habits. They must be fitted to attack and destroy other animals. Their five or four toes are armed with sharp claws, which, in the cat, are retractile into a sheath by which they are protected when not in use. The teeth are adapted for seizing, biting, holding or cutting, in contrast to the nibbling or grinding teeth of the herbivores. The usually six incisor teeth are small. The canines are long, strong, and conical, fitted for tearing, and the premolar in the upper jaw and the first molar in the lower jaw, called the "carnassial teeth," are developed into thin, sharp, three-pointed fangs, shutting down past one another like scissor-blades, while the cusps of the molars form more or less angular and sharp ridges.

The stomach is simple, and the cecum small or wanting. The clavicle is reduced, the radius and ulna well developed. As to manner of walking, there are several gradations from the plantigrade bears, which walk on the soles of their feet, to the digitigrade cats, which walk on the tips of their toes. The coloration is varied to conform to their habits. Some are spotted, others striped, while many adults are quite modest in their plain, uniform colors. The brain is large and well convoluted, and the sense organs well developed, giving them a high degree of intelligence.

This provision of nature, wherein some animals feed upon vegetable matter and others feed upon animals—for every living thing, from the microscopic algæ in the water to large animals like the deer and horse, becomes food for some animal—is a wise one. For thus the vegetation of the earth supports not only the herbivorous animals feeding directly upon it, but the carnivorous animal has his food very largely prepared for him by the vegetable-feeding animals. But the carnivorous animal also aids the herbivorous survivors in their struggle for existence, for, was not the number kept within bounds, the rapidly multiplying herbivores would soon absolutely destroy the vegetation of the world.

These animals are usually clothed in dense, soft hair, and many of them are valuable for their fur. The cat and dog have been domesticated.

**The Terrestrial Carnivora** (*Fissipe'dia*).—The number of digits may be five on each foot, but is often reduced to four on the hind feet, as in cats and dogs, and sometimes to four on the front feet, as in *Hyæ'nidæ*, but the reduced first toe may bear a claw.

The **cat family** (*Fe'lidæ*) includes the lions, tigers, leopards or panthers, jaguars, pumas, lynxes, wildcats, etc. They are widely distributed in both the Old World and the New, but are absent in Australia. They seem to have evolved in the Old World first, migrating to North America at the close of the Pliocene, and from thence to South America. The legs are relatively short and the claws are retractile. The terminal

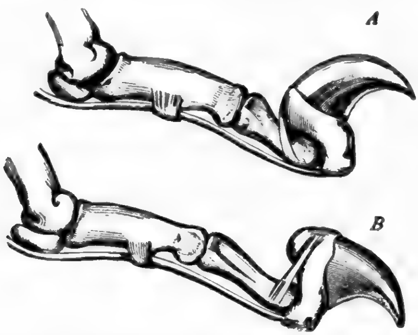



Fig. 291.—Bones and ligaments of the toe of a cat, showing the claw retracted (*A*) and protruded (*B*).

joint bearing the claw (Fig. 291) folds back into a sheath by the outside of or above the middle joint, and is held there by a strong ligament. This is the natural position of the claw and prevents it from friction. When wanted for aggression or defense it is pulled into position by the flexor muscles bearing the claw.

The **raccoons** (*Procyon'idæ*), placed by some with the bear family, are plantigrade and omnivorous, eating anything in the way of fish, oyster, crayfish, flesh or fowl, and green vegetables especially corn. They have the peculiar habit of washing their food. They are nocturnal. The limbs are long and the soles of the feet naked. "The raccoon is at home in the timbered regions of the southern and eastern United States where there are swamps," for it loves to play and to fish in the water. It has long active fingers, and uses its hands as cleverly as a monkey. It makes its home in the hollow limb of a tree. The annual family of five or six young follow the mother about for a year. In August the "coons" are fat and the flesh is tender and juicy, and "coon hunting" is a great sport. The young are easily tamed, but are annoying on account of their curiosity and the skill with which they open doors with their hands. The fur is much used. The family includes also the civet-cats of the Southwest, the kinkajou of the tropics, and the South American coati.

The **bears** (*Ur'sidæ*) are clumsy, omnivorous animals, with thick limbs and naked-soled, plantigrade feet, bearing strong non-retractile claws. The tail is short and the hair coarse. The "molar teeth are more adapted to grinding than to cutting and the flesh teeth are massive and blunt." Some species are especially fond of insects, such as day-flies, grubs, and termites. The latter they obtain by digging into the nest and sucking them into the mouth with inhalations strong enough to be heard two hundred yards away. They are also fond of honey and fish. They live upon the ground, few species being able to climb trees. The den may be in a hollow tree or in a cave in a hillside, either natural or dug out by the mother. Two cubs, not larger than rabbits, almost hairless, blind, and helpless, are born in mid-winter, and the mother guards them solicitously. It takes seven years to reach maturity. Bears rarely breed in captivity. The male bears wander about singly, "the females are accompanied by their cubs, often as big as themselves."

Bears are naturally good tempered. The majority of the instances of unprovoked attacks, says Hornaday, have been probably by mother bears who fancied their cubs in danger—even those bears which ate up the children in Elijah's day were "she-bears."[1] When a bear is aroused it is exceedingly formidable. It deals killing blows with one of its paws, having been known to kill a buffalo with one blow. It does not hug its victims to death. The grizzly flees from man unless cornered. In cold, snowy countries, where bears are unable to obtain food they pass the winter in a sort of sleep, living upon their fat stored up in the fall, but they do not become torpid, as the cold-blooded animals do. In some species the males, which hibernate singly, come out from time to time. They do not hibernate in the tropics nor in captivity, leading us to believe that the winter sleep of the north is only another adaptation to environment.

According to Beddard, the polar bear hunts "by scent rather than sight or hearing, both of which senses seem to be somewhat dull." All American bears, except the polar bear, change their color, being darkest in late summer and lightest in spring. There are a number of well-marked types of bears, eight of which live in Asia and Europe, and four, the polar bear, the brown bear, the grizzly, and the black, live in America. One group is found all around the North Pole and another group in South America. The oil, fat, and fur of bears are used.

Not until the Pliocene in the Old World and later in the New did the true bears (*Ursus*) appear. So this family, which is highly specialized in some features and very primitive in others, is among the youngest of the *Carnivora.*

The **fur-bearers** (*Mustel'idæ*) are blood-thirsty robbers, often killing many times what they can consume, seemingly from a spirit of mere wantonness. "The testimony of the rocks," says Ingersoll, "shows that this family is either an ancient branch from the civet stock, or that it has sprung from the same root." The genus *Lutra* is widely distributed. It includes the otter. The front and hind feet are webbed, and the claws on the hind feet flattened and nail-like.

The **North American otter** is still occasionally found "in Florida, Carolina,

[1] II Kings ii, 24.

Canadian provinces, in a few localities in the Rocky Mountain region, and from British Columbia to central Alaska." The home for the rearing of the two young is a burrow in the bank of a stream. The **sea otter** (*Latax lutris*) feeds largely on sea-urchins and shell-fish, and its molars are flattened and the tubercles very blunt, for crushing the shells. This animal has been so much hunted for its exceedingly valuable fur that it has changed its habit of feeding upon the shore to hunting in the deeper waters, and makes its bed on floating masses of kelp. It is rare except in Alaska, and is one of the wildest and wariest of animals. At present the otters are among the most valuable of all fur-bearing animals, a single skin of the sea otter having been sold in London for £250, or about $1250.

The **badger** (*Meles*) has naked soles and the claws of the fore feet are much longer than those of the hind feet. The true badger of Europe and eastward is nocturnal, omnivorous, and burrowing, loving the woods. The South American badger resembles the European one, but is smaller. Its three or four young are born naked. Its body, which is about 2 feet long, is broad and flat, and its legs very short. It has a sullen, savage disposition. It feeds on ground squirrels and prairie-dogs. It ranges over the Great Plains, the Rocky Mountains and westward, and from Mexico to Alaska. In the United States it is more or less active all winter, being able to find food, but farther north it is forced to spend the severest portion of the winter in semitorpidity. There are a number of species in Asia. The Teledu (*Myd'aus melictes*), of Java and Sumatra, is said to rival the skunk in the odor of its secretion.

The **skunks** (*Mephi'tis*), of which there are nine species, are widely distributed in America. They are distinguished by their jet black color, variously banded, with longitudinal bands or spots of pure white, making them conspicuous. This is surely a fine example of warning colors, for both man and beasts are well aware of the strong offensive odor of the anal secretions which can be ejected for a distance of several feet. Despite this efficient means of defense the skunk is sometimes devoured by the puma, the harpy eagle, and the great horned owl. It is destructive of poultry, but is a destroyer of myriads of noxious insects and mice. The fur is extensively used, first being dyed.

The **marten** and **weasel tribe** is distinguished by a long slender body, short legs, and cat paws. These small, agile creatures have valuable fur. The group includes the Siberian sable, the North European marten, and the Canadian pine marten. The marten is 18 inches long, with a rather bushy tail of 7 or 8 inches. It is brown above, lighter below, and varies according to the age, sex, and season. "The winter fur is thick, soft, 1½ inches deep, of the richest hue, and has scattered through it coarse, black hairs which the furrier pulls out." The six or eight young are born high up in a hollow tree or in a rocky crevice. The Canadian marten is not a poultry thief nor wanton murderer, but kills what it wants to eat of squirrels, hares, and grouse, trailing them with the nose to the ground like a hound. Few animals will eat the marten unless extremely hungry.

The *mink* is small and of a chocolate or yellowish-brown color, with a round hairy tail. It is scattered throughout North America along the banks of streams. It feeds chiefly upon birds and is a "wanton murderer." The black-footed ferret is nearly always found in the prairie-dog villages. The English ferret is simply a domesticated variety of the polecat (*Puto'rius fetidus*).[1]

[1] Beddard, p. 436.

The *weasel* is the smallest animal of the group. The body is very long and "no thicker than a man's thumb." Its fur changes from brown in summer to white in winter. This winter fur is known as ermine, and comes from Alaska, Canada, Lapland, Russia, and Siberia. It is used not only for ladies' garments, but for the robes and crowns of kings. The smallest of all Carnivores is *Putorius rixosus*, of northwestern Canada. It is only 6 inches in total length and brown to the tip of its tail. In all other species the end of the tail is black. The change of color to white helps to retain the body heat, and helps also to conceal the animal from its enemies and its prey. Poulton believes that the cause of this change of color is the lower temperature acting upon the skin, and that existing dark hairs become white at the tips. Others maintain that in cold regions the summer pelage is replaced in winter by hairs which come in wholly white, while in warm regions the new winter coat is brown. However, Doctor Coues says he has seen many autumnal skins which were white at the roots and dark at the tips. In any case, natural selection has preserved those individuals having the power of changing the color of the fur until this character is now general.

The **dog family** (*Canidæ*) is universally distributed, with the exception of New Zealand. These animals have a simple, cylindric cecum and usually five toes. Perhaps the most striking feature of the family is the bladder-like inflation of the auditory *bulla*, that part of the skull containing the internal ear. This apparatus and sense is perfected in the dogs. Many of this family are familiar.

There are several genera, but the principal one is *Canis*, including our dogs, wolves, foxes, and jackals. Huxley divides them into fox-like and wolf-like dogs. The foxes are more active than the wolves, with a "broad skull, sharper muzzle, larger ears, a more bushy tail, and, usually, longer fur." They are notably clever and quick witted, and often show skill in meeting new situations made by the advent of man.

The typical fox is the **common red fox** (*Vulpes fulvus*), of wide distribution. Our American form varies from the typical yellowish red, darkest on the back and shoulders, to a very bright or very pale yellowish red. It may have the markings on the spine and withers very dark and distinct, making it a "cross-fox," or be totally black with a white-tipped tail, or black with the tips of most of the hairs white, giving the fur a frosted or silver appearance. Either of the last two cases is called "silver fox." These rare and valuable variations may occur in the same litter with the normally reddish ones. Foxes feed upon ground birds and their eggs, rodents, frogs, lizards, insects, and fruits. They may be caught by rapid chase, by digging the burrowing forms out of the ground—for the fox is naturally a burrower—by stealthily creeping up on them, or by lying apparently dead until the victim approaches, and then pouncing upon it. While it does sometimes raid the hen coops, the fox does good service in destroying rats, mice, and gophers. It sometimes stores its surplus food. Its enemies are all the large cats and wolves, as well as man and dogs in the so-called sport of fox chasing. The red fox has a litter of seven or eight young; the southern gray fox, of four or five. The gray fox is smaller. It climbs trees to get the "sour grapes" and persimmons, but it cannot adapt itself to the prairies. The arctic fox (*Vulpes lagopus*) furnishes another example of color variation under the influence of a different climate. In the extreme north it is snow white all the year round. A little farther south it is brown, with the under parts lighter in summer and white in winter, while in the southern part of its range, as in the Aleutian Island and parts of Greenland, it is most often bluish or slate gray. That these are not different species is proved by the fact that occasionally one or two "blue foxes" occur in the litter where all the rest become white; for all the young are blue. The arctic fox is valued for its fur. The blue variety, being less abundant, is worth twice that of the white. Commercial companies are, therefore, making attempts to breed these foxes on the islands of the Alaska coast. In the extreme north the arctic fox stores its food in summer for the long, desolate winter. There are a number of other species of foxes.

The wolf-like dogs include the dogs, jackals, and wolves. **Domestic dogs** of to-day comprise about two hundred breeds. They are owned by natives of all countries except the South Sea Islands. They have been associated with man for thousands of years, their remains having been found in Danish kitchen-middens, in the Swiss lake-dwellings, and in the remains of the Bronze Age in Europe generally. It is only since the invention of firearms that hunting with dogs has become general, as stealth was necessary to the successful hunter and the dog might frighten the game. It might have been used in running down such animals as the deer, but it seems from obtainable evidence that it was used for the protection of the camp, to watch while the master slept, and to give the alarm if beast or man came near; or it served as food in time of necessity. Authorities vary in their opinion as to what stock gave rise to the domestic races. "The jackal, bunasu, and the Indian wolf have been suggested as ancestors. It is probable there has been much mixture and that different wild types have been selected by man in various countries."[1] The intelligence of dogs and their ability to learn by training are well known and utilized by breeders and dealers.

There are many species of African and Oriental **jackals.** Some feed chiefly on carrion, but also commit depredations upon the hen roosts and farmyards; others live upon figs, and others chiefly upon fruits. Their cry is a long howl, ending in a series of short yelps. Anderson says "they often congregate near one's tent and make the night hideous with their howls."

The **wolf** of the present time is distributed over most of Europe, northern Asia, and North America, wherever a rough country affords it shelter.

Hornaday says "there is no depth of meanness, treachery, or cruelty to which they do not cheerfully descend. They are the only animals on earth which make a regular practice of killing and eating their companions and devouring their own dead. But in the face of foes capable of defense even gray wolves are rank cowards, and, unless cornered in a den, will not stop to fight for their own cubs." The five or more sooty brown whelps are born in a cave (which is often dug by the mother) early in May, but usually only two or three survive. In winter wolves form a pack to assist each other in attacking the prey. Travellers through infested regions have been boldly pursued and killed by them. The prolonged deep-chested bass howl, which "multiplies itself by its rapid echoing until one wolf sounds like a dozen," is not broken into a bark like that of the coyote. The **timber** or **gray wolf** (*Canis occidentalis*) is very much like the European (*C. lupus*). It can adapt itself to almost any situation, being at home in the timbered regions or on the treeless prairies of the West, in the evergreen or on the treeless prairies of the West, in the evergreen forests of British Columbia, and on the desolate barren ground of arctic America. Its winter coat is long and shaggy, and varies from the standard gray (black and white mixed) to black in Florida and rufous in Texas, while in the North it varies from black to the predominating white color of arctic animals.

[1] Beddard, p. 423.

The **coyote** (*C. latrans*) (Fig. 292)of the western plains is one-third smaller than the gray wolf, and carries the tail low, as befits a coward, while that of the wolf points above the horizon. The cry is a dog-like yelp, half howl, half bark. They feed upon prairie-dogs, ground squirrels, sage grouse, and rabbits, and, probably, sheep and pigs. They are not dangerous to man. The five to seven puppies are born in deep holes or washouts in the banks of streams in May.

The **cat family** (*Fe'lidæ*) includes lions, tigers, cats, and the hunting leopards. The distribution is worldwide, with the exception of Australia and a good deal of the Australian region. In genus *Felis* the claws are retractile.

The **lion** (*F. leo*) differs from all others by the possession of a mane by the adult male. The largest lions come from south Africa. The adult is uniform pale tawnish or yellowish gray. The young is spotted. It inhabits Africa, India, parts of western Asia, and formerly ranged into Europe.

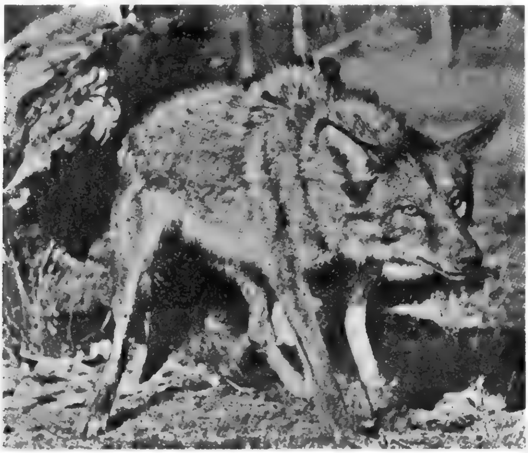


Fig. 292.—Coyote. (Circular 63, Biologic Survey, U. S. D. A., April, 1908.)

It is mainly nocturnal in its habits, though it often feeds in daytime or at dusk, as the animals go to the spring for water. It feeds on anything it can capture, or even on carrion. The male may hunt alone, while his mate cares for the two to five whelps or cubs in some dense cover, bringing the food to his mate. It is said, however, that the males eat at the first table, leaving the rest of the family to take what is left. When the cubs are old enough the mother joins in the search for prey, which is usually obtained by "stalking," that is, by stealthily creeping up through the tall grass and leaping upon it, striking a fell blow, and clutching it with claws and teeth. Failing in this, they sometimes give chase. Lions cannot climb trees. "The choice of mate seems to lie with the female," says Ingersoll, "and the continuance of the union appears to depend on the power of the lion to hold his fickle spouse to her allegiance." She tries to flirt with every new male, but her mate bounds between her and the intruder and then ensues a fierce struggle for possession unless the intruder slinks away. The female fawns upon the conqueror, whichever he may be. There is some, though insufficient, evidence, that the male is sometimes a polygamist. Lions will live for thirty or forty years and breed well in captivity.

The **tiger** (*F. tigris*) is about the same size as the lion, the female being 12 or 15 inches shorter than the male. He is more quick, sly, subtle, and cunning. The tiger is exclusively Asiatic, ranging northward, even into icy Siberia. Tigers are creatures of the mountains rather than the open plains. The northern ones are adapted to the cold climate by longer and closer fur. Tigers can climb trees and can swim considerably. Naturally, they hunt in the evening or night, but extreme hunger may drive them to hunt in daytime. The Malays and Hindus hold them in superstitious terror and oppose their destruction.

The **leopard** or **panther** (*F. pardus*) is both African and Asiatic. It varies from almost black to a tawny color. It is spotted with small rosettes or rings of black surrounding spots of light or tawny color. Some of the spots are solid black. It is as ferocious as a tiger, but sly and cautious, and far lighter and more active. It can climb a tree like a cat. It necessarily preys upon smaller animals than do lions and tigers, playing havoc with poultry, sheep, goats, dogs, wild birds, monkeys, and wild pigs. Carrion also furnishes it food. Its cry is a "harsh, measured, coughing roar." The snow leopard or ounce (*F. uncia*) is a beautiful creature, white, with larger black spots. It is confined to the highlands of central Asia.

The **jaguar** (*F. onca*) is the largest and handsomest of the American cats. The head is large and the tail short. It has a golden-yellow coat, marked on the back and sides with large black rosettes, between which run the narrow lines of yellow ground color. The spots on the legs, head, and under parts are solid black. It is found in South America, Mexico, and as far north as Texas. Hornaday believes that it has the strongest jaws of any member of the cat family. It is fierce, powerful, and dangerous, but is afraid of man. It also climbs trees.

The **puma** (*F. concolor*) is found in "all the great western mountain-ranges and in many tracts of the bad lands of Wyoming and Montana, in British Columbia, in the Adirondacks and Florida," and south to Patagonia. Hornaday says that although the puma has been known "to follow belated hunters out of curiosity, this animal is less to be dreaded than a savage dog." It sometimes screams like a terrified woman or boy; it always flees from man if there is a way of escape. It is a thin, tall animal of a brownish drab color.

The **lynxes** of North America are "short-tailed, heavily furred, tree-climbing cats," distributed over nearly all the wild portions of the country north of Mexico, whether forests, mountains, plains, canyons, or even deserts. They are neither courageous nor pugnacious unless cornered. The Canada lynx (*L. canadensis*) has a long pencil of stiff black hairs rising from the tip of each ear. It has large, hairy paws, and is a good climber. It swims well, but runs rather poorly on land. A full-grown one weighs 22 pounds. There are two young. The Bay lynx, or wild-cat, is usually a mixture of rusty red, gray, and blackish brown, with red prevailing. It is found in both the East and West and in Texas. No lynxes are found in the lowlands of tropical or South America.

The **domestic cat,** says Beddard, is regarded as the descendant of the eastern *F. caffra* or the closely allied *F. maniculata*, or from both and from their interbreeding with the wild-cat of Europe, for many species of cats, even the lion and tiger, it is said, will interbreed. Whatever was the source, they have been crossed and interbred with many varieties before reaching the "house cat" of to-day. The domestication of the cat is very remote. A tablet dating from 1600 B. C. has on it the representation of a cat. "Rows of skilfully wrapped mummies of cats in richly adorned cases" may be seen at Cairo, showing that ancient Egyptians must have held them in reverence.

The **hunting leopard** (*Cynælu'rus jubatus*), of Africa, India, Persia, and Turkestan, has longer legs and less retractile claws than the true cats. In India it has been trained for ages to capture game for its masters.

The **civets** (*Viver'ridæ*) are comparatively small animals, with usually five digits and with non-retractile or very incompletely retractile claws. There is usually a scent gland, which is the source of the civet perfume.

The genus **hyena** (*Hyen'idæ*) comprises three living species. The body is bulky, the legs strong, the head big and dog-like, and the jaws strong. They are nocturnal scavengers, though sometimes seizing small animals. They are found in Europe, Asia, and Africa, but not in America.

*Geologic Distribution.*—"The first Carnivores appear in the order *Creodon'ta*, plantigrade forms of slightly differentiated dentition (no carnassials); they present marked resemblances to marsupials, insectivores, as well as to the *Condylar'thra*, the ancestral ungulates."[1] There is a long gap, both in time and structure, between the few Eocene carnivores and their supposed ancestors among the Creodonts, which are generalized types as hinted above. In the late Miocene the present groups of *Carnivora* become more or less distinct by the intermediate "stock forms becoming extinct."

*Use to Man.*—Hundreds of lion skins are sold annually, thousands of wild-cat skins, and more than a million skins of the common cat are made into cheap furs.

The **aquatic carnivora** (*Pinnipe'dia*) include the seals, sea-lions, and walruses. They have acquired a somewhat fish-like form. The limbs are flattened into broad flippers, the five long toes are webbed, and the nails are often rudimentary. Molars and premolars are similar (carnassial absent).

The **northern fur seal** (*Ota'ria ursina*) and the Patagonian **maned sea-lion** (*O. jubata*) belong to the genus *Otaria*, which is mainly antarctic. The harbor seal is the common form along the Atlantic Coast. There is a colony of sea-lions on the Pacific. In the fur seals there is a dense, soft under fur. The Alaska seal has its summer residence and breeding grounds in one or two islands of the Behring Sea. In winter they are absent from these islands, and "their whereabouts is a matter of much speculation." They live in groups, consisting of a single old male and five to twenty females. The young males a year or two old herd by themselves, maturing at the

[1] Hertwig.

age of six. The females mature younger. The males are six or eight times as large as the females. The rivalry between the males is intense. In the fighting, great strength of neck and jaw is used. The fur seal industry represents many millions of dollars.[1]

The walrus family (*Trichech'idæ*) belongs to the aquatic carnivores. The walrus is arctic and circumpolar. It is characterized by the enormous canines of the upper jaw, which form tusks sometimes 30 inches long. The walrus is from 10 to 12 feet long, and, though it can move about on land, it is very ungainly. The hair is short and scanty. As in the true seals, there are no external ears. The flesh, fat, and hide are much used in the North.

The **true seals** (*Pho'cidæ*) have the nostrils in a dorsal position and have no external ears. The hind limbs are bound up with the tail and are useless on land. The largest is the elephant seal, about 20 feet long. The male has a proboscis of about 15 inches. This seal is mild and inoffensive except when enraged, and, of course, during the breeding season. The whole animal is invested in a mass of blubber which is as thick as that in a whale.

**Order IX. Insectiv'ora.**—These are small, plantigrade, long-snouted, chiefly nocturnal mammals, which feed on insects and earthworms. The eyes are small or hidden by fur. The clavicle is usually present; the cecum, absent or minute. As a rule, there are five digits. All of this order are provided with sharp teeth. The front teeth in both jaws are inclined outward, being less adapted for seizing the prey. The brain is of simple structure, the hemispheres usually smooth.

**Hedgehogs** are covered with spines, but they are not barbed as in the porcupine, and they are firmly attached. Hedgehogs feed upon insects, chickens, young game birds, and even vipers. They are less than a foot in length, about the size of a big rat. They disappear in hot weather, and come out in rainy weather. They hibernate in winter. *E. europæus* defends itself by rolling up into a ball, with its head tucked between its fore feet and the hind feet drawn up close together, thus presenting, on all sides, its sharp spines to its enemies, few of which will attack the hedgehog. Hedgehogs are not found in the Western Hemisphere. Their voice is described as a sound between a grunt and a squeak.

The **shrews** (*Soric'idæ*) (Fig. 293) are small, nocturnal, fur-covered insectivores, which are often mistaken for mice, but the teeth show they are not rodents. They are of wide distribution, but are not found in Australia nor in South America. Several species are found in the United States. *S. personatus* is chestnut brown, with large ears and short tail. They are thinly covered with hair. Their length is $2\frac{3}{4}$ inches; the tail, 1 inch. They are found from Massachusetts to Alaska. The water shrew (*S. palustris*) is the largest of our shrews, measuring 6 inches, with the tail $2\frac{1}{2}$ inches long. The lesser shrews of Great Britain are burrowing, nocturnal animals, and secrete a disagreeable odor for protection. They are among the smallest of all mammals.

[1] See Hornaday, or Jordan's "Report of the Fur Seal Investigation," 1896–97.

The **moles** (*Tal'pidæ*) are subterranean animals, with broad front feet and vestigial eyes. The common prairie mole (*Scalops aquaticus machrinus*) (Fig. 294) is well known by its habit of burrowing in gardens for earthworms and grubs. It eats also the roots of vegetables. Its powerful front limbs are clawed for digging. Its hind limbs are weak, the tail short, and the nose pointed. The star-nosed mole of the eastern United States (*Condylu'ra*

Fig. 293.—Common shrew. (After Coues.)

*cristola*) has the tip of its snout encircled with fleshy projections. *Talpa* is an Old World form. The Russian Desman (*Myog'ale moscata*) lives in burrows in the banks of streams. It feeds on fresh-water insects and larvæ.

An Oriental insectivore is an aberrant form. It is much larger than most of the order and has an integumentary membrane, connecting the neck with the fore limb, the fore limb with the hind limb and the hind limb with the tail.

Fig. 294.—Common mole (*Scalops aquaticus*), Linn. (After Coues.)

*Geographic Distribution.*—This order is represented in every region except South America and Australia. The moles are confined to the temperate regions of the Northern Hemisphere. Hedgehogs are not found in the Western Hemisphere nor in Australia.

*Geologic Distribution.*—In North America they date back to the Eocene Period. The Miocene *Palæoerina'ceus* differs so little from the existing genus, *Erina'ceus*, that the latter may be called " one of the oldest living genera of mammals."

*Use to Man.*—Many mammals of this order have fine soft fur. They are also of value as insect destroyers. A single mole is said to devour twenty thousand insects annually.

**Order X. Chiroptera.**—The **bats** have many points of resemblance and structure with both lemurs and insectivores. But they are distinguishable from all other mammals by their power

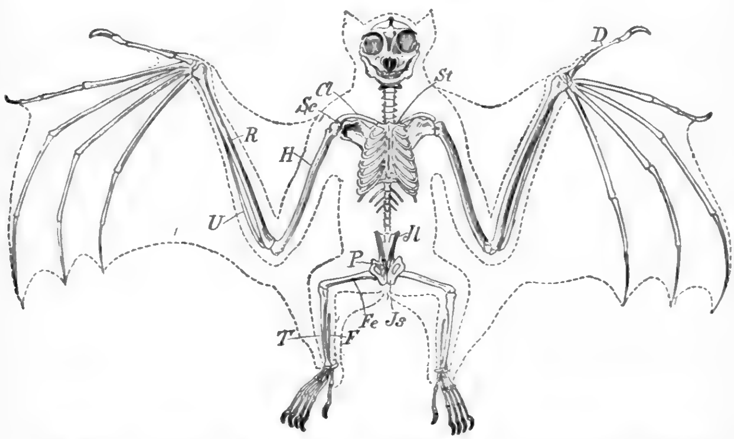



Fig. 295.—Skeleton of *pteropus: St*, Sternum; *Cl*, clavicle; *Sc*, scapula; *H*, humerus; *R*, radius; *U*, ulna; *D*, thumb; *Jl*, ilium; *P*, pubis; *Js*, ischium; *Fe*, femur; *T*, tibia; *F*, fibula. (After Owen.)

of zigzag flight. " The wings " (Fig. 295) consist of an integumental membrane, supported by the digits (two to five), which are greatly elongated and are folded together like the ribs of an umbrella when the wings are folded. A membrane between the hind legs and tail, when present, is used for steering.

The expanse of wing, compared with that of the body, is greater than that of most birds, but the muscles are weaker. The first digit, or thumb, is short, free, and strongly clawed, " and sometimes a sucker, by which bats scramble about rocks and trees, recalls the similar organ in that primitive lizard-like bird, the *Archæopterix*." The bones of this order are slender and light. The skull and teeth present many extraordinary variations. The radius is long and curved, the ulna is rudimentary, and the knee is directed backward. The sternum is keeled for the attachment of the pectoral muscles, the chief muscles of flight. The ribs are flat and sometimes ankylosed together by their margins. The fibula is rarely fully developed. The hind limbs are small and serve as a means of hanging the body head downward in rest or sleep, but are almost useless for walking. The skull is almost as large as the chest. The ears are sometimes much longer than the head. The nostrils are wide and are often surrounded by highly complicated sensitive membranes, which sometimes give the face a comical or even hideous expression. These are often more strongly developed in the male. The cheek teeth of the insectivorous bats terminate in sharp points, and are designed for cutting to pieces the hard parts of hard-shelled insects. The fruit-eating bats have molars with rather smooth crowns, while the vampires (Fig. 296, p. 371) have molars with scissor-edges and large canine teeth with sharp, cutting edges. The eyes are minute except in the fox bats. The wing membranes are sensitive, containing intricate network of blood-vessels, nerves, and "end organs," and thus, by the aid of their sensitive wings and sensitive membranes on the face, bats are enabled to fly without touching bodies in their way, though they be in utter darkness or when their eyes are so minute and fur-buried that they could not detect the intruding object. The cerebral hemispheres are smooth and do not extend over the cerebellum. Bats are small and nocturnal and generally insectivorous, generally feeding on the wing, thus they are beneficial. Some are fruit-eating, and others, as the vampires of South America, are blood-sucking, attacking warm-blooded animals, and will even withdraw a quantity of blood from a sleeping man. There is nothing whatever to fear from the bats of the United States, for their claws and teeth are weak. The fur is usually brown or gray, "but a few Oriental species are mottled or variegated with orange, bright yellow and black," as is shown by the "painted" bat of Ceylon. This bat hides by day in the folded leaf of a plantain, and when disturbed, looks more like a butterfly than a bat. Mr. Swinhoe, a naturalist long residing in China,[1] says that these colors are highly protective, for the brilliant bat inhabiting Formosa resorts to the longan tree. This evergreen tree always has some portion of its foliage decaying, making these dying leaves orange and black, while the fruit is reddish yellow. Thus the orange and black bat, suspended from the branches, is concealed from its enemies by its protective resemblance. Owing to their nocturnal habits very little is known of the activities of bats. "We know that in the winter some of our species live in caves in a semidormant condition," and Dr. Hart Merriam has proved that some species do migrate in fall and spring. All bats living within the snow limit of the Temperate Zone must either migrate or hibernate, for the fruit-eating bats could find no food, and the delicate wings of the vampire, which might find food, would be frozen stiff in zero weather, so the latter are chiefly tropical. Bats usually inhabit caves, a million sometimes hibernating in one cave. The thick layer of guano on the floor of the cave may represent the deposit of centuries. Bat guano is a valuable fertilizer. In warm countries bats live in hollow trees. The cry is a shrill squeak. They are widely distributed, being found on islands where there are no other mammals. The occurrence of the same genus of bats in India and Madagascar has led some to believe that there must have been at one time some connection between these countries, as these slow-flying creatures could hardly have traversed these vast stretches of ocean by their power of flight alone.[2] However, Hornaday tells of a British long-eared bat which was found clinging to the rail of an Atlantic steamer 30 miles from land, with no breeze going from the land.

Bats are divided into two groups: the large diurnal (*Meg'a-chirop'tera*), or fruit-eating bats, and the nocturnal (*Mi'cro-chirop'tera*), or insect-eating bats.

**Megachiroptera.**—The ordinary *fruit bats* or *fox bats* number about forty species. The fur is fox red, the muzzle long and pointed. The eyes are big and the ears upright, giving them a fox-like appearance. They live in colonies of from five to fifty. Hornaday killed some having 40 inches spread of wings. He says "of all creatures that fly, none are so uncanny when outlined against the sky as the big black-winged, half-naked flying fox (bats). They suggest demons and calamities." The fruit-growers of California, being fearful of their introduction into the United States, have

[1] Ingersoll, p. 63. [2] Beddard, p. 525.

secured a law prohibiting their importation even into zoölogical gardens. In the Ethiopian region this family is represented by the large, grotesque, hammer-headed bat (*Epomoph'orus*). Its head, particularly the muzzle, is enlarged, giving it a resemblance, in profile, to the head of a moose. The larger fruit bats are eaten by natives of their countries and even relished by white men. They make affectionate pets, but it would seem strange, weird ones.

**Microchiroptera** includes five families. Here belong the leaf-nosed bats already mentioned, the "bonneted bats," and the naked bats, the vampires (Fig. 296), and the common smaller bats. The naked bats of Borneo have thick, leathery, elastic skin. A scent gland for defense is situated between two folds about the neck. The most remarkable thing is the mammary pouch under each arm—a wide pouch of rubber-like skin in which the young are carried until able to fly. The mammary gland is in the lower portion of the pouch.

Fig. 296.—Head of *Phyllos'toma* (*Vampyrus*) *spectrum*. (Claus.)

Of the **vampires** or blood-suckers, the javelin bat (*Phylos'toma hastatum*) bites horses, cattle, and even sleeping man. The sharp-edged, dagger-like teeth make a small round hole in the skin, from which the vampire draws the blood by mouth suction. The blood sometimes flows freely after the bat has left its victim, but there is no poison attending a wound. The digestive organs of the vampires are extremely modified, these bats living upon predigested liquid food. The gullet is too narrow for any solid food to pass through and the stomach is intestine-like.

The **common bats** (*Vespertilion'idæ*) range over all parts of the world, and number over two hundred species. Most of the bats of the United States, about eighteen species, belong to this family. They are very common along the Atlantic coast and there are several species along the Pacific. The commonest is the little red bat, which flies about in the early twilight. It is constantly on the wing from sunset until dark. In its flight it can turn abruptly and with great accuracy. It is remarkable that it can turn and double so quickly and dart in all possible directions without striking anything. The gray bat of the northeastern United States and Canada and the big-eared bat of the South Atlantic coast are members of this family. The North American bats never make any nests. The little bats are born in crannies, and, from the first, cling about the mother's neck when she chases the "numberless little flying things of the dusk. When there are twins, the male takes his share of the responsibility."

*Geologic Distribution.*—Bats appear for the first time in the Eocene Epoch, according to the records of the rocks.[1]

**Order XI. Prima'tes.**—This order includes all animals with hands and hand-like feet. With but a few exceptions the members of this order inhabit the tropics. Except in man, they reach their highest development near the equator. Hornaday says that there is no human being of sound mind to whom the human likeness of the lower Primates does not appeal. They are, at any rate, very much like man in their structural development. As a rule, they have five fingers and toes, each covered at the tip by a flat nail. The inner finger or toe, or both, are opposable, making the hand, and often the foot, a grasping organ. The feet are plantigrade. The limbs are quite free from the body, as compared with those of other chordates. The skull of the *Anthropoi'dea* is characterized by the bony partition between the orbital and temporal vacuities. The stomach is simple. The cecum is always present and sometimes large. They are chiefly arboreal, except terrestrial man.

The sub-order *Lemuroi'dea* includes the aye-aye, tarsier, and the lemurs. The head lacks the human-like expression, being more like a fox, with a sharp muzzle. There are no cheek pouches. The tail, which is never prehensile, varies from none, in *Loris*, to the long and bushy tail of the "aye-aye." The thumb and great toe are well developed and the second toe has a sharp nail unlike the flat nail of the other digits. The brain case is small and the temporal and orbital fossæ are in communication. The placenta is non-deciduate. The vermiform appendix is never present and the cecum varies in length. They are now found only in Madagascar, tropical Africa, and the Orient. In the Tertiary Period the ancestors of these animals were scattered all over the globe.

The **lemurs** (*Lemur'idæ*) have round heads with fox-like muzzles, small ears, and a long tail (Fig. 297). The wooly fur, which is often beautifully tinted, is soft and thick. In size they vary from that of the squirrel to that of the cat. They are omnivorous, and, as a rule, diurnal or crepuscular. They are found in Madagascar. In trees they run about on all fours, but on the ground they walk erect on their hind legs. The one or two young are carried about by the mother as they cling to her breasts, or, later, ride upon her back. One of the most interesting is the ring-tailed lemur, which

[1] Scott's "Geology," p. 506.

scrambles over the rocks, its leathery palms being furrowed with sucker-like grooves, enabling it to go where man cannot. The ruffed or black and white lemur is perhaps the most beautiful. It is the size of a large house cat, has a long tail, and is clothed in long, soft, silky, fine fur. The mouse lemurs, dwarf lemurs, and fat-tailed lemurs estivate during the hot and dry seasons, curling up in their nests, just as northern animals do in hibernation. "They go in fat, subsist by absorption of this stored tissue, and come out thin and weak" at the approach of the rainy season. Lemurs are all perfectly harmless, but their weird actions, big eyes, and loud cries have led to their being reverenced and feared by the superstitious natives.

The female aye-aye constructs a globular nest in a tree for the rearing of her single offspring.

**Sub-order Anthropoidea** differs from the lemurs in having the mammary glands always thoracic, the orbital and temporal fossæ separated by bone. The cerebral hemispheres are highly developed, almost or quite concealing the cerebellum. There are over two hundred tropical and subtropical species.

**American monkeys** (*Platyrrhi'na*) differ from the Old World forms in having the nostrils directed downward and separated by a broad septum. As a rule, they are also smaller and have but thirty-two teeth. The tails are usually long and prehensile. No American form has cheek pouches. Most of them are arboreal. All American monkeys are small, varying in size from that of young kittens or chipmunks to 20 inches long. They are hairy or woolly. One baby monkey is born to each female each year.

Fig. 297.—*Otolicnus galago* of Africa. (From Vogt and Specht.)

The **marmosets** are lowest in the scale of development, indeed, they sometimes look very little like monkeys. They range from southern Mexico to southern Brazil. They are small, delicate creatures, with hairless faces, large, bright eyes, and long tails. In some species the long silky hair stands up on the head like a white ruff. The digits are, for the most part, clawed, the great toe only bearing a flat nail. They are arboreal, but the tails are not prehensile.

The second family of American monkeys (*Ceb'idæ*) is distinguished from the marmosets by thirty-six teeth, and by the generally long and prehensile tail, which is naked on the under side of the end.

The **Saki monkeys** (*Pithe'cia*) of tropical South America east of the Andes have long, bushy, non-prehensile tails, and, sometimes, a long, black chin beard.

The **squirrel monkeys** (*Sai'miri*) are little creatures with a long head, the occiput projecting. The proportions of the cranium, as compared with the face, are greater than in other monkeys or in man. They are gregarious and arboreal, feeding upon insects, small birds, and eggs.

The **howlers** are the most hideous looking of the American monkeys and have the least intelligence. The brain is less convoluted than that of the *At'eles*. Their howl, made to intimidate enemies, can be heard two miles.

Fig. 298.—Spider monkey. (American Museum of Natural History.)

The natives hate the howlers and kill them for food, selling the hide to white traders. The hair is twisted into cordage.

The **spider monkey** (*Ateles*) (Fig. 298) is the most typically arboreal of American monkeys. With its prehensile tail held erect over its head, it "feels" for a place to grasp, which it does by wrapping the end of its long slender tail tightly around the branch. It then swings itself far across toward another limb, which it grasps with its thumbless hands by hooking them around the limb and thus suspending its body. "They have a very uncanny look and can come as near tying themselves into a knot as any living mammal can." They are weak and cowardly. The Mexican spider monkey is the most northern one in America, sometimes coming up to latitude 32°.

Perhaps the most typical of this family is the genus *Cebus* of twenty species, ranging from Costa Rica to Paraguay. The common monkey of the organ-grinder belongs to this genus. The thumb is well developed. The color is usually dull brown, but one is brick red and others have white about the shoulders. They are gregarious. Contrary to the general belief that they are strictly herbivorous, they are very fond of caterpillars.

"No monkeys ascend high in the Andes nor reach the west coast, and none are found south of the forests of Brazil or north of south central Mexico. Fossil remains of monkeys are rare everywhere, and known in the New World only in the Santa Cruz Miocene formations of Patagonia; and they show no more kinship with the Old World types than do the existing species."[1]

**Old World** monkeys (*Catarrhi'na*) have the nostrils close together and directed downward. There are open cheek pouches and but thirty-two teeth. The tails are non-prehensile or even absent. Often there are hard patches of hairless, bright-colored skin (ischial collosities) upon the haunches. Catarrhine monkeys are larger and more intelligent than the Platyrrhine forms. These distinctions are ancient, "since no fossil remains of monkeys at all intermediate have so far been discovered, another evidence of the very early time at which South America became isolated."

**Macaques** and **baboons** (family *Cer'copithec'idæ*) contains eight or nine genera divided into two subfamilies. The first (*Cer'copitheci'næ*) consists of rather large monkeys represented by macaques and baboons. They have cheek pouches in which to store the food. All the macaques but one are Asiatic. They are from 13 inches to 3 feet long, the male being larger than the female, with larger canine teeth. They are gregarious, noisy, and active, "scrambling about rocks, and some swim and dive well." In some parts of India they damage gardens. Their dog-like teeth and strong nails are able to inflict severe wounds. As examples, the bonnet monkey, the Gibraltar ape, and the pig-tailed monkey may be mentioned. The latter is trained by the natives to climb the cocoanut-palm tree and to select and throw down the ripe cocoanuts.

The **baboons** (*Cynoceph'alus*) are found in Africa and Arabia. The African forms vary in size from that of a spaniel to that of a mastiff. Their stout limbs are about equal, the nose and head are dog-like, and the canine teeth long and sharp. They are the fiercest of all Primates. It is said that even a hungry lion will not attack a baboon. The great ischial collosities are strikingly colored, adding to the ugliness caused by overhanging eyebrows, small eyes, ferocious disposition, and filthy habits. It is said these collosities attract the kite bird, which mistakes them for raw meat, and the baboon makes a meal of the bird. The color is blackish or a greenish or yellowish gray, grizzled by each hair being ringed with various colors. The Gelada has a black body and a brown mane, with a gray chest. It looks like a small lion with a baboon's hands and feet. Baboons like the open country and the rocky hills and deserts. They go in troops.

The second sub-family (**Semnopitheci'næ**) includes guerezas, the langurs, or Asiatic holy apes, and the Bornean genus *Nasalis*. They are slender apes with no cheek pouches and have a sacculated stomach.

The **anthropoid apes** (*Simi'idæ*), though chiefly arboreal, walk erect or semi-erect when they come to the ground. Their hands and feet are fitted for a half-arboreal, half-terrestrial life. When they put their hands to the

[1] Ingersoll, p. 37.

ground to aid in walking they rest upon the back of the knuckles. Cheek pouches and tail are lacking and the hair is more scanty than in the baboons. These entirely Old World forms have a vermiform appendix.

The **gibbons** (*Hylob'ates*), slender, monkey-like Indo-Malayan forms, stand at the base of the series. They are the smallest and most arboreal and their arms are the longest of any of the group, being long enough to reach the ground even when standing erect. The canines are large in both sexes and the jaws and nose are prolonged. The brain is simpler than in the higher forms. One of the most remarkable habits is their descending flight through the trees, though they never come to the ground. They leap incredible distances, says Hornaday, catch and swing with their hands, catch again with their feet, turning again, and so on, by a series of revolutions almost as fast as the flight of a bird. The largest is the Sumatran Siamang, which stands 3 feet tall and is shining black. The gray gibbons are very timid, but show strong affection for their young and great courage in their defense.

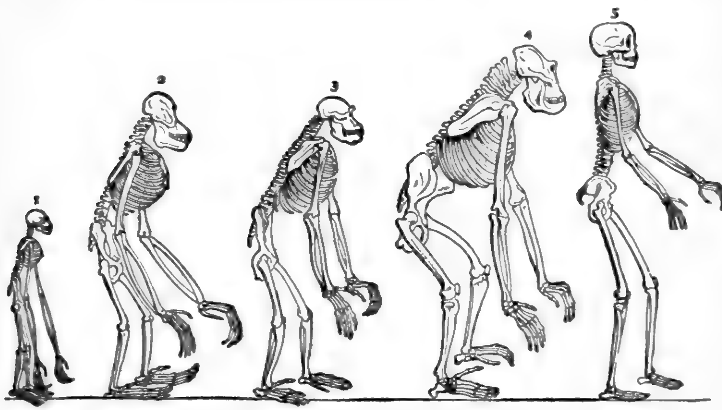



Fig. 299.—Comparison of skeletons of primates: 1, Gibbon; 2, orang; 3, chimpanzee; 4, gorilla; 5, man.

The **brown orang-utan** lives in Borneo and Sumatra, wholly in the tree-tops, coming to the ground only for water. On the ground it moves slowly and swings its body along between its arms like a pair of crutches. In the trees, too heavy for leaping, they swing underneath the branches with their long arms, "grasping a limb with their hook-like hands, and swinging underneath to the next hold, and so on, at great speed."[1] It subsists upon wild fruits, fleshy leaves, and shoots of the screw pine. It is shy and uncertain if captured. When young it is easily tamed; when grown, wild and ferocious. Hornaday says "in 1901 the zoölogical park contained four orangs, all of which were taught to wear clothes, sit in chairs at table, eat with fork and spoon, drink from cups and bottles, and perform many human-like actions without nervousness in the presence of two thousand visitors. Each of the orangs learned its part in about two weeks' training, and at the

[1] Ingersoll.

dinner table acted with gravity and decorum." In captivity young orangs are affectionate as children and are fond of their human friends. At night the wild orang makes a nest to sleep upon by breaking off leafy branches and laying them crosswise in the forked top of a sapling, where it lies flat upon its back, grasps the branch firmly in each hand and foot, and is rocked to sleep in the tree-top.

The **chimpanzee** (Fig. 300) has a " brain, face, ears, and hands more man-like than those of any other ape." Its face, ears, hands, and feet are naked. It has a large brain and a higher

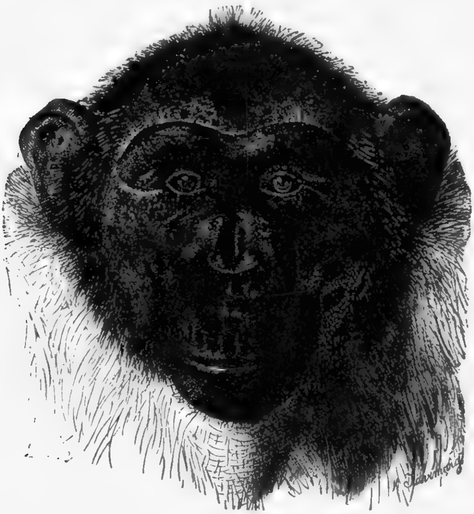


Fig. 300.—The chimpanzee, variety Tshego. (From Brehm's "Thierleben.")

intellect than any of the Primates below man. It is bright and cheerful and, having a good memory, is easily taught. The young are affectionate, but the old males are dangerous. There are at least two species. They are natives of Africa. Mated pairs seem to remain together permanently, and missionaries, when they tried to teach that polygamy was wrong, have been told by the natives " that they did not wish to be like apes." They spend much time hiding in thickets in family groups, sometimes gathering in such numbers as to do considerable damage to young bananas. They are crepuscular. They show great affection for their families, the father often taking the baby from the mother and carrying it, especially in dangerous places, and they seek to assist one another when hurt or in trouble. They seem to delight in noise, uttering loud shrieks and howls, and drumming with sticks on resonant logs. This is the only employment of an instrument or tool, and, in itself, shows a wide difference between the chimpanzee and the lowest human savage.

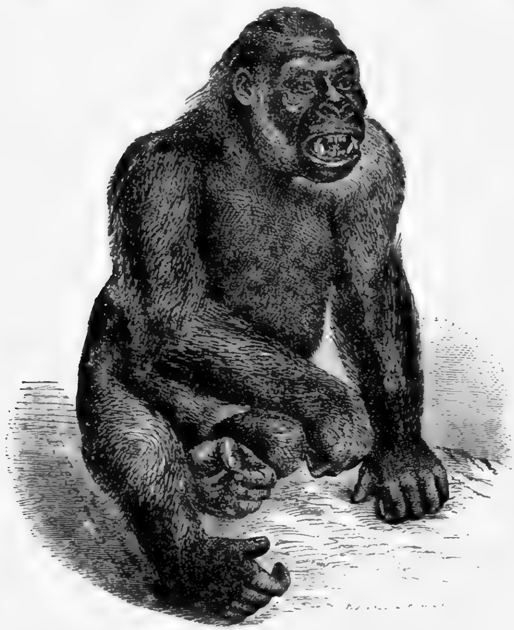


Fig. 301.—*Gorilla engena.* (Vogt and Specht.)

A rude platform of branches is built for the family bed, the father, perhaps, sleeping curled up in a crotch of the tree beneath it.

**The Gorillas.**—Both in kind and number "the bones below the skull are the same in the skeletons of man and the gorilla. They differ only in their proportions" (Fig. 299, 4). The widest differences are in the skulls. In the gorilla the high forehead and intellectual faculties so characteristic of man are entirely wanting, indicating a low order of intelligence. "The long and powerful canine teeth are alone sufficient to proclaim the savage wild beast." The gorilla is not teachable like the chimpanzee, but is sulky and ferocious. The gorilla is the only ape that walks erect. Its arms are relatively short and its legs long. Its hands reach a little below the knees when standing erect. It has big feet and a pronounced heel. The digits are webbed.[1] The brain is larger than that of the chimpanzee, but so is the body. The great similarity of structure to that of the human body is due largely to the plantigrade walk and the terrestrial life. The gorilla is more primitive than the chimpanzee and, therefore, nearer to the common ancestral stock. It is found in a small area in West Africa on the equator, and between the Gaboon and Congo Rivers. Hornaday declares that if the head of a chimpanzee were placed on the shoulders of a gorilla, we should have the "missing link," and that if the missing link is ever found, it will be in the "Tertiary deposits of the fertile uplands that lie between the gloomy equatorial forests of the black apes and the bushmen of South Africa."

**Man.**—Fossil remains of a man-like ape, *Anthropopithe'cus erectus*, have been found in the upper Pliocene of Java. It is generally thought that these fragments belong to an exceedingly large gibbon-like animal having an enormous cranial cavity and a brain nearly equal in size to that of some of the savage races of man to-day. There is no doubt that man lived on the earth at the beginning of the Pleistocene times, and it is thought by many anthropologists that he lived in the latter part of the Tertiary Period, though this has not been satisfactorily proved.

The family *Hominidæ* contains but a single genus, *Homo*, and one species, *H. sapiens*. The different varieties of this species are now generally classified in three great groups: the Ethiopian, of Africa; the Mongolian, of Asia; and the Caucasian, of Europe. Man is distinguished from other primates by a less development of hair on the body, by the erect walk, and by the consequent modification of the hind limbs and feet (he is a true biped). The face does not project so much as that of the anthropoid apes. The skull of man is a smooth,

[1] Beddard, p. 572.

rounded case, while that of the apes is smaller and deeply ridged and contains a smaller brain. Man's outstretched hand does not reach the knee and the thumb is much more useful. The hallux (great toe) is not opposable. There are no laryngeal pouches. "The minute diverticula, the ventricles of Morgagni, alone remain to testify of a former howling apparatus in the ancestors of man."[1]

Man has the power of articulate speech and the faculty of reason. As to whether this vast difference in reason be one of kind or degree, psychologists disagree, but all concede that the reasoning power of man is far in advance of that of any other animal.

Man's superiority over animals lies in his highly developed powers of abstract thought, reason, and will. Through these powers he is able to adapt himself to his environment, make a new environment, or migrate to one better suited to his needs. He can control the lower forms of animal life and modify them by artificial selection and breeding to satisfy his wants. From them he procures clothing, leather, food, ornaments, weapons, fertilizer for his land, and materials used in his houses. He uses them as beasts of burden or as means of travel. Through undue use or slaughter he has caused the extinction of various species.

The student has missed the greatest value of the study of zoölogy if he has not discovered that the great underlying principles which permeate and control all animal life from the lowest to the highest forms necessarily apply also to the life, development, and history of mankind. Descent with adaptive modifications is amply illustrated in the descendants of one man during his lifetime. The influence of environment, growth and decay, heredity, variation, adaptation, the survival of those best adapted to conditions in the physical or the business world, the strengthening of powers of body or mind by use, the degeneration of powers by dependence upon others, the sacrifice of the parent for the offspring everywhere seen in nature, or the triumph of altruism over egoism in the service of one's family or his fellow-men—these are some of the biologic principles directly applicable to man.

[1] Beddard, p. 589.

**Classification.—**

| *Order.* | | *Examples.* |
|---|---|---|
| I. | Monotrem'ata. | Duckbill, Spiny Ant-eater. |
| II. | Marsupia'lia. | Kangaroo, Opossum. |
| III. | Edenta'ta. | Ant-eater, Armadillo. |
| IV. | Sire'nia. | Manatee, Dugong. |
| V. | Ceta'cea. | Whales, Porpoises. |
| VI. | Ungula'ta. | Cattle, Sheep, Deer, Horses. |
| VII. | Roden'tia. | Rabbits, Squirrels, Prairie-dogs. |
| VIII. | Carniv'ora. | Cats, Dogs. |
| IX. | Insectiv'ora. | Moles, Shrews. |
| X. | Chirop'tera. | Bats. |
| XI. | Prima'tes. | Apes, Monkeys, Man. |

## THEORIES OF DEVELOPMENT

**Origin of Life.**—Many scientists to-day advocate that life is the action of chemical and physical forces in connection with a peculiar substance called protoplasm. But no one has yet been able to explain all the phenomena of life by means of these forces. Until this is done, we must believe that life from life is the universal rule, or that no living organism originates except from some pre-existing living form.

**Protoplasm** is the physical basis of all life, both plant and animal, and without this complex substance life cannot exist. It is a protein which is known only as a product of living substances.[1] It is chemically and physically unstable, but it is impossible to obtain a satisfactory chemical analysis since the dead material differs from the living protoplasm both in its power and structure.

There is little direct proof of the character of life in the Archæan Era, but it must have been marine. Since plants usually feed upon inorganic matter and animals cannot manufacture organic compounds from inorganic ones, and as plant life is thus a necessity for the existence of animal life, it is thought that plant life may have been first. However, the view that plant and animal forms originated side by side and have developed along diverging lines is common.

Since the simplest form of life to-day consists of a single cell, it is believed that primitive life began as a single cell.

**The Cell Theory.**—Cells were first described by Hooke, an Englishman, in 1665, and were so named from the resemblance of the compartments in the structure of a piece of cork to the cells in a monastery. Schleiden, in 1838, showed that plants were composed of cells, and in 1839 Schwann discovered the same general fact concerning the bodies of animals, thus revealing the common plan of organization of plants and animals.

The cell theory involves: (1) that all organisms are made up

[1] McFarland's "Biology."

of single cells or combinations of cells; (2) that all organisms begin life as a single cell, giving rise in metazoans to a body of more or less complexity, and (3) that the function of this complex (multicellular) organism may be expressed in terms of the activities of the individual cells of which it is composed. The third proposition may need some modification. "It was through the cell theory that Kölliker, Remak, Nägeli, and Hofmeister opened the way to an understanding of the nature of embryologic development, and the law of genetic continuity lying at the basis of inheritance. It was the cell theory again which, in the hands of Goodsir, Virchow, and Max Schultze, inaugurated a new era in the history of physiology and pathology, by showing that all the various functions of the body, in health and in disease, are but the outward expressions of cell activities. And at a still later day it was through the cell theory that Hertwig, Fol, Van Beneden, and Strasburger solved the long-standing riddle of the fertilization of the egg and the mechanism of hereditary transmission. No other biologic generalization, save only the theory of organic evolution, has brought so many apparently diverse phenomena under a common point of view, or has accomplished more for the unification of knowledge. The cell theory must, therefore, be placed beside the evolution theory as one of the foundation stones of modern biology."[1]

**Cell Structure.**—In the typical cell are found the following parts: (1) the cell wall; (2) the cytoplasm, or cell substance, which includes the *plasma* (that is, the living protoplasm around the nucleus) and the *chylema*, or "cell-sap"; (3) a nucleus which is usually inclosed by a delicate membrane, and which contains chromatin and achromatin fibers and one or more nucleoli, and (4) one or two centrosomes or attraction spheres.

**Cell Division or Mitosis.**—The centrosome divides into two parts, which gradually separate, and each of which becomes the center of a system of fine achromatin fibers radiating about it. A spindle of achromatin fibers is also extended from one centrosome to the other. At the same time the chromatin granules scattered throughout the nucleus are arranged into a continuous thread or skein of closely contorted filaments. The nuclear

[1] Wilson, "The Cell."

membrane generally disintegrates and the chromatin thread is broken up into U-shaped fragments (chromosomes). These U-shaped chromosomes are arranged as the equatorial plate half-way between the centrosomes and across the axis of the spindle. Either before or after the formation of the equatorial plate the chromosomes split longitudinally, so that each part contains an equal amount of the chromatin. The chromosomes now move along the spindle (or its fibers contract), so that one-half of each original chromosome is drawn to one centrosome and the other half to the other centrosome. These chromosomes, with their apexes pointing toward the center, are now arranged about their respective centrosomes. The protoplasm of the general cell becomes constricted in the center, each group of chromatin loops rearranges itself into a nucleus like that of the mother cell, and an investing membrane becomes apparent. A furrow appears on the surface of the protoplasm and gradually deepens until the protoplasm is divided into two equal segments, each containing its own nucleus and centrosome and being a complete daughter-cell.

**Maturation.**—Metazoans usually reproduce by means of fertilized eggs or ova. Egg cells vary in size from less than $\frac{1}{200}$ to about $\frac{1}{100}$ inch in diameter. By this is meant the minute germ cell without the enormous amount of nutritive material which usually accompanies it.

Before the process of fertilization takes place (about the time of the entrance of the spermatozoön, which, however, takes no part in the process) the ovum undergoes a process of maturation, in which one-half of the number of chromosomes is thrown off. A spindle-shaped structure is formed from minute fibers in the cytoplasm. The centrosomes, one at each pole of the spindle, seem to control its formation and activities. This spindle draws from the egg nucleus a definite number of chromosomes which are arranged across the center of the spindle, which now moves endwise toward the surface of the egg. A small protrusion is made, the spindle divides across the center, and the first polar cell, consisting of a nucleus with chromosomes and a small amount of cytoplasm, is formed and thrown off. The remaining portion of the spindle disappears. The other centrosome divides into two and forms another spindle, on which the chromosomes are again arranged as before, and the second polar cell is formed. These polar cells disintegrate. The nucleus of the ovum now contains only about half the number of chromosomes present before the process of throwing off the polar bodies. This remaining portion of the nucleus retires from the circumference and is called the female pronucleus, or *macrogamete*, which is ready for fertilization. The spermatozoön previous to entering the ovum undergoes a similar reduction of chromosomes, though the resulting cells form sperms.

**Fertilization.**—The enveloping membrane of the ovum contains one or more minute openings through which the spermatozoön, or male germ cell, enters for the purpose of fertilization. The spermatozoön consists of a nucleus or extremely minute head, a centrosome, and a flagellum or tail, which is for the purpose of locomotion and disappears upon the entrance of the spermatozoön into the ovum. The nucleus, called the male pronucleus or *microgamete*, enlarges, the centrosome divides, and a mitotic figure is formed which moves toward the female pronucleus, which moves toward the male pronucleus. Finally, male and female nuclei meet in the midst of the spindle formed about the male nucleus; thus the male and female nuclei are united into one nucleus or zygote.

**Segmentation.**—This zygote or fertilized ovum now contains the normal number of chromosomes or "hereditary threads" for its species, one-half of which have been furnished by the maternal cell and one-half by the paternal cell. When the process of mitosis is completed, this zygote is divided into two daughter-cells, each containing the same number of chromosomes, half of which have been derived from the sperm and half from the ovum. Each of these daughter-cells subdivides into two, and the resulting four, into eight cells, and so on, the number varying with different species. When there is little or no yolk or nutritive material the whole egg divides equally; when there is much yolk the division is unequal or partial.

**Differentiation of Tissues.**—From the ectoderm are produced the outer portion of the skin and its outgrowths and the whole nervous system; from the endoderm come the lining of the digestive tract and the essential parts of the glands connected with it. The mesoderm gives rise to the bones and muscles, the circulatory system, and the muscular walls of the alimentary tube. All metazoans pass through these early stages of development, and embryology teaches that from these simple beginnings the most complex animal body is developed.

This sphere of cells is known as the morula or mulberry stage (Fig. 5), and is succeeded by the blastula stage, in which the cells are arranged in a circle about a cavity filled with watery fluid. On account of inequalities, one portion of this sphere becomes pitted, this pitting-in grows deeper until there is a complete invagination of this portion, like the pushing in of one side of a hollow rubber ball until the two sides touch. This is called the gastrula stage, and occurs in all the main divisions of the animal kingdom. (In many vertebrates delamination supercedes or follows invagination, but this, perhaps, "is a later development or, possibly, improvement upon gastrulation."[1]) This gastrula stage is an open sac composed of two layers of cells, the outer or ectoderm, and the inner or endoderm. In most cases a third mass of cells, the mesoderm or middle layer is formed, probably from the endoderm. The opening of this sac-like body becomes the primitive mouth.

**History and Theories of Evolution.**—Evolution is not a new theory. Traces of such an idea are found in old Greek philosophy. Empedocles (about 500 B. C.) believed that "plants first sprang from the earth while the latter was in process of development. After them came the animals, their parts having first formed themselves independently and then been joined by love." After ceaseless trials, nature succeeded in producing fit tribes for perpetuation. Osborn says this is the germ of the "survival of the fittest." Aristotle (384–322 B. C.), though believing in separate creation, taught vaguely that living beings formed a gradual succession from the "less to the more perfect." Aristotle laid great stress upon the inductive method of study, and he was so great an observer of animals as well as a collector of the statements of others concerning them that he has been called the founder of zoölogy. If only his principle—that "we must not accept a general principle from logic only, but must prove its application to fact; for it is in facts that we must

[1] Romanes' "Darwin and After Darwin."

seek general principles, and these must always accord with facts"—had been remembered and applied by him and his successors, science need not have progressed so slowly for so many centuries.

The special creation theory interrupted scientific thought and investigation for many centuries. Philosophy preceded science in the line of evolutionary thought. Leibnitz, a German philosopher (1646–1716), believed that "living beings form an unbroken series from the simple to the complex, some steps in the series having become extinct."[1] Buffon (1707–88) thought that organisms could be modified by changes in food and environment or by domestication, and that parts could be modified by disuse. He was one of the first to attempt an explanation of the geographic distribution of animals.

Erasmus Darwin (1781–1802), grandfather of Charles Darwin, author of "The Origin of Species," was a physician and physiologist as well as a gardener and lover of plants. He thought that the various plants and animals were descended from "few ancestral forms or possibly from one and the same kind of vital filaments." He emphasized function, saying that "from their first rudiment or primordium to the termination of their lives all animals undergo perpetual transformations; which are in part produced by their own exertions in consequence of their desires and aversions, of their pleasures and their pains, or of irritations or of associations; and many of these acquired forms or propensities are transmitted to their posterity."

Lamarck (1744–1829), although unappreciated in his own day, scientists of the present day, whether agreeing with him or not, admit to be one of the bravest of pioneers. Haeckel says "to Lamarck will remain the immortal glory of having for the first time established the theory of descent as an independent, scientific generalization of the first order as the foundation of the whole of biology." To quote Lamarck, "Nature in all her work proceeds gradually and could not produce all animals at once. At first she formed only the simplest, and passed from these on to the most complex." He gives four laws as the summing up of his ideas:

[1] McFarland's "Biology."

(1) "Life by its inherent power tends continually to increase the volume of every living body, and to extend the dimensions of its parts up to a self-regulated limit.

(2) "The production of a new organ in an animal body results from the occurrence of some new need which continues to make itself felt, and from a new movement which this need originates and sustains.

(3) "The development of organs and their power of action are constantly determined by the use of these organs.

(4) "All that has been acquired, begun, or changed in the structure of individuals during the course of their life is preserved in reproduction and transmitted to the new individuals which spring from those which have experienced the changes."

But the man whose work is most completely identified with organic evolution is Charles Darwin (1809–82), who after spending many years in travel, observation, and investigation, published in 1858 a paper of great scientific interest. At the same time, by the arrangement of friends, Wallace, then in the Malay Archipelago, published his paper, giving essentially the same conclusions. In 1859 Darwin published his great work, "The Origin of Species," in which natural selection was more fully elaborated.

All organisms vary. These variations may be due to environmental changes or to excess of food, to the inherited effect of use or disuse of parts, or to *atavism*, reverting to the characteristics of a remote ancestor, or to *reversion*, a character or structure found in more recent ancestors. Darwin emphasizes the fluctuating or indefinite variations as of most use in natural selection. Every plant or animal must struggle for existence because of the vast number of other plants and animals and because of conditions of environment, such as cold, heat, or drouth. This struggle is threefold: (1) with its own species; (2) with other species of plants or animals which may prey upon it or its food, and (3) against unfavorable conditions of climate or weather. Those which most frequently survive do so because of certain individual characteristics which have made them able to win in this struggle for existence, or, as Spencer says, "the fittest survive." Now, according to Darwin, nature takes advantage of these favorable variations possessed by the survivors, and they are transmitted by heredity to their offspring, while those having less favorable adaptations do not survive and, hence, are eliminated. Thus did Darwin think that species came into existence—by a gradual improvement of advantageous variations until the type was best adapted to its surroundings. "I am convinced," he said, "that natural selection has been the main though not the exclusive means of modification."

One of the many objections offered against this theory is the perpetuation and improvement of disadvantageous modifications, such as the beautiful colors and songs of birds and adaptations for fighting which render them conspicuous. Darwin explained many of these cases by his theory of sexual selection. Among the higher animals it is a fact of common observance that in mating the members of either sex prefer the most attractive individuals of the opposite sex. The successful rival wins the mate, and, of course, it is his characteristics which are transmitted and improved in succeeding generations. Adaptations for rivalry by battle among males are explained in the same way.

Among the helpful contemporaries of Darwin several must be mentioned. To Herbert Spencer (1820–1903), the philosopher and author of "Principles of Biology," we owe the phrase, "the survival of the fittest." Haeckel summed up the recapitulation theory of Von Baer (published in 1828)—*i. e.*, that the embryonic phases of higher forms resemble or pass through the corresponding embryonic stages of lower forms—in his fundamental law of biogenesis, that ontogeny recapitulates philogeny. Huxley was the author of "Man's Place in Nature."

Dr. August Weismann (born in 1834) is the foremost opponent of Lamarck as to transmission of acquired characters. He led to the critical examination of reported cases, and he claims that no case really shows the transmission of acquired characters. He recognizes the chromatin as the hereditary substance or idioplasm, and calls the idioplasm of the germ cells germ plasm. This germ plasm, he says, is "never formed *de novo*, but it grows and increases ceaselessly; it is handed on from one generation to another like a long root creeping through the earth, from which at regular distances shoots grow up and become plants, the individuals of the successive generations." He further states "that only those characters are transmissible which have been controlled—*i. e.*, produced—by determinants of the germ, and that consequently only those variations are hereditary which result from the modification of several or many determinants in the germ plasm, and not those which have arisen subsequently in consequence of some influence exerted upon the cells of the body. In other words, it follows from this theory, that *somatogenic or acquired characters cannot be transmitted.*

"This, however, does not imply that external influences are incapable of producing hereditary variations; on the contrary, they always give rise to such variations when they are capable of modifying the determinants of the germ plasm. Climatic influences, for example, may well produce permanent variations by slowly causing gradually increasing variations to occur in the determinants in the course of generations. The primary cause of variation is always the effect of external influences. When deviations only affect the soma they give rise to temporary non-hereditary variations; but when they occur in the germ plasm they are transmitted to the next generation and cause corresponding *hereditary variations in the body.*"

*The Mutation Theory.*—De Vries is the chief exponent of the mutation theory, though Bateson also emphasizes its importance. This theory assumes that new species and varieties are produced from existing forms by sudden leaps. These may arise simultaneously and in groups, or separately and at more or less widely distributed periods. This new theory does not try to account for these sudden variations, but claims that "when they occur it is a striking fact that the characters tend to be transmitted." When a mutation appears, it will survive and leave descendants if it is adapted to its environment. Only a comparatively small amount of evidence has been found to support the zoölogic side of proof for this theory.

*Orthogenesis* is believed by many specialists, among whom may be mentioned Eimer, Whitman, Tower, and Ruthven. Development in a definite, predetermined direction, even if this development is harmful to the race, is called orthogenesis. "According to this theory, certain lines of development remain stationary while others advance." The explanation most favored "ascribes the control of these modifications to the direct effects of physiochemical factors on organisms." Professor Whitman says, "Natural selection, orthogenesis, and mutation appear to present fundamental contradictions, but I believe that each stands for truth, and reconciliation is not distant."

*Mendel's law* affirms that when mating takes place between two animals unlike in some characteristic, the offspring will often exhibit the characteristic of only one parent. This characteristic is said to be dominant, while the character which does not appear in the immediate descendants is said to be recessive. The hybrids which result from the crossing of animals will produce a number of germ cells which bear only the pure character of one parent and the same number which bear only the pure character of the other parent.

From this law follows the occurrence in the next and succeeding hybrid generations of a definite number of forms in definite numerical proportions. Thus, when gray rabbits are crossed with albino rabbits, all the immediate offspring are gray, while in the next generation produced by the breeding together of these gray hybrids there will occur in nearly every case three gray young to one albino. This is explained in the following way: the second generation is all gray because in the zygote, or fertilized germ cell, the chromosomes, or hereditary units, which bear the gray character are more potent in the color of the young than are the chromosomes bearing the albino character. This gray character is said to be dominant; the recessive albino characters are not destroyed, but are carried over and give rise to chromosomes of their own character, so that in the breeding of two hybrids one albino germ cell from each of the two sexes unite to produce one albino descendant. If one of the hybrid dominants (gray) is mated with a recessive animal, half of the young are hybrid dominants and half recessive. One who has found out by experiment which are dominant and which are recessive characters may produce several distinct types within a species. If future experiments add support to this law, it will then be explained how races suddenly spring into existence and become established.

By collecting evidence and arranging it in the form of pedigrees, it has been possible to demonstrate in man the existence of several characters which show Mendelian inheritance. Though most of the evidence has relation to abnormal or diseased conditions, investigations are now being made concerning pedigrees of normal characters. One of the most easily observed is the natural color of the eye. "To what extent eye color may be valuable as a criterion of race it is at present impossible to say, but if it is ever to become so, it will only be after a searching Mendelian analysis has disclosed the factors upon which the numerous varieties depend.

"A discussion of eye color suggests reflections of another kind. It is difficult to believe that the markedly different states of pigmentation which occur in the same species are not associated with deep-seated chemical differences influencing the character and bent of the individual. May not these differences in pigmentation be coupled with and so become in some measure a guide to mental and temperamental characteristics?"[1]

[1] Punnett's "Mendelism."

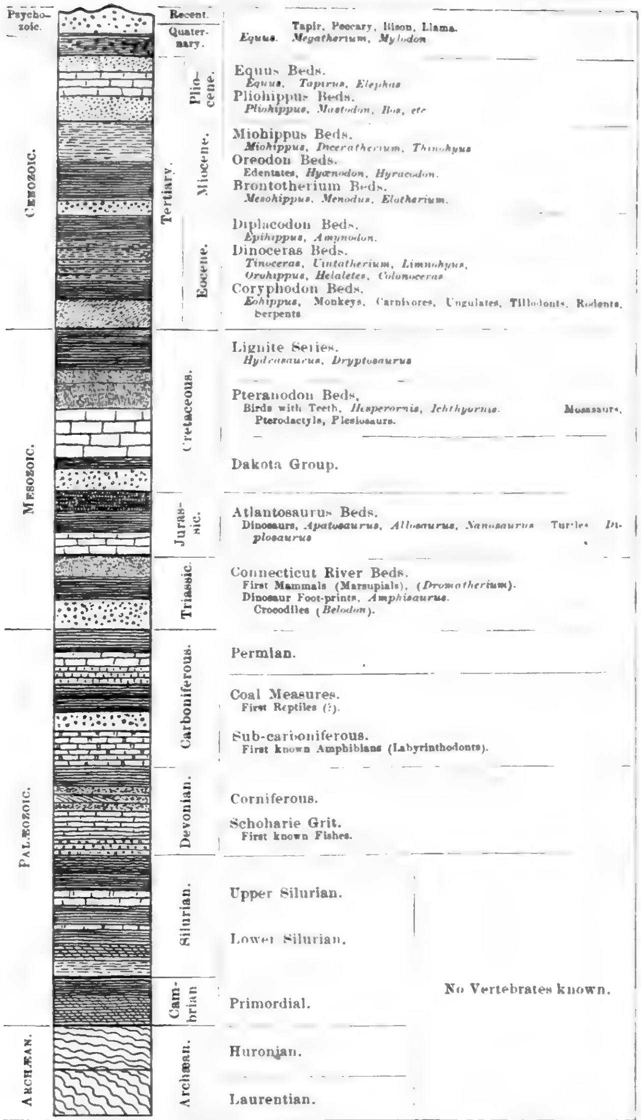



FIG. 302.–Section of the earth's crust, to illustrate vertebrate life in America. (After Marsh.) (From Le Conte's Geology, American Book Co., Publishers.)

## GLOSSARY

**Agamically.** Without fertilization.

**Altricial.** Hatched in a helpless condition, being wholly dependent upon the care of the parent.

**Analogous.** Similar in function.

**Ankylose.** To consolidate or grow two bones into one.

**Anthropologist.** One versed in the science of the structure and function of the human body or the development of the human race.

**Apodal.** Having no feet.

**Atrophy.** The wasting away or degeneration of an organ.

**Biramous.** Consisting of two branches.

**Callosities.** Spots of hard and thickened skin.

**Caviare.** The roes of sturgeons, salted and prepared for food.

**Commensalism.** The association of two species of organisms, where one, at least, is benefited and the other not perceptibly injured.

**Crepuscular.** Feeding in the dusk or before sunrise.

**Degeneration.** The substitution of a lower for a higher form of structure, the hereditary deterioration of type.

**Diastema.** An intervening space, especially between the teeth.

**Dimorphism.** "The condition of the appearance of the same species under two dissimilar forms."—Darwin.

**Distal.** Away from the place of attachment to the body.

**Diurnal.** Active or feeding by day.

**Diverticulum.** A blind tube branching out of a longer one.

**Estivate.** To pass the summer in a state of torpor.

**Gregarious.** Many individuals of one species banding or herding together for mutual protection.

**Gular.** Pertaining to the gula or throat.

**Hermaphroditism.** The possession of both male and female reproductive organs by the same individual.

**Heterocercal.** Having an unequally divided tail or caudal fin.

**Histolysis.** Disintegration or dissolution of organic tissue.

**Homocercal.** Having the caudal fin symmetric as to its lobes or halves.

**Homogeneous.** Alike throughout, having parts of only one kind.

**Homoiothermal.** Having a uniform temperature unaffected by environment.

**Homologous.** Similar in structure or origin.

**Irritability.** That power or property by which an organism is able to respond to stimuli.

**Littoral.** Pertaining to the shore.

**Lophophore.** A disk which surrounds the mouth and bears the tentacles.

**Medusoids.** Medusa-like structures.

**Metabolism.** The process by which food is built up into living tissues, and living material broken up into simpler products in an organism or cell.

**Milt.** The spermatic fluid of fishes.

**Myrmecophilous.** Living with ants, said of insects which inhabit the formicaries or nests of ants.

**Natural selection** "implies that the individuals which are best fitted for the complex and, in the course of ages, changing conditions to which they are exposed generally survive and procreate their kind."—Darwin.

**Nocturnal.** Feeding or becoming active in the night.

**Omnivorous.** Eating both animal and vegetable food, feeding indiscriminately.

**Ontogeny.** The development of an individual organism from its incipiency in the egg to the adult state.

**Operculum.** A lid-shaped structure closing the aperture of a tube or shell.

**Ovoviparous, Viviparous.** Hatching the eggs within the parent body, or bringing forth living young.

**Parthenogenesis.** Reproduction by supposedly unfertilized eggs.

**Pendactyl.** Having five digits.

**Pentameral.** Arranged in fives.

**Philogeny.** The study of the ancestry of organisms, or the history of the race.

**Placenta.** The vascular membrane which connects the embryo with the mother and supplies it with nutriment.

**Poikilothermal.** Having a body temperature varying with that of the environment.

**Polymorphism.** The condition of having many forms.

**Precocial.** Able to run about when hatched.

**Proximal.** Near the place of attachment to the body.

**Pseudopodium.** Any protoplasmic protrusion from a unicellular organism.

**Recognition Mark.** Coloration of special parts by which the members of one species may recognize their own kind, particularly beneficial in the recognition of parents by the young.

**Reversion.** A return toward a recent ancestral type or character.

**Rheotropism.** The directive influence upon growth exerted by currents of water or air.

**Roe.** The ova or spawn of fishes and amphibians, especially when still inclosed in the ovarian membranes.

**Rudimentary.** In an early stage of development.

**Sarcode.** The gelatinous material forming the bodies of sponges and other low animal forms.

**Somites.** The segments of which an articulated body is composed.

**Stomodeum.** The primitive mouth and esophagus found in actinozoans and in the embryos of annelids and arthropods.

**Symbiosis.** The living together of two species of animals or plants, intimately and permanently, to their mutual advantage.

**Syndactylous.** Having the toes united for some distance, but without a web.

**Trochosphere.** That larval form of various worms, mollusks, and molluscoids which has a circlet of cilia.

**Vestige.** A structure of the past left behind; a degenerate organ or structure.

# INDEX