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NATURAL HISTORY.

A DESCRIPTION OF ANIMAL LIFE, FROM THE
LOWEST FORMS UP TO MAN.

BY

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Profusely Illustrated.

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PREFACE.

IT has been the endeavor, in the preparation of these volumes, to present a popular account of Animal Life; but while scientific technicalities have been carefully kept in the background, it is hoped that scientific accuracy has not been sacrificed in the operation. To some there may appear an inequality in treatment. This, in part at least, has been intentional. Insects and Birds have already an enormous popular literature, while the other forms have been more or less neglected. Believing that these other animals have their points of interest and claims upon our attention, they have been given a prominence possibly greater than they deserve. Another feature in these pages has been the collection of bits of "unnatural history" from the pages of the older writers. These have of course no place in our present science, but they belong to the history of zoology, and as such, have no small value, aside from their interest as scientific curiosities.

It is hardly necessary to call attention to the fact that there is another side to the animal kingdom which is fully as interesting and attractive as that presented here. In the last twenty years zoology has taken a new departure and a new lease of life. No longer are zoologists content with watching the habits of well-known animals, and imposing long Latin names on those which are new. Museums are no longer necessary for the better class of work. To-day the student is trying to solve deeper problems. He is finding out how all animals grow from the egg to the adult condition; he is tracing resemblances, rather than differences, and showing the essential unity of all life, however great the apparent differences.

CONTENTS TO VOLUME I.

	PAGE
ANIMAL LIFE	1
PROTOZOA	5
SPONGES	11
CœLENTERATES	17
ECHINODERMS	40
WORMS	52
MOLLUSC-LIKE ANIMALS	73
MOLLUSCS	77
ACEPHALS	80
GASTEROPODS	96
HETEROPODS	109
PTEROPODS	109
CEPHALOPODS	110
ARTHROPODS	123
CRUSTACEA	127
SPIDERS, MITES, AND SCORPIONS	155
CENTIPEDES AND MILLIPEDES	167
INSECTS	169
Bristle-Tails and Spring-Tails	173
Cockroaches, Crickets, and Locusts	175
Dragon-Flies and their Allies	185
Beetles	194
Ants, Wasps, and Bees	216
Bugs	244
Flies	255
Butterflies and Moths	265
SOME DOUBTFUL FORMS	288
VERTEBRATES	289
THE TUNICATES AND THE LANCELET	290
LAMPREYS AND HAG-FISHES	293
SHARKS AND SKATES	295
THE TRUE FISHES	304
LUNG-FISHES	356
BATRACHIA	358
Salamanders	359
Frogs and Toads	363
Cœcilians	368

POPULAR NATURAL HISTORY.

NATURAL HISTORY.

ANIMAL LIFE.

THERE is a marked difference between living and non-living matter; and, while we do not yet know what life is, we are familiar with many of its phenomena. We find, for instance, in all living bodies a peculiar chemical compound, or group of chemical compounds, known as *proteids*, the principal constituents of which are carbon, hydrogen, oxygen, and nitrogen; and these compounds occur nowhere except as a result of life. A simple, undifferentiated form of these proteids is *protoplasm*,—a substance about which much has been written, while in reality we know but little about it.

All living bodies have the power of growth; and this takes place, not, as in non-living bodies, by additions to the exterior, but in each and every part of the substance. They have the power of taking other substances, either living or non-living, and of working them over and adapting them into such new forms as are needed for nutrition. In other words, they have the power of digestion.

A part of the material thus added goes to make an increase in size; another portion is required to make good the constant waste, for to a certain extent we can compare a living body to a steam-engine. The coal under the boiler is burned, and the heat thus obtained is converted into molar motion by the steam produced acting on a piston. So with living bodies: there is a constant chemical alteration going on within them, and the result is the production of what are known as *vital forces*. The food represents the coal, the body itself the boiler and engine. If food or fuel is lacking, the body dies—the engine stops; as the engine wears out, just so after a certain time a wearing out occurs in living bodies, and death ensues.

Life is dependent on certain external conditions besides food. Thus it needs a certain amount of moisture, while if the temperature rise too high or fall too low, life ceases. These extremes of temperature between which life is possible vary, of course, with different forms; but if we except some spores of the lower plants, we may say that a heat of 208°

will kill all animals and plants, while the amount of cold which a few are capable of withstanding in a dry state has not definitely been ascertained.

The line between living and non-living matter is well marked; not so that between the two great groups of living bodies,—animals and plants. With the higher forms no difficulty is experienced in making a separation, but when we study some of the more minute and simpler species, the characters on which we before relied lose much of their value. A sensitive-plant or a sundew seems to have more sensibility than some forms which are undoubted animals; many of the lower plants move about freely, while the coral is as firmly fixed as any tree. And so on through the list: each character has its exceptions. Plants as a rule derive their nourishment from the non-living world; but the group of fungi (mushrooms, moulds, etc.) are like animals, in that they must have living bodies or the products of life for food. So far as is known, there is no undoubted animal which can convert non-living matter into protoplasm. With this brief statement we may dismiss the subject, for in almost every case which will occur to any but the special student, the ordinary distinctions between animals and plants will prove valid.

The protoplasm of which an animal body is composed is not in one solid mass. Just as a brick house is built of numbers of separate and distinct bricks, so one of the higher animals (or plants) is formed by the union of individual and distinct bits of protoplasm. Each of these bricks of the animal structure is known as a cell. Here, however, the simile ends, for while a brick is of the same constitution throughout, a cell is a complex body, and under the microscope we can distinguish various structures which chemical tests show to vary in composition.

FIG. 1.—Diagram of a cell, showing the cell-wall (*w*), the extranuclear protoplasm (*p*), and the nucleus (*n*), with the nuclear filaments (*f*).

First, the bulk of the cell is made up of protoplasm, while inside of this a smaller mass is distinguishable, usually nearly spherical in shape,—the nucleus. In the older works, smaller particles—nucleoli—were described inside the nucleus, but now it is known that these minute spots were optical sections of nuclear filaments. The accompanying diagram illustrates the general features of a cell. Sometimes a limiting membrane, cell-wall, surrounds the whole cell, but this may occasionally be wanting.

In still another respect our simile fails: a single brick does not make a house, while an animal (or a plant) may consist of a single cell which exercises in itself all the functions which are, in the higher animals or

plants, divided up among the diverse organs. It can eat and move, it reacts under external stimulus, and it can reproduce its kind.

In the higher animals (Metazoa they are called, in contradistinction to the Protozoa, or unicellular animals just alluded to) the body consists of a multitude of cells, and as we rise in the scale of animal complexity the functions of each cell are more and more circumscribed, one group of cells performing one single function in the animal economy, while another is similarly limited. With this increase in size and physiological and anatomical differentiation occurs the formation of tissues. Thus certain cells are sensory, others digestive, and so on through the whole category of animal phenomena, the corresponding groups of cells forming nervous, digestive, excretory, and reproductive tissues.

There is, however, a connection between the Protozoa and the more complex animals, in that the latter always arise from a single cell—the egg. This divides, and the result is two cells; again, and we have four cells, and so on, the product being finally an immense number. With increase in the number of cells, differentiation goes hand in hand, outlining the various structures and organs of the adult. The study of these changes is known as embryology,—a study which is producing some of the most profound conclusions with regard to the animal world.

In order to be readily available and easily grasped, any group of facts must be arranged and classified according to some natural or arbitrary standard. With regard to animals and plants the same is true; and naturalists have consequently constructed systems of classification in which every known animal has its place. The key to these arrangements is a more or less evident similarity in structure or mode of growth of the forms concerned, those which most closely resemble each other being placed nearer or in a lower category, while those which have fewer points in common form larger or higher groups. The case is partially paralleled by the civil divisions found in our geographies,—a number of towns occur in one county, a number of counties in one state, and several states in a country. The parallel holds farther; for, as the boundaries of the major and minor civil divisions are constantly changing, so with the limits and arrangement of groups of animals: in the one case the change is the result of conquest, purchase, or separation; in the other, of further studies into the secrets of nature.

A single example will make plain the philosophy which embodies classification. All of our domesticated cats have many points in common, and every one recognizes a cat at once, no matter whether it be white, maltese, or brindled. We say that the numerous individuals all belong to one species. Now lions and tigers have many points of similarity to

our domestic tabby, — a similar skeleton, teeth almost exactly alike, — so cat, tiger, and lion are regarded as belonging to one genus; and so on through higher divisions — family, order, class, and branch in the order named.

It must, however, be noted that classification, though professedly natural, is in reality largely artificial, and that the apparent distinctions between not only the different species of a genus, but also of the higher groups, are but indicative of our ignorance; for did we know all the forms that exist or have existed, they could be so arranged that no one could draw the line and say, here one genus ends, here a family begins. We divide time into years, days, hours, minutes, and seconds, but this is an arbitrary division: time, like the living world, forms an unbroken series, becoming lost in eternity at either end.

Proceeding upon the principles just outlined, most naturalists to-day divide the whole animal kingdom into nine grand divisions or "branches," — Protozoa, Sponges, Cœlenterates, Echinoderms, Worms, Molluscs, Molluscoidea, Arthropods, and Vertebrates. Concerning some of these some doubt may exist. Thus, the sponges may possibly have to be united with the cœlenterates, while the groups of worms and of molluscoids may each require to be broken up into two or more groups; but this we can dismiss without further mention, and can adopt the scheme just indicated.

PROTOZOA.

THE Protozoa have already been alluded to as animals consisting of a single cell. Their form is so minute that they can only be seen with the microscope, and hence they have received no common name, if we except the term *animalcule*, which is applied indiscriminately to any minute animal or plant. All Protozoa need an abundance of moisture for their existence; and while a few live as parasites in other animals, and still fewer in moist earth, the great majority are aquatic, abounding in the sea as well as in fresh water. There is a common idea that under a microscope every drop of water is seen to be teeming with animalcules, — an idea which doubtless had its origin in some of the pictures in which the artist had combined as many forms as possible. Fortunately, animalculæ are not so common as these illustrations would indicate, and yet no one need have any difficulty in finding them, for they abound in the ooze lying at the bottom of stagnant water, or in the muddy shores of the sea. Good drinking-water is comparatively free from them.

One of the common forms, certainly the one best known, at least by reputation, is the Amœba, a minute jelly-like form found both in salt water and in fresh, and protean in shape. It forms a favorite and valuable object for microscopic study, for in its atomy one has a whole epitome of physiology. When first put upon the microscope slide the disturbance makes it contract into an approximately circular form, but soon it begins to move; a slight prominence forms on one side, and towards this the jelly, or, better, protoplasm, of which it is formed, begins to flow, the prominence soon becomes a lobe, and finally it becomes the animal itself, the former position of the body being indicated by a small prominence like that with which we started. Thus it travels. On its course it meets with something digestible, and swallows it. It has no hands to capture its prey, no mouth to put it in; it simply crawls, or seems

FIG. 2. — An Amœba eating a *Spirogyra* (s). n, nucleus; c, contractile vacuole; d, a diatom which has been ingested. The arrow shows the direction in which the Amœba is crawling.

to flow around its food, and that is all. By carefully watching we can see the digestion taking place. The green of the plants is changed to a yellowish brown, the protoplasm is extracted, and finally the indigestible portions are cast out, or, rather, the *Amœba* leaves them behind as it moves along.

Continued feeding makes an *Amœba* fat, and its body soon becomes unwieldy. Corpulence is as great an inconvenience to it as to human beings, but it has a remedy which they have not. It proceeds to divide itself into two *Amœbæ*, each like the other; and, as one watches, he cannot say which of the two was the parent and which the child. This capacity for reproduction by division, taken together with some other facts, led, a few years ago, to the idea that death, except as a result of accident, was an unknown thing among the Protozoa; but it would seem that an error may exist here, and that among the Protozoa, as among all living bodies, death is the regular sequence of life. The details of these facts are too abstruse for repetition here, and, besides, to settle the question, long and delicate experiments must be carried out.

The *Amœba*, like others of the Protozoa, has another mode of reproduction. At certain times it draws itself together, while the external portion secretes a protective envelope. The internal protoplasm now divides into a number of minute portions, which finally rupture the enclosing wall, and escape as young *Amœbæ*.

There are many other Protozoa which, like the *Amœba*, have the power of sending out large or small protoplasmic lobes or filaments. These are the group known as Rhizopods (root-footed). Some can secrete a protective envelope, often of the most delicate texture and beautiful pattern; others cement together the grains of sand in which they dwell, and form a case to live in. Of the former group the Radiolaria and the Foraminifera deserve mention. The Radiolaria are without doubt among the most beautiful products

FIG. 3.—A radiolarian. In life the silicious skeleton is transparent and crystalline, the granular contents orange.

of nature. A red or yellow protoplasm, enveloped in the most exquisite tracery of silicious spicules, sometimes simple like the form figured, sometimes of the greatest intricacy, is a poor description of the general beauty of a Radiolarian. One needs to see them to appreciate them, or, in default of opportunity, to turn over the plates of Haeckel's splendid monographs.

The Foraminifera would take a high place were there no Radiolaria; but their shells, though beautiful, are heavy in comparison with those of

A RETICULARIAN RHIZOPOD (*Polystomella*) GREATLY ENLARGED.

In the centre is the chambered shell, and from it radiate the filaments of protoplasm.

their relatives. Our plate shows the general appearance of one of the forms, the delicate rays which extend to the margin being filaments of

FIG. 4.—A Protozoan (*Gromia*) which lives in moist earth.

or filaments, but they are usually enclosed in a protective envelope, and bear either one or more long whiplash-like vibratile filaments (flagella), or numbers of more rapidly vibrating hair-like bodies (cilia), the presence of one or the other of these serving to divide the group into ciliated or flagellated Protozoa.

Of the former group, Vorticella, the bell-animalcule, is known to every tyro with the microscope, and well repays careful study. It consists of a bell-shaped body, supported on a long, slender stalk, and is sure to quickly attract attention from its peculiar motions. As one is looking through the microscope, the body of the Vorticella suddenly disappears, and on looking to see what has become of it, the observer soon finds it drawn closely down to some solid object, its long, slender peduncle coiled in a spiral. Gradually it straightens out, and as it does so it unrolls the

protoplasm, by means of which locomotion is effected, and food brought to the central mass within the shell. In certain localities, as at the Bermudas, Charleston, S.C., Petersburg, Va., etc., are large deposits of dead or fossil foraminiferal shells, and these places are the delight of the microscopist. Every pinch of the sand placed under the microscope shows their dead shells in numbers, while the variety of patterns is enormous.

Another group of Protozoa is the Infusoria, so called from the fact that some of its earliest known members were first found in infusions of hay, pepper, etc. The Infusoria are regarded as being a step higher than the Rhizopods which we have just left, because there is more of a differentiation of parts in them. They do not have the power of sending out protoplasmic lobes

circle of cilia around the farther end, and sets them in such a rapid motion that they resemble the spokes of the wheel of a rapidly passing carriage.

Closer observation shows that this motion creates currents in the water, and that these currents have a uniform direction, and always pass down into a cavity hollowed out of the bell. The currents bring with them a quantity of minute particles, and these soon form a ball of considerable size at the bottom of the cavity. This ball then passes into the protoplasm of the body, and there undergoes digestion, like the food of the Amœba.

Another feature which also deserves mention is the contractile vacuole. This is a space in the body of the Vorticella, which gradually enlarges, and then suddenly collapses, to again repeat the operation. It is supposed to be respiratory and excretory in its functions.

Others of the Infusoria are free, moving or swimming about at will. Some live a parasitic life in other animals, and one has even been claimed to be the cause of hay-fever. Among the flagellate forms, those with a delicate collar around the flagellum are most interesting, since they recall the feeding-cells of the sponges, to be described farther on.

A third great division of Protozoa, the Gregarinida, need to be but mentioned. All are parasitic in the digestive tract or body cavity of other animals.

In all of the remaining groups of animals the body consists of a large number of cells. In the Protozoa, as we have seen, the single cell performs all the func-

FIG. 5.—A bell-animalcule (*Vorticella microstoma*). A, extended; B, retracted; C, encysted; c, cilia; f, balls of food; n, nucleus; p, peduncle; r, contractile vacuole.

FIG. 6.—A stalked infusorian (*Cothurnia socialis*).

FIG. 7.—A ciliated Protozoan (*Stylonichia mytilus*) greatly enlarged.

FIG. 8.—A collared flagellate infusorian (*Salpingoeca acuminata*).

tions of animal life. In the other animals a group of cells will have certain duties to perform, and will be unconcerned in all others. In the lower forms one of these cell-groups may perform several functions, but as we ascend in the animal scale we find a constant specialization and differentiation of cells and cell-groups; and just in this respect do we speak of one animal being higher or lower than another. Looked at from the standpoint of adaptation of means to ends, one is as perfect as the other; but in one the subdivision of labor is carried to a greater extent than in the other, and this is largely the criterion of rank.

SPONGES.

THE ordinary sponge of commerce gives a person no idea of what a sponge is, since it is but the skeleton of the animal from which all the soft parts have been removed; and even were the flesh present, the commercial form would not be the best to begin the illustration of the group, on account of its great complexity. For this purpose it is better to take one of the simpler forms, or even a diagram like that shown, from which all unessential features have been removed, remembering that all sponges are found on essentially the same plan, only further elaborated.

In this simple diagram we have a great advance over the Protozoa, in that the body is composed of a multitude of cells. This form consists of a vase-like body made up of two layers of cells; an outer layer of flattened forms (the ectoderm) and an inner layer of larger flagellated cells, each with a collar. These are the entoderm, or digestive cells. The vase is open at the top, while through the sides are several openings. The flagella of the entoderm are in constant motion, creating a current of water which passes, in the direction shown by the arrows, into the central chamber through the lateral openings and out through the one at the top. It is from the water thus constantly drawn through the sponge that the food is obtained, and this is eaten and digested by the entoderm cells in exactly the same way as by the single cells of the Protozoa.

FIG. 9. — Diagram of a simple sponge. *a*, ciliated cavity; *d*, digestive cells; *e*, excurrent canal; *i*, incurrent canal; *p*, ectodermal cells. Compare the digestive cells with Fig. 8.

From this simple type we may derive any sponge by two processes. — one a complication of the structure found here, the other the insertion of a third layer (the mesoderm) between the two. The complication consists in a multiplication of the number of digestive cavities, and the production of the lateral pores into longer canals which may further branch. This is shown in the next figure, the same letters being used as before.

Connected with the mesoderm and ectoderm is the formation of the skeleton. In some forms only one of these layers is concerned, in others

FIG. 10. — Diagram of more complex sponge; letters, as in Fig. 9, except *e*, cloaca; *o*, osculum. Each of the chambers, *a*, corresponds to the whole of Fig. 9, but the scale is so small that the collared cells can only be represented diagrammatically.

the other, while in still others both layers may contribute. In the sponges which are used for domestic purposes only the mesoderm is involved. The cells of this layer secrete horny fibres, and it is these fibres alone that form the sponge as sold in the shops. The ectodermal skeletal elements are smaller and more regular in shape, and but rarely do they form a fine, solid network capable of retaining its form after the soft parts have been removed. In different sponges, or even in the same sponge, they may differ greatly in shape, but from the fact that usually they are more or less needle-like in shape they are called spicules. Our cut shows a few of the forms.

According to the system most in vogue, sponges are divided into groups according to the nature of their skeleton. Those which have no skeleton are *Myxospongiæ*; those with calcareous skeleton, *Calcispongiæ*; with horny fibres, *Fibrospongiæ*; while the last group have a silicious skeleton, and are consequently known as *Silicispongiæ*. Only the last two of these groups need detain us longer; but one of these is interesting from the economic importance of some of its members, while the individuals of the other group are noticeable for their beauty.

FIG. 11. — Different forms of sponge-spicules, greatly enlarged.

Not all of the fibrous sponges are suited for use, for in many the fibres when dry are extremely brittle, and the sponge crumbles to powder in the hand. The "dead man's finger" sponge (*Chalinula*), so common along the northern Atlantic coast, is an example of this. When taken from the water it seems as elastic as any bathing-sponge, but the fibres when dry have no strength. Other forms when dry are not brittle, but are lacking in elasticity. Only the members of one genus (*Spongia*) are possessed of sufficient resilience to make them of value to man, and these vary considerably among themselves in this respect.

All of the commercial sponges are inhabitants of the warmer seas, those from the Mediterranean being the most valuable, those from the Red Sea standing next, while the Florida and West Indian forms are still coarser. Even within the Mediterranean a difference exists, the sponges from the Adriatic and the shores of Greece ranking highest. None of marketable value are found in the western Mediterranean, nor in the Indian or Pacific oceans.

The sponge-fishing is an important industry in many places. The sponges rarely occur in water deeper than twenty fathoms, and the majority are obtained in much shallower water. They are taken from the bottom by means of hooks and spears on long poles, or by means of divers. Occasionally dredges are used to obtain the coarser kinds. After the sponges are obtained, they need to be freed from their animal matter. This is accomplished by exposing them to the air for a short time, and then placing them in large tanks in the sea to allow the flesh to decay. This is a rather offensive operation, and no one who has ever smelled a decaying sponge can doubt that sponges are animals. Gradually the flesh disappears, and nothing but the fibrous skeleton remains. These skeletons are now washed, dried, packed in bales, or strung on strings, and sent to market. The sponge as we use it is but a very complicated network of interlacing fibres, in which, however, we

FIG. 12.—Dead man's finger sponge (*Chalinula*).

FIG. 13.—Fibres of common bath-sponge.

can trace in a rough way the general course of the canals of the living animal.

The boring sponge (*Cliona*) is a small form, which always attacks calcareous objects in the sea. It obtains a lodgment on some shell, and then proceeds to excavate its galleries in all directions until the shell is completely riddled. In this way it destroys the shell, and plays an important part in the economy of nature. How it bores is an unsolved question. It had been thought that it was by means of the spicules, but it has recently been shown that the young sponge begins to bore before any skeleton is formed.

All sponges are not marine; a few live in fresh water, several species being found in the United States. While the marine species reproduce their kind by means of eggs, the fresh-water sponges have, besides, another method of perpetuating the species. In the colder climates the frosts of winter kill the fresh-water sponges, while in the warmer zones the heat of summer may dry up the ponds in which they live. By the second method of reproduction both of these dangers are avoided. At certain times portions of the sponge tissue become enclosed in hardened capsules, and thus are able to withstand drought or cold. When winter comes, the sponge dies down, leaving its skeleton standing, and entangled among the fibres are these reproductive buds. With the return of spring the buds burst, and rapidly grow into a new sponge, frequently utilizing the last year's framework as a scaffolding for the new growth.

Fresh-water sponges sometimes become a nuisance, for they especially affect the sluggish water of the storage basins of water-works, and by their death in the fall so pollute the water that it is offensive both to taste and smell. Several of our eastern cities have been badly troubled in this way.

The silicisponges (those with a silicious skeleton) embrace the so-called glass-sponges, the beauty of which is well known, as they have now become quite common, not only in museums, but even as ornaments in houses. First among them stands the Venus's flower-basket (*Euplectella*), in which the delicate spicules form a most beautiful reticulating network. The first specimens brought to European markets caused no little discussion, but soon their true nature appeared. They are found in the seas around the Philippine Islands. Another interesting form is the glass-rope sponge (*Hyalonema*), in which a portion of the spicules take the form of a loosely coiled rope. This rope is merely an anchor which extends down into the mud, holding the sponge in place. The last form of glass-sponge which we need mention is the *Holtenia* figured, which needs no further description.

In a large proportion of the Venus's flower-baskets occurs a small crustacean. It was formerly thought that the ingenious Chinese cut holes in the sponge, inserted the shrimp, and then deftly concealed the traces of

FIG. 14. — Venus's flower-basket sponge (*Euplectella*).

the operation. It would appear, however, that the association is a normal one, for we do not find that diversity in the enclosed shrimp which would

naturally occur if man were to make the selection. It is always the same species of shrimp which occurs in the sponge, and this species has not yet been obtained except from these sponges.

FIG. 15. — A glass-sponge (*Holtentia*), with the glassy filaments which served to anchor it in the muddy bottom shown below.

COELENTERATES.

THE term Coelenterates is applied to the group of animals which includes corals, jelly-fish, sea-anemones, and the like, from the fact that the digestive and the body cavities are not distinct. Formerly these animals were united with the next group (the Echinoderms), under the name Radiates, but it has long since been shown that they have almost nothing in common. A still older name is zoophytes, or "animal-plants," which, when applied to many of the species, is very apt, for they are superficially much like some of the sea-weeds, and are often collected with them.

With about half-a-dozen exceptions all of the Coelenterates are marine, but one of the fresh-water forms is very interesting. It is the fresh-water hydra. It is fond of stagnant or semi-stagnant water, and at times is very abundant, attached to plants or to the glass of aquaria. In color it may be green or a dirty reddish brown, while a specimen half an inch in length is a large one. At one end of the body is the mouth, and surrounding it are from four to seven long, slender, flexible, tapering arms, or tentacles. It is with these arms that the hydra obtains its food. As the animal hangs in the water these tentacles are extended in every direction, keeping up a slow but constant waving motion. When some small animal, for instance a cyclops, swimming through the water, comes in contact with one of these arms, it stops instantly, as if paralyzed. The arm now slowly curls around the victim, and lazily conveys it to the mouth.

Why does the prey stop so short? It is really paralyzed, and the method by which this is accomplished is extremely interesting. Scattered over the arms are bunches of peculiar cells, much larger than their neighbors. Inside of each is a long, hollow filament, and a quantity of fluid, closely similar to, if not identical with, formic acid, and at the slightest touch the filament shoots out and penetrates the body of the victim. Then the contents

FIG. 16. — Fresh-water hydra, with (a and b) young budding from it.

of the cell pass out through the tube into the tissues of the victim. It of course takes many of these cells to produce paralysis, and after once being used they cannot return to their former condition. New ones are being developed continually.

FIG. 17. — Discharged nettle-cells of hydra.

These structures, called variously nettle-cells, thread-cells, and lasso-cells, are very characteristic of the whole group of Coelenterates; and while those of the hydra are too small, too few, or too weak to affect man, those of some of the jelly-fishes are capable of producing considerable pain. On our northern coasts there is but one jelly-fish which has the reputation of nettling human beings. This is the large blue-jelly (*Cyanea*), to be mentioned again farther on. It would appear, however, that this form differs in its nettling powers, or that different persons are differently affected; for the writer, though he has often experimented with it, has never felt any of the stinging sensations which others describe. In more southern seas there are several forms which nettle severely, the "Portuguese man-of-war" being possibly the worst. Those who have been stung by it describe the pain as very severe, and use such comparisons as "liquid fire" to describe their sensations.

The hydra is very simple in its structure. It consists merely of two layers of cells, those of the inner layer being digestive, those of the outer layer protective. There does not, however, seem to be much essential difference between the two layers, for two naturalists have turned the animals inside out, just as one would invert a bag, and then to all appearances the former skin digested as well as the proper stomach layer.

The hydra reproduces in two ways, — by eggs and by buds. In our figure two of these buds are shown, the upper one being more advanced than the lower. After the appearance of the tentacles in the bud a mouth is formed, and soon after the young one separates from the parent. It not infrequently occurs that a second individual will bud from the young hydra before the separation is complete.

The hydra is the type of a large group of animals called Hydroids, which are especially abundant in the sea, where they present some of the most astonishing features. Some of the marine forms are very much like the fresh-water hydra, but others add features which make them, at least in certain stages of their growth, greatly different.

All along our northern Atlantic coast, near the low-water mark, one can find quantities of snail-shells, each occupied by those most interesting animals, hermit-crabs. On examining one of these shells one usually finds

it covered with a sort of pinkish moss, which closer study shows to be hydroids, much like the hydra of fresh water; and yet there are many important differences. The buds excepted, each fresh-water hydra is separate from its fellows, but these forms on the snail-shells (*Hydractinia* they are called) are all united by a common base which covers the shell. In the fresh-water hydra only one sort of individual is found. It eats, and develops the male and female reproductive elements. In the *Hydractinia* colony three different kinds are found. One has a mouth, and is much like the hydra; this form does the feeding for the whole colony. The other kinds have no mouths, and cannot eat. They are merely for reproductive purposes, and between themselves they are distinguished in that one furnishes only eggs, the other only spermatozoa. Having no mouths, how are they nourished? The answer is simple. The feeding forms have their digestive tracts in connection with those of the reproductive ones, by means of canals in the common base. This feature is common to almost all marine hydroids, and is illustrated diagrammatically in Figure 20.

FIG. 18. — Portion of a colony of hydroids (*Hydractinia*), greatly enlarged. The longer individuals eat for the colony, the others are solely concerned in reproduction.

On the rock-weed between tide-marks another of these forms, *Clava* by name, occurs, forming pinkish or flesh-colored patches of considerable beauty when expanded. Even more beautiful are the Tubularian forms, which thrive in tidal pools, where they are never exposed to the air, as are the two forms just mentioned. Our plate represents their general

appearance, as far as this can be done in black and white, but their colors are their greatest attraction. The figure shows the ramified, root-like base, from which arise the straw-colored stalks, each supporting a red hydroid, with its numerous tentacles, between which the racemes of brightly colored reproductive organs hang gracefully down.

In others of the hydroids an additional complication is introduced; for the reproductive organs, instead of producing eggs to be set free, develop jelly-fishes, which finally burst from the enclosing walls, and begin a free life. All of these hydroid jelly-fishes are small, but size is not a requisite of beauty. For grace of outline some of these forms cannot be excelled.

FIG. 19.—Jelly-fish of *Melicertum campanula*.

The adjacent figure (Fig. 19) will serve as the type of our description. It is a common form on the New England coast during August and September. It consists of a crystalline bell, or umbrella, about three-quarters of an inch in diameter, from the margins of which arise a number of slender tentacles. Inside the bell a proboscis hangs down, bearing the mouth at its extremity. The digestive tract is simple, consisting merely of a central chamber, with which the mouth communicates, and from which eight canals radiate to the margin of the bell. On these canals the reproductive folds occur. Inside the margin of the bell is a delicate membrane, perforated with a circular opening, which considerably contracts the aperture of the bell.

In the form figured, the proboscis and the reproductive organs are a pale yellow, or straw color, but in others red, pink, green, and gold occur.

It is not only in the day-time that these forms are beautiful, for by night they have a charm. The naturalist knows that many forms seek the lower waters by day; but at night, when the surface of the sea is smooth, they rise to the surface, and so the student at the shore goes "skimming." He has a net made of fine, thin cloth, which he drags along the surface behind a slowly moving boat, taking it up at intervals, and rinsing its contents into a pail. At such times, if the night be dark, he can occasionally see floating gracefully through the water one or more of these jelly-fishes, their crystalline bell lighted up just enough to show its outlines, by the pale phosphorescent glow which proceeds from the proboscis. In the pail in which the captives are taken the jelly-fish are

A COLONY OF TUBULARIAN HYDROIDS (*Tabularia indivisa*).

numerous, but their pale light is there lost in the more brilliant phosphorescence of the other forms.

A few lines above mention was made of the fact that there are reproductive organs in hydroid jelly-fishes, and this leads to a series of very interesting facts, common not only to these animals, but to many others. The reproductive organs of a single hydroid colony will give rise to a large number of jelly-fishes. These in turn produce eggs, which do not develop into other jelly-fishes, but into colonies of hydroids. In short, among these forms any individual does not in the least resemble its own parents, but is just like its grandfather and grandmother. It is a case of what is called alternation of generations. When the egg from a jelly-fish hatches, and the young settles down on some submerged object, it begins to grow in two directions. The upward growth soon produces a hydroid fitted for eating, while laterally from the base grows out the root-like portion of the colony. This at intervals sends up branches, which develop into other feeding hydroids, or into those which are to serve only reproductive purposes.

In many hydroids there are but the merest traces of a nervous system. The naturalist finds scattered among the superficial cells of the jelly-fishes cells, which, from their general appearance, he knows to be nervous; but there is nothing like a brain, no nervous cords. Still the jelly-fish has its organs of sense, and these pretty well developed. At the base of certain of the tentacles (see the figure of *Obelia*, p. 23) there are eyes, differing in structure in the different species, while in some forms some of the tentacles are modified to form ears; in others the ears are open pits. In other hydroids a nervous ring exists.

One of these hydroid jelly-fishes possesses considerable interest, not only from the fact that it is the only fresh-water jelly-fish known (it has been reported that there is a jelly-fish in the lakes of Central Africa), but from the great uncertainty which surrounds its origin. In Regent's Park, London, there is a tank containing specimens of the enormous water-lily, *Victoria regia*. A few years ago some pickerel-weed (*Pontedera*) was placed in the tank, and the next year the jelly-fish made its appearance, causing no little excitement among naturalists, for nothing of the kind had ever been known before. Whether it was introduced with the pickerel-weed, or in some other way, is also uncertain, and until 1885 it was not known that it had a hydroid condition; but in that year hydroids, far simpler even than hydra, were found attached to the plants in the tank, which, presumably, were connected with this jelly-fish (*Limnocodium*) in the same way as in the case described above.

In our seas we have many of these hydroids which produce jelly-fishes.

each with its peculiarities. Thus in one group the zooids are seated in bell-shaped cups, and since the Latin *campanula* means a little bell, this group is called Campanularians. The diagram illustrates the history of the group, which is like that detailed above. In the reproductive capsule, *g*, can be seen the young jelly-fishes in various stages of development, while the dotted tissue extending through all parts of the colony indicates the canals by which all are connected, and shows the way in which the food taken by the feeding-forms is able to nourish all parts of the colony.

Obelia is the musical name of another genus represented in our figures, which show a portion of a colony, and also a young jelly-fish, just as it escapes from the reproductive capsule. Specimens of *Obelia* are very common on the large sea-weeds known as "devils' aprons," the white, root-like portion being attached to the frond, and at intervals sending up stalks bearing the hydroids. The jelly-fish, it will be noticed, differs from those already described, in that it is a nearly flat disc.

FIG. 21. — Hydroid stage of *Obelia*. One of the zooids has the tentacles expanded, while farther down on the stalk is a reproductive capsule, from which the young jelly-fishes (Fig. 22) are soon to escape.

jelly-fish exactly like the parents.

In an entirely distinct group of jelly-fishes the individuals are much larger than those we have been describing; indeed, some of them are enormous. On our New England coast two of these species are very abundant, and at times a strong sea-breeze will drive them in-shore, so that the surfaces of the harbors are absolutely covered by them. The most abundant is the large blue jelly-fish (*Cyanea*). This may well lay claim to the front rank among all the jelly-fishes on

FIG. 20. — Diagram of a campanularian hydroid, showing the feeding-zooids (*h*), supported on their long stalks, which arise from the root-like base (*r*); at *g* is a reproductive capsule containing young jelly-fishes (*m'*), while at *m* is one which has escaped. The dotted portions of the figure show the way in which all the zooids are connected.

FIG. 22. — Jelly-fish of *Obelia*, greatly enlarged.

account of its size. Mr. Agassiz says that one which he saw had a disc seven feet and a half in diameter, and tentacles streaming behind to the distance of one hundred and twenty feet. Even larger individuals occur, the disc occasionally measuring ten feet in diameter. When alive their color is a dirty reddish brown, which after death changes to light blue, whence both the common and scientific names. When we consider this and the next species, the appropriateness of the common name "jelly-fish" is at once apparent, for in consistency they closely resemble wine jelly. The broad frills and the long tentacles which hang down from the disc have a little more consistency, and it is on these that the nettle-cells occur which give this species its unenviable reputation mentioned on a preceding page.

Our other common species is *Aurelia*, a form creamy white in color, and without the long tentacles so characteristic of *Cyanea*. Both this and the last species swim lazily through the water by slow yet forcible contractions of their discs. The young *Cyanea*, which is figured (Fig. 25), is but rarely seen by naturalists, possibly from the fact that its habits do not correspond with those of man. Mr. Alexander Agassiz writes, "Having accidentally visited the wharves of Provincetown harbor early one morning, between four and five, I was astonished to perceive what a large number of young *Cyaneæ* were floating about, measuring all the way from a quarter of an inch to three inches in diameter. On my return to the same place at seven o'clock, although not a breath of air had ruffled the surface, they had all returned to deeper water."

FIG. 23. — Hydroid (*Scyphistoma*) stage of the big sun-jelly, *Aurelia*.

Both the sun-jelly and the blue-jelly pass through an alternation of generations considerably different from that described above. From the egg there hatches out a young animal which swims freely for a short time, and then becomes attached to some submarine object, when it begins to grow into a form much like a hydra, but with shorter tentacles. This form can eat, and with growth it soon begins to divide transversely into a series of discs. Our figure shows the stage of this division at the time when three of the discs have been formed, while below them is a long undivided portion of the stock. As the process goes on, the discs become thinner, flatter, and very numerous, so that the whole resembles in miniature a pile of saucers on the shelves of a china-closet. One by one the discs detach themselves and float away, each one becoming a young

FIG. 24. — Strobila stage of *Aurelia*, showing a few of the saucers into which it divides. In later stages the whole stem becomes divided into a large number of saucers.

jelly-fish, which by growth gradually becomes like the parent form. Here the effect of the alternation is to form many jelly-fishes from one egg. The young of the blue-jelly here figured was taken but a short time after it had left the pile of saucers, and yet had begun to grow the long tentacles so characteristic of the adult form.

Closely allied to these two forms is a third one, which differs markedly in that it never swims freely. It is a small form, readily overlooked by the casual observer, and which consequently has received no common name. *Lucernaria* is what the naturalist calls it. One species is common on our northern shores. It has a quadrangular body supported on a stout stalk, and is colored green, like the seaweed on which it occurs most abundantly.

FIG. 25.—A young blue-jelly (*Cyanea*) soon after escaping from the pile of saucers.

The tubular jelly-fishes, the Siphonophores of naturalists, contain many beautiful forms, which, however, are far more abundant in tropical waters than in colder climes. The whole life of most of the species is spent in a free condition, and they are even more abundant on the high seas than near land. In our figure is represented a form occurring in Massachusetts Bay. At the top is a small float (*f*), while below it come a number of swimming-bells (*n*), each with much the same structure as the hydroid jelly-fish described above. These, however, have nothing to do

FIG. 26.—Tubular jelly-fish (*Agalmopsis curata*).

except to force the whole colony along. From the float a long axis extends downward, bearing besides the swimming-bells a large number of organs: some for feeding (*p*), some for reproduction, while others are protective (*b*). At intervals long tentacles (*t*) spring out, curling in every

direction; while all parts are so connected by the tubular axis that the eating of one serves for all. The species figured is a small one, our cut representing it of natural size. Its colors, as described by Mr. Agassiz, are as follows: "The float is of a brilliant garnet color; from it hangs the rosy-colored axis with its pale swimming-bells, and, further down, the scales, protecting the different kinds of feeding-polyps, with them various kinds of tentacles projecting in all sorts of angles and curves from the main axis of the body, like the festoons of a chandelier; the darker-colored polyps, tipped and mottled with scarlet, being visible underneath the protecting scales."

Other forms are much larger, some exceeding twenty feet in length. Some are glassy clear, while others are brightly colored, red being the prevailing color. With most of these forms we can have nothing to do here; but there are two which demand more mention, not only from the fact that they differ considerably from the form figured above, but from the popular interest that surrounds them.

First comes the "Portuguese man-of-war," whose stinging qualities were referred to several pages back; indeed, so strongly can it sting that the part of man affected by it remains benumbed for several hours. But this animal (*Physalia* it is called) appeals to the eye if not to the sense of feel, for it is most beautifully colored. There is a large pear-shaped float, sometimes ten inches long, which rides on the surface of the water, while a crest on the top acts as a sail, driving the animal hither and thither over the waves. This float is bright blue, shading to rose, but, instead of giving rise to the long axis of the preceding form, it directly supports all the tentacles, feeding-polyps, and the like, which trail behind as the animal floats along. The *Physalia* is common in the tropical Atlantic, and is occasionally drifted as far north as the southern coast of New England.

The other form of which we would speak is *Velella*, the general appearance of which is shown in our cut. Here the float is shaped like a raft, and from the centre arises a flattened leaf-like "sail." On the under side of the raft are suspended the various zooids, corresponding to those of the "Portuguese man-of-war," and the other form described. The *Velellæ* are smaller than the *Physalia*, specimens three inches in length being large. One species of a blue color is common on our southern Atlantic coast, sometimes drifting north to Massachusetts. Another occurs on the Pacific shores. It is usually

FIG. 27. — *Velella scaphidia*.

stated that the *Velellæ* float on the surface, the sail being influenced by the wind. Whether this ever occurs is a question, since naturalists have always found it capsized, the "sail" in reality forming a keel to catch the currents of the water.

Still another group of jelly-fishes are the so-called Ctenophores (comb-bearers), which derive their name from the rows of comb-like vibratile cilia found on the surface of the body. These are shown in the adjacent cut of a portion of one of the species found on our coast. The whole animal is shown in the plate facing page 28. These jelly-fish are much more complex in their structure than any of those which we have passed. Here, as among them, there is considerable diversity in form. Some lack the long trailing tentacles of the form figured in the plate; some are spherical, some with a very marked bilateral symmetry, even with wing-like processes extending from either side, making one think, as he views them, of the cherubs on the tombstones of some old cemetery; some are delicately colored, some as limpid and translucent as the water in which they live, but of all none can compare for peculiar form with the Venus's girdle, of which a figure is here given. Imagine a ribbon of transparent gelatine five feet in length, two inches or more wide, its edges with cilia, and with a mouth half-way between the two ends, the whole coiling and uncoiling gracefully, while the cilia keep up a constant motion, and you have a vague conception of this the most curious of all the jelly-fishes.

FIG. 28. — A Ctenophore (*Pleurobrachia*), with only a portion of the tentacles; at *c* are the rows of "combs," from which the name of the group is derived.

In treating of any group of the animal kingdom, it is impossible to follow straight lines, for none exist in nature. It is like climbing a tree. We follow one branch to its tip, then descend to the next branch and follow that out. But when we put our account on paper we are constrained to follow a linear arrangement, but it must be understood that this does not indicate a similar arrangement in nature. For instance, we have just followed out the groups of jelly-fishes to the end. We now descend to the main trunk, and follow out another limb of the zoological tree.

Of all the animals so far described, the hydra is the most similar to the sea-anemones and the corals, the group of cœlenterate animals now to be taken up. To be sure, there are many and important points of difference, but with these we need not trouble ourselves. All that needs descrip-

JELLY-FISHES.

At the left, side and ventral views of a hydroid jelly-fish (*Bougainvillea*), enlarged; at the right, a ctenophore (*Pleurobrachia*), natural size.

ening the body, then unrolling the free end, from which it soon protrudes a large number of long, tapering tentacles, in the centre of which is the slit-like mouth. Inside of the body is a sac open at the lower end, which serves as a stomach, while from the periphery of the body to this stomach run a number (six) of partitions. The whole may roughly be compared to a wheel, the stomach being the hub, the partitions the spokes, while the outer body wall is the rim and tire. Between these six principal partitions are others which do not reach to the stomach. The whole object of this complexity of structure seems to be to gain additional digestive and absorptive surface. In the higher animals, as is well known, the products of digestion are carried by the blood to the various organs which need

FIG. 30. — A fully expanded sea-anemone (*Crambactis arabica*).

nourishment; but here there is no blood, no heart, no organs of circulation. Each part of the body picks out the nourishment it needs from the partially digested mass.

The habits of a few species of anemones may be mentioned. Most of them live attached to submerged objects; but while most of these are usually found on stones, etc., a few prefer a living anchorage. Thus, in the Eastern seas there is one species which goes about on the back of a crab, and it is stated that neither is found without the other. On our own coast there are similar relationships. Here it is a hermit crab that is utilized by the anemone, which settles down on the shell occupied by the interesting crustacean. Usually hermits have to change their houses with growth, — a feature to be referred to again; but the hermit with this

associate does not need to, for the anemone grows as he grows, and furnishes him with a living house. Further, the old shell would be a nuisance to the hermit after he had outgrown it, were it not for the fact that the anemone, by some chemical process, gradually dissolves it. Other species have other habits even more closely allied to true parasitism. Thus in the summer almost every specimen of the large blue jelly-fish (*Cyanea*) is found to have one or more anemones (*Philomedusa*) imbedded in the tissues of the lower surface of the disc. Still other forms live buried deeply in the mud, so that only the mouth and tentacles can be exposed.

It may be said in passing that all of the sea-anemones reproduce by eggs, and that in but few is there that alternation of generations which has been described in the preceding pages, and which we shall meet again in the worms. They also have the power of budding, and our common fringed anemone may often be found with young budded from its base. This budding explains some of the facts concerning the corals now to be taken up.

We can best understand the structure of the corals by first considering one of the simpler forms grouped under the common name, "mushroom corals,"—a term which is given from the fact that their frequently circular outline, with the radial partitions, bear a striking resemblance to

FIG. 31.—Side and top views of a mushroom coral.

FIG. 32.—Star coral (*Astræa*).

the under surface of a mushroom. These forms live free in the water, resting on the bottom, and are attached only in the young state. Above we described the radial partitions (the spokes of the wheel) in the common anemone. In life each mushroom coral supported a polyp much like an anemone, which had the power of secreting carbonate of lime; and the partitions (septa) of the coral were inserted between those of the polyp.

Now if a form like this were to bud, and the buds not to separate

completely from the parent, but to live right beside it, then each to bud again, the result would be a compound organism, which might become of considerable size. It is in just this way that the large masses of coral do arise, a few of which are illustrated in our cuts. For instance, in *Astræa* the budding takes place in such a manner as to form a hemispherical mass. The illustration shows a small specimen, in part of which the polyps are expanded and in part retracted.

In another group the polyps do not separate even so far as in *Astræa*, but remain more or less intimately connected with each other. Some of these also form hemispherical masses sometimes two feet in diameter,

FIG. 33.—Brain coral (*Heliastrea*). The cut on the left shows the coral in the living condition; that on the right only the calcareous portion after removal of the flesh.

which from their shape and from the convolutions on their surface bear a resemblance to the human brain, whence the common name, brain coral. Our figures show the coral as it looks in the living condition, and also after the animals have died and the fleshy portions have been removed. The next cut shows three polyps from a brain coral enlarged. The three mouths are visible, and the rows of tentacles are shown along the sides; but the reader will readily see that separation is not carried so far as in *Astræa*.

FIG. 34.—Three brain-coral polyps, showing the tentacles and mouths.

Such corals as *Astræa* and the brain corals are massive, and play an important part by their solidity in the formation of coral reefs and islands, to be described shortly. Their dead bodies form a foundation for other forms to build on. All corals, however, have not this massive character; some are delicate branching forms which alone would be ill adapted to the formation of a coral reef, but, taken in connection with the others, they are a considerable element, for their broken branches fill up the interstices between the larger forms.

Only one of these can be figured, the deer's-horn coral (*Madrepora*), one species of which is very common on the Florida coast. Here the

budding takes place in a different manner from that of the massive forms, and the result is a branched condition. Our figure shows a portion of one of these corals, all over which may be seen little prominences or tubes, each of which was in life occupied by a polyp not essentially different from a sea-anemone or from the polyps forming the *Astræa*, and yet how different the result!

The mode of growth of one of these corals is interesting. At first there hatched from the egg a single polyp, which settled down and began its secretion of carbonate of lime, especially at its base. A bud was soon formed, and this followed the example of its parent. As the secretion of lime went on, each polyp was forced upwards in its tube, leaving behind a solid calcareous mass. As they grew their courses diverged, and each kept on budding, until at last each original bud was the parent of a branch, from which other branches arose in a similar manner. In every branch, therefore, the terminal polyp is to be regarded as the parent of the branch.

In all the sea-anemones and corals so far mentioned the primary number of partitions is six. To this group, with this mathematical basis, the name Actinaria is given,—a name derived from the generic name of one of the European anemones, *Actinia*. There is another group of coral-producing polyps, in which, as will be seen from the cuts introduced, eight is the ruling number. Thus each has eight tentacles; and, were we to examine the internal structure, the same number would be found to prevail throughout the organism. The name applied to this group is Alcyonaria, and its origin is interesting.

Among the ancients the alcyon, or, better, halcyon, enjoyed a high repute. It built its nest in the winter, and at that time the sea was always calm. The old story still survives in our "halcyon days." The

FIG. 35.—A branch of deer's-horn coral (*Madrepora*). Below, a magnified section, showing the cavities occupied by the polyps.

halcyon's nest was said to be in the sea; and, when the fishermen hauled up the branching stalk of one of the corals, they said that this was the tree in which its nest was placed. The name stuck, and in the zoologies of to-day the same coral still bears the name *Alcyonium*, from which it has been extended in the modified form used above to the whole group. Our plate shows the general appearance of this form, which, from its texture when dried, has received the common name of cork polyp.

FIG. 36.—A single polyp of red coral (*Corallium*).

The Alcyonids are not of much importance in the formation of coral reefs, for the reason that they form but little solid matter, and this never in the massive condition which prevails in the Actinarian group. Still one species has a considerable economic importance, since it furnishes the red coral so prized in jewelry. The red coral is a native of the Mediterranean Sea, and in some places the fishery for it constitutes a considerable industry. This is especially true of the western coast of Italy, the islands of Sicily and Sardinia, and the coasts of Tunis and Algiers. It is a slow-growing form, and branches over a foot in length are uncommon. The fishery is conducted by lowering large, coarse nets to the bottom, in the meshes of which the coral becomes entangled, and is then drawn to the surface. The animal portions are then allowed to decay, and the hardened axis is sent to the market. Naples is the great seat of the coral trade, and annually consumes many hundred pounds. The value differs according to the size of the fragments, but even more in the color and the freedom from faults and blemishes. The pink varieties command a much higher price than the darker red.

The sea-fans (Gorgonids) are very characteristic forms in the warmer seas, and many species have been described. Many of them assume a flattened, fan-like shape, formed by numerous interlacing branches. The outside of all the branches is covered by a soft, easily broken "bark" placed upon a harder, horny axis. In the bark are numerous spicules, the delight of the amateur microscopist. To obtain them, the bark is scaled off and boiled in caustic potash, which dissolves all but the spicules. Color in the sea-fan is of but slight importance, for the same species may be red, yellow, or purple. Allied to the sea-fans are the sea-whips, which consist of a long, slender, unbranched stalk, often several feet in length. In the old days of the East India trade the sea-captains of Salem, Newburyport, and Newport brought the black, horny axes of these sea-whips home, and used them for canes.

The organ-pipe coral, a native of the Eastern seas, is a peculiar form.

CORK POLYP (*Alcyonium*).

consisting of a large number of parallel tubes bound together at regular intervals by horizontal floors. Each tube is the home of a single polyp, with eight feathery tentacles. The color of the organ-pipe coral is a deep red, and the skeleton is rather fragile.

The group of sea-pens, one example of which is figured, bear, as their common name indicates, a considerable resemblance to a quill pen. There is a central axis corresponding to the quill proper, and from the upper part of this on either side are rows of leaf-like discs which bear the

FIG. 37. — Organ-pipe coral (*Tubipora*).

FIG. 38. — Sea-pen (*Pteroides*), with a single polyp, enlarged.

polyps, and which correspond to the barbs of the feather. The sea-pens are brightly colored, red in one shade or another being the prevailing tint.

Corals play an important part in the history of the earth, from the fact that they form large reefs and islands. Not only is this the case to-day, but so it was in geological time. In many places in the rocks we find the remains of the old coral reefs of ages ago, one of the best known being the large deposit of fossil corals at the Falls of the Ohio, at Louisville, Ky., which dates from Devonian time. Here the resemblance to a modern reef is perfect, and large coral masses six and eight feet in diameter occur.

To-day the distribution of reef-building corals is limited by temperature, no reefs being formed outside of the isotherm of 68°, a limit which, however, does not at all agree with the parallels of latitude laid down on the globe. Still, it never passes the latitude of 35°, and in the Atlantic the Bermudas are the farthest north of all the coral islands. The largest existing reef to-day is that on the northeastern coast of Aus-

tralia, a thousand miles in length. It varies from ten to a hundred miles in distance from the shore, and while between it and the land the sea is rarely more than thirty fathoms deep, "at a few hundred yards outside this 'barrier reef' no bottom can be obtained with a sounding-line of a thousand fathoms."

This leads to the mention of the fact that reef-building corals do not exist alive at a greater depth than fifteen or twenty fathoms, and that the different species exhibit even within these limits considerable differences. How, then, are we to explain the coral islands so abundant in the Pacific, which arise abruptly from an almost bottomless sea? The most satisfactory explanation of this and other phenomena is that given by the late Mr. Darwin. It is that these islands and reefs occur only upon some volcanic island, or in the place where one has existed within comparatively recent times. As is well known, the Pacific Ocean is the seat of a marked volcanic disturbance, and at times islands are suddenly thrown up from

FIG. 39.—An island with fringing and barrier reefs.

the bottom of the sea. Let us follow the history of one of these islands, as it will explain many facts.

As soon as the rock thus elevated from the bottom cools down to a temperature where coral life is possible, coral embryos, drifted by the currents from other reefs, would obtain a foothold and begin their growth. Little by little they would rise towards the surface, until at length they form a fringe around the volcanic island, extending out from the shore until the twenty-fathom line, the limit of coral life, was reached. Here the reef would stop abruptly, and its outer edge would form a sheer precipice a hundred and twenty feet in height.

Coral needs for its nutrition an abundance of fresh water, bringing to it food and oxygen; hence that portion of the reef exposed to the ocean waves would be best nourished, and consequently would grow most rapidly. Suppose, now (a supposition warranted by many known examples), that the island should slowly sink at a rate not exceeding a few feet a century.

The edge of the reef would continue its upward growth, and so keep at the surface, as fast as its foundation sank, but between the edge and the shore a strip of clear water would be formed, because the coral here would not be properly nourished, and would also be smothered by the debris broken by the waves from the edge of the reef. In this way the former "fringing reef" would be converted into a "barrier reef." If the subsidence still continue, at last there will be a circular reef containing a central lake or lagoon, a type of island to which the name *atoll* (a Polynesian word) has been applied. True atolls, however, are rare. Usually the island has a gap on one side, through which entrance may be had to the lagoon. This is due to the fact that the prevailing winds and currents are almost constantly in one direction, and that the windward side thus is better fed, and hence grows more rapidly than that to the leeward, and the entrance to the lagoon is always to the leeward side of the atoll.

FIG. 40.—A circular coral island (atoll), with a lagoon in the centre.

This matter of wind and current has lately been thought to be a very important element in the determination of the shape of coral islands, and in the case of the Florida Keys this certainly is the case. If we examine the most of these islands, we see that they are all long, and that their longer axis is parallel to the principal current which passes them. At first sight it would seem that there were one or two exceptions to this, a few having their longer axes at right angles to the general direction of the Gulf Stream, but in these cases it is found that there are secondary currents flowing down the western coast of Florida, and that these have modified the islands in question.

Besides the mere growth of the coral, there are other elements to consider in the growth of a coral island. A coral reef is constantly dying, and the dead branches are broken into fragments and ground into sand by the waves. Some of this sand is of course carried out to sea, but much

of it settles down among the corals and converts the reef into a solid mass. Little by little the accumulation goes on, the waves constantly throwing the sand inward, until at last a firm land is obtained, upon which plants begin to grow and animals to live.

The distribution of the coral islands on the face of the globe seems most capricious, and still it is to be explained by the direction of the prevailing currents. In the western Pacific coral islands are most numerous; next comes the Caribbean Sea, in which the Bahamas are the largest examples of purely coral islands and reefs. There are also extensive banks in the Indian Ocean, as around Mauritius, Madagascar, and at the entrance to the Red Sea. They are almost entirely lacking from the western shore of Africa and from the eastern shore of South America, as well as the whole western shore of both Americas.

ECHINODERMS.

IN the older zoological system, that founded by the great French naturalist Cuvier, one of the four great groups into which all animals were divided was called Radiates, in allusion to the marked radiate structure which the individuals possessed; but this was a character of secondary importance when compared with many others, and deeper study has conclu-

FIG. 41.—Common New England Sea-urchin (*Strongylocentrotus*), with its tube feet extended.

sively shown that the group of Radiates was not a natural one, but that it included two very different kinds of animals. — one the Cœlenterates just passed; the other the Echinoderms now before us.

If we examine one of the typical Echinoderms, like a sea-urchin, the name of the group will be seen to be peculiarly appropriate, for the word Echinoderm means spiny skin, and the urchin is seen to be well provided

in this respect, for all over the exterior are numerous spines which in some species are much longer than on the form here figured, being occasionally two or three times as long as the diameter of the body itself. Still the name Echinoderm is not literally applicable to all, for in many forms there are no spines on the skin, and yet there can be no doubt of their near relationship to the urchin. None of the group possess any great economic importance, and yet there are many interesting facts connected with them.

First in order come the Crinoids, a group now nearly extinct. In the oldest rocks occur the remains, sometimes in enormous numbers, of long, jointed columns, on the summits of which may frequently be found the remains of the rest of the animal. The jointed stalk frequently became broken up, and these fossil joints were long known as "St. Cuthbert's beads." When, however, the stalk remained entire and retained the rest of the animal on its summit, it was known as a stone-lily; and the name was appropriate, for the whole often resembled a flower more closely than even the living form figured in this connection. For many years the living stalked crinoids were exceedingly rare; only one species was known (from the West Indies), and of this, up to 1856, only seven specimens existed in all of the museums of the world. Now, since the deep-sea dredge has explored the sea, both species and specimens are much more numerous, and all of the large museums contain one or more of them.

For many years there was known in the seas of Europe a peculiar star-fish, represented in the accompanying cut. From its color, and from the pinnations on the long, curling arms, it had received the common name of the rosy feather-star. There was hardly a suspicion but that it was what it appeared to be until in 1836 Mr. J. V. Thompson showed that in its earlier stage it was a veritable crinoid, living on a stalk and agreeing in all its essential characters with the fossils so plentiful in the rocks. It had a mouth in the centre of the arms, while around the place where it was

FIG. 42. — A living crinoid (*Pentacrinus*), with the region of the mouth on a larger scale.

joined to the stalk arose a circle of tentacles. When full grown it left its stalk and swam freely, pausing occasionally apparently to rest, and at such times the tentacles came into play as clasping organs, holding the star firmly to any object in the manner shown in the figure.

FIG. 43.—A free-swimming crinoid (*Comatula*), attached to the tube of a worm.

eye in derision as it went down to the depths from which it came! These long arms are capable of considerable motion, and motion of such

The starfishes (*Asteroids*) are much more numerous than the crinoids. They abound in all the seas from low water-mark down to two thousand fathoms or more. They all consist of a central disc, from which radiate five or more arms. In the group of brittle-stars this disc is better marked, and the arms are longer, more slender, and more easily moved than in the true starfish. These arms are very brittle, and frequently on taking these animals from the dredge they will all tumble to pieces, apparently at times from sheer spite, and the late Edward Forbes claimed that one fine specimen which broke all up in his hands actually winked its

a character as to readily explain the other name, "serpent-stars," which is frequently applied to them. Indeed, the scientific name of the group, Ophiuroids (serpent-like), alludes to this very character.

In both serpent-stars and true starfish each of the arms, as well as the disc itself, is strengthened by an external skeleton of plates of carbonate of lime which may bear spines and other protective structures. Concerning the brittle-stars there is little of general interest to be said. About four hundred and fifty species are known from the whole world. The general appearance of the great majority is shown by the adjacent cut; but there is one group of forms, the so-called basket-fish, which differ considerably, for the arms branch again and again, so that the number of terminal branches is enormous. Usually, the number is stated in the books as eighty thousand, but this seems to be much too large, for Mr. Lyman, who recently investigated the subject, has shown that the number is less than six thousand. The common name, "basket-fish," is suggested by the shape the animal takes when drawn from the water. Its many arms roll upwards and inwards, making the resemblance to a shallow basket quite marked. Old Governor John Winthrop first described the species from a specimen obtained near the shoals of Nantucket, calling it net-fish as well as basket-fish. Their colors are not very attractive, dull yellows and browns prevailing.

A little more interest attaches to the true starfish, for they are known to every visitor at the shore. Their five spiny arms, the red, orange, or purple colors, and the curious little coral-like spots make them attractive, while the immense numbers of them to be found on the mud flats, and especially on the mussel and oyster beds, after the tide has gone out, only increases the interest in them. At favorable localities the whole bottom is covered with them. One of the most common questions concerning them is, "What do they live on?" and the answer that their food consists of mussels, oysters, and other shell-fish only increases the curiosity. The question concerning the diet of the shell-fish themselves never arises, —

FIG. 44. — A brittle star (*Ophiothrix*).

these animals are too commonplace. — but the bizarre “five-finger-jacks” are so curious that they must have some peculiarity in every part of their economy as well as of their anatomy; and so they actually have.

As has just been said, they feed on shell-fish, but their mode of feeding is very peculiar. They have no teeth, so they cannot gnaw a hole through the solid shells of their prey; their mouth is small, and, further, is surrounded by a bony framework, so that they cannot swallow the entire animal, shell and all, as do some of the fishes. How, then, do they eat? “If the mountain will not come to Mahomet, then Mahomet will go to the mountain.” If the oyster will not go into their stomachs, then their stomachs will go out to the oyster. The starfish settles down upon the mussel, wraps all his arms around it and holds it firmly by his numerous curious tubular feet, and then sticks his stomach out through the mouth and wraps it round the unfortunate mollusc. The oyster is soon killed; its shell then gapes, and into the interior goes this curious stomach, digesting, when thus turned inside out, the animal which it could by no possibility swallow. When the feast is concluded, the stomach is again safely tucked away in the body of the starfish.

The starfish does not need to move rapidly. His food is stationary; and he does not fear enemies, since he is protected by his spiny coat. Still, some motion is necessary, and this is effected principally by means of the tubular feet, already mentioned. These are very peculiar organs, which are not confined to the starfish, but are found in other Echinoderms as well. Our figure shows three pairs of these feet, each of which consists of an external tubular portion terminating in a sucking-disk, and an internal globular portion. The interior is filled with fluid, and hence when the globular portion is contracted the external portion is extended. Other motions are controlled by muscles; and, further, all the feet

FIG. 45.—A few of the tubular feet of the starfish.

on one arm are connected with a tube running the whole length of the arm. The starfish can extend one of these feet, attach it to some foreign object, then extend another, and so on, until a firm hold is obtained, and then the whole animal can be drawn along in the same way that a ship “warps” its way up a channel against wind and tide.

In the starfish, as in all the Echinoderms, there is none of that reproduction by budding or by division which is so common in the groups already discussed. Reproduction by means of egg is the only mode, but among the starfishes there is no alternation of generations. Each egg pro-

CORALS, ECHINODERMS, AND WORMS.

In the background is a madreporic coral; the worm-like object in the right centre is a holothurian; in the foreground serpulid worms are shown, projecting their gills and tentacles from their calcareous tubes.

duces but a single adult, but before arriving at the adult condition many of the species pass through most wonderful changes. Who would recognize this peculiar-looking animal as the young of a starfish or as having anything to do with one? and yet it is. On the side a young starfish is soon to grow out, gradually absorbing all of the old larva, and then changing directly into the adult.

FIG. 46. — Side view of a young starfish with the starfish (*s*) just beginning to form; *m*, mouth; *a*, vent; 1 to 5, paired; 6, unpaired arm.

The common starfish on our shores have but five fingers, but below the lowest tides there are many other kinds. In some of the so-called sun-starfish the central disc is much larger, and it is fringed with shorter arms set as thickly as possible, so that the resemblance is close to the conventional figure of the sun. In others the disc is enormously developed and the arms are scarcely noticeable. — the *starfish* is but a pentagonal disc, and still it shows all the essential characters of its more regular relatives. Not all of these forms feed on shell-fish, for there are some which fill their stomachs with mud; and in these there is no necessity for that protrusion of the digestive apparatus which is found in our common form.

The economic importance of the starfish is comparatively slight. They are of no value as food or in any other way. On the other hand, some of them are decidedly injurious, and the oystermen complain loudly of the depredations of the “five-finger.” If a number of them get on a bed of oysters they will eat many, and hence the fishermen, when they catch one, quickly proceed to cut it up so as to stop the depredations of one starfish; but usually their efforts are of no avail, for if but one arm be left attached to the central disc, the others will soon grow out again. The collector at the shore often picks up starfish with one, two, or more rays smaller than the rest, and these smaller arms are records of accidents which the corresponding arms have suffered at some recent time.

The sea-urchins (Echinoids), though considerably different in shape from the starfish, are somewhat closely related to them. The typical sea-urchin is nearly spherical in form, and yet we can trace the same structures in it as in the five-finger. In a specimen from which the spines have been removed, there will be seen rows of dots running from one pole to the other. These indicate the openings through which the

tube-feet are protruded ; and if we should examine the whole of the urchin, there would be found five of these pairs of rows, exactly the same number as in the starfish, and as in that form, the mouth is at the centre of these rows. Now were we to split the urchin between these pairs of rows in the same way that one often peels an orange, and flatten it out, the result would be that the urchin would be a starfish in shape.

There are, however, other differences to be noted. The sea-urchin has teeth, and these, like the parts of the shell, are five in number, all meeting in the centre ; and it is interesting to note that in the way these grow and in the way they sharpen each other they present a close resemblance to the teeth of squirrels and other rodents, to be described later in this volume. These teeth are supported in a bony framework, and from the shape of the whole apparatus, and since the whole was first studied and described by the old Greek father of zoology, it is called "Aristotle's lantern."

The sea-urchins, like the starfish, pass through a metamorphosis in the course of their development, and the changes in this case are even more marked than in the other. The embryo is provided with several long and slender arms, each supported by a delicate calcareous rod, and yet all these are temporary. The young urchin grows out of the side of the body of the embryo, and gradually all these long arms are absorbed. The purpose of these and similar long spines in various animals is to increase the size of the whole, so that the risk of being swallowed will be diminished.

The sea-urchin (Fig. 41) is common to both our northern coasts and those of Europe. It is blessed with an enormous scientific name, *Strongylocentrotus drobachiensis*. It lives in comparatively shallow water and is especially fond of rocky localities. In some places where the rock is soft these and other urchins gradually wear nests for themselves — round, deep hollows in the solid stone. How they manage it is still a mystery. It may be that the spines are the means of this excavation, but their tips never show any great wear. "Constant dropping wears away the stone," and these nests are probably not excavated by one, but by a long series of individuals, each wearing its part.

Even more common on the shores of Europe than this form is the common sea-urchin or sea-egg. This latter name refers not only to its shape, but to the fact that it is edible, whence its scientific name, *Echinus esculentus*. In other and especially in tropical species the spines may attain an enormous development, being in length three or four times the diameter of the disc. Again, they may be large and like slate-pencils, or short and with little caps at the top. These spines are frequently cut across, and the sections thus produced, with their intricate, lace-like structure, are great favorites with microscopists.

In a second group of sea-urchins the rows of tube-feet, instead of extending from one pole of the animal to the other, are restricted to a smaller space on the side opposite the mouth. One of these forms, the common "sand-dollar" or "sand-cake" which is here illustrated, shows this well, the feet being restricted to the flower-like region on the surface shown. The sand-dollar is almost perfectly flat, and in life of a rich

FIG. 47. — Sand-dollar (*Echinarachnius*).

purple color, inclining to brown, but soon after being taken from the water the color changes to green. The color is permanent and occasionally is made the basis of an indelible ink. The spines and skin are rubbed off from a number of sand-dollars, ground to powder, and then mixed to a paste with water, and with this the articles are marked.

Others of these flat urchins are common in the warmer waters of the world, some of them attaining considerable size. Some are as regular in their shape as the sand-dollar or the common sea-urchin, but in others there occurs a marked division into right and left halves, and a consequent tendency to the obliteration of the radial symmetry so emphasized by the older zoologists. In some forms the eggs do not hatch into larvæ so different from the adult, as in the case of the common sea-urchin. The eggs, after escaping from the parent, are frequently received in a brood-pouch formed as a hollow, overarched by the spines of the external surface. Here they hatch, the young looking like sea-urchins, and here they live until able to take care of themselves. Most of the time is spent in this brood-pouch, but occasionally the young crawl out on the spines of the mother's shell as if to look about and see what the great world is like. A curious and as yet unexplained fact may be mentioned in this connection. In the northern hemisphere a great majority of the Echinoderms pass through a metamorphosis in passing from the egg to the adult condition, but in the southern hemisphere the proportions are reversed, it being the rule there for the egg to develop directly into the adult condition, and only exceptionally do curious larval forms occur.

The last group of Echinoderms to be mentioned are the "sea-cucumbers," the Holothurians of science. In these the body becomes elongate and

A GROUP OF HOLOTHURIANS (*Cucumaria*).

worm-like; the mouth is without teeth, and the body usually lacks the hardened envelope so characteristic of the starfish and sea-urchins. The common name, "sea-cucumbers," is very descriptive of the typical forms as they appear when brought to the surface. The general shape of the body is the same, and the resemblance is strengthened by the fact that the tube-feet of the marine animal closely simulate the spines on the surface of the familiar vegetable; the color, however, is usually greatly different in the two, shades of green being far from common in the sea-cucumbers.

In their native element the sea-cucumbers show many features which are not seen in the specimens brought to the air. Our plate shows three individuals, two of which have the crown of tentacles surrounding the mouth widely expanded, while the tube-feet along the sides of the body are distended to their fullest extent.

While the sea-cucumbers (except in forms like *Psolus*) lack a hardened investment of the body, still all show traces of such a protection, for in the skin are numerous plates of carbonate of lime. Usually these plates form an irregular network, perforated by innumerable holes, and scattered irregularly through the skin; but in some species they are very regular in their shape, and are among the favorite show specimens of the microscopist. Thus in a few genera these plates, microscopic in size, take the shape of wheels, with their hub, spokes, and rim. One of these wheels from a northern species is figured here. In another genus (*Synapta*) the plates are very peculiar. They occur in pairs, each pair consisting of a flat, fenestrated plate and a calcareous anchor, which in shape is almost exactly like the large anchors used in mooring vessels.

FIG. 48.—One of the "wheels" embedded in the skin of *Myriotrochus*.

One species of *Synapta* closely like that shown in our figure is common on our Atlantic coast. It forms slender burrows in the sandy shore, near low-water mark, and it is said that the anchors covering the skin are of use in holding the animal in place in the tube. The animal is transparent, and when taken from its burrow is a very attractive object. Placed in a dish of water it soon expands its tentacles, and empties its digestive canal of sand, and then almost every detail of structure can be seen. The cut shows one of these forms, in which it will be noticed that the body is constricted at intervals. These constrictions are caused by the contraction of the circular muscles, and may take place

at any part of the body. In preparing specimens they frequently prove very inconvenient, for they may be so violent as to break the animal into several pieces.

Sea-cucumbers are hardly more important from an economic point of view than are the other members of the group of Echinoderms. In the tropical seas they play a part in the building of coral islands, for they feed on the coral fragments for the sake of the contained organisms, and thus farther comminute it and prepare it for an element of soil. In the far East they also form an important dietary element. In the southern portion of China "trepang" is an essential element in the preparation of soup, and the trade in it is very considerable. The price paid varies from seven to fifty cents a pound, according to the quality, and upwards of four hundred tons, valued at \$100,000, are annually brought to the market. Trepang is merely dried sea-cucumbers, or, as they are called, "bêche-de-mer."

The trade is now almost wholly in the hands of the Malays, though in former years it was largely controlled by the sea-captains of Salem, Mass. Every year a large fleet of vessels sets sail from Macassar and the Philippines to the Fijis, and other islands of the South Seas, for their lading of bêche-de-mer. Arrived at their destination, the fishing begins, being carried on by spearing and by diving. When caught the sea-cucumbers are split open, boiled, and then placed on bamboo frames to dry in the sun. When thoroughly dry they are smoked over a fire of green wood, and then packed in bags for transportation to the Chinese market.

The dried and smoked sea-cucumbers are "trepang," and supply the place of gelatine in the soups of the East. When cooked they swell up, and finally dissolve to a large extent. To the European palate trepang soup is not over-savory, for the smoky taste is very strong.

FIG. 49.—*Synapta*, with some of its anchors and plates enlarged.

WORMS.

THE term worm is rather indefinite. To the ordinary mind the word is associated with something loathsome; yet among the forms enumerated among the worms are some of the most beautiful objects of nature, while the history of others furnishes some of the most interesting facts in the whole realm of science. From the scientific standpoint the term worms, or its Latin equivalent, *vermes*, is also indefinite. The group bearing this name is a most heterogeneous assemblage of animals, which doubtless will be broken up into many distinct branches. For our purposes, however, it is not necessary to descend into details, and we will accept the group of worms in its widest sense, but without attempting to define it.

Worms exist everywhere,—on the land, in fresh water, and in the sea,—while a large number spend a part, or even the whole of their existence as parasites in other animals. Though this subject of parasitism is not a pleasing one at first sight, yet some phases of it are really very interesting and very important, as will be seen from the following pages.

In the first of the groups of worms,—the flat worms, or Plathelminthes,—we meet all the conditions of life enumerated in the preceding paragraph, and this “environment” has its modifying influence on the members of the group. A form living in moist earth must needs be differently constituted from one living in the water, and one of these latter in turn from one infesting the organs or tissues of another animal. A free life calls for means of protection and locomotion which are entirely unnecessary in a form living in the flesh or digestive tract of another animal. These latter, of course, can have no use for eyes; all they need is means for eating and for reproducing their kind, and insuring the young finding the proper place for their further life.

FIG. 50.—A fresh-water planarian (*Polycetis*).

Most common of the free forms are those known as Planarians. These abound in both fresh and salt water. In the ooze at the bottom of ponds one can readily find a number of oval, flat worms, some dark, others nearly white, the body of all being very thin. In the lighter specimens, which rarely measure over three-quarters of an inch in length, we can see more or less distinctly all the features of structure. With the naked eye we

can see no organs of locomotion, and yet these animals glide smoothly along. The microscope, however, shows that they move by means of cilia, very like those of the ciliated protozoans described on a preceding page. If carefully watched, the process of feeding can be seen. From the under surface (not shown in the cut, but a similar structure exists in Figure 52) is a long, extensible proboscis, which can be turned in every direction in search of food. These animals eat everything small enough to enter the proboscis; and as a good deal of mud enters with the food, the result is that the outline of the digestive tract in the transparent forms can be clearly seen through the walls of the body. It is not a simple tube in the Planarians, but is rather a blind pouch, from which numerous lateral pouches are given off.

Some of the marine forms are much larger than the terrestrial ones, the figure here shown illustrating a form which attains a length of an inch. It is represented as crawling upon a bit of sea-weed, the anterior end of the body being upturned and showing the two very sensitive tentacles. Only one of the land planarians has as yet been described from the United States, but in Europe several are known; their home seems to be in the tropics, South America possessing twenty-seven of the sixty-four known species.

FIG. 51. — A marine planarian (*Thysanozoon*).

Associated with both the fresh-water and the marine planarians are other worms, which differ in having a straight, unbranched digestive tract. One of these forms from fresh water is illustrated here, greatly enlarged (Fig. 52). The cut shows the cilia covering the whole surface of the body, the large proboscis, two eggs (large, dark-colored bodies on the left of the figure), as well as other structures. In still others of the fresh-water species, the body divides transversely to form new individuals, and frequently a second or even a third division will begin before the first is complete, and the result is a compound worm with several mouths repeated in serial order. It is a process which recalls the formation of jelly-fishes by division of a hydroid-like stock, as described on page 22.

The flukes and the tape-worms will represent the parasitic flat worms in our pages. In various parts of the world sheep and other herbivorous animals are occasionally victims of a disease known as "sheep-rot" or "liver-rot," the latter term having reference to the degeneration of the liver, which results in death. This disease is not so common in America as in Europe. In the British kingdom the disease in 1879-80 destroyed three million sheep. For a very long time it has been known that a peculiar worm, the liver-fluke, was the cause of the disease, but the question of how it gets from one animal to another was not fully settled, although many had worked at it, until 1882, when Mr. Thomas traced the whole life history. A brief abstract of this is given, because it is of itself interesting, and because it may be used as a type of the subdivision of trematode worms.

FIG. 52. — A fresh-water turbellarian (*Opisthocotylum*), enlarged.

The scientific name of the fluke is *Distoma* (two mouths), and alludes to the fact that the animal has two suckers which were formerly supposed to be mouths. The adult fluke occurs in the liver of sheep and other mammals, and there produces its hundreds of thousands of eggs. These pass out through the bile-ducts into the intestine, and thence are cast out with the droppings over the field where the sheep feed. Were another sheep to eat them now, they would come to naught; they need other stages

and only those eggs which may chance to find their way into the pools of water in the pasture have any chance of developing. These soon hatch out an embryo conical in shape, and furnished with a retractile papilla on the larger end. The whole outer surface is clothed with long cilia, by means of which the embryo swims freely, or at times spins on its longer axis like a top. This free life lasts about eight hours, and if in that time the embryo has not found a host in which to spend the next stage of existence, it dies.

Many are the experiments that have been tried to ascertain what this host may be, but so far only one form has been found to act in this capacity, and this is a pond-snail known to conchologists as *Lymnæa truncatula*. It is a small species which is amphibious in its habits, being found as often on the land as in the water. The embryo fluke seems to recognize at once the presence of these snails among all the rest, and swim towards them. On touching the body of the snail the motion of the embryo becomes changed to a

FIG. 53. — Young embryo of the liver-fluke before it bores into the pond-snail.

rotary one, and around and around it spins, as though it were trying to screw its way into the snail. This is really what it does do; the papilla on the head becomes shaped like an awl, and this gradually forces aside the tissues of the snail, so that at last the whole of the embryo squeezes in.

Arrived in the body of the snail, a marked change takes place. The embryo casts off the ciliated cells, secretes a cuticular envelope, and becomes converted into a 'sporocyst,' which rapidly increases in length to ten times its former dimensions. During this growth the granular contents of the cyst become converted into spores, and these in turn into worm-like bodies with a mouth and stomach. These forms are called 'redia,' and in each cyst will usually be found one well-developed redia, and others less advanced. As each redia becomes mature, it breaks through the walls of the cyst and travels through the tissues of the snail. The redia in turn has its own peculiar contents, tadpole-like bodies called 'cercaria,' and one redia may produce twenty-three of these. As the cercariæ reach the limit of their development, they escape from the redia by an opening which exists for the purpose; and then, wriggling like a tadpole, these work their way out from the host.

Suppose that the infested snail during the processes described has crawled out upon the land; then the cercariæ escaping from the body will be distributed over the field.

They are fully prepared for this, for they soon come to rest, the tail drops off, and the external cells of the body secrete a mucilage which soon hardens into an impervious envelope, fastening the cercaria to the grass. Here it is able to exist for a considerable time; but when the grass to which it is attached is eaten by a sheep or other animal, this external envelope is dissolved by the digestive fluids, setting the worm free. It then bores through the wall of the stomach, and makes its way to the liver, where in the space of about six weeks it grows into the adult fluke and begins to produce eggs, and the cycle is complete.

FIG. 55.—Cercaria stage of the liver-fluke.

FIG. 54.—Redia stage of the liver-fluke with several well-developed cercariæ in it.

The history of this fluke has been worked out the most thoroughly of any, but all have somewhat similar cycles so far as known. In some there is no necessity for an intermediate host, while in others there may be two. As will be seen, there is an alternation

of generations here as in the hydroids: the adult worm produces eggs, each of which produces a single embryo; each embryo gives rise to several rediæ, each redia to several cercariæ, while each cercaria makes an adult worm. The sexual generation alternates with two asexual buddings. Occasionally a redia will produce several generations of rediæ, thus still further complicating the history, while a sporocyst may divide into several sporocysts before the formation of rediæ begins.

Flukes are comparatively common, and the molluscs are fearfully subject to their attacks. Sometimes three or four different kinds of cercariæ will occur in a single snail. Fishes and frogs are often hosts of the mature fluke, and without doubt the parasites enter their bodies from the snails which they eat. Even man himself is not exempt from their attacks, five distinct species of fluke being enumerated as being human parasites. Mr. Thomas suggests that the liver-fluke may obtain entrance to the human system along with water-cress eaten as a relish.

The animal shown in the next illustration is, possibly, one of the greatest wonders of nature, for it is a double animal. It is not one of those

FIG. 56.—*Diplozoon* enlarged. The black, branching portion is the digestive tract.

queer and unexplained freaks like the Siamese twins, which startle us because they are so rare. Monstrosities occur in the worms as well as in the human species, but this is really a regularly occurring phase in the history of a worm allied to the flukes. *Diplozoon* (the name means double animal) was found by Nordmann, a German professor, in 1831, and in more recent years its life history has been studied by several

observers. It occurs as a parasite in the gills of the bream, and consists of two individuals, each a little less than half an inch in length, joined together in the form of a cross, the left tail belonging to the right head and *vice versa*. The two are not always united; when young they exist separately; but when they meet on the gills of a fish one applies his sucker to a projection growing on the back of the other, and thus they hold together. Gradually the union becomes more intimate, until they grow together and literally as well as metaphorically the twain become one flesh.

Last of the flat worms come the tape-worms, a group usually regarded with unpleasant feelings, though their habits render them both important and interesting. All are parasitic and affect man and other animals. Of these there are many, far too many, forms; some are comparatively sim-

ple, while others are far more complex, but most of them have a shape which renders their common name appropriate. They are long and flat like a ribbon, and unlike most worms they are without a digestive system. Their parasitic life has caused a degeneration, and at last a disappearance, of all of the alimentary canal; but the lack of this is of no great importance, for they obtain their food from the intestine of their host largely in a digested condition. They do not need a mouth, because the whole surface of the body possesses absorptive powers.

Several very distinct groups of tape-worms exist, differing not only in their general appearance, but in their life history; but of these we need concern ourselves only with those which inhabit mankind, merely saying that almost every species of the higher animals, and many of the lower forms, have their peculiar species. For most of our knowledge of these, as well as of almost every branch of exact zoological knowledge, we are obliged to go to those indefatigable students, the Germans, notwithstanding the fact that America is as fully provided with these pests as is the Old World.

Most important of all are the species of *Tania*, of which three species are comparatively common in man, *Tania solium* being the most abundant and the best known. It has a small head, about as large as the head of a pin, but this has no mouth and but the merest apology for a brain. It in reality serves as an anchor for the rest of the animal, and for this purpose it is well adapted. This head burrows beneath the lining membranes of the intestine, and the hold thus obtained is further strengthened by the four suckers on the sides and a crown of hooks on the top. From this head proceeds a long, slender, ribbon-like neck, which at first is even narrower than the head, but it gradually widens out until the body reaches a breadth of a quarter of an inch. Behind the head, the whole body is broken up into a series of joints or 'proglottids,' which increase in length with their distance from the head. These joints arise just behind the head, and as newer ones are formed the older ones are pushed farther back. With this increase in distance comes one in size, and gradually each joint forms eggs, until at last, when fully "ripe," it may be regarded merely as a bag of eggs. When the proper time comes, each joint drops off from the chain and is discharged from the body with the egesta. After thus escaping, the eggs contained in the joint pursue a part

FIG. 57.—Diagram of the different parts of a tape-worm, showing the head, neck, and the character of the segments in different regions of the body. The entire animal could not be shown on account of its great length. Above is the head, enlarged.

of their development, the wall of the joint forming an enveloping sac. Their farther history is thus described by Dr. T. Spencer Cobbold :—

“The growth of the multitude of embryos within their interior causes the proglottid sooner or later to burst, and the embryos thus become dispersed ; some are conveyed down drains and sewers, others are lodged by the roadsides, in ditches and waste places, while great quantities are scattered wide by wind or insects in every conceivable direction. Each embryo within the egg is furnished with a special boring-apparatus, having at its anterior end three pairs of hooks ; after a while, as it were by accident, some animal, a pig perhaps, coming in the way of these embryos, or of the proglottids, swallows some of them along with matters taken as food. The embryos, immediately on being transferred to the digestive canal of the pig, escape out of the egg-shell and bore their way through the living tissue of the animal to lodge themselves in the fatty parts of the flesh, where they await their further destiny. The flesh of the animal thus infested constitutes the so-called measly pork.” Here they drop their hooks and take on a form which for a long time was supposed to be a distinct animal. If, now, a man were to eat a bit of this infected pork in a raw or partially cooked condition, these animals would be transferred to his intestine, where they would fasten themselves and complete their development into the form with which we started.

The species of whose history we have thus given an abstract is *Tenia solium*, which may reach a length of nine or ten feet. *Tenia mediocanellata*, a species without the hooks on the head, and which may reach a length of twelve feet, passes the intermediate stage of its life in cattle, while *Tenia echinococcus* is scarcely a sixth of an inch long, and is further peculiar that its adult condition is found in dogs, while the intermediate stage is passed in man and other animals. The largest of the human tape-worms belongs to the genus *Bothriocephalus*, which has but two suckers on the head. It sometimes reaches a length of thirty feet. What its history is is not yet known, but certain facts render it probable that a part of its life is passed in fishes. It is an interesting fact in the distribution of these forms that *Bothriocephalus* is the common form parasitic in Russians, Poles, and Swiss, while other Europeans and Americans are attacked by *Tenia*. *Tenia echinococcus* is abundant in Iceland and not infrequently proves fatal to its victims.

Next in order come the round worms, or, better, thread-worms, the latter name being an equivalent of the scientific name Nematodea, which means thread-like. Their habitat is as comprehensive as that of the flat worms ; some live in moist earth, some in water, and some are parasites. The terrestrial forms are far more abundant than the terrestrial flat

worms, and may readily be found in the rich, moist humus of the woods, where they are seen as little white threads, rarely reaching an inch in length. Of our American species almost nothing is known, though we have them in the greatest abundance. Should the reader wish to study them, he can follow the process adopted by Anton Schneider in studying the European species. He took a pot with a lot of earth in it and poured in a little blood or milk and kept the whole moist. The earth was filled with eggs and embryos, and these speedily made their way to the putrefying milk or blood and there attained maturity.

Of the aquatic forms and their allies mention need be made of but two types. One is comparatively abundant in pure cider vinegar and is known as the vinegar-eel; the other is occasionally found in stale paste and is known as the paste-worm. These worms are less than a tenth of an inch in length and so transparent that, under the microscope, the whole of their anatomy stands revealed. The paste-eel has lately come to the front as an aid to play a part in a fraud. Traveling vendors of so-called microscopes declare that their

FIG. 58. — Vinegar-eel (*Leptodera*).

worthless instruments will show “the animalcules in water,” and to prove it they show these paste-eels. As described by Dr. James, they take a drop of perfectly clear water with a toothpick and place it on a glass, but the toothpick has previously been dipped in sour paste filled with the worms. No wonder the would-be purchaser sees “animalcules” in abundance.

The parasitic forms are more important than the free-living forms. First to be mentioned of these is that dread of all travelers in the tropics of the Old World, especially on the west coast of Africa, — the famous Guinea-worm. Of its history but little is known. In some way the young obtains a lodgment under the human skin, usually of the feet or legs, and there grows to an enormous length. It forms a bad ulcer, and in the centre of the sore appears the head of the worm. The process of extraction is difficult, and if great care is not exercised, one of extreme danger; for if the delicate animal be broken, the eggs which it contains will remain

in the tissues and cause the death of the unfortunate man from the enormous number of worms which they will produce.

The Ascarids are less dangerous to man, but two of the species are worthy of mention. One of these is the round worm of the human intestine (*Ascaris lumbricoides*) which reaches a length of several inches; the other is the "pin-worm" (*Oxyuris vermicularis*), so distressing to children. It is a small species which breeds in the human rectum, producing the most intolerable itching. Yet small and delicate as it is, it will travel over the sheets from one child to another, thus infecting a whole family.

Worst of all the human parasites is the round worm, familiar by reputation to all, — the dreaded trichina. For many years it has been known that the eating of pork was dangerous and that not infrequently death ensued from the sickness caused by it. Indeed, there is good reason to believe that the Levitical prohibition was a sanitary measure based upon a knowledge of this fact. But it was not until the last half of the present century that the whole history of this sickness was known and the worm *Trichina spiralis* recognized as the effective agent in trichinosis. The history of the discovery is an interesting one, but it is surpassed in this respect by the life history of the animal concerned.

Swine are particularly liable to attacks of trichina, as of all other parasites, on account of their omnivorous habits. They will eat almost

FIG. 59. — *Trichina* encysted in a piece of human muscle.

anything, and hence run a greater risk of swallowing the eggs of parasitic animals than almost any other animal. If the eggs of trichina be swallowed along with the food, they hatch in the digestive tract of the pig, the young bore their way through the walls of the intestine, and wander to all parts of the body. After a wandering life of short duration they settle down, preferring the muscular tissue as their future home. Here they feed and grow, and eventually each encloses itself with a firm, white capsule just large enough to be visible with the naked eye. Inside of the capsule the worm lies coiled in a spiral, whence the specific name of the animal, *spiralis*. Here it may remain, maturing its eggs for an indefinite period, until at last the pig is killed, and its flesh eaten by man. If the pork be not cooked sufficiently to kill the encysted trichina, the digestive juices quickly dissolve the capsule and set the worm and its multitude of eggs free in the stomach and intestine. The eggs soon hatch, and the embryos quickly bore their way through the intestine to repeat in the human flesh their history in the body of the pig.

It is while the myriads of worms are travelling through the body that

the danger occurs. The migration of, literally, millions produces the greatest suffering and causes a fever resembling, in some of its symptoms, typhoid, and which not infrequently terminates fatally. If the victim, however, have the strength to survive this migratory period until the worms are encysted, he may entirely recover, notwithstanding the fact that his muscles are filled with the worms.

In this matter of parasitism, as in many others, an ounce of prevention is better than a pound of cure. If we eat our meat thoroughly cooked, the chances of any parasites obtaining entrance to the human system are reduced to a minimum. In the cases of trichinosis, for instance, investigation has shown that the victims invariably have eaten pork raw, or in a partially cooked condition. One of the worst epidemics of trichinosis on record was one occurring in Saxony in 1884. All the cases were traceable to the flesh of one pig, and out of a total population of sixteen hundred, three hundred and sixty-one were infected, and fifty-seven of these died within one week. When trichina or any other parasite obtains entrance to the body, no reliance should be placed in so-called vermifuges or quacks, but a reputable physician should be called in at once.

Another round worm is the so-called 'horse-hair snake,' which everyone will tell you is a hair turned into a worm by soaking in water. The writer was told this story when a boy, and he persistently soaked horse-hairs for several weeks, but not a single worm was formed by the operation. It is hardly necessary to say that these hair-worms are really true worms, and that they have not the remotest connection with the hair of the horse. The fact that they are hair-like, frequently dark colored, and often occur in water, is the sole cause of the myth.

Scarcely less marvellous, however, is their history, so far as known, but it must be said that concerning this, really but little has yet been found out. According to the studies of Dr. Leidy, a single specimen will produce over six million eggs, which are laid in water, and soon hatch out the young, which, as shown in the figure, differ extremely from the adult. These larvæ, according to another observer, soon bore their way into some aquatic insect, which in turn is swallowed by some fish, thus transferring the worm to a second host, where they pass through the remainder of their development, until at last they escape into the water to lay their eggs. This account is good so far as it goes, but it fails to explain the frequent occurrence of these forms, fully grown, in insects which never go near the water. A figure of the adult worm is hardly necessary; it would be merely the picture of a hair eight or nine inches long.

FIG. 60. — Embryo of hair-worm (*Mermis*), showing the retractile hooks around the anterior end.

One more parasite must be mentioned, — the spine-headed worm (*Echinorhynchus*). — which is very abundant in pigs. It and its numerous brothers belonging to the same genus are raised to a group equivalent in rank to the flat worms and the thread-worms, under the name *Acanthocephali*. — a term which is merely a translation of the common name into Greek. The history of these parasites is as yet almost unknown, but their anatomy has been carefully studied. We only need say that they have neither mouth nor digestive tract, but, like the tape-worms, obtain their nourishment by absorbing it through the skin.

FIG. 61.—Sea-arrow (*Sagitta*).

While we know but little of the place where the spine-headed worms belong, we know but little more concerning the relationships of another form, known as *Sagitta*, which lives a free life in the ocean. The name *Sagitta* means an arrow, and describes well the shape of these animals. They are an inch or two in length, nearly transparent, and furnished with two bunches of bristle-like jaws, one on either side of the mouth. On either side of the body and on the tail is a fold which frequently becomes broken up into separate fins. *Sagitta* swims freely at the surface of the sea, and the surface-net of the naturalist often takes it in large numbers.

The student of natural history at the sea-shore soon learns that the sand and mud between tides are full of life, and 'worm-digging' plays an important part in his investigations. Occasionally the spade will expose to view a portion of an enormous, flat, dirty white or flesh-colored worm. He seizes it, when, with almost lightning-like rapidity, a slender, fleshy thread is thrown out from the head of the worm; round and round his hand it goes, stretching out to an incredible length, running up his arm, and no matter how strong his nerves, and how often he has had the experience, he cannot help being startled at the occurrence. He has found a Nemertean worm, and this long, binding thread is its proboscis, with which it captures its food. It cannot cause the slightest harm to man, but it never fails to excite feelings of disgust. This form, whose habit we have thus alluded to, is one of the largest of the group. It bears the name *Meekelia ingens*, and when extended to its fullest length, the worm, without its proboscis, may reach the length of fifteen or even twenty feet. Others of the Nemerteans are much smaller, and are among the most common of marine objects. Some are white, others blood-colored or green, and still others nearly black.

The Gephyreans are a group of marine worms, interesting to the naturalist, but rather from structure than from anything in habits or appearance, and so we dismiss them without further mention.

The Annelids—ringed or jointed worms—stand highest in the vermician series, and some of the species may detain us for a few moments. The group contains the leeches, the earthworms, and an innumerable host of fresh-water and marine forms, some interesting from their habits, others attracting attention by their bizarre shapes, or the great beauty of the colors.

The leeches, or blood-suckers, are usually esteemed as loathsome forms, from the fact that they live solely by sucking blood; yet if one watches them as they loop themselves along, or swim by the graceful undulations of the body, the beautiful pattern of the colors is bound to excite admiration. The leeches all live on blood. Some extract it from the snails or fishes, while others attack other forms, even man, when the opportunity offers. Blood is a necessity, and unless they have it they starve. Yet a meal will last them for an incredible time, for the blood in their stomachs does not decay, but retains its fluidity for months.

Best known of all is the medicinal leech, once in high favor in the days when man was bled for every ailment. They are bred for the market in enormous numbers in France, and from thence exported to all parts of the world. This form is some three or four inches in length, and, like most of its allies, has a sucker at either end of its body. The anterior sucker surrounds the mouth, and is armed with three radiating jaws, each like half of a buzz-saw. With these the leech cuts the skin of the victim, and then pumps itself completely full of blood, when it loosens its hold, and drops off. Leeches are ready swimmers, but they have also another means of progression. They lay hold of some object with the anterior sucker, and draw the body up in a loop, and then fastening themselves with the hinder sucker, again extend the body to obtain a fresh foothold in front.

Others of the leeches are useful in drawing blood, but still others are not adapted for surgical purposes, because they lack the jaws and cannot pierce the human skin. All the leeches are not aquatic. In Ceylon occurs a terrestrial species which Professor Haeckel describes as follows:—

“But, as the proverb says, ‘Man may not walk under the palms and never rue it!’ While I was wandering enchanted through the tall grass by the river, under the tall crown of an oil-palm, and carefully tracing the convolutions of a climbing rattan, I suddenly felt a sharp nip in my leg, and on baring it discovered a few small leeches which had attached themselves firmly to the calf, and saw at the same time half a dozen more of

the nimble little wretches mounting my boot with surprising rapidity, like so many caterpillars. This was my first acquaintance with the much-to-be-

FIG. 62. — Land-leeches of Ceylon, running after their prey.

execrated land-leeches of Ceylon, one of the intolerable curses of this beautiful island, of all its plagues the worst, as I was afterwards to learn by much suffering. This species of leech (*Hemadipsa ceylanica*) is one of the smallest of its family,

but at the same time the most unpleasant. Excepting near the sea and in the highest mountains, they swarm in myriads in every wood and bush; and in some of the forests, particularly near the river banks and in the marshy jungle of the highlands and the lower hills, it is impossible to take a single step without being attacked by them. Not only do they creep along the ground seeking what they may devour—they are on every bush and tree, from which they frequently drop on to the head or neck of the passer-by, while they always creep up his legs; nay, they can even spring to reach their victim. When they have sucked their fill they are about as large as an ordinary leech; but when fasting they are no thicker than a thread and scarcely more than half an inch long. They wriggle through the elastic texture of a stocking with the greatest rapidity. Often the bite is felt at the time, but as often it is not. Once at an evening party I first became aware of a leech by seeing a red streak of blood running down my white trousers.

“To be rid of the leech a drop of lemon-juice suffices, and for this purpose, when you walk out in Ceylon, you always put a small lemon in your pocket. I have often used instead a drop of the carbolic acid or the spirit I carried about for preserving small animal specimens. The result of the bite is very different with different persons. Those who have a tender skin—and I am unfortunately one of them—feel a painful throbbing in the wound for some days, and a more or less disagreeable inflammation of the surrounding skin. As these leeches always by preference attack these inflamed and irritated spots with fresh bites, the wound by constant aggravation often becomes so serious as to be even dangerous. When the English seized Kandy in 1815 they had to toil for weeks through the dense jungle of the damp hill country, and they lost a great many men from the incessant attacks of the swarms of leeches. In neighborhoods which are

most infested by them the Europeans wear leech-gaiters, as they are called, as a protection — high overalls of india rubber, or of some very thick material, which cover the shoes and are secured above the knees. I protected myself in the jungle by painting a ring of carbolic acid round above my high hunting-boots, and this line the leeches never crossed. In some parts of the island, however, the swarms of leeches make any long stay almost impossible, as do the ticks in other places."

A second group of segmented worms is distinguished by the presence of bristles or spines on the joints of the body, and these spines may be either few and small or numerous and large. In the first division they seem to arise directly from the body itself, while in the second they are seated on more or less prominent projections which may be so large as to act as feet or oars.

Most prominent of the forms with few spines are the familiar earth- or angle-worms, which abound almost everywhere. Our native species are small, but very recently an enormous species has turned up at the Cape of Good Hope. How long it really is, is as yet unsettled. One account says that the animal had already stretched to the length of six feet, and what its further capacities in this direction were time alone could determine. The account further states that it is a loathsome animal, which can readily be believed. Long and familiarly as our native species are known there has never been the slightest attempt to classify them. They figure always as *Lumbricus terrestris*, but there is not a person who really knows anything about our forms except that we have several distinct species.

Besides affording bait for the angler, earthworms have an importance which has only recently been realized. The late Mr. Darwin shortly before his death published a work on this lowly animal, which is doubly interesting, not only as a record of long and careful experiments and observations, but as showing the really great importance of these forms. As is well known, the angle-worm makes its burrows in the earth, descending at times of drouth or cold to a distance where it is not affected by these conditions, while in warm and moist weather it lives near the surface. Its time of greatest activity is at night. Then it excavates its burrow, bringing up the earth to the surface; then it goes after its food; and then it visits its neighbors and friends.

Its food is largely vegetable, and one can frequently see the blades of grass which it has tried to drag into its hole. It also swallows the earth in which it lives, and in the morning after a damp night one can see the coiled piles of earth near its holes which have passed through the intestine of the worm. Here is where the great importance of the earthworm comes in, for by this eating of earth soil is made. Material from below is

constantly brought to the surface, and thus slowly but surely new layers are added on top, while the older ones sink, thus increasing the thickness of the soil or loam. Did space permit we could make many an extract from Mr. Darwin's work which would show this and many other facts, but a few will have to suffice to show how slowly yet how constantly the earthworms, unnoticed by man, are doing an enormous work:—

“Near Maer Hill, in Staffordshire, quicklime had been spread about the year 1827, thickly, over a field of good pasture land, which had not since been ploughed. Some square holes were dug in this field in the beginning of October, 1837, and the sections showed a layer of turf formed by the matted roots of the grasses one-half inch in thickness, beneath which, at a depth of two and a half inches (or three inches from the surface), a layer of lime in powder or in small lumps could be distinctly seen running all round the vertical sides of the holes.” This layer above the lime was almost entirely brought there by the earthworms.

Every one is familiar with the fact that old stones in a meadow gradually sink beneath the surface. The writer remembers an old mill-stone which had sunk so that its face was level with the surrounding ground, and yet it had lain there for less than fifty years. This sinking was caused by the fact that the earthworms had burrowed beneath it, allowing it to subside gradually, while around it their deposits had gone on, thus elevating the surrounding surface. Again Mr. Darwin writes:—

“When we behold a wide, turf-covered expanse, we should remember that its smoothness, on which so much of its beauty depends, is mainly due to all the inequalities having been slowly levelled by worms. It is a marvellous reflection that the whole of the superficial mould over any rich expanse has passed, and will again pass, every few years, through the bodies of worms. The plough is one of the most ancient and most valuable of man's inventions, but long before he existed the land was in fact regularly ploughed, and still continues to be ploughed, by earthworms.”

Allied to the earthworm are many other forms, occurring in the earth, in fresh water, and in the sea. Along the whole New England coast, under stones below and above low-water mark, one of these (*Clitellio* by name) occurs in large numbers; it is very slender, about two or three inches long, and red in color, but these marine forms yield in interest to some of those occurring in fresh water. One of these is *Tubifex*, the tube-builder, which constructs its long tubes in the ooze at the bottom of ponds as well as in the aquarium. *Nais* is another small fresh-water genus, remarkable for its ability to divide itself into two individuals. Our cut shows a specimen, greatly enlarged, with this division going on. At the left end of the worm (which is crawling over a bit of fresh-water alga) is seen the head,

with its eyes and the long proboscis-like appendage, while at about the middle part of the body these are repeated. These latter belong to the new worm, which is about to separate from its parent.

FIG. 63. — Fresh-water worm (*Nais*) reproducing by fission.

The worms with many bristles (Polychæta) are almost exclusively marine; indeed, the only exception that suggests itself at the moment of writing is a form found in the Schuylkill River, near Philadelphia, to which the barbarous name *Managunkia* has been applied. The Polychæta are divided into two divisions, in which details of structure agree more or less closely with habit. The first group—that which follows out the main vermian line—embraces forms which wander freely through the water, or the mud and sand; the members of the second group are sedentary in habit; most of them build tubes.—sometimes of sand or gravel cemented together, sometimes of carbonate of lime,—and in these their life is spent.

Of the errant forms, the most familiar are the ‘clam-worms,’ the nereids of science. Of these there are many species, which sometimes burrow through the mud, while frequently they may be taken swimming at the surface of the water. They are well known to the clam-digger,—he throws them up by the hundreds as he digs for his clams.—but you

cannot persuade him that they are not the male clams. He *knows* they are. These clam-worms are beautifully colored; they are of a general greenish hue, but this is relieved by iridescent reds and yellows. Along either side of the body are complicated 'feet,' bearing bristles, while the mouth is provided with a formidable pair of jaws. for the clam-worm is a savage, predaceous animal, and his wanderings through the mud are in search of his prey.

FIG. 64. — Clam-worm
(*Heterouercis*).

Along with *Nereis* are other worms, one of which is noticeable from the fact that when caught it throws out a balloon-shaped proboscis, armed with four sharp hooks which are strong enough to puncture the human finger. This is a form known as *Rhynchobolus*. In *Nephtys* the proboscis is much shorter. It is an interesting sight to see these forms burrow. Placing one on the surface of the sand, it crawls about for a few moments, and then forces its proboscis beneath the surface, and then draws the body together, the proboscis serving as an anchor. Again the proboscis is forced forward, and again the body is drawn forward, until in a very few moments the whole worm is beneath the surface.

In others of these wandering worms the body is covered with large scales. Small species of these are abundant under stones below low-water mark, while from deeper water the dredge occasionally brings up a form four or five inches in length, in which the bristles are very long and highly iridescent, so that the effect is very beautiful. From the fact that these colors are not lost even after prolonged immersion in alcohol, it would seem that they are not produced by pigments, but are rather of the nature of diffraction spectra. To these larger scaly worms the term 'sea-mouse' is applied, although the reason therefor is not very evident. The hairs are too long, the body too flat, and the colors too bright to suggest the familiar rodent. The smaller scaly worms have their beauty as well, though this is not evident in the day-time. In the dark, when their scales are irritated, a beautiful green iridescence is seen.

There is one of these worms which is frequently taken in the skimming-net which, though small, has an interest for us. It is called *Autolytus*, and Mr. Alexander Agassiz over twenty years ago discovered the peculiar

features of its history. From the eggs there hatch out individuals which have no sexual organs, and hence would not be able to perpetuate the

species, were it not for the fact that they divide in almost the same way that does the *Nais* described on a previous page, and these worms thus budded off are male and female. This genus is also noticeable from the fact that it belongs to a family in which portions of the feet become long and jointed, thus simulating the structure which we shall find farther on among the Crustacea and Insects.

The tube-dwelling worms are modified to accord with their habits. Living as they do a sedentary life there is

FIG. 65.—Scaly marine worm (*Hermione*).

no necessity for well-developed feet, while the fact that they live in a tube necessitates the existence of structures to bring food within reach of the mouth and oxygen to the blood.

Among the least modified of these forms is the lob-worm (*Arenicola*), which is abundant, buried in the sand near low-water mark. It occurs on our coast north of Cape Cod, as well as in Europe. It is really beautiful. The body is a dark green, varied with a lighter yellowish brown, and studded with black spots, while the bushy gills shown in the figure are a beautiful dark red. With us this worm is regarded as of no account, but in Europe it is dug extensively, and used as a bait in fishing. Its burrows can readily be recognized from the peculiarly shaped coils of sand near them.

On the rock-weed one finds abundantly little white shells, coiled in a spiral much like that of a snail. These are the tubes of a small worm known as *Spirorbis*, while the dredge frequently brings up a very similar but larger form (*Serpula*)

FIG. 66.—Lob-worm (*Arenicola*) taken from its burrow.

from deep water. Several of these are shown in the foreground of the plate facing page 44, and there the reader can see the beautifully banded tentacles which project from the mouths of the tubes. Among these tentacles a larger conical structure is shown, which serves as a door to the tube. Disturb the animal, and in go all the variegated, feathery tentacles, this plug following them and closing the aperture completely. Almost identical structures, though on a smaller scale, are found in the minute *Spirorbis*.

FIG. 67.—
Tube of a
tube-worm
(*Cistenides*), com-
posed of
grains of
sand.

These serpulid worms construct the tube in which they dwell by a secretion of carbonate of lime. Others of the tube-worms are regular masons, taking particle after particle of sand or gravel, and building up their tube, using, instead of mortar, a cement secreted by themselves. One of the most common of these tubes is shown in Figure 67; others are formed of larger particles. One of these species — a long and slender form — lives on sandy shores, and builds long, straight tubes, which extend downwards to the depth of several inches. Frequently the sand around these is washed away, leaving the tubes projecting an inch or so above the surrounding surface, so that they present the appearance of stubble on a newly mown field. This form is known as *Clymenella*.

Though protected from sight by their tubes, these tube-worms embrace the most beautifully colored examples of all the great group of worms. There is not a color or a shade of color in the rainbow which cannot be paralleled among them, though most are ornamented with the more delicate shades rather than the more vivid colors. Some are one uniform color, while others are banded or spotted in the most agreeable manner. In the tropics some of these tube-worms live closely associated with the corals, and then their hues agree with the colors of the polyps around them. If these are green or purple, the worms are the same. This seems to be a protective resemblance, for no fish, however fond he might be of a diet of worms, would care to attack a coral.

There are many forms usually regarded as worms the exact position of which is very doubtful, but which need a moment's attention. First comes a curious parasite, known as *Myzostoma*, which lives upon the feather-star (*Comatula*) described on a preceding page. In general appearance it conforms but little to our conception of a worm, for it is oval and flat, shows no traces of joints, and is provided with pincers to hold it in place upon its host.

Phoronis is the euphonious name applied to a second of these forms,

which is remarkable for the wonderful change it undergoes in the course of its development. The young larva has a peculiar hood over the mouth, and below this is a circle of tentacles, while at the opposite end of the body is the vent. A peculiar pouch now begins to grow inside of the body; and then, at what is termed the critical period (Fig. 68, *B*), this pouch bursts forth and forms the bulk of the body of the adult, while the mouth and anal ends of the young are drawn close to each other as shown in Figure 68, *C*. The process may almost be summarized as a turning inside out.

FIG. 68.—Metamorphosis of *Phoronis*. At *A* is shown the larva with its whorl of tentacles (*t*); and at *p* the internal pouch; in *B* the pouch is in process of eversion; in *C* the pouch (only part of which is shown) now forms the greater part of the body, the tentacles and posterior extremity of the body (*a*) being drawn close together.

The 'whale's-tongue' worm (*Balanoglossus*) is also to be noticed. For many years a peculiar larva was known which was supposed to be a young starfish. Indeed, there was not the slightest doubt on the subject until Metschnikoff, a Russian naturalist, and subsequently Mr. Alexander Agassiz, proved beyond a doubt that it was the larva of a very peculiar worm comparatively common on our northern coast as well as on the shores of the Mediterranean. The subject was supposed to be settled until, in 1883, the development of another species occurring in North Carolina was studied. This, in its external appearance, closely resembled the more northern form studied by Mr. Agassiz, but, strange to say, has an entirely different life history. It does not have a metamorphosis; there is no larval stage suggestive of a young starfish, but the whole development is strikingly like that of some of the lower vertebrates! Where, in a systematic arrangement of the animal kingdom, we shall place the 'whale's-tongue' is a question not yet decided.

The rotifers or wheel-animalcules are another group the position of which is not settled. At various times they have been placed among the molluscs, the crustacea, and the worms. It now seems probable that their nearest relatives are to be found among annelid embryos, although in their general appearance they differ widely from them. Wheel-animalcules are very familiar objects to microscopists. They occur in both fresh and salt water, but most abound in stagnant pools. In size they rarely exceed the

head of a pin, but their transparence renders it an easy task to study their whole structure. In the typical forms there is a circle of cilia surrounding the mouth, and the rapid motion of these cilia gives one the same impression as a rapidly turning wheel, whence both the common and the scientific names. In others the circle of cilia is drawn out into lobes or slender processes, as shown in Figure 69, *B*, while in still others the cilia may be entirely lacking.

FIG. 69. — Two rotifers, one of which (*A*, *Brachionus*) leads a free life; the other (*B*, *Stephanoceros*) builds a tube.

In habits there is a considerable difference among rotifers. Some live attached to some submerged object, while others swim freely and rapidly through the water. Many of the attached forms build a protective case, which in most instances is gelatinous, but in one form (*Melicerta*) it is so peculiar as to deserve a moment's notice. That charming writer on natural history, the late Mr. Gosse, first described the way in which this case is built. The continual motion of the cilia of the animal drives the minute particles in the water to the mouth. Here the edible portions are swallowed, while the indigestible ones are formed into little pellets, fastened together by a glutinous secretion. Then the animal bends over and places this pellet on the supporting object. Again and again is the process repeated, until at last, just as the brick-layer erects a building, the animalcule constructs a circular wall around his body. In Figure 70 but a portion of this case is shown.

FIG. 70. — A tube-building rotifer, with a part of the tube removed to show the body.

Among the free forms of rotifers three kinds of motion may be seen. Most species only swim, the motion of the cilia propelling them gracefully and rapidly through the water. A few, however, progress with a looping motion like a leech, while still fewer have a jumping or skipping motion, which is effected by long arms which project from the body. Rotifers are especially noticeable from their power of withstanding desiccation. They may be so dried that their bodies will blow hither and thither with the wind, and yet a short soaking in water will revive all of their activities. This fact readily explains their presence in what are apparently the most unfavorable situations, as temporary roadside pools or the water in the gutters of buildings.

MOLLUSC-LIKE ANIMALS.

Two very problematical groups of animals are frequently united under the name Molluscoida, which means mollusc-like forms. The two groups are not nearly related to each other; indeed, many naturalists to-day deny that they have any connection, but until the question is settled it is convenient in a popular work to consider them together, especially since there is very little of general interest to say concerning them. In their general appearance they do not in the least resemble each other; one looks to the casual observer much like a bivalve mollusc, while the other bears a strong superficial resemblance to a coral. The members of the first group are called Brachiopods (arm-footed), the second Polyzoa or Bryozoa (many animals or moss-animals respectively). The brachiopods are all marine, but a large number of the moss-animals are found in fresh water.

The history of the various positions assigned to these two groups is worth mentioning, as it affords an excellent example of the way in which each new discovery changes our previous conceptions of nature. The position of neither is, as we have just said, still unsettled, but how long it will remain so is a question. For many years there existed not the slightest doubt but that the moss-animals should be ranked with the corals. They formed a calcareous skeleton containing numerous little pits, in each of which an animal was seated. This animal further resembled a coral polyp in that it had a circle of tentacles surrounding the mouth.

When a true study of these forms was instituted, it was soon realized that they had not the slightest affinity with the corals, but that in every point of structure they differed from them. The attempt was then made to find some other group with which to place them. In those days naturalists recognized only four great divisions of the animal kingdom; indeed, within very recent times it was considered the rankest heresy to suggest that there might, by any possibility, be more. Therefore if it were shown that the moss-animals were not radiates, they *must* belong to one of the other three great groups. It was readily seen that they were not vertebrates, and the question of their being articulates was settled as readily, and also in the negative. Therefore they could only be molluscs.

Now, in the then existing scheme of classification, the brachiopods were included in the molluscs from the simple reason that they had a bivalve calcareous shell, while all the differences between the animals were ignored. These brachiopods, for instance, had two long tentaculated arms near the mouth, and from this as a basis the moss-animals were associated with them, and were thus quickly transmogrified into molluscs. The next step was a study of the brachiopods. It was shown that in internal structure they had nothing in common with the clams and oysters, and that even the shell was very different. As we shall see, the shell of the clam consists of two halves, one placed on the right, the other on the left side of the

FIG. 71. — A brachiopod (*Lingula*).

body; but in the brachiopods, one half was placed above the body, the other below it. This study of the internal structure revealed several coincidences between the brachiopods and worms, and hence they were quickly declared to be worms. The Polyzoa were of course carried with them; for since their only claim to be considered molluscs rested on their

resemblance to the brachiopods, the separation of these latter and their union with the worms necessitated a similar course with the moss-animals. The next step was a questioning of this vermian relationship, and next of the relationship of the moss-animals and brachiopods to each other.

Brachiopods are to-day comparatively rare in the sea; but such was not the case in geological times, for in the older rocks they make up the great proportion of the fossils both in species and in specimens. On our whole east coast to-day only three species are at all abundant. In short, the group of brachiopods is dying out.

The moss-animals, on the other hand, are very numerous both in species and specimens. Rocks, shells, and sea-weeds below low-water mark reveal some of the forms forming a delicate lace-like network on the surface, or like the species figured here, known as "Neptune's frill," forming more substantial growths. This calcareous mass is not the product of one, but of many animals. If magnified, the surface shows innumerable little cells, each occupied by a polyzoan, just like the polyps in a bit of coral. The analogy goes farther, for these moss-animals increase like them by budding, and each colony, no matter how large it be, is the result of a single egg.

We have used the name 'moss-animals' several times. If we study a colony of some of the species, we at once recognize its applicability; for the multitude of animals, each protruding from its cell, presents a striking resemblance, in all but color, to a bit of moss. Many are the patterns of the animals, while each has a cell peculiar to itself. Possibly most interesting of all the structures connected with some of the marine forms are

FIG. 72.—Neptune's frill (*Retepora*).

the 'birds' heads.' These, as their name implies, are shaped like a bird's head, with its upper and lower mandibles, and under the microscope the student can see them open and close, now shutting on nothing, now grasping some worm that happens near. Many theories have been advanced as to the functions of these curious bodies, but none that is wholly satisfactory.

The fresh-water moss-animals are common in slowly running brooks and ponds, where they seek the shade, forming delicate branching filaments on the under side of stones, or large gelatinous masses on some submerged log. One needs to see them under the microscope to appreciate

their beauty. It is interesting to note that, like the fresh-water sponges described on a preceding page, they form 'winter eggs' or 'statoblasts,' to enable them to pass the winter months. These are not true eggs, but are to be regarded rather as modified buds. Each is enveloped in a hardened case, usually flattened, and resembling two watch-glasses placed together, and bearing around the edge a series of anchor-like hooks, the purpose of which is to prevent the whole from being washed away by the freshets of spring.

MOLLUSCS.

BOTH in number of species and importance of forms the molluscs far surpass any of the groups of animals so far enumerated in these pages. Many of them, like the oyster and the clam, have an economic value; others, like the ship-worm and the 'drill,' are to be regarded as injurious. Some furnish pearls, while the shells of others are of value as furnishing the material for cameos. In ancient times it was molluscs which furnished the celebrated Tyrian purple, while, in all probability, it is to the squid, eaten by the sperm-whale, that the ambergris is to be attributed.

The beauty and variety of the shells of the molluscs have rendered them great favorites with collectors ever since the revival of letters, and two hundred years ago every king had his cabinet of curiosities, in which shells occupied possibly the most prominent place. As time rolled on, the fever increased, and though it never reached the height of the tulip mania, still rare shells were a safe investment and brought high prices, of course not from any intrinsic value, but merely on account of their variety. Thus two hundred years ago, the shell known as the precious wentle-trap sold for forty pounds; to-day it is worth but a dollar or two. Even within twenty years some high prices have been paid for shells, sometimes fifty dollars for a single specimen, and that not because the species was extremely rare, but merely on account of a certain fashion.

These various considerations have led to a great interest in molluscs among scientific men which has evinced itself in an enormous literature, possibly greater than that devoted to any other subject of natural history, except birds and insects. Still, notwithstanding all the books and papers relating to the group, our real knowledge of it is relatively small. The species are well known, but more exact observations on the anatomy, embryology, and physiology are greatly needed.

The name Mollusc is derived from the Latin *mollis*, soft, and is descriptive of a molluscan character which, while very desirable in an oyster, is really of but little scientific importance. It is beyond our scope to enter into exact definitions, but in order to render the following pages intelligible, a few details are absolutely necessary. In the typical mollusc the body is produced on either side into a broad flap which, from the way in

which it envelops the rest of the body is known as the 'mantle,' while the lower surface of the body is produced into a 'foot,' which greatly varies in shape and size. The cavity between the body and the mantle is the 'mantle cavity,' and in this are usually the organs of respiration, and into

FIG. 73. — Diagrammatic section of a mollusc: *b*, gill; *f*, foot; *g*, genital organ; *l*, liver; *m*, mantle; *n*, nerve; *r*, kidney; *s*, stomach; *v*, heart.

it open the various reproductive and excretory organs. Figure 73 illustrates a transverse section of a typical mollusc, in which the features mentioned as well as others are represented.

As may be inferred by what has already been said, shells are very characteristic of molluscs. A shell is not to be regarded as the 'home' of the animal; it is an integral part of it; and, except in the case of the paper-sailor, no mollusc is able to leave its shell behind. The shell subserves two purposes: it acts as a rigid skeleton, thus giving the muscles greater efficiency, while at the same time it is protective. The molluscs are not quick in their actions; indeed, "slow as a snail" is proverbial; but enclosed in its calcareous armor, an oyster or a snail is as surely protected against external foes as if it were able to dart away like a fish, at the first sign of approaching danger. Still the protection thus afforded is not perfect, for

FIG. 74. — Diagrammatic section of a clam-shell, showing the way in which the successive layers (each larger than its predecessor) are deposited.

many of the fishes swallow the molluscs, shell and all, while, as we have already seen, the starfish has its own way of obtaining the meat enclosed in stony walls. Besides, there are some of the molluscs, as we shall soon see, which subsist solely upon their fellows, and are provided with instruments which perforate the hardest shell.

In some molluscs the whole outer surface of the mantle has the power of secreting shell, in others the secreting surface is more restricted, and a small number have no shell at all. The shell consists of a peculiar animal substance with which is combined a large, though varying proportion of carbonate of lime. The more lime present, the harder the shell; the less, the more elastic it is. The shell is not all formed at once, but during the life of the animal constantly increases in thickness and in extent. The secreting surface deposits layer after layer on the inside of the previously formed shell, thus increasing its thickness; but, at the same time, the mantle is continually growing and so each layer is larger than its predecessor, and consequently extends beyond it. This results in a series of parallel lines on the external surface—the lines of growth. In the

section of a clam-shell figured these points are illustrated diagrammatically. Thus, in a way, these lines of growth correspond to the rings of a tree, but it is impossible to correlate them with time—to declare the age of a certain shell by counting its lines of growth.

Shell has also its microscopical side, and according as the shell is pearly, horny, porcellaneous, or the like, so its minute structure varies. Our figure shows magnified sections of a horny shell (*Pinna*), and of a pearl. The latter deserves a moment's attention, since it illustrates well the feature to which pearls and all iridescent shells owe their peculiar beauty. As will be seen, the pearl is made up of a large number of thin, undulating, but still approximately parallel lines, and it is a curious quality of all such structures to break up light and produce a spectrum, just as does a prism.

FIG. 75.—Section *a* of a shell (*Pinna*), and *b* of a pearl, the former showing a prismatic structure, the latter the peculiar laminated condition on which the iridescence depends.

Indeed, the same means is used to-day in the physical laboratory in the study of light, parallel lines being ruled very close together upon polished steel or speculum metal, and these 'diffraction gratings' produce spectra better adapted for study than those caused by the prism.

Shells vary greatly in shape, yet all except the Chitons may be grouped in two categories,—the bivalves and the univalves. They also differ in color, all colors, except those of iridescence, being pigments secreted by the mantle. Though faster than most animal colors, those of shells are not absolutely permanent. The shells which were once the treasure and pride of Linnaeus, long ago lost almost every trace of their color and markings.

Molluscs reproduce solely by eggs. We do not find anywhere the slightest trace of that budding or fission which is so common among the worms, as also among the still lower types of animals. Yet it may be said that the molluscs and the worms have many points in common, and that the general structure of their common ancestor is well known. To-day we divide the molluscs into three great groups,—the Acephals, the Gasteropods, and the Cephalopods. Of these, the gasteropods seem to represent the central stem from which the others have diverged, and some of the lower gasteropods, even in their adult condition, clearly show their vermian affinities.

ACEPHALS.

The acephalous molluscs can be readily recognized by the bivalve shell, one valve being on the right, the other on the left side of the body, the two being hinged together on the back. There are, besides, many other and far more important characters common to all the group, some of which will appear below, while one may be mentioned now. In contradistinction to all other molluscs, the present group has no distinct head to the body; indeed, the term 'Acephal' is but the Greek for 'without a head.' Where the head should be there is simply a hole—the mouth—without any accessories beyond four fleshy flaps, which form a sort of funnel and thus increase the size of the aperture.

To better understand the general structure of one of the Acephals, and

FIG. 76.—A clam (*Mya*) in its burrow, with its siphons extended to the surface of the mud.

the way it lives, a description of some of the features of the common clam (*Mya*) of the New England coast is given. This clam lives buried in the sand or mud between tide-marks, the shell being sometimes twelve, or even fifteen inches below the surface. From this depth a chimney extends up through the sand to the surface, and this chimney is occupied by a fleshy tube, or, rather, a double tube, known as the siphon, which forms the sole medium of communication of the clam with the outer world. Through one tube there constantly flows a current of water, bringing the clam food and oxygen,—all it needs to supply its wants. Just as constantly through the other tube the current flows outward, carrying away with it the waste of the body and the eggs, which are destined to form other clams like the parent.

What is it that produces this constant current, always taking the same course? Cut open the clam, and examine it as closely as possible with the naked eye, and you will fail to see the impelling cause. It takes a microscope to see it. The mechanism consists of myriads of minute hairs or cilia, lining almost every part of the mantle cavity, each one keeping up a constant motion, and doing its part, no matter how small, in producing a current of water. When one, by the aid of a little powdered carmine, studies the currents flowing in and out of the siphon of a large

clam, noting their size and velocity, and then turns to his microscope, and sees the minuteness of the means involved, he is sure to receive a realizing sense of the greatness of small things.

The water in the mantle cavity flows over the two pairs of broad, leaf-like gills, conveying oxygen to the blood, and thence continues its course to the mouth, which selects the microscopical animals and plants so abundant in the water of the sea-shore, and swallows them. The gills just mentioned, two in number on either side of the body, arise from the angle of the mantle cavity, where the mantle springs from the body. In the oyster the gills are known as the 'beard.'

Others of the acephals differ considerably from the clam in many points. Some lack the siphon, while others have it but slightly developed; some live a life of freedom, wandering at will over the bottom of sea or pond; and many have the power to open or close the valves of the shell to a far greater extent than the clam. From one valve to the other pass one or two strong muscles, which, when they contract, draw the two halves of the shell. When they relax, the valves fly apart; but this is effected, not by muscular action, but by a spring at the hinge. The foot in the clam is small, and capable of being only slightly protruded; but in many forms it is much larger and more muscular, and is in fact as well as in name an organ of locomotion.

As they are usually arranged, the oysters are the lowest of the acephals, but scientific and popular estimation here differ considerably. Oysters are too well known to need illustration or extended description. The shells possess not the first element of beauty, but are extremely irregular in shape,—a fact which makes it difficult to say how many species there are. An oyster will start and grow for a while, and produce one style of shell, and then suddenly the whole tenor of life will change, and the shell will take on a new set of characters. Still it is now pretty well settled that all the oysters upon our east coast—whether short and broad or long and narrow, whether smooth or fluted—all belong to one species, while both Europe and our Pacific coast are each blessed with two species. Others occur in various parts of the world.

In times not very remote our oyster existed in abundance from the Gulf of St. Lawrence along the coasts of Maine and Massachusetts, and so to the Gulf of Mexico. At various points north of Cape Cod there are shell-heaps which mark the spots where, before the discovery, the Indian had his feasts, and in most of these heaps oyster-shells are found, occasionally, as at Damariscotta, Me., in great abundance, thus showing the former existence of native beds in close proximity. Even since the settlement by the whites beds existed at various points in Maine and on the

shores of Massachusetts Bay. To-day, except in one or two localities in the Gulf of St. Lawrence, there are no natural beds north of Cape Cod. Each year the oystermen of these regions bring a cargo of small or 'seed' oysters from the south, and 'plant' them in suitable localities along the shore. Here they live, and increase in size, but they fail to breed, and so each year the stock has to be replenished from more favored localities.

South of Cape Cod, and especially around the Chesapeake, the oyster breeds freely, and natural beds are abundant, but besides these large numbers are planted. The requisites for an oyster-bed are a hard bottom (old oyster-shells are good), fresh water, and an absence of quantities of sediment, which would soon smother the molluscs. Baltimore is the great centre of the oyster trade, employing thousands of hands. Philadelphia and New York stand next as distributing points. According to the census of 1880 the annual product of the American oyster-fishing amounted to over twenty million bushels, the first cost of which amounted to \$13,000,000.

Our American oyster is much larger and better flavored than the European species, and we export large numbers to England every year. They have to fight against a considerable prejudice on the part of the English, who feel willing to pay three times as much for their own 'natives' as for the American oysters. In Paris 'green' oysters are highly esteemed. In these the flesh is of a decidedly green color, to explain which, various theories—such as disease, presence of copper—have been advanced. It is now known that it is caused by an element in the food, a diatom very abundant in certain 'oyster-parks' in France, where at times it forms a thick green scum on the flats when the tide goes out. It does not appear that the color is in any way connected with any appreciable difference in taste, yet in Paris green oysters will bring a much higher price than the natives.

In the tropics there occurs an oyster which is said to grow on trees. It really grows on the roots of the mangroves in the swamps, and twice each day, as the tide ebbs, these oysters are left high and dry in the air.

The tinkle-shells, or, as they are also called, silver—or gold—shells (*Anomia*), are without economic importance, but are introduced here as an instance of the way in which for years inference will pass for demonstration. *Anomia* was regarded as an intermediate between the brachiopods and the molluscs, from the fact that, while it possessed the general structure of the latter, it was fastened to foreign objects, like a brachiopod, by a peduncle which passed through one of its valves. The similarity at first seems striking, but the peduncle is really totally different in the two

forms. In the tinkle-shell it is a 'byssus' (a structure exactly comparable with the byssus of the mussel, soon to be described). This at first passes out from the foot to the point of attachment between the valves; but as these grow, a notch is left for the byssus, which gradually becomes deeper, and at last is converted into a hole, through which the byssus passes. Our figure shows the young tinkle-shell at about the middle of the process. The scientific name, *Anomia*, refers to the irregularity in the growth of these forms, while the common name, tinkle-shell, refers to the musical note produced when several are shaken together; the other two terms refer to the colors of the dead shells. The living animals occur most abundantly attached to rocks or to other shells.

FIG. 77. — A very young tinkle-shell (*Anomia*), showing the large notch made by the byssus.

The scallops (*Pecten*), of which there are some two hundred species now living, are relatives of the oysters. The shells are flattened, and the hinge line is nearly straight, while the rest of the outline is circular, the surface being coarsely or finely ribbed, and sometimes beautifully colored. One species which is abundant on our coast from Cape Cod to Florida is extensively used as food, some esteeming it highly, while others do not relish its sweetish taste. In England two species are eaten, one being called scallop; the other, quin.

The scallops are noticeable from the fact that they possess well-developed eyes. Were these placed near the mouth, they would be of but little use, for they would be too far within the shell; but seated on the edge of the mantle, just within the margin of the shell, they are where they are of the most use. Other bivalve molluscs, like the thorny oysters, have eyes in the same position; but to those which, like the clam (*Mya*), live buried in the mud or sand, eyes in a corresponding position would not be of any advantage to the animal. In these forms the siphon is the most exposed portion, and here the eyes are situated.

FIG. 78. — Portion of the integument of the quahog, greatly magnified, showing the patches of pigment which is perceptive of light.

One must not think that these eyes are highly complex organs. They are really very simple. All that is necessary to form an eye is a refractive body, pigment to absorb the light, and nerves to carry the sensation to the central nervous system. In the clam and oyster these parts are present. In the proper places one can distinguish with the naked eye slight patches of dark pigment, and, when examined under the higher powers of the microscope, is seen to be made of cells covered with a refractive cuticle, and containing a deposit of pigment in their outer

ends. In the scallop the structure is more complex, a regular lens being introduced. These eyes can see but little. It is impossible that by their aid the mollusc sees as we see; all that is possible is merely a recognition of light and darkness. In the higher molluscs, as we shall see later, the eye is much more perfect, and able to recognize the shape of objects.

While on this subject of sense-organs, it may be well to refer to the ears of the acephals, for all are provided with them. These, like the eyes, are very simple, but they are more permanent in position, being situated in or near the foot. Each consists of a sac filled with fluid in which one or more solid particles are suspended. The sac is lined with ciliated cells, and has a nerve supplying it. The mechanism is simple; a noise jars the water, and sets the granules in the ear in motion, and these, hitting against the cilia with which the sac is lined, affect the cells, and these in turn communicate the motion to the nerves.

FIG. 79.—Ear of a mollusc (*Pterotrachea*), greatly enlarged. The concretion in the centre is set in vibration by the water, and hitting the hairs lining the cavity, conveys the sensation to the nervous centres.

Scallops and some allied shells have a peculiar style of locomotion.—a sub-aquatic flight it has been termed. They rapidly open and close the valves of the shell, and thus swim through the water with considerable rapidity.

The thorny oysters (*Spondylus*) are large forms, with very thick and heavy shells, one valve being much larger than the other. The name 'thorny oyster' has reference to the spines with which the outer surface of the shell is ornamented, and these in some species are very long and slender. One of the thorny oysters (*Spondylus regius*) is considered as a rare shell, and perfect specimens are extremely rare, so easily are the spines broken off. Indeed, during the present century a perfect specimen was sold in Paris for several thousand francs, and even in 1876 the same specimen brought thirty-six dollars. One species of thorny oyster produces pearls of value.

It is, however, to the true pearl-oysters that we must turn for the largest supply and most valuable pearls. They are natives of tropical seas, and occur in the Indo-Pacific and the Western Atlantic, beds of considerable size being found on the shores of Madagascar, the Persian Gulf, Ceylon, the western coast of Mexico and Central America, and in the West Indies. Externally the shells themselves are far from beautiful, but the pearly surface of the inside of the valves, shading off into dark brown or black at the edges, makes them very attractive. The shells themselves

have a considerable commercial value, as they are the source of the mother-of-pearl used for buttons, knife-handles, and various ornamental purposes.

The Pearl Islands in the Persian Gulf are said to produce the finest pearls, but the Ceylon fishery is the largest and oldest. In America, the fishery at La Paz, Lower California, stands first in importance, its fisheries having produced pearls to the value of a quarter of a million dollars, and shells worth as much more, in a single year.

In Ceylon, during the fishing season, each morning a large fleet of boats sets out for the pearl-banks, which lie about ten miles distant from

FIG. 80.—Pearl-oysters (*Meleagrina margaritifera*).

the northern shore. Each boat has a crew of about twenty-five men, ten of them being divers, who are divided into two gangs, — five resting while the others are below. For each diver there is a rope with a large stone sinker and a loop for the foot, while a large wicker basket to hold the shells is fastened farther up on the rope. Each diver further has a sharp knife to use against sharks in case his amulets prove of no avail. Arrived on the beds, work soon begins. Placing one foot in the loop of the rope, the diver is quickly lowered by the crew to the bottom. Here he works

as rapidly as possible, tearing the oysters loose with his hands and placing them in the basket. When his breath is almost exhausted he jerks the rope as a signal, and is quickly drawn to the surface, where, sitting on the rail of the boat, he rests while another is down. The depth at which the oysters occur varies between eight and thirteen fathoms, ten being perhaps the average. The pressure of the water even at this depth is very great, and upon first entering upon the life of a diver, the blood usually gushes from mouth and nostrils when one is drawn from the water. This failing is gradually overcome, and a constant life of this sort soon renders the divers able to stay below for an almost incredible space of time. It also produces another effect,—it ruins the health and brings on an early death.

One of the fishing-boats will hold about sixty thousand shells, and when it is full it stands in for the shore, and discharges its cargo. On the shore are the yards or pens where the oysters are allowed to die and decompose. These pens are quadrangular, and have a low earthen wall about them and a floor of beaten earth. Placed here, the oysters soon die, the operation being sometimes hastened by drenching them with fresh water. Soon decomposition begins, and then the whole decaying mass of flesh is carefully examined to see if there be any pearls loose in it, for these loose pearls are more apt to be perfect than those which adhere to the shell. After the flesh is disposed of, the shells are examined, and any pearls adhering to them are broken off with forceps. This of course makes a blemish, but the fractured surface is finished carefully with fine files, and then the pearl can be used in a setting without the flaw showing. Lastly, the whole floor of the pen is carefully examined, to see if any pearls may have fallen from the shells. The stench arising from these pens under the rays of a tropical sun is beyond description.

Here, on the north shore of Ceylon, the pearl fishery has been carried on almost exactly as to-day for two thousand years, and no one knows how much longer. For miles the shore is covered to an average depth of four or five feet with the dead shells of the pearl-oyster, and still the deposit goes on.

Pearls are abnormal products. Under normal circumstances the outer surface of the mantle secretes a nacreous shell, which is added to the shell already formed; but when a grain of sand, a parasitic worm, an egg, or some other foreign body gets between the mantle and the shell, it receives the secretion, which is probably stimulated by the irritation, and so increases rapidly.

The value of a pearl, like that of any precious stone, depends on several elements,—shape, color, size, etc. The finest pearls rarely exceed a

pea in size, but more or less imperfect ones, much larger, are common. The largest pearl known was two inches in length and four in circumference, and weighed three ounces and three-quarters. While the precious stones can have their value enhanced by judicious cutting, there is no such chance with a pearl. In a gem the beauty lies in the polish of the facets, but a pearl is not polished, and no art can make a surface like that of nature. White pearls are most common and most prized, but other colored pearls — red, purple, and black — are not uncommon. Recently black pearls have advanced in favor, and to-day command ten times their former price.

Many other molluscs besides the pearl-oyster produce pearls, but only those which have a pearly lining to the shell can afford pearls of value. It is not rare to run across pearls in the common oyster or clam, but these are always of a dirty white, and are absolutely without beauty or value. Many of the fresh-water mussels, on the other hand, have pearly shells, and these afford pearls, some of which are worthy of position alongside of those produced by the true pearl-oyster. As long ago as the Roman occupation of Britain, pearls were collected from the fresh-water mussels, and the same is true to-day; for in Scotland and Bohemia, as well as in other parts of Europe, the fresh-water pearl fishery is an industry of considerable importance.

In 1857 a pearl was found in a fresh-water mussel in New Jersey, which was sold by Tiffany & Co. for twenty-five hundred dollars. It is now in the possession of the ex-empress Eugenie, and is valued at ten or twelve thousand dollars. This find created great excitement, and all over the United States people went to examining the mussels in the streams and ponds, in the mad search for pearls. Some rivers were completely cleansed of molluscs, and the result was the finding in all of pearls to the value of about ten thousand dollars. Since that time the search has greatly fallen off, but each year some are found, Texas to-day furnishing the most. In looking for pearls in fresh-water mussels, one should neglect all the young and the perfect individuals, and examine only the old, sickly, and distorted specimens. The Indians knew that the fresh-water mussels produced pearls, and they also apparently prized them, for numbers of them are found in their graves and mounds. The largest find of this character was that by Professor Putnam, who exhumed over sixty thousand of them from a single mound in the Little Miami Valley, all of them so altered and decayed by their long sojourn underground as to be of no value, except as archæological specimens.

A curious belief regarding the origin of pearls is that given by Tonti, in 1698. He accompanied La Salle in his voyage down the Mississippi,

and while stopping with the Natchez tribe made the following observations: "There is a great many divers of that nation, who dive to the bottom of the water and fetch up these precious shells from the lowermost part of the rocks. On a fair day you may see the shells on the rocks open themselves to receive the dew of heaven, which dew breeds the first seeds of the pearl within the shells, which appear like little white grain that sticks fast to the shell. These small, soft grains do in time become hard and white, as we see they are. It is observed that the pearls which are fetched from the bottom of the sea are fairer than those which are found on the rocks, because the sun tarnishes these, and the thunder is destructive to their seeds."

Of the fresh-water mussels there are some twelve hundred so-called species scattered in all parts of the world; but nowhere are species and specimens so abundant as in the limits of the United States. Indeed, we have so many that naturalists have gone crazy over them, and described species after species upon the slightest variation in shape or color, until it seems as if every stream and pond — yes, almost every mud-puddle — must have 'species' peculiar to it. Yet, notwithstanding all this abundance of individuals and superabundance of species, notwithstanding good old Dr. Lea's thirteen ponderous volumes of "Observations on the Genus *Unio*," it would seem as if no other group of molluscs could be of as little value to man as this. Aside from its producing pearls and the occasional use of its valves for spoons by campers-out, the fresh-water mussel is useless. Its flesh is of no value, while it does not feed on forms injurious to human interests. It lives a lazy life, slowly ploughing through the gravel in the bottoms of rivers or the mud in the bottom of ponds, swallowing microscopic forms for food, and at the suitable time hatching out its half a million, or even two million, young.

These young, however, have a history which is interesting, since it furnishes almost the sole example of parasitism among the Acephals. When it escapes from the parent, the young fresh-water mussel differs extremely from the adult. It has a bivalve shell, as has the parent; but here the resemblance ends, for the shell bears on the free edge of either valve a strong, toothed hook. These embryos swim about through the water until they come in contact with a fish, the presence of which they are able to recognize by means of peculiar sense-organs, which subsequently become lost. Then the valves close together, and the hooks serve as an anchor, holding the embryo fast to the skin of the fish. Here it

FIG. 81.—Young (*Glochidium*) stage of the fresh-water mussel, showing the hooks by which it attaches itself to fishes.

undergoes a considerable metamorphosis, replacing almost every feature of its anatomy with new structures, until at last it drops from the fish to the bottom, and there slowly grows into the adult. The parent mussel is also capable of recognizing the presence of fishes; for if none are present, the embryos are retained for a long time in the branchial pouches.

The salt-water mussels are more like the forms already enumerated than are their fresh-water namesakes. They occur in all the northern seas south to about the thirty-fifth parallel of latitude. In some places they form enormous beds on the mud-flats, or attached to rocks and piles, seeming to prefer shallow estuaries, where there is considerable mud. On examining one of these mussel-beds, it is quickly seen that each individual shell is firmly anchored to some other object by means of a bundle of

FIG. 82.—Common salt-water mussel (*Mytilus edulis*) attached to a branch by means of its byssal threads.

silken cords. This bundle is the 'byssus,' to which reference has already been made. These silken threads are the product of a gland in the foot. When first secreted, they are fluid in nature, but contact with the water immediately hardens them. Besides serving to moor the shells, these byssal threads can even be used as organs of climbing. The animal extends its foot upwards as far as possible, presses it against some pile or rock, and then draws out one of these silken threads; again and again the operation is repeated, the elasticity of the united threads serving to lift the animal a little and allow him each time to extend his foot to a higher point on the pile than before. Gradually in this way the shell is lifted,

rarely an inch a day ; but time does not trouble the mussel. As he goes higher, the old byssal threads become useless : but the mussel is able to cast them off, for otherwise they would soon become an absolute bar against further upward progress.

The common sea-mussel (*Mytilus edulis*) is extensively eaten in Europe, but here is almost wholly neglected. On the shores of France there are immense 'parks' devoted to its culture. Stakes are driven into the mud, and between them the space is filled by wicker-work, which serves as a support for the molluscs. Here, nourished by the multitude of microscopic forms in the water, they rapidly grow, hanging down in large clusters. At intervals, when the tide is out, they are collected for the

FIG. 83.—Date-shells (*Lithodomus lithophagus*) in their rocky burrows.

market, the fisherman pushing his flat-bottomed boat over the slippery surface of the mud, between the rows of stakes, and picking the larger mussels from the basket-work, much as one would gather grapes from a trellis. Still, mussels are not very palatable ; indeed, they have been known to cause serious sickness.

The form illustrated in the cut above is a near relative of the species just described. It has received the common name, date-shell, but by naturalists it is known as *Lithodomus* (stone-house). This name is very appropriate ; for while the young *Lithodomus* anchors itself by a byssus, like the common mussel, the adult bores a hole for a home in the soft rocks which are found in the seas where it occurs. How it or the other boring molluscs excavate their burrows is a problem which naturalists have not

yet settled beyond a doubt. Various explanations have been advanced, but none are perfectly satisfactory. Some believe that the edges of the valves are the effective agents; but were this the case, one would expect them to be themselves abraded far more than they really are. Some suppose that the mollusc secretes an acid which softens or dissolves the rock; but no one has yet proved the presence of such an acid in the secretions of these burrowing animals, although they occur in a few other forms, which never form burrows. A third, and the most satisfactory, explanation is that the foot is the burrowing apparatus, and this receives some confirmation from the fact that in these forms it is covered with a hard cuticle. The operation may be accelerated by grains of sand getting between the foot and the rock, and by constant motion wearing away the substance. There is another feature connected with these burrowing molluscs, for which it is not easy to assign a reason,—all of them are highly phosphorescent.

Dreysseus was a celebrated Belgian physician, and his name modified into *Dreissensia* is given to a mollusc which we must not neglect. In shape it is much like a common marine mussel, and like it, it forms a byssus. It is, however, a fresh-water form. It was first discovered, in the Aral and Caspian seas, by Pallas, a naturalist who traveled in the East near the close of the last century. From the Caspian it gradually extended its range up the Volga and its tributaries, and in some way or other gained entrance to the European river systems, and to-day it is distributed over almost the whole of Europe. It is a most wonderfully variable form, and in the early days each naturalist who found it imagined he had something new, and hence it has been described under a host of names.

The largest of all living bivalves is the giant clam of the South Seas. Alexander the Great at one time sent a naval expedition to Southern India, which brought back many wonderful things, as well as tales, of what they saw. Among the other stories was one of an oyster so large that it required three bites (*tri daeno*) to eat it. Alexander and all his hosts passed away, but the story lived; and so when the explorers brought home specimens of the giant clam from the far East, there was no alternative,—they had to be called *Tridacna*. Still, the term is not strictly accurate, for it would require considerably more than three ordinary mouthfuls to make way with a clam, the fleshy parts of which occasionally weigh twenty pounds. The shells are proportionately large, and occasionally a pair of valves will be found which will weigh five hundred pounds. Besides the flesh (which is said to be good) the shell of the giant clam is of value to the natives of the coral islands of the Pacific. Stone is entirely lacking with them, but this shell takes its place. From it they make their knives,

axes, and war-clubs, all of a delicate creamy white color, and considerable hardness. Some of these axes will weigh seven or eight pounds. Mr. Forbes, in his account of the Cocos-Keeling Islands, speaks of "the giant clams of the genus *Tridacna*, whose mantle, edged with turquoise beads, forms a beautiful object to look down upon; but one must shudder for the diver who should accidentally thrust his head or limb into its gape, which the slightest touch causes to close with a snap." He also had evidence that one individual reached a length of twelve and a breadth of ten inches in three years.

Some of the heart-shells, or cockles (*Cardium*), are beautiful, both in shape and color, while others are less attractive. Some are good for food, and are eaten to a considerable extent in Europe and the East. In these forms the foot is large and peculiarly shaped, as is shown in the cut. It is,

FIG. 84. — Cockle-shell (*Cardium*) pulling itself along by its muscular foot.

in fact as well as in name, an organ of locomotion. The cockle will at times hook it around some stone or shell, and with this anchorage warp itself along; or, again, it will extend it to its full length and then, by suddenly bending it, will throw himself forward and over and over.

Next to the oyster and clam, the quahog (*Venus mercenaria*) is our most valuable shell-fish. It is distributed in abundance all along our eastern coast, from Cape Cod to Florida, and more rarely north of those limits. It frequents sandy bottoms, crawling along on the surface or burrowing just below. In edible qualities it is inferior to either of the forms mentioned above, but the length of time it will live after removal from its native element renders it a valuable species for shipment to the interior. Indeed, a few hundred miles from the shore it is *the* clam, and the far better *Mya* is absolutely unknown.

To the Indians the quahog was very important, for it furnished their black wampum, and wampum was a necessity with them. Wampum was bits of shell dressed to a circular outline, perforated and strung on cords. Some of the wampum belts were very large, containing thousands of beads. Wampum passed as money, but more important was the part it played in sealing contracts and confirming treaties. In a council one party would give the other a wampum belt for each article of the treaty, explaining as he did so exactly what its meaning was; and the tribes each had an officer whose duty was to keep these wampum belts and to remember the signification of each. Wampum was of two colors, white and black, the latter being twice as valuable as the other. The white was obtained from various shells; the black, almost exclusively from quahogs.

The long-clam (*Mya arenaria*) is a native of both continents, being especially abundant in the northern waters, and in favorable localities the whole surface of the sand-flats will be filled with their holes. In edible qualities the long-clam stands next to the oyster among shell-fish, and it is estimated, though the estimate is a mere guess, that the annual amount of clams dug is about two million bushels. In personal appearance the clam is far from beautiful: it has a coarse, dirty white shell, which is never large enough to cover the entire body, but from this portion protrudes a bit of dirty brown skin, from another the black 'head,' the whole being strikingly suggestive of a schoolboy who has outgrown his clothes. We have already described the way that this species lives buried in the sand; as it grows it enlarges and deepens its hole, which it can never leave. — it is a prisoner for life. Before taking leave of this species it may be well to remark that the so-called 'head' of the clam is in reality the siphon; acephals, be it remembered, are headless.

The common name razor-clam is highly appropriate for the long and slender shells which in shape, and frequently in color, resemble a closed razor. In science they parade as *Solen* and *Ensis*. They are not so abundant as the long-clam, and then, besides, they are not so easily obtained; these two facts explain why they are used so little as food. A clam-digger in digging the common clam has an easy task; he knows that just so far down are the clams, and they cannot run away. But with the razor-clam there is no such certainty. The common clam lives constantly at the bottom of his burrow, extending his long siphon to the surface for food and water; but the razor-fish has no such conveniences. He has to climb to the mouth of his hole for his daily food, and he has to dart to its depths for protection from danger, — and he makes these passages in pretty quick time for a mollusc. In digging them one has to be quick, for the clams are very alert, and have their senses well developed. On the slightest

alarm down they all go, and then the task of obtaining them is a difficult one. The common way of catching them is to try and grab them before they are aware of the danger, or with a spade, to cut off the bottoms of their burrows. These tubes are not vertical, but incline at an angle of about sixty degrees, so that a spade stuck vertically behind a clam at the mouth of its burrow is pretty sure to cut off its retreat.

The burrowing is peculiar: the process can readily be seen by placing a live razor-fish on the surface of the sand. First the foot is protruded, and its extremity drawn out into a sharp point, which is easily forced a short distance into the sand. Next the fluids of the body are forced into the foot, swelling out the portion which just now was so sharp and slender into an oval mass. This forces away the sand and also affords a foothold, so that the process can be repeated, the sharpened tip of the foot now being driven still farther into the soft sand. In a short time the burrow is so deep that the shell is held upright, and then progress is even faster than before.

The *Teredo*, or ship-worm, forms a marked contrast to all the molluscs so far enumerated; for while all these are of use to mankind, the *Teredo* is a positive injury: indeed, it may be regarded as, of all molluscs, the most injurious to human interests. It begins its life of destruction in a condition when one would hardly regard it as injurious. At this time its general appearance is shown in our cut, — a small spherical mollusc, not larger than the head of a pin, with bivalve shell, long and slender foot, and swimming freely through the water by means of the circle of cilia projecting from one end of the shell. Arrived at this condition, it must have wood or it dies. As

FIG. 85. — Young of the ship-worm (*Teredo*), before it begins its sedentary life, greatly enlarged.

soon as it obtains lodgment on a bit of timber, it begins its burrow, — how, no one knows, — and is soon beneath the surface. Here it grows rather rapidly, increasing more rapidly in size than in length, and excavating a nearly cylindrical gallery, which it lines with lime, in the solid wood. It does not feed upon the wood, as many have supposed, but receives its nourishment through the hole by which it entered the wood.

In this way hundreds of ship-worms will obtain entrance to the same bit of timber, and will riddle it in every direction by their galleries; and yet, strange to say, none of these tubes, no matter how contorted, will encroach upon its fellows. How it is that one ship-worm realizes the proximity of another, is a question. They also show a similar care against breaking through the sides of the timber, so that while from the surface

it may seem all firm and sound, yet it is in reality but a shell, the worms having honeycombed it in every direction.

It is a peculiar feature of animal pests that they seem to have no gradual growth into prominence, but seem to spring into existence at once. Of this we shall have numerous examples — the buffalo-bug, Colorado beetle, and many others — before we finish this volume. It is true of the form before us. All of a sudden in 1731-32 it appeared, and caused great damage to the wharves and shipping of Holland. A government commission was appointed to study its habits and check its ravages, but it was not very successful. Gradually mankind discovered methods of checking or circumventing the ship-worm, and to-day it is of far less importance than it was a century ago. Iron ships and copper sheathing on wooden ships are beyond its powers. Still, it has the wharves and smaller boats still left as its prey. Soaking with creosote is of but slight avail, but iron rust seems to be distasteful to them, and so timber covered with broad-headed nails seems tolerably secure. Paint containing copper or verdigris is also, to a degree, repellent to the ship-worm.

The piddock (*Pholas*), though greatly different in external appearance, is really a close ally of the Teredo. Like it, it is

FIG. 87. — Piddock-shell (*Pholas*) in its burrow.

FIG. 86. — Adult ship-worm (*Teredo norvegica*) taken from its burrow; natural size. The arrows at the upper end show the directions of the siphonal currents. The valves of the shell are shown at the lower end.

a borer, but it prefers stone or clay to wood for its excavations. We have several species of piddocks on our coast, but from their burrowing habits they are only occasionally eaten, and do not form an article of diet as they do in Europe.

GASTEROPODS.

There is quite a contrast between the gasteropods and the acephals. In the present group the shell consists of but a single valve (except in the chitons), and is usually, but not always, coiled in a spiral, — a feature

FIG. 88. — Chitons.

which destroys to a greater or less extent the symmetry so characteristic of other molluscs. There is also a well-developed head supporting the sense-organs, and the mouth with a very few exceptions is provided with a 'lingual ribbon' — a peculiar apparatus

for comminuting food — which is lacking among the acephals, but which reappears again in the squids and cuttle-fishes.

This lingual ribbon is really an animal file with teeth of quartz, and coiled up just inside the mouth. It is constantly growing at one end, to make up for the constant wearing away by use at the other. When in use, the ribbon and its supporting cartilages are advanced and pressed against the object, and then the ribbon is rasped over the surface, at each stroke taking off small particles of it. The pattern and number of teeth on one of these ribbons varies with the species, and hence characters derived from these organs are used to a considerable extent in systematic work.

The chitons are the only gasteropods with more than one shell; here there are several parts, one ranged after another, giving the body a banded appearance. The numbers of these parts never exceed eight. From a popular standpoint the chitons possess almost no attractive features, but to the naturalist they are among the most interesting of all molluscs, on

account of the peculiarities of their structure and growth. One feature must be mentioned. For years chitons had been studied, and every text-book stated them to be blind until, in 1884, Professor Moseley stated that some species were not blind, but that they had hundreds, and even thousands, of eyes scattered all over the back, and along with them were other thousands of sense-organs, also unknown before. With the growth of the animal the eyes also grow old, and the calcareous cornea becomes scratched and worn away, so that the optic apparatus is of but slight value; but at the same time new eyes are being developed at the free edge of the shell, so that the loss of the old is made good by the new. The chitons are all marine; some are small, others reach the length of a foot. On our east coast the species are few and small, but on the shores of California and farther north they are very abundant, both in species and individuals.

FIG. 89.—A section through an eye (*f*) and the large (*a*) and small (*b*) sense-organs of chiton. The lens of the eye is shown at *g*, and the retina at *n*.

The naked molluscs, the so-called Nudibranchs, are among the most beautiful animals in the sea. They are very abundant, and yet they are rarely seen except by the experienced collector. The reason for this is their wonderful protective coloration. On the green fronds of the sea-lettuce (*Ulva*) sharp eyes will occasionally detect a slug-like animal, as green as the plant on which it lives, while in the parti-colored hydroids occur naked molluscs whose hues and tints agree exactly with their surroundings. In a group where this protective resemblance is so well developed, it is hard to say what species show it best; one example seems to serve almost as well as another, but possibly the forms known as *Seyllaea* and *Dendronotus* are the most striking.

Seyllaea occurs on the gulf-weed which forms such banks in the tropical Atlantic. In its shape it resembles a bit of the gulf-weed, and the similarity is heightened by the lobes which project from the body. The color, too, is the same, and until the animal leaves the plant one but rarely is conscious of his presence. Even when it loosens its hold and sinks slowly through the water, it takes sharp eyes to recognize the difference between it and a bit of the sea-weed. The other form, *Dendronotus*, is more northern in its distribution, occurring on our shores as well as on those of Europe. Its general appearance is shown in our figure and it can readily be seen how easily the animal can escape observation

as it crawls over the Laminaria and the plant-like hydroids. Its colors are brown and white, in varying shades.

These naked molluscs are so called because they have no shells in the

adult; but it is perfectly evident that they have descended from shelled forms, for in the young they have a delicate shell, almost exactly like that of forms which are shelled through life. Some of their nearest relatives are always shelled, but none of them are of especial interest. We figure the shell of one of our east-coast species as the

FIG. 90.—Naked mollusc (*Dendronotus arborescens*).

type of a genus (*Bulla*) embracing the bubble-shells, which are very common in collections.

An enormous number of species of gasteropods, unlike the forms just mentioned, are adapted for breathing air. Inside the mantle cavity is a chamber, in the walls of which the blood-vessels ramify, and which, both in structure and function, closely simulates the lung of higher animals; and this fact renders the name Pulmonates especially applicable to them. The great majority of them are terrestrial in their habits, and most of the remainder are inhabitants of fresh water, only a very few being found in the vicinity of salt water.

FIG. 91.—Bubble-shell (*Bulla*).

The name snail, though used rather indiscriminately, in reality belongs to the species of the Linnean genus *Helix*, of which some thirty-five hundred forms have been described. Snails occur everywhere, from the poles to the equator, but reach their highest development in the tropics. They may be found in dense woods or in the open fields; in greenhouses and in cellars; and some are even given to climbing trees. They are almost exclusively vegetarians, although occasionally a taste for flesh crops out, and once in a while a snail will show that he is not above eating his fellows. The

FIG. 92.—Garden-snail (*Helix culicaria*).

fondness for a vegetable diet frequently renders them a pest in market gardens, and at times they have been so abundant and so destructive in Europe, that the power of the Church has been invoked, and by papal bull they have been excommunicated along with comets and other foes to mankind, which, of course, at once checked their ravages.

Snails do not make very attractive pets, since they are almost wholly lacking in intellect, and yet one by watching them can make numbers of interesting observations. They thrive well, and by feeding them with leaves, etc., one can readily see the way they eat and watch the operation of the lingual ribbon described on a preceding page, while by placing one on a bit of glass the peculiar processes involved in walking are easily seen.

FIG. 93. — Agate-shell (*Achatina*).

A few species of snails are used for food, and have been for thousands of years. The Romans bred them for the table, as do the French to-day. In France they are highly esteemed, but the English-speaking races, for some reason or other, do not take kindly to them. Some are imported from France, but it is impossible to obtain any statistics of the amount, for in the custom-house reports they are included under the head of 'fancy groceries not otherwise provided for.'

In the tropics the species of *Helix* and its allies are enormously developed, both in species and in individuals. Here grow huge *Bulimi* and *Achatina*, some of which lay eggs as large as a pigeon's, while in some of the islands of the South Seas the variety of forms is almost incredible. Thus the Hawaiian Islands are filled with varieties of the beautifully

banded *Achatinella*, while the Samoan Islands are, or were, almost equally rich in species of *Partula*. In both groups of islands these forms are being rapidly exterminated. In the Samoan Islands a tornado a few years ago destroyed the plants on which the molluscs fed, while in the Hawaiian Islands the same result is brought about by the sheep eating the low shrub on which the *Achatinella* subsisted.

Mention should here be made of the curious tropical slugs, which have no common name, but which figure in the pages of scientific works under the name *Oncidium*. They live on the shores of the ocean, above low-water mark, where they creep about and feed upon vegetable matter just like any other slug. Most remarkable is the fact that in some of the species living in the eastern seas, the whole back is covered with eyes, and these organs in their structure more closely resemble those of the vertebrates than those of the nearly related snails.

FIG. 94. — Pond-snails (*Lymnæa*).

Among the pulmonates are numbers of fresh-water forms occurring in every pond and slow-running brook. In external appearance they have little that is attractive. Their shells are horn color or dirty brown, and in life they are usually so covered with mud and dirt that even the little natural beauty they possess is hidden. Of these fresh-water forms, four types occur with us. One is that figured (*Lymnæa*). *Succinea* is much like it, only smaller; *Physa* is like *Succinea*, except that the shell is coiled in the opposite direction; while in *Planorbis* the shell is a flat spiral, like a watch-spring or a roll of tape. All these forms are air-breathers, and are not to be confounded with other fresh-water forms to be mentioned further on. All at intervals come to the surface to obtain a supply of oxygen, climbing up the stem of some plant to the air, and there opening their lung, expelling the air contained in it, and taking a new supply.

The slugs, so familiar in woods and in gardens, are also air-breathers, and, like the snails, are injurious to agricultural interests. Frequently the gardener finds some favorite plant cut down, and leading to it is a glistening track, which at once proclaims who did the damage. Apparently the slugs (*Limax*) have no shell; in reality they have a small internal one, which much resembles a fish-scale in appearance.

The limpets (*Patella*, *Acmæa*, etc.) are all marine, and, like all the remaining molluscs, they breathe by means of gills. In the tropical forms the shell shows no traces of a spiral, but is rather a low conical roof, covering the soft parts of the body. Limpets are everywhere common, adhering to rocks and shells. If we approach one carefully and suddenly try to pick him from his seat, we will be successful; but if he have warning, that broad, flat disc shown in the cut will adhere so strongly that the shell will break before the hold can be loosened.

A strange story is told of the limpets, and yet there is good reason to believe its truth. When the tide comes in, the limpet wanders off to find pastures of delicate seaweed coating the rock, until in some way or other he recognizes the fact that the tide has turned, and then he makes his way back to his former resting-spot, where he stays with his shell drawn close down until the tide again turns. How the apparently stupid animal knows when to return in order not to get caught away from home by the falling tide, and also how it finds its way back, are problems in molluscan psychology which have not yet been solved.

The ear-shells or, as they are called on our west coast, abalones, cling to the rock like the limpets. In their shape they but distantly resemble an ear, while a row of holes through the shell is a peculiarity by which these forms may at once be recognized. These holes are for the admission of water to the gills, and when in an expanded condition the gills can be seen to protrude. The holes appear as if punched through from the inside; and as the shell grows, the older ones are closed up by a deposit of lime, although the traces of the openings are not obliterated. Abalones are eaten in various parts of the world, and are described as "exceedingly nutritious, but indigestible." Their value lies not in their use as food, but in their iridescent shells. On the outside they are rough and homely, but

FIG. 95.—Under surface of a limpet (*Patella*), showing the broad foot (a), and the gill (c) surrounding it; natural size.

the inner surface is a rich red and green, which makes it valuable for papier-maché and lacquer inlaying. The trade in it is considerable, San Francisco alone exporting, in 1867, 7426 bushels, which were valued at thirty-six thousand dollars.

The wentle-traps (*Scalaria*) are noticeable only from the high prices which one of the species has brought in times past. To-day it is worth but a dollar or two, but a hundred and a hundred and fifty years ago it sold for one hundred or even two hundred dollars. It is not a handsome species, and nothing about it would indicate that it had any particular value. One of the volutes (*Voluta*), on the other hand, has brought high prices; but this species has a beauty of its own. *Voluta junonia* has sold for two hundred dollars, and even to-day will bring seven or ten dollars. Others of the genus are worth even more to-day.

The olive-shells (*Oliva*) have always been favorites with collectors, although they have never brought prices to compare with those quoted

FIG. 96. — Black olive-shell (*Oliva maurus*).

in the last paragraph. They have had to depend for favor upon their own beauty, and their polished and porcelain-like surface makes them very attractive. The mitres (*Mitra*) are long and slender, but bear but a slight resemblance to the mitre of a bishop. Both mi-

tres and olives live in tropical seas, the former being nocturnal in their habits. During the day they hide under some rock or bit of coral, but after dark they sallly forth to feed on other molluscs.

There are several molluscs which secrete substances suitable for use as dyes, but probably those from which the ancients obtained the celebrated Tyrian purple are entitled to the first place. There is considerable uncertainty as to the exact processes which were followed, but of some of the steps there is not the slightest doubt. In the rocky shores of the eastern Mediterranean there remain to this day the traces of the old dye-works of two and three thousand years ago. In the rocks still remain the excavations which served as mortars for bruising and crushing the molluscs, and in some of the mortars, fragments of shells still remain, so that we know beyond a doubt the species employed in coloring, although we may not be able to tell exactly the proportions of each used, an element which seems

to have considerable influence in the preparation of exactly the right shade of color. The species employed were *Murex brandaris*, *Murex trunculus*, and *Purpura patula*.

These shells were gathered in enormous quantities and broken in the stone mortars already mentioned. To the mass thus obtained soda was added, and then sea-water. At first the liquid was yellow, but under exposure to the sun and atmosphere it slowly changed until a purple color was assumed, the change being accompanied by the production of an odor much like that of assafoetida. When the purple color of the liquid was obtained, it was ready for dyeing; and wool dipped in it for a few hours would be indelibly colored. Some of the shades of color were very cheap, but others brought enormous prices, a slight difference in shade being frequently worth a great deal. Indeed, wool dyed one particular shade was enhanced one hundred times in value, while if not exactly that color was obtained, the increase in value by dyeing would not be a tenth as much.

Murex brandaris, one of the species just referred to, causes great damage to the shell-fisheries in Europe, and an allied form, the drill (*Urosalpinx*), is a pest on our own shores. The drill is but an inch in length, and yet the oyster succumbs to it. It settles down upon the oyster, and begins to bore through the shell. The boring-tool is the lingual ribbon described above, its sharp teeth cutting through the shell quite rapidly. Slowly but surely the shell is cut away, the hole produced being round and as neatly countersunk as if a mechanic had finished it. At last the shell is punctured, and the oyster falls a victim to its much smaller enemy. Many others of the predaceous molluscs bore through the shells of their fellows in exactly the same way as does the drill: and a casual walk along the sea-shore will show many shells bored and countersunk, which can thus be recognized as the remains of some molluscan dinner.

Our American purple shells (*Purpura*) are very common, and all secrete the same yellow fluid, which changes to purple; but no use is made of it now. Modern chemistry has produced colors from coal tar which are fully as brilliant as any produced by either the animal or vegetable world, and far cheaper than they. They may not be so permanent; but this matters little, for most of them will outlast the fabric colored by them.

The cones (*Conus*) have a shape well indicated by their common and scientific names. All the species are tropical or sub-tropical, the eastern seas being the home of the great majority of them. Their shapes and bright colors have long made them favorites with collectors, and in all museums the visitor will find large series of them. They also have another

interest. for they are the only molluscs whose bite is known to be poisonous. The teeth of the lingual ribbon are long and hollow, a structure

FIG. 97. — Poison cone-shell (*Conus textile*), with the animal extended.

which at once recalls that of the poisonous serpents; and it seems probable, though no exact observations have been made, that these are the means by which the poison is introduced into the victim. According to the Rev. W. Wyatt Gill, the species figured in the cut has been known to cause the death of a man by

its bite, while other species have often been accredited with producing severe and painful sores. Mr. Arthur Adams, the naturalist of the voyage of the 'Samarang' to the eastern seas, thus describes the effect produced by the bite of *Conus aulicus*: "Its bite produces a venomous wound, accompanied by acute pain, and making a small, deep triangular mark, which is succeeded by a watery vesicle. At the little island of Mevo, one of the Moluccas, near Ternate, Sir Edward Belcher was bitten by one of these cones, which suddenly exerted its proboscis as he took it out of the water with his hand; and he compares the sensation he experienced to that produced by burning phosphorus under the skin." *Conus marmoreus* and *Conus tulipa* are also known to poison, while the natives of New Britain frequently suffer from the bites inflicted by *Conus geographicus*.

Some of the cones are regarded as rarities by the collectors, and bring to-day high prices. In 1865 a large collection of shells was sold at auction in London, and some of the cones brought the following high prices: *Conus omaicus*, sixty dollars; *C. cedonulli*, ninety and one hundred and ten dollars; *C. cernuus*, nearly ninety dollars; and *C. gloriamaris*, two hundred dollars!

The cones are all predaceous, and live upon other molluscs, worms, and the like. Yet, notwithstanding their habits and their poisonous qualities, they are timorous in disposition. They crawl slowly and sluggishly over the coral reefs, and upon suspicion of danger they retreat into the numerous cavities in the bottom. The figure shows the conical ringed proboscis, flanked on either side by the tentacles, at the middle of which may be seen the eyes: while curling up over the shell is the siphon, by which water is conveyed to the gills.

The periwinkles, with their solid globular shells and their strictly vegetarian habits, contrast strongly with the forms just described. We have several small species natives of our coast, but within the last few years the genuine periwinkle of Europe has become acclimatized on our shores. How it first gained a foothold is uncertain, but once here it has rapidly increased in numbers, so that now from Nova Scotia to New York it is the most abundant mollusc. In 1857 it was first noticed by Mr. Willis, at Halifax; in 1870 it appeared on the shores of Maine; in 1872 it had reached Massachusetts; and in 1874 it had passed Cape Cod. It now occurs as far south as the New Jersey coast, but it is probable that temperature and other causes will soon put a limit to its further southward spread.

FIG. 98. — Periwinkle (*Littorina littorea*).

The generic name of the periwinkle is *Littorina*, a derivative from the Latin word *littus* (the shore); and most appropriate it is, for these forms are pre-eminently littoral in their habits. When the tide goes out, rocks, mud-flats, sea-weed, piles, etc., are covered with their slowly moving bodies. In Europe, the periwinkles are extensively used as food, but here they have not yet come into favor, a neglect doubtless due to an ignorance of their qualities. The orthodox way of eating them is to boil them and then extract the meat from the shell by means of a bent pin. They taste much like clams, but are much more delicate and tender. Their only fault is the small amount of meat in proportion to the shell.

In fresh water we find a group of pond-snails much like the periwinkles in structure, but, unlike them, of no value as food. They are almost solely confined to the temperate regions, the United States having many species. In all the shell is a dirty olive-green, and all bring forth their young alive. The generic name, *Paludina*, from the Latin *palus* (a marsh), is suggested by their habits. The somewhat closely allied Melanians, which are also inhabitants of fresh water, derive their name from the dark brown or even black shells, which are of a long conical shape. They are especially abundant in our Western rivers, where the variety of forms almost equals that of the fresh-water mussels, and, as in the case of that group, has given rise to an almost endless series of so-called species.

FIG. 99. — Pond snail (*Paludina*), with its body extended, as when creeping.

Of a somewhat similar shape are a group of marine shells which are parasitic or semi-parasitic in their habits, all occurring on echinoderms and molluscs. Some merely live on the surface of the host, but Professor Semper, who spent years in the Pelew Islands,

describes a species occurring there in which parasitism has produced considerable changes. Its proboscis has become greatly elongated and

adapted for piercing the skin of the sea-cucumber, on which it lives, while through disuse, its lingual ribbon, eyes, etc., have entirely disappeared. This degeneration is carried to its farthest extent in *Entoconcha*, a genus which occurs in Synapta, in the Mediterranean. The adult is strikingly worm-shaped, and lives attached, as shown in our figure, to the alimentary tract of its host. Indeed, were we to study the adult alone, there would not be the slightest suspicion of its being a mollusc; but its young are undoubted molluscs. They have every appearance of young molluscs,—the ciliated swimming-lobes, the spiral shell, and all. The life history of *Entoconcha* is unknown. The adult and young are familiar; but how the young obtains entrance to the body cavity of the host has not yet been discovered.

On a preceding page worms were mentioned which built a calcareous tube much like a mollusc shell, while among the molluscs there are forms whose shells are even more irregular than those of some of the worms. *Vermetus* is the name of the genus, and it is very

FIG. 100.—The left-hand figure shows a *Synapta* in outline, with the parasitic *Entoconcha* attached to the alimentary canal; the figure on the right represents the same, enlarged; the embryos being seen through the walls of the coiled parasite.

appropriate, as it implies the vermiform character of the shell of these aberrant forms. In early life these molluscs start off as well-behaved molluscs should, and build a regular spiral shell; but with increase in age

it would seem as if they became depraved, for the shell soon loses its spiral character, and twists about this way and that in the most independent manner; the specimens figured being pretty regular for a *Vermetus*.

The species of *Natica* have the common name of sea-snail. They are abundant on the whole New England coast, while the other species are found all over the world. The common New England species are large, with rounded, almost spherical shells. They occur on sandy shores, either in estuaries or where they are exposed to the full force of the sea, where they burrow along just beneath the

FIG. 101. — Shells of *Vermetus*.

surface of the sand, hunting for the clams and mussels on which they feed. Their mode of operation is exactly like that of the drill already described. At the proper season of the year their egg-masses are very abundant, scattered all over the flats, and from their peculiar appearance they excite no little curiosity on the part of the non-scientific. They have the common name 'sand-saucer,' but they differ from a tea-saucer in lacking a bottom and in the fact that the two ends never meet. Held up to the light, one can easily trace in them the different eggs of which they are composed, each appearing as a light spot in the surrounding sandy mass. Their peculiar shape is due to the method of their formation. The eggs, surrounded with a sticky envelope, come out in broad sheets from the oviduct, and then pass between the shell and the foot, which by their curvatures mould them into shape. As soon as they pass out, the sand adheres to the sticky surface, and in a short time they become hardened into their permanent shape.

The cowries (*Cypræa*) are tropical shells, possibly the most beautiful of all molluscs. They are covered with a porcelain like enamel, through which the plain, delicate hues or the beautiful markings are seen. Some two hundred species are known, some of which are among the rarities of collections, and in the great sale of 1865, which has already been quoted, specimens of *Cypræa guttata* and *Cypræa princeps* each brought two hundred dollars. One species (*Cypræa moneta*, the money-cowry) has almost value of itself, for through all the interior of Africa it passes for money.

It is not a rare species, and its colors — white shading into yellow — are not beautiful, but with the negroes it takes the place of gold, silver, and bank bills. Every year large numbers are brought from the South Seas to England, and thence shipped to the west coast of Africa to be used in trade with the natives; in one year some sixty tons being used. In Africa with a string of cowries one can buy almost anything. — gold dust, ivory, pepper, or a wife.

The cowries are all carnivorous, and in the tropics they play an important part as scavengers, as it makes no difference to them whether their prey be alive or dead. In this respect, however, they are excelled by the large and active strombs or wing-shells (*Strombus*), which are also tropical forms. One of the largest species occurs in Florida, and its rough shell with its delicate pink interior is one of the most common ornamental shells. While most molluscs crawl with a slow but gradual motion, the

FIG. 102. — Helmet-shell (*Cassis*).

wig-shells have a hopping or leaping mode of progression which sometimes throws it several inches from the bottom.

Last to be mentioned of the gastropod series are the helmet-shells (*Cassis*), of which some fifty species are known from the warmer seas.

One of them which occurs in Madagascar is used for the manufacture of shell-cameos. In this form the outer layer of the shell is white, but beneath it occurs a dark, almost black layer, and it is to this arrangement that the whole value of the shell for cameos is due. In the manufacture of cameos the shell is first cut into pieces of a suitable size by means of an iron wheel fed with emery or diamond dust after the manner so familiar in lapidary work. The artist takes one of these pieces and traces on it the outline of the figure to be reproduced, and then by means of fine chisels and files carefully works out the design. The thinner he makes the white layer, the more the black shows through, and in this way he works out the lights and shades. This operation requires great care, and at first the workman leaves every projection in excess, reducing

them as the work approaches completion. "Shell-cameos some years ago were a good deal in fashion; and even now a well-executed, artistic Roman shell-cameo is an elegant piece of art. Genoa and Rome are the seats of the best work, although many common ones are cut in France. In Rome there are about eighty shell-cameo cutters, and in Genoa thirty, some of whom also carve in coral. The art of cameo-cutting was confined to Rome for upward of forty years, and to Italy until the last twenty-six years, at which time an Italian began cutting cameos in Paris, and now over three thousand persons are employed in that city."

HETEROPODS.

The heteropodous molluscs are but little known except to naturalists. — a fact due both to their structure and their habits. They are almost perfectly transparent, and usually occur on the surface of the sea far from land. Some, like the form figured on the plate, have no shell, while in others it is well developed; but like the rest of the animal it is perfectly transparent. They are all predaceous in their habits, and play havoc with the other surface-swimming forms. They swarm at the surface at night, and at such times the fortunate naturalist who is situated so as to use a surface-net on the high seas receives his reward in individuals of this and the following group.

PTEROPODS.

The Pteropods, or wing-footed molluscs, are also pelagic; that is, they occur on the surface of the sea far from land. Only occasionally do they occur near the shore, and then their presence is to be explained by peculiarities of wind or current. This was the case where, a few years ago, the harbor of Portland was filled with specimens of *Clione*, a small form about an inch and a half in length. This species properly belongs to the far north, and in the Arctic seas it forms large schools which sometimes discolor the sea for miles. To the whalers this form is known as 'brit,' and through these schools the huge right-whales swim with open mouth, straining out these seemingly inconsiderable forms, and yet so abundant are they that the whales can live and grow fat upon them.

FIG. 103. — A Pteropod mollusc (*Clione*), which forms a large part of the food, or 'brit,' of the whalebone whales.

On reference to our figures the appropriateness of the name Pteropods (which means wing-footed) can readily be seen, for the wing-like projections on either side of the body are but the lateral expansions of the foot of the animal. By the aid of these wings they swim — one might almost say fly — through the water, some progressing in a steady manner, others jerking this way and that after the most erratic fashion. All are carnivorous and rapacious; and one begins to realize the amount of life in the sea when he considers the immense numbers of individuals necessary to keep the immense schools of brit alive.

The brit and some of its allies have no shell, but others of the Ptero-

FIG. 104. — *Hyalea*.

pods are shelled. In some cases the shell is thick and opaque, in others hyaline or glassy; sometimes it is straight and needle-shaped, sometimes coiled in a spiral, or, as in the *Hyalea* figured, almost globular. This form is abundant in tropical and semi-tropical seas, and is the genus most frequently represented in collections. It swims rapidly, but in a jerking manner, through the water, reminding one somewhat of the erratic flight of some of the smaller butterflies. Another genus (*Cymbulia*)

has a cartilaginous shell, shaped much like a slipper, and studded all over the surface with projecting points.

CEPHALOPODS.

The squids and cuttle-fishes form the group of cephalopods, the most highly developed of all the molluscan series. Here we find animals with eyes worthy of comparison with those of the human species; here the brain is partially enclosed in a cartilaginous capsule which at once suggests the skull of the vertebrates; here, too, the circulatory system acquires a high development. Among the squids we also find the largest of the molluscs, — huge monsters which seem to lend countenance to the old stories of krakens, devil-fish, and the like; but it is to be remembered that mere size is no criterion of rank in the animal kingdom.

There are two great groups of cephalopods: in one there is but a single pair of gills, in the other there are two pairs; and these features are correlated with a number of others which need not be discussed here, as

A HETEROPOD MOLLUSC (*Pterotrachea*).

they belong more properly to the more technical works on science. These gills, however, may be mentioned. Each consists of two tubes, one of

FIG. 105.—A gill of the cuttle-fish, to show the blood-vessels and the method of arrangement of the gill-leaves.

which conveys the blood to, the other from, the respiratory portions, which consist of delicate leaf-like plates, extending from one tube to the other.

Of the forms with four gills but a single genus now exists,—the genus

Nautilus. In geological time allied forms were common, even abundant. The older strata are filled with their shells, which figure in geological textbooks as Ammonites, Orthoceratites, and the like, some being of moderate size, others perfectly enormous. Some of the Ammonites have a coiled shell two or three feet across, while the straight Orthoceratites were occasionally six or seven feet long. One of these forms, found by Professor Newberry in the rocks of Ohio, weighed several tons.

The shells of the pearly nautilus are very common to-day; but the animals are still among the rarities of museums. Why this is so does not readily appear; for in the South Seas they are said to be common in water of moderate depth, crawling slowly over the bottom, or swimming like a squid by means of water expelled from the siphon. They are carnivorous in their habits, and are often caught in fish-pots and crab-traps. Possibly the fact that the natives of the South Seas are fond of them as food explains this rarity. There are several points of interest concerning their structure which need to be mentioned.

First is the peculiar shell. On the outside this is dull and opaque,

FIG. 106.—A section of the shell of the pearly nautilus (*Nautilus pompilius*), showing at A the chamber occupied by the animal, and at a the old chambers connected by a tube or siphuncle.

but the lining layers are as pearly as those of the pearl-oyster; and sailors take advantage of this structure to manufacture cameos from them. They paint the design on the surface with grease or wax and then immerse the shell in acid, which eats off all the surface not protected, leaving the design raised from a pearly ground. Even more interesting is the chambered structure of the shell, a feature found in the fossil as well as the recent forms. The animal lives in but a portion of the shell, and the rest is divided by trans-

verse partitions into a series of chambers, all connected together by means of a tube. No perfectly satisfactory explanation of this structure has yet

been advanced. It would appear, however, that there is a periodicity in growth, and at intervals the animal moves forward, building a new partition behind it. The chambers are filled with a gas which differs from common air in having a greater percentage of nitrogen; and the suggestion at once arises that these chambers thus have a buoyant function; but why the nautilus needs buoying up more than any other mollusc does not at once appear. The eye, too, is interesting. Every boy is familiar with the 'pin-hole camera.' He takes a pill-box, punctures the bottom with a needle, replaces the cover with a bit of ground glass or tissue paper, and then sees on the surface external objects in a reversed position. The eye of the nautilus is built on exactly the same plan. As shown in the figure, there is the same small aperture, while the ground glass is replaced by the retina, which is in connection with the terminations of the optic nerve. The cavity of the eye is in full communication with the exterior, and, of course, is filled with salt water. It is interesting to compare this figure with that of the eye of the quahog (Fig. 78) on a preceding page, and see really how slight are the modifications of the simpler plan.

FIG. 107.—Section of the eye of the nautilus, formed on the principle of the pin-hole camera. At *r* is the retina; *n*, the nerves. The opening above *c* is minute, and no lens exists.

Of the forms with but two gills there are two types: in the one, the cuttle-fishes, there are eight arms surrounding the mouth; in the other, the squids, there are ten of these arms, and associated with this difference in number are considerable differences in form of body, as will be seen by our cuts. In connection with the reproduction of these forms a very peculiar fact must be noted. Years ago the great French naturalist, Cuvier, found adhering to the body of a cuttle-fish which fell into his hands, a peculiar worm-like body which he had no doubt was a parasitic worm, and which he at once called *Hectocotyle* in allusion to the eight suckers by which it adhered to its host. Now the truth is known, and it has been placed beyond a doubt that this seeming parasite in reality is not a parasite at all, but is merely one of the arms of a male squid or cuttle-fish peculiarly modified for reproductive purposes. At certain times of the year the male matures its supply of milt, and then a packet of it is forced into one of the arms, which is then ready to be cast off and to adhere to the female, thus effecting a fertilization of the eggs. Before the next breeding season a new arm grows to take the place of the lost one.

We have just alluded to the suckers of the hectocotyle, and since these are very characteristic of the squids and cuttle-fishes, we may be pardoned a word concerning them. On all of the arms of squids and cuttles occur

little cups; sometimes sessile, sometimes elevated on peduncles, but varying in size according to the species and the position on the arm. Each cup has a fleshy rim, just inside which there is frequently a horny ring of hooks. In the centre is a movable piece controlled by appropriate muscles, and acting like the piston of a pump. The cuttle fastens its suckers on some object, the fleshy rim fitting close, and the horny hooks increasing the hold, and then the piston is drawn out, creating a vacuum, — the whole forming a prehensile apparatus of the most perfect description. The writer has frequently allowed one of the smaller squids to seize his fingers with this apparatus, and the feeling produced can be described by no other word than uncanny. It feels cold and disagreeable, sticky, shagreeny, and arouses sensations which cannot be put in words.

Squids and cuttles have other means of defence than these suckers and the parrot-like jaws which we must pass without further mention. This defence is furnished by means of the ink, so familiar to all as the pigment sepia. Close to the intestine is a gland which secretes a black or brown pigment in large quantities. When danger approaches, the animal expels the contents of this gland into the water, thus creating a dense cloud under cover of which it escapes. This pigment is almost indestructible, and fossil squids are found in which the ink-bag is perfectly preserved, and the contents of which only need mixing with water to be used by the artist. Indeed, the story is often told that Buckland, the English geologist, drew the picture of one of the fossil squids occurring at Lyme Regis, England, with ink taken from its own body.

FIG. 108. — Shell of the paper nautilus (*Argonauta argo*), reduced.

One of the most beautiful shells in the cabinets of collectors is that of the *Argonauta*, or paper-sailor, of which a figure is inserted here; but our cut fails to do justice to its peculiar delicacy. — no engraver could do that. It is almost as thin as paper, white in color, shading off into points and spots of a rich brown. This shell, however, is not to be regarded

as part of the animal, like all those which have gone before; it is in reality but a nest for the eggs. Among the *Acephals* and *Gasteropods* the body is connected to the shell by muscles, but here there is nothing of the sort. The female merely sits in the cavity during the breeding season.

This lack of connection between the animal and the shell led to many disputes in olden times. One party claimed that the shell was really the product of the animal found with it; the other, that the animal was but the occupant of a shell formed by some unknown mollusc. In the older works the paper-sailor was pictured and described as floating in its shell, like a man in a boat, over the surface of the waves, and holding up two of its broad and flattened arms like sails to catch the favoring breezes. It turns out, however, that there is more poetry than truth in the story, and that these arms, instead of being sails, are really specialized for the building of the shell. The paper-sailors are all inhabitants of the warmer seas, but they are occasionally drifted by the winds to the colder shores.

The *Octopus* is possibly the best-known, certainly the most maligned, of all the molluscs. It has served as the basis of many a weird and horrible tale, but nowhere has more injustice been done it than in the oft-quoted, oft-refuted description of the devil-fish in Victor Hugo's 'Toilers of the Sea.' Every one is familiar with his horrible monster, and the perfectly devilish way in which he closed upon and killed his victim, and yet no such animal as the novelist describes exists. There is a famous passage in 'Pickwick' describing the way in which an article on Chinese metaphysics was composed; the author consulted the encyclopædia for 'China' and for 'metaphysics,' and then combined the two. The French author confused the terms polyp (a term for Coelenterate animals) and poulpe (the *Octopus*); read the descriptions of each in the encyclopædia, then turned to the 'devil-fish,' one of the skates, and stole its name *Cephaloptera* for his new nondescript; and then, after adding certain other features evolved from his own inner consciousness, the whole account was launched to curdle the blood of the reader.

Still the *Octopus* has its own faults, and large specimens are disagreeable to meet under certain circumstances. In appearance they are far from prepossessing, as may be seen from the adjacent plate. Mrs. Hartt has told her adventure with one in the following graphic language:—

"It was during my first visit to Brazil, that one day, while busily engaged in examining a reef at a little town on the coast called Quarapary, my eye fell on an object in a shallow tide-pool, packed away in a crevice in the reef which excited my curiosity. I could see nothing but a pair of very bright eyes; but concluding that the eyes had an owner, I determined very rashly to secure him. I had been handling corals and seemed to have forgotten that all the inhabitants of the sea are not harmless. I put down my hand very quietly so as not to ruffle the water, when suddenly, to my surprise, it was seized with a pressure far too ardent to be agreeable, and I was held fast. I tugged hard to get away; but this uncivil individual,

whoever he was, evidently had as strong a hold on the rocks as he had on my hand, and was not easily persuaded to let go of either. At last, however, he became convinced that he must choose between us and so let go his hold upon the rocks, and I found clinging to my right hand by his long arms a large octopod cuttle-fish, and I began to suspect that I had caught a Tartar. His long arms were wound round my hand, and these arms, by the way, were covered with rows of suckers, somewhat like those with which boys lift stones, and escape from them was almost impossible. I knew that this fellow's sucking propensities were not his worst ones; for these cuttle-fishes are furnished with sharp jaws, and they know how to use them too; so I attempted to get rid of him. But the rascal, disengaging one slimy arm, wound it around my left hand also, and I was a helpless prisoner. In vain I struggled to free myself, — he only clasped me the tighter. In vain I shouted to my companion, — he had wandered out of hearing. I was momentarily expecting to be bitten, when the '*bicho*' suddenly changed his mind. I was never able to discover whether he was smitten with remorse and retired with amiable intentions, or whether he only yielded to the force of circumstances. At any rate, he suddenly relinquished his hold upon my hands and dropped to the sand. Then raising himself on his long, limsy arms, he stalked away towards the water, making such a comical figure, that in spite of my fright I indulged in a hearty laugh. He looked like a huge and a very tipsy spider, staggering away on his exceedingly long legs."

It would appear that Mrs. Hartt had an adventure with one of the smaller species of cuttle-fishes; for one form which occurs in the West Indies and the Mediterranean sometimes attains a length of nine feet and a weight of sixty pounds, while another species which is abundant in Alaska "reaches a length of sixteen feet, or a radial spread of nearly twenty-eight feet, but the whole mass is much smaller than that of the decapodous cephalopods of lesser length. In the *Octopus* above mentioned the body would not exceed six inches in diameter and a foot in length, and the arms attain an extreme tenuity towards their tips." Mr. Emerton has made paper models, life size, of this species, which may be seen in the museums at Cambridge and New Haven.

Professor Verrill has the following remarks upon the *Octopi*: "There is no satisfactory evidence that any of these species of *Octopus* ever intentionally attack man, or that any one has ever been seriously injured by them. They are rather sluggish and timid creatures, seeking shelter in holes and crevices among rocks. They feed mainly upon bivalve molluscs and crustacea, but will also eat fish, and may, perhaps, like lobsters and crabs, devour the bodies of persons who have been drowned. There

COMMON POULPE OR CUTTLE-FISH (*Octopus vulgaris*).

is good reason to believe that most of the supposed cases of *Octopus* attacking and drowning persons (like that of an Indian girl of the Oregon coast, often cited) are merely instances of accidental drowning or suicides, and that the presence of an *Octopus* is a post-mortem circumstance. Their power and ferocity, as well as their size, have often been excessively exaggerated."

The squids are characterized by a more cylindrical body and ten arms, two of which may be greatly longer than the rest. Some are common along the shore, while others are of rarer occurrence. Possibly the most abundant is the species figured here, which we may take as the type of the

FIG. 109. — A squid (*Ommastrephes ilicebrosa*) in the position it occupies in swimming backwards. The caudal fin is folded around the body, and the siphon, projecting below, is directed forwards. One-half natural size.

group. It occurs in large schools both north and south of Cape Cod, following the mackerel in their migrations and feeding on their young. Its shape is shown in the cut; its colors are very variable, and as one watches a specimen they may be seen to change almost instantaneously. At one moment the whole body will appear a dirty translucent white on which by closer examination minute scattered black specks may be seen; as one watches, this will give way to a delicate rose-colored blush suffusing one part of the body after another; or perhaps giving way to shades of purple, and then returning to the original translucent white.

This change of color is highly characteristic, not only of this squid, but of all the cephalopods. The mechanism can best be studied in very young individuals, so small that they can be placed under the microscope. It is then seen that the little black specks mentioned as visible on the white surface are really subcutaneous sacs of pigment capable of great expansion and contraction. When expanded to their fullest extent the layer of pigment becomes much thinner, and as the adjacent pigment-sacs almost touch, the color of the thin layer of pigment is given to the whole surface; when the sacs contract a little, the color becomes darker.

Squids do not live well in confinement, yet in aquaria they show many features which could not otherwise be studied. In this way one can observe the changes of color described in the preceding paragraph, and can also see the way in which they swim. The whole body up to just behind the eyes is enveloped in a muscular sac-like mantle, while from the

edge of this the tubular siphon protrudes. The animal fills the mantle-cavity with water, and then by violently contracting the mantle the water is forced out through the siphon, the reaction produced forcing the animal in the opposite direction. When the siphon is in the position shown in the cut, the animal will go backward; but the tube can be flexed in any direction, and so the squid can by means of it dart straight forward or move to the right or left. The whole of this swimming is well described by the term 'pumping.'

There is no sight more interesting than watching a small school of squid in their native element, from the deck of a vessel. As the young mackerel dart hither and thither, the squid follow them closely, now moving slowly, almost imperceptibly, now darting with the rapidity of a trout. As they pass from one kind of bottom to another.—from one of white sand to one of dark mud,—the color of every individual instantly changes so as to correspond to the bottom and render them less easily distinguished. Once in a while a person can see them catch their prey,—a sudden dart backward, a quick turn to the right or left, and a fish is in their tentacles, when a nip from the parrot-like beak cuts a bit from the neck of the victim. Squid are largely nocturnal in their habits, and occasionally in the morning the mud-flats will be found thickly covered with their stranded bodies. The fishermen say that like moths they are attracted by a light, and that often lured by the moon, they swim into shoal water, and that when they touch the bottom they begin a vigorous pumping which as often forces them on the beach as it does in the opposite direction.

Squid are extensively used by fishermen as bait, and it is said that cod will bite at nothing else as readily as at the flesh of these molluscs. Around Cape Ann the fishermen depend mostly on seining for their supply of squid, but farther north 'jigging' is resorted to, a process which has thus been described by Mr. H. L. Osborn: "The only gear is a peculiar hook called a 'jig' and a couple of fathoms of 'mackerel-line.' No bait is employed. The jig is of lead, two inches or thereabouts in length, armed at its base with sharply pointed unbarbed pins radially arranged, and curving upward and outward, as represented in the accompanying figure. The jigging is conducted in water of from eight to ten feet, usually from small boats, but occasionally from the vessel's side. The jig is allowed to sink nearly to the bottom, where it is kept constantly vibrating up and down, till the squid is felt upon it. Frequently two jigs are used, one in each hand.

"In its mode of taking the hook the squid differs from any other animal

FIG. 110. — Squid-jig.

I have ever met. In place of a nibble followed by a snap with the subsequent struggle for escape, there is a sensation as of some one grasping the hook with his fingers. The squid does not use his mouth in 'biting,' but merely clasps his tentacles round the jig. The pain from the sharp pins doubtless induces him to escape instantly, but the fisherman, who is constantly jerking the jig up and down, pulls in as rapidly as possible, entangling the squid's arms among the pins, and drawing him through the water so rapidly that escape is impossible.

"The instant he emerges from the water he contracts his body, discharging through his siphon a jet of salt water. This is followed by a sucking in of air by successive respiratory acts, till in its middle portion his cylindrical body has become almost spherical. By a second contraction, the squid now ejects from his siphon a stream of his black, inky secretion. He will usually make one or more contractions in an effort to escape, after which he becomes resigned. Not infrequently it happens that the luckless wight has not the squid unhooked before the inky discharge, and may have this sent at himself, since the siphon points away from the animal and upward. I have often seen a fellow struck full in the face by the inky stream, which event was invariably followed by a stream of almost as black abuse intended for the benefit of the squid. The squid is unhooked by simply turning the jig upper-end downward, when he readily drops off."

According to Mr. Osborn the squid sell from twenty-five to forty cents a hundred. "The number used by a single vessel in only two months is astounding. One vessel, a small one, made three baitings, fishing each time about two weeks, and used in that time eighty thousand of the squid. A larger vessel, carrying two more men, would in the same time have probably used over one hundred thousand. As to the whole number of squid used in a single season by Americans alone, I have not sufficient statistics to give an accurate statement; it would, however, be reckoned high in the tens of millions."

For many, many years the sea-serpent has been a favorite theme. Sometimes he appeared as a veritable snake, while among the Scandinavians he took more the form of a giant cuttle-fish. In one old picture one of these monsters is represented as scuttling a ship, its long arms being twined about the masts and yards, while the sailors very naturally are in a state of extreme fright. It was not, however, until recent years that anything authentic was known concerning the giant squid, but now they are known to exist in the North Atlantic, in the Japanese and Alaskan seas, and near New Zealand, while tales less authentic occur of their existence in other parts of the world; as for instance, one speaks of a dead one among the South Sea Islands "as big as a schooner." Those of the North Atlantic

are, however, best known, for which we are indebted to Professor Steenstrup, Professor Owen, and especially to Professor Verrill.

These giant forms are closely similar in general appearance to the common squid except that a pair of the arms are much elongated. In size they differ greatly. As yet no perfect specimens have been seen, all of them being more or less injured before measurements were made. Newfoundland seems to be their centre and now some thirty specimens have been recorded. The largest of all is thus described by the Rev. Mr. Harvey, of St. Johns :

“On the second day of November last [1878], Stephen Sherring, a fisherman residing in Thimble Tickle (Notre Dame Bay), not far from the locality where the other devil-fish was cast ashore, was out in a boat with two other men; not far from the shore they observed some bulky object, and supposing that it might be part of a wreck, they rowed toward it, and to their horror found themselves close to a huge fish, having large glassy eyes, which was making desperate efforts to escape, and churning the water into foam by the motion of its immense arms and tail. It was aground, and the tide was ebbing. From the funnel at the back of its head it was ejecting large volumes of water, this being its method of moving backward, the force of the stream by the reaction of the surrounding medium driving it in the required direction. At times the water from the siphon was black as ink.

“Finding the monster partially disabled, the fishermen plucked up courage and ventured near enough to throw the grapnel of their boat, the sharp flukes of which, having barbed points, sank into the soft body. To the grapnel they attached a stout rope which they carried ashore and tied to a tree, so as to prevent the fish from going out with the tide. It was a happy thought, for the devil-fish found himself effectually moored to the shore. His struggles were terrific as he flung his ten arms about in his dying agony. The fishermen took care to keep at a respectful distance from the long tentacles, which ever and anon darted out like great tongues from the central mass. At length it became exhausted, and as the water receded, it expired.

“The fishermen, alas ! knowing no better, proceeded to convert it into dogs’ meat. It was a splendid specimen. — the largest yet taken. — the body measuring twenty feet from the beak to the extremity of the tail. It was thus exactly double the size of the New York specimen, and five feet longer than the one taken by Budgell. The circumference of the body was not stated, but one of the arms measured thirty-five feet.”

The last paragraph describes the fate which has befallen many of these monsters. A specimen caught in Labrador was fifty-two feet in length,

the long arms measuring thirty-seven feet. This, too, was fed to the dogs. The New York Aquarium specimen alluded to was exhibited in all parts of the country, but not in such a shape as to give any one the slightest idea of its size or appearance when alive. Its tentacular arms were thirty feet long, and its body seven feet in circumference.

It is supposed that these huge monsters live in the depths of the fjords which cut up the Newfoundland coast, but rarely coming to the surface, and there is reason to believe that the few which have been recorded have not been in good health. These forms are frequently eaten by the sperm-whale, and for years the whalers have told their tales of these animals in their 'flurry' vomiting pieces of huge squid.

ARTHROPODS.

IN number of species, the present group far outranks all the other divisions of the animal kingdom. Statistics are proverbially dry reading, but a few figures will show how large the present group is. The molluses, which we have just left, are represented by about twenty thousand species in the whole world; there are about twelve thousand different kinds of birds, and ten thousand fishes; but these numbers are comparatively insignificant when we take the arthropods into consideration. Of beetles alone, one catalogue enumerates seventy-seven thousand and eight species; the bugs are estimated at fifty thousand, and the butterflies and moths at half as many more. In short, the total number of arthropods may be safely set at between a quarter and half a million species, and probably nearer the larger than the smaller of these limits.

The arthropods betray their vermician ancestry to a greater extent than do the molluses or the vertebrates. They have the same ringed body, and essentially the same internal structure as do the worms, but they have certain other features which mark them off strongly from their relatives. From a superficial point of view, the most prominent of these differences is that implied in the name of the group. Arthropoda is but the Greek for jointed feet, and all the members of the group, except those excessively degraded by parasitic habits, show, to even the most casual observer, this structure of the appendages. But if we study the development of the parasitic forms, even these are found to be no exceptions to the rule. for in their young stages their feet are jointed just like those of any other form. They have the same hardened skin, which is interrupted at points to allow one portion to move on the other; but with growth and the adoption of parasitic habits these are lost, to a greater or less extent, until, finally, in some forms the adult does not retain even the slightest character that would suggest relationship to the typical arthropods.

Concerning the arthropods there are many interesting and important points, but we must forego mention of all but two in this connection,—the compound eyes, and the wonderful metamorphoses through which many of these animals pass in acquiring their adult condition. There are several

distinct types of eyes found in arthropods, but our space will allow but a brief description of the compound eyes, a form which occurs nowhere else in the animal kingdom.

FIG. 111. — Section of a portion of a compound eye of a fly (*Musca*), greatly enlarged. The undulations of the upper margin represent the separate lenses, and each of the rods forms a separate optical and percipient apparatus.

As the name indicates, these eyes are composed of a number of eyes united together. As shown in the cut, each of these elements consists of a lens for concentrating the light upon the percipient portions, which are in direct communication with nerves from the brain. How an insect or a crab sees with one of these complex organs has not yet been settled. At first thought, it would seem that the production of so many images — one to each of the thousands of elements of the compound eye — would result in confusion. It would appear, however, from our present knowledge that each element can see only the object directly in front of it, and hence the impression on the retina may be regarded as a mosaic,

composed of thousands of distinct images. Further, it is probable that the vision resulting from this complex organ has none of the distinctness of that of the human eye; form is but very roughly seen, and the principal function of the organs is the recognition of color and differences in the strength of the light.

While many of the arthropods have a gradual growth, from the egg to the adult, — part after part forming in its proper sequence, thus, at first, sketching out the broader outlines of the adult, and then gradually working in the details, — others at first develop into forms which in nowise resemble the parents, and then suddenly change their whole appearance, the succeeding stage in nowise resembling its predecessor. This last is metamorphosis. Compare, for instance, the silk-worm, with its chrysalis enveloped in its silken house, and this in turn with the delicate moth which emerges from it, and which lays the eggs from which a new brood of silk-worms are to hatch, and one will see how enormous are the changes involved. One of the stages bears not the slightest resemblance to either of the others, but still generation after generation of these animals go through these seemingly useless modifications.

We shall recur again to these changes in the moths, and show how the changes are not so abrupt as they seem. In the crabs and shrimps similar modifications occur. The long-drawn-out embryo represented in Figure 112 does not apparently bear the slightest resemblance to the next figure,

FIG. 112. — Young (*Zoea*) of the porcelain crab (*Porcellana*), greatly enlarged.

but still it is the young of it. In the young the body is prolonged into spines, which, while they add but little to the weight of the body, so increase its size that it is not so easily swallowed by some of the other animals which frequent the same waters. These changes in shape, in both insects and Crustacea, are accompanied by a molting or shedding of the skin. The hardened external envelope of the body is rigid and does not stretch, while its structure is such that it does not admit of interstitial growth; but the animal is constantly feeding, and with assimilation of food there is a constant increase in size, and to accommodate this the integument splits at intervals, more or less regular, and the animal escapes from the opening, and soon becomes clothed with a new skin larger than the old, which gradually acquires the hardness of the one which was lost, and then in turn is cast off to be replaced by a new and still larger one.

FIG. 113. — Porcelain crab (*Porcellana*) developed from the larva shown in Figure 114.

As we have said, these molts are frequently accompanied by changes of form sometimes enormous in extent, but these changes are really more gradual than one would imagine were he to study merely the cast skins. When studying the embryos under the microscope, the naturalist sees the new shape gradually building itself up under the old skin, as is shown in the adjacent cut, which represents the outline of one of the mouth parts of an embryo mud-crab, inside of which the shaded portion shows the shape which will be assumed after the next molt.

FIG. 114. — One of the mouth parts of an embryo mud-crab, showing the outline of the skin soon to be cast, and within it the shape to be assumed after the molt.

The study of these metamorphoses is fraught with interest to the thoughtful naturalist, for they show him a record of the descent of the animals. The occurrence of this feature or that is an indication that

the ancestor of the form had those peculiarities in its adult condition, and by comparing the embryos of various animals he can perceive their relationship one to another. and can say at once which form is higher and which lower in the systematic scale. At the same time, in drawing his inferences, he has to weigh his facts and ascertain what of the features before him are of ancestral value, and what are adaptive; what are derived from the adult progenitor, and what have been acquired during the larval stages. Processes of this sort call for reasoning powers of the highest class. In mathematics one is forced to just such and such conclusions—he has no alternatives; but in natural history other elements enter in and must be weighed and estimated before valid conclusions can be drawn; and besides, there is always an unknown quantity and a considerable personal equation to be allowed for.

There are several well-marked groups of arthropods, the relationships of which are not yet settled, but for our purposes we may group them all in five great divisions, typified by (1), the crabs and shrimps; (2). the spiders; (3), the centipedes; (4), the six-footed forms like beetles and flies and butterflies; and, lastly, a peculiar form, *Peripatus* by name, the position of which is far from certain.

CRUSTACEA.

In their habits most of the Crustacea are aquatic; and although there are a few forms which live on land, in these the presence of moisture is necessary for respiration. The great majority of the aquatic forms live in the sea, the fresh waters having but few, and the land but an inconspicuous number of representatives. How many species there are in the whole world is very uncertain; it is usually put at two or three thousand, but this number is far too small. Of the single group of ten-footed forms, the North American seas alone contain about a thousand species, which would indicate not far from five thousand species of decapods from the whole world. With this as a basis, it seems safe to estimate that the whole number of species of Crustacea in the world cannot fall far short of ten thousand.

The central stem from which all the Crustacea seem to branch are some small forms known as Phyllopods, a name given in allusion to the leafy character of their feet. These forms are largely inhabitants of fresh water, and are especially well represented in the United States. West of the Mississippi River some of the species almost fill the ponds, while in the east their numbers, or variety, is not so considerable. In the

FIG. 115. — Fairy-shrimp (*Branchipus vernalis*), enlarged.

east the most familiar species is a delicate form occurring in early spring or even in midwinter, in pools in the fields and by the roadsides. It is about an inch in length, colored red, yellow, green, and purple, in the most attractive shades, while its outlines are so graceful and its texture so delicate, that no artist has yet been able to draw its portrait in a satisfactory manner. It swims slowly through the water with its back downward, and its leafy feet waving backwards and forwards with a perfect poetry of motion—turning now this way, now that, rising to the surface or descending to the bottom. It is, indeed, worthy the name

'fairy-shrimp' often applied to it, for no fairy could excel it in shape, color, or delicacy.

In some of the roadside pools formed by the melting snow these fairy-shrimps occur in great numbers. Visit the place a month later, and not one can be found; the pool itself has vanished, and its place is occupied by the young grass. Yet the next year the pool will be there, as the snow melts, and in it will be the same beautiful forms. The question at once arises, Where did they go and how did they return? The answer is a simple one now that we know the life history of the form in question. During their brief life they formed their eggs and dropped them on the bottom, where they remained through the summer's heat, to reproduce the species the next year. The parents died with the drying-up of the pool, but the eggs remained. A number of years ago a European naturalist wished to study the growth of these or allied forms, so he obtained a number and placed them in an aquarium. They matured their eggs, dropped them on the bottom, and then died. With the new year he expected to obtain the young and to study them. All through the summer and fall the water stood in the tank; winter passed, and spring came, but not a young fairy-shrimp was to be found. Another year passed, but brought no better results. What was the matter? Had the eggs died? or were the circumstances unfavorable? You would never guess the true reason. The eggs have to dry and then be moistened again before they will develop. The summer's heat does not injure them, but, on the contrary, is an absolute necessity. Since this fact was known, the study of these forms has become an easy task. All that one needs to do, is to take some of the mud from the bottom of one of the pools in which they live, dry it, and then put it in an aquarium, and the young will hatch from the eggs in the earth, in the greatest abundance. It was in this way that Professor Siebold, in Germany, was able to study forms from the interior of Africa, and Dr. Gissler, in Brooklyn, the development of a species from Kansas.

FIG. 116. — Young (nauplius stage) of the fairy-shrimp of Europe, enlarged.

These forms all pass through a metamorphosis in the course of their growth. From the egg there hatches out a curious larva, much like that shown in Figure 116, which, as will readily be seen, bears not the slightest resemblance to the adult. It has a single median jet-black eye, and but three pairs of appendages. Larval forms like this are very abundant in the sea, and have long been known. Years ago, be-

fore any one had the slightest idea that the Crustacea passed through a metamorphosis, these six-footed larval forms were regarded as adults, and were described as belonging to the genus *Nauplius*; and to-day this same term is retained to designate a peculiar larval stage, occurring not only in the development of the fairy-shrimp, but in many other Crustacea.

Forms closely allied to the fairy-shrimps, both in structure and general appearance, occur in all parts of the world. It is frequently stated that there is no life in the great Salt Lake of Utah, but this is not the fact; for one of these fairy-shrimps occurs there in immense numbers, along with larvæ of one of the flies to be described farther on. A similar form is found in the salt-vats at Syracuse, while another locality deserves a moment's attention. All along the New England coast, where railroads cross arms of the sea, tubs of water are kept on the bridges to be used in case of fire. As the water evaporates, more is added from the sea below, so that soon the tubs contain brine. In these tubs one frequently finds these same forms. Whence they came is a question. Nothing like them occurs in the sea, and where their eggs could have come from, no one knows.

Besides the fairy-shrimps two other types of leaf-footed Crustacea occur. In the one the body is enclosed in a bivalve shell which so closely resembles that of one of the molluscs, that did one not open the valves and see the shrimp inside, he would not have the slightest idea that it was a relative of the crabs. In the other type, the general appearance of which is shown in our cut, the anterior part of the body is covered with a shield, but on the under side are the same type of feet as in the fairy-shrimp. These forms occur somewhat abundantly in Europe. In the eastern United States there are none, but in the pools west of the Mississippi they sometimes occur in great abundance. It is a peculiar fact that among these forms males are but very rarely seen; indeed, of the European species *Apus cancriformis* no males were known until 1858. The late Professor Carl von Siebold of Munich, who studied these forms, hunted a long time for the males. "On one occasion he had the whole

FIG. 117.—*Lepidurus* (*Apus* lacks the paddle-like plate between the caudal appendage).

contents of a little pond removed with the greatest care, so as to feel sure that he had obtained every *Apus* present. He obtained on this occasion 5796 specimens of *Apus*, every one of which being carefully examined proved to be a female."

First among the offshoots from the Phyllopods comes a group of microscopic forms, some species of which may be found in every stream or pond, while in the sea their abundance is beyond description. In their essential features all are much like the *Cyclops* figured here, a form which is perfectly familiar to every worker with the microscope. For the amateurs it may be well to say that no one knows what *Cyclops quadricornis* is, and yet the name is used in every text-book and microscopic manual. The *Cyclops* and its allies have a peculiar style of locomotion. They use the long antennæ seen projecting from the front of the body as a pair of oars, taking a strong stroke, and dart quickly forward, and then settle down for a few moments, soon to rise again and go through its evolutions.

FIG. 118. — Fresh-water *Cyclops*, enlarged.

From *Cyclops* a long series of forms lead by insensible gradations from this free-living active form to those wholly given up to parasitism. In some of the parasites the departure from the normal type is but slight; one can readily distinguish in them all the parts of the *Cyclops*, and the various organs are but slightly modified. In others the degeneration and consequent degradation has gone so far that in the adult not the slightest crustacean feature can be recognized. All the jointed appendages are gone, or are modified into organs for holding to the host or sucking its juices; the eyes and other organs necessary for a free life have disappeared, and the body has acquired a disgusting worm-like appearance. A parasite can take life easy. It has no struggle for its food; all that is necessary is to sit still and suck the juices of its host. One would think that, from the crustacean point of view, such a life would be an enviable one, but it has its drawbacks. It involves a loss of personal beauty, it compels a stay-at-home life, and resolves the animal into a mere machine for digestion and the formation of eggs.

Fishes are especially affected by these parasites. They may be found with these unbidden guests fastened to the jaws, hanging from the gills,

or with the head deeply sunk beneath the skin. The poor fish cannot escape from them; turn and twist as he may, they adhere as tight as his own scales. They are found on fresh-water fish as well as on salt; in the Arctic seas as well as in the tropics. Some are small and inconspicuous, while others reach a length of several inches. How much pain and inconvenience they cause we have no means of knowing. It may be that their entrance and growth are so gradual that the fish is not seriously incommoded by them, but still it is probable that had he his own way he would not tolerate their presence.

Turning now from *Cyclops* in another direction we meet another series of forms microscopic in size and enclosed in bivalve shells. They progress through the water with a skipping motion, and at times they occur in such immense numbers as to fairly color the water in which they are found.

From the popular point of view they are of but little importance, but still they play their part in the economy of nature. Some of them feed on animals smaller than themselves, while others swallow anything that comes handy—decaying animal matter, the ooze from the bottoms of ponds, or the silt at the bottom of the sea. On this nourishment they wax and grow fat, and then perchance fall victims to the fishes. Indeed, many of our valuable food fishes obtain their whole food supply from these apparently insignificant forms.

The barnacles are still more distant relatives of the Phyllopods, and in treating of them we are following out one crustacean branch to its farthest limits. They are larger forms than the forms just mentioned, and hence there is more known concerning them and more to say about them. All of them are marine, and almost all of them are enclosed in a thick, hard, calcareous shell. This latter fact caused them to be regarded by the older naturalists as molluscs. What then was the surprise of the scientific world when, in 1830, Dr. John V. Thompson of Cork announced that these animals were Crustacea rather than molluscs. He for the first time showed the wonderful development through which they pass; the nauplius stage with which they leave the egg and the subsequent free-swimming life which ensues before they become attached. Twenty years

FIG. 119.—Two species of Crustacea (*Siphonostoma*) which occur as parasites on fishes. The young pass through a nauplius stage much like that shown in Figure 118.

later Darwin attacked the group and published a monograph in two thick octavo volumes which will never be superseded. In turning its pages or examining the plates one cannot but recognize the accuracy and thoroughness with which he did his work — characteristics which reappear in all his later works.

In marked contrast to this accuracy stand some of the old beliefs connected with these animals. The story has oft been told, yet so interesting is it that it will bear another repetition. It occurs in many of the works of the fifteenth, sixteenth, and seventeenth centuries, with minor variations, but with the same substratum of the marvellous. Gerarde, writing in 1633, says: "There are founde in the north parts of Scotland, and the islands adjacent, called Orchades, certain trees whereon doe growe certaine shell fishes, of a white colour, tending to russet, wherein are contained little living creatures; which shells, in time of maturitie do open, and out of them grow those little living foules, whom we call Barnakles, in the north of England Brant Geise, and in Lancashire tree geise; but the other that do fall upon the land do perish and come to nothing." This tale he relates not as coming to him by hearsay, but as something that he himself has witnessed. — "But what our eies have seen and hands have touched we shall declare." He gives a rude woodcut of the whole process, showing the geese inside the valve of the barnacle, and others swimming freely. "They spawne, as it were, in March and Aprill; the Geise are found in Maie and June and come to fullnesse of feathers in the moneth after. And thus having through God's assistance, discoursed somewhat at large of Grasses, Herbes, Shrubs, Trees, Mosses, and certaine excrescences of the earth, with other things more incident to the Historie thereof, we conclude and end our present volume, with this woonder of England. For which God's name be ever honored and praised."

The myth did not originate with Gerarde; Max Muller, in his work on the Science of Language, traces its whole course and shows that its source was in the similarity of names of bird and crustacean. Nor did it end with Gerarde; for Walton in his 'Compleat Angler' says:—

"So slow Boötes underneath him sees
In th' icy islands goslings hatched of trees,
Whose fruitful leaves falling into water
Are turned 'tis known to living fowls soon after.
So rotten planks of broken ships do change
To Barnacles. O transformation strange!
'Twas first a green tree, then a broken hull,
Lately a mushroom, now a flying gull."

The influence of the myth went even farther; for since the barnacle-geese were developed from barnacles, they could not be flesh, but were rather fish, and hence they could be eaten during Lent. This view was long held by both priests and the laity for five hundred years. The story was often contradicted, but still it lived and spread. Æneas Sylvius, afterward Pope Pius II., when on a visit to King James enquired anxiously for the barnacle-tree, "and complains, somewhat petulantly, that miracles will always flee farther and farther; for that when he came to Scotland to see the tree, he was told that it grew further north in the Orcades."

It would appear that the myth also took another shape in the far East, though its origin has not yet been pointed out. Sir John Maundeville, "Knyght of Ingelond, that was y borne in the toun of Seynt Albans, and travelide aboute in the worlde in manye diverse countreis. to se mervailles and customes of countreis, and diversiteis of folkys, and diverse shap of men, and of beistis," in the first half of the fourteenth century tells what he saw in Cathay:—

"And there growethe a manner of Fruyt, as thoughe it were Gowrdes: and when thei ben ripe, men kutten hem a to, and men fynden with inne a lytylle Best, in Flessche in Bon and Blode as thoughe it were a lytylle Lomb, with outen Wolle. And men eten both the Frut and the Best; and that is a gret marveylle. Of that Frute I have eten; alle thoughe it were wondirfulle: but that I knowe wel that God is marveyllous in his Workes." Maundeville also gives a figure, which we reproduce here after Professor Galton's copy.

The barnacles differ considerably in appearance. In one group the calcareous shells are directly attached to rock or pile; in the other, there is a long flexible fleshy stalk which intervenes between the body and the point of attachment. The former are known as acorn-barnacles, and are the most familiar examples of the group. On all the shores of the North Atlantic Ocean, both European and American, occurs the species figured in the adjacent cut. Almost every rock and pile, between

FIG. 120.—The Barnacle Myth, as given in Chapter xxvi. of Sir John Maundeville's 'Voiage.'

tide-marks, is covered. with their hard, white shells tightly closed with their folding-doors, when the tide is out; but when the water covers them, the scene changes. Each individual barnacle opens

FIG. 121.—Common acorn-barnacles (*Balanus balanoides*), slightly enlarged.

wide his ivory doors and extends a delicate feathery hand, which keeps constantly beckoning all small objects to enter and accept his hospitality. Alas for them that come. His invitation reminds one of the celebrated spider and fly. His constantly moving hand is creating currents in the water, and these bear him oxygen and food. When danger threatens, he withdraws into his shell and shuts it up, and it is a considerable time before he ventures out again, and then, at first, in a most cautious and suspicious manner.

In our northern seas, in deeper water, other acorn-barnacles are found much larger than this familiar form, but it is in the tropics that they acquire their greatest development. One form occurring on the coasts of Chili is nine or ten inches long and three or four in diameter. As may be seen, such an example would furnish a considerable amount of flesh, and the natives consume them to a large extent as food. Other species which occur in other parts of the world are also eaten; but none reach such a size as this South American form. Others of the allies of the acorn-barnacles live a semi-parasitic life, their choice of a habitat being often very interesting. Thus one species is only found on the large sea-tortoise which furnishes the tortoise-shell of commerce, while others are only found imbedded in the skin of whales, and still others on the branches of the sea-fan corals. These forms are not true parasites; they do not feed on their hosts, but take their food from the water just as do their more common relatives which whiten the rocks along our coast.

The barnacles with the fleshy peduncle are not so common in our seas as are the acorn-barnacles. The general appearance of the most common form in the warmer seas is well shown in our cut. The barnacles are represented as hanging down from a bit of floating pumice-stone, and from the lower ones the feathery arms are represented as protruding from the valves in the position they occupy when drawing water and food to the mouth inside the shell. Some of these forms may reach a length of sixteen inches. One species of stalked barnacle which is comparatively abundant along the New England coasts, and which is frequently thrown up on the beaches after a storm, has the power of secreting a bladder-like float for itself, and thus is independent of foreign support.

Possibly barnacles are best known from their relations to navigation.

some small forms, one of which is illustrated in our cut. These are small, inconspicuous forms of but little interest to any but the professional natu-

FIG. 123.—*Nebalia*, enlarged.

ralist, and are introduced here merely as an illustration of the fact that in nature there are no sharp transitions. As will be seen this animal bears a general resemblance to the fairy-shrimp figured on a preceding page, but there are certain other features superadded. Thus the anterior part of the body is enveloped in a shell, or carapax, as it is called, and this carapax, though occurring in other groups, is very characteristic of the decapods.

The term decapod means ten-footed, and almost all the members of the group are characterized by the possession of ten feet adapted for prehensile or locomotor purposes. They have besides twenty segments in the body, and the eyes are seated upon movable stalks which are short in most forms, but occasionally reach a considerable length. In size, although they embrace many small forms, they also include the largest of the Crustacea, or indeed of the Arthropods. A spider-crab which occurs in Japan has a proportionally small body, but its legs stretch out to a great extent, and specimens are found which, measured from the tip of one leg to the tip of the opposite member, will exceed twenty feet. None of the other forms begin to reach this size, but there are several which considerably exceed it in the size of the body.

Lowest of the decapods are the prawns and shrimps, which embrace a large number of species of both salt and fresh-water forms. Most of them are small, but one of the tropical species reaches a length of twenty inches from the end of the abdomen to the tips of the out-stretched claws. One

FIG. 124.— West Indian prawn (*Palaeomon jamaicensis*).

of these species from Mexico and Central America is represented one-fourth of the natural size in the cut. It occurs in great abundance in the fresh waters of that locality, and is used as food. In the northern seas occurs the true shrimp (*Crangon vulgaris*), which is found on both coasts of

America as well as in Europe. In color it is of a dirty, sandy hue, which while not pleasing to the eye is eminently adapted for its habits. It frequents sandy shores, advancing and retreating with the tide, now swimming actively back and forth, and now burrowing beneath the sand with only the anterior part of its body above the surface. Its colors are almost exactly those of the shores on which it occurs, and it needs sharp eyes to see the animals. In New England, where they are very abundant, they are but sparingly used as food, only appearing on the table in the form of shrimp salad, but in Europe and our Pacific coast they are extensively taken. The shrimper walks through the water, dragging behind him a net fastened to a short stick. His motions startle the shrimps, and they dart up from the sand only to be caught in the net. In France they are taken even more extensively, and frequently a horse is used to drag the net, which is much larger, and consequently adapted to take more of the shrimps. In California the business of catching shrimps is almost wholly in the hands of the Chinese, who boil them and then dry them for export to China. According to Mr. Rathbun the amount exported amounts to about one hundred thousand dollars annually, while two hundred thousand pounds are consumed by the Chinese in California.

In striking contrast to the shrimps, so far as color is concerned, are some of the deep-water forms. One species, which comes up in vast quantities in the dredge on the New England coast, is of a delicate translucent amber color banded and mottled with pink, while through the thin shell the beautiful green liver and the golden stomach are clearly seen, the whole presenting an appearance which charms the eye. Of habits, there is but little to be said concerning the shrimps. They are mostly uninteresting forms, yet there are two which deserve mention. First comes the genus *Alpheus*, of which there are nearly a hundred species. Many of these live a burrowing life, in sponges or in coral mud, and, as a consequence, the carapax completely covers the eyes, so that these organs can be of no use in distinguishing shape, but only in recognizing the varying intensity of the light. In all, one of the feet is greatly larger than the others, sometimes almost equalling the body in size, and the movable claw of this foot is frequently provided with a stout tooth which fits

FIG. 125. — Common shrimp (*Cragon vulgaris*).

into a corresponding cavity in the 'thumb.' When alarmed, these animals rapidly open and shut their pincers, and this tooth, acting like the pulling

FIG. 126. — *Alpheus heterochaelis*, showing the enormous development of the pincer; slightly enlarged.

of a cork from a bottle, makes a noise like that of snapping the finger-nails, and so loud that it is out of all proportion to the size of the animal. Other species of *Alpheus* are almost parasitic, and live, as do some allied genera, inside the shells of bivalve molluscs.

The other genus to be mentioned is like *Alpheus* in having no common name. In science it figures as *Spongicola*, and this name is very appropriate, as the animal is found within the cavity of the Venus's flower-basket sponge, as was mentioned on a preceding page. It obtains entrance when very young and still small enough to pass through the meshes of the sponge, but it soon grows so that it remains a prisoner for life. Another crustacean, which we will meet later in these pages, shares this habitat with the shrimp, and is even more abundant than it.

The lobsters and cray-fishes are near relatives of the shrimps and prawns, but they exhibit such modifications of their structure as to place them in a higher plane. When alive, the lobster is prettily colored, his shell being marked with green and purple, dotted and spotted here and there with bright red; while the size and strength of his large pincers render him formidable and rather dangerous to handle. There are three species of true lobsters (*Homarus*), but the differences between them are not appreciable by the layman. Our plate represents on the left the European species; but for all practical purposes, it will answer for the American as well. They are all found near the shore in water of moderate depth, and, like almost all crustaceans, are scavengers, feeding on dead and decaying animal matter. It is astonishing how quickly a dead animal will be cleaned of its flesh if put in the sea. It soon swarms with crustaceans of all sizes, from the large lobster and crab to the small and even microscopic forms, the smaller individuals making up in numbers what they lack in size.

Our American lobster is one of the largest of crustaceans. To-day extensive fishing does not allow it to reach its full size, and now it is rarely that big ones are taken. In former times they were not uncommon. The largest specimen which the writer has seen weighed twenty-five pounds, but he has also seen the claw of one taken years ago, at Gloucester, Mass., which was said to weigh thirty-nine pounds, and the size of this member

COMMON LOBSTER (*Homarus*).

SPINY LOBSTER (*Palinurus*).

was such as to give the statement probability. Massachusetts, New York, and Maine have each passed stringent laws limiting the size of the lobsters sent to the market, it being illegal in the former state to have in possession lobsters less than ten and a half inches in length, measured from the tips of the claws to the end of the body.

From New York to Labrador the lobster-fishery is an important industry. The animals are taken in 'lobster-pots,' — semi-cylindrical framework of laths furnished at either end with a cord netting, in the centre of which is the opening for the entrance of the crustaceans. Inside the trap is placed the bait, which usually consists of dead fish, always of some worthless sort like sculpins, cod-heads, etc. This attracts the lobsters and crabs, and they soon make their way in; but like rats in a trap, they do not so soon find their way out again. The traps, each anchored by a heavy stone, are sunk in favorable localities, — usually muddy or rocky bottoms, — and the position of each is indicated by a wooden float or buoy, marked with an initial or cipher indicating the owner. A fisherman will have from ten to a hundred of these pots, and each day he visits them, hauling them to the surface and taking out the catch, at the same time replacing the bait by new if necessary. It is made a crime to steal from the lobster-pots, and yet such depredations are frequent.

The lobsters caught are kept until needed for the market in large lattice-work boxes or 'cars,' which are moored in such situations that there will be an abundance of fresh water. The lobstermen handle them with great fearlessness, and but rarely do they 'plug' the claws. Occasionally this is done, a wooden plug inserted so that the claws cannot be opened, and hence the animal is deprived of all power of 'biting.' Still, notwithstanding their apparent carelessness, the lobstermen are always careful to pick the animals up in one way, and it is seldom that they get pinched. When needed for the market, the lobsters are plunged alive into boiling water and cooked, a process which converts their dark green body into a vivid brick-red. There is a celebrated picture of 'The Fisher's Return' in which the artist depicts red lobsters. It is needless to say that he went to the market for his models, for fishermen do not obtain boiled lobsters from the sea.

The bulk of the lobster-fishery is conducted on the coasts of Massachusetts, Maine, and the Maritime British Provinces. In Massachusetts most of the catch is sent direct to the market; but farther down East there are immense canning establishments which pack the lobsters in tin cans for shipment to the markets of the interior. Of these factories there were twenty-three in Maine in 1880, which that year put up some 9,500,000 pounds of lobsters, while the Provincial canning establishments used an even larger

amount. New York, Boston, and Portland are the great markets for the fresh lobsters, and in 1880 they handled 2,500,000, 3,637,000, and 2,000,000 pounds respectively. The total catch in that year was estimated at 4,315,000 pounds in Massachusetts waters, and 14,234,000 pounds on the coast of Maine; having a total value, fishermen's prices, of \$425,000.

So far we have had nothing to say of the physiology of the Crustacea, but there are many interesting features connected with it, which may be illustrated by the examples furnished by the lobster. Like the majority of aquatic animals the lobster breathes by means of gills, — delicate membranous outgrowths through which a transference of oxygen from the water to the blood is easily effected. These gills are concealed under the sides of the shell covering the interior part of the body, where, without special provision, the supply of water would be rather limited. To obviate this there is a broad plate in front of the gills which keeps constantly moving back and forth, at each stroke pumping a supply of water over the gills.

Lobsters, like all other ten-footed crustaceans, are provided with ears which are situated in the basal joint of the smaller feelers, or antennæ, shown in our plate. Each ear consists of a sac, closed on one side by a thin membrane, and provided internally with a row of hairs, each of which is in connection with a termination of a nerve. Inside of the cavity is a fluid in which are several minute granules. Any vibration of the water is communicated to the membrane, and this sets the granules in motion, and these, in turn, hitting against the hairs, affect the nerves. The structure is comparatively simple and doubtless has a very limited capacity. The

FIG. 127. — Opossum-shrimp (*Mysis oculata*), enlarged.

opossum-shrimp, figured here, presents a peculiar condition in its auditory apparatus, in that its ears are not near the head, but, on the contrary, are in the tail, where they are just indicated by the oval marking in the cut. This peculiarity recalls the fact that one of the relatives of the opossum-shrimp is said to have, besides the normal organs of vision, accessory eyes distributed along the sides of the body.

We have already alluded to the fact that the Arthropods, at intervals, molt the hardened integument. This with the lobster seems to be a serious operation; for, as the time approaches for the change of skin, the animal

retires to some secluded spot, where he is tolerably safe from danger in the defenceless condition which ensues. The first process is the absorption of the limy salts from certain parts of the big claws, for the shell of these is cast as well as of the rest of the body. At last the large anterior buckler, or carapax, splits down the middle, and through this opening the animal extricates himself, pulling out its abdomen, legs, feelers, and even leaving the lining of his stomach behind. Immediately the molt has taken place his new skin is very delicate, and the once formidable claws have lost their power: but quickly the salts of lime are deposited in the new skin, and it gradually becomes even harder and thicker than before. The flesh of the newly molted lobster is flabby and watery and not good for food, and it would seem as if a large amount of water was absorbed, so as to distend the new skin and allow the lobster room to grow inside it after it had become so hard and dense as to have lost all elasticity. Apparently connected with the molting is the formation of concretionary bodies of lime, one on either side of the stomach. They are of considerable size in the lobster, but only weigh a few grains in the cray-fish. They are composed almost entirely of carbonate of lime arranged in prismatic crystals; and it is supposed that they serve as stores of lime to harden the new integument. The argument, that because of their small size in the cray-fish this explanation cannot be the true one, lacks validity. The shell of the cray-fish contains far less lime than does that of the lobsters and crabs, and besides, it is not necessary that their integument harden so rapidly, for they are not exposed to nearly so many dangers and enemies as are their salt-water relatives.

The cray-fishes, of which there are a large number of species, are all inhabitants of fresh water. The forms are all much alike, and they so intergrade that the discrimination of species is a matter of much difficulty, and scarcely two authors are agreed in the limits of the various forms. Indeed, one naturalist, who had paid especial attention to the Crustacea, used to declare that "either we have but one species of cray-fish east of the Rocky Mountains, or else each mud-puddle has its own peculiar species." This of course was an exaggeration, but the fact that the latest revision of the group enumerates fifty-two species in the limits named shows that he had grounds for his statement. Some species live in rocky brooks, while others seem to prefer muddy streams, where they burrow in the banks and at times throw up towers of mud. This burrowing habit renders them nuisances at times; for they bore their way through dams and levees, making holes which the water soon enlarges into serious breaches.

In the southwest cray-fishes are extensively eaten, but farther north they do not occur in sufficient numbers to render them of economic importance. In Europe, and especially in France, they are cultivated for

the market in vast numbers, large ponds being devoted to the purpose. To catch them for the market, bundles of twigs are sunk in the ponds, and the cray-fishes seem to delight in crawling into the interstices, and are thus drawn to the surface. One of our American species deserves mention from the fact that it is found in the streams in the caves of Indiana and Kentucky, Mammoth Cave having furnished large numbers of specimens. Living in these absolutely dark abodes, eyes are of no necessity to it, and so these organs have become obsolete through disuse. Instead of the highly developed eye of their relatives, here barely more than the eye-stalks remain, while the optic nerve has dwindled to a mere rudiment.

In the plate opposite page 138 there is figured a spiny lobster, a form which usually occurs in warmer seas than the true lobsters. As will be seen, the differences between the two forms is considerable; in the one now under discussion the body is covered with strong spines, while the feet instead of being armed with pincers terminate in simple claws. In their development the differences are even more marked than in the adult. The young lobster bears a considerable resemblance to the adult, but who would suspect that the form figured here was the young of the spiny lobster? It is a flattened form scarcely thicker than a sheet of paper, and so transparent as to warrant the name glass-crab which is applied to it. Naturalists were for a long time

FIG. 128.—Glass-crab or leaf-crab, natural size. This crab, which is scarcely thicker than the paper on which this volume is printed, is the young of the spiny lobster (*Palinurus*) shown at page 139.

unaware that these forms were the young of the spiny lobsters, and it was not until 1857 that the true state of affairs was even suspected. The spiny lobsters frequent rocky bottoms, and in Europe and our southern states they are extensively eaten; the flesh and the eggs being esteemed as delicacies in the countries surrounding the Mediterranean. On the Pacific coast, where the true lobster is unknown, species of spiny lobsters take their place, and in speaking of them the adjective spiny is almost invariably dropped.

Possibly the most interesting of all crustaceans are those forms known as hermit-crabs. The hinder part of their body lacks the hardened integu-

ment characteristic of the rest, but is clothed by a membranous skin. This part is therefore extremely vulnerable, and hence the animal protects this part by inserting it in the deserted shell of some mollusc. So long has this habit been followed that the abdomen has become distorted, and has taken a spiral form. The form figured in our plate occurs in Europe as well as on the American shores, and may be taken as the type of the nearly two hundred known species. When young it inhabits a shell proportionate to its size; but as it grows it needs larger quarters, and many interesting accounts have been written of the hermit on his house-hunting expeditions, or, better, of his search for a new cell. He goes about dragging his old shell with him, and turning over every empty shell he meets, apparently sounding its depths and measuring its size with his stony claws. The chances are that it does not suit him; it is either too large or too small, and so he goes along until he finds another vacant tenement, which is examined and measured as before. This time, perchance, it suits, and then in an instant he leaves his old home and takes up his residence in the new, moving with him being quickly performed, and lacking the inconveniences and discomforts of our first of May. In the foreground of our plate this transfer is represented in the very act.

At times two hermits will find the same shell at the same time, and then they show themselves close imitators of the doughty 'Friar Tuck,' who proved himself a muscular hermit in the days of Robin Hood. Both want the house, and neither will give in: whether they resort to words to settle their quarrel is uncertain; but no such doubt attends the fact that they immediately proceed to blows. Pincers are flourished in the most excited manner, nipping off here a feeler, there a leg, until at last one is vanquished, and the other, unless too badly maimed, proceeds to occupy the house which is his by right of conquest.

In our latitudes all the hermits are marine; but in the tropics some are terrestrial in their habits, dragging their heavy shells over rocks and sand in the open air, as do our northern forms beneath the sea. One of these terrestrial forms, while a hermit in structure, is not so in fact. In almost every feature it is like the forms living in shells; it is, however, much larger than any of them, and since its abdomen is hardened, it does not require to protect itself like the others. It is most abundant about the palm-trees in the islands of the South Seas, and from this fact it receives its common name palm-crab and cocoanut-crab: its scientific name is *Birgus*. It makes its nest in burrows which it digs in the earth near the shore, and inspired by a desire for softness or for warmth, it lines its hole with the outer fibre of the cocoanut. Mr. Forbes, in his account of this species in the Cocos-Keeling Islands, describes its habits in a way which

contradicts many of the wonderful details given in most books concerning it. He says: "It has a habit of climbing the cocoanut palms, but whether to take the air or for temporary lodging is doubtful; it does not rob the trees, however, as has been charged against it, since it feeds only on fruits that have fallen. One of its pincer-claws is developed into an organ of extraordinary power, capable, when the creature is enraged, of breaking a cocoanut-shell, or a man's limb. The inner edges of the claw are armed with a series of white enamelled denticulations whose resemblance to teeth is singularly close, even to the irregular scarlet line below them, which might pass for gums. The *Birgus* feeds on the nuts almost exclusively, using its great claw to denude the fruit of the husk surrounding it, and to get at the eye of the nut, which it has learned is the only easy gateway to the interior.

"Of the three eye-spots seen at the end of a cocoanut, only one permits an easy entrance. The *Birgus* does not waste its energies in denuding the whole nut, and it never denudes the wrong end. Having pierced the proper eye with one of its spindle ambulatory legs, it rotates the nut round it until the orifice is large enough to permit the insertion of its great claw to break up the shell and triturate the contents, whose particles it thus carries to its mouth by means of its other and smaller cheliferous foot.

"From this nutritious diet it accumulates beneath its tail a store of fat which dissolves by heat into a rich, yellow oil, of which a large specimen will often yield as much as two pints. Thickened in the sun, it forms an excellent substitute for butter in all its uses. I discovered it to be a valuable preserving lubricant for guns and steel instruments. And only when a small bottle of it which I had had for two years was finished, did I fully realize what a precious anti-corrosive in these humid regions I had lost."

There is one feature, however, which is even more strange than any of the tales—true or fictitious—told of the habits of the palm-crab, and which, farther, is an undoubted fact. The palm-crab spends all its time on the land, and this habit has developed new structures, unknown in any other crustacean. It has the normal crustacean gills, but besides these organs of respiration there is developed a peculiar organ richly supplied with blood-vessels, and which acts exactly like a lung.

All of the forms of decapods, so far mentioned, have a large abdomen, sometimes exceeding the rest of the body in size; in all those to follow—the true crabs—the abdomen is much smaller, and folds away on the under side of the body, so that one, at first sight, does not recognize its presence. In their development but few of the decapods have a nauplius stage, but most of them pass through another type of development with its peculiar

embryonic forms. One of these stages is known as the *Zoea*, a name used at first, just as was the case with nauplius, under the belief that the animals included were adult. For the discovery of their true relations we are indebted to Mr. Thompson, who also was the first to discover the metamorphosis of the barnacles. Previous to his time two or three had studied the growth of the cray-fish, which passes directly from the young to the adult condition by gradual stages and without any abrupt transitions; and hence when Mr. Thompson, in 1828, published a memoir, entitled "On the Metamorphosis of the Crustacea, and on *Zoea*, exposing their simple structure, and demonstrating that they are not, as has been supposed, a peculiar Genus, but the Larva of Crustacea!" the amount of discussion provoked was considerable. Every naturalist at once proceeded to controvert him, citing this or that fact and this or that authority as being totally opposed to him and his views. But at last the correctness of his observations were acknowledged, and the Crustacea were recognized, not, as had been stated in the *Encyclopædia Britannica*, as undergoing no metamorphosis; but, on the other hand, as being the group where metamorphosis was most nearly universal. Our figure shows the general type of *Zoea*: the long dorsal spine is characteristic of most of the crabs.

FIG. 129.—*Zoea* stage of common European crab.

We have already figured one of the porcelain crabs and its young on a preceding page (Figs. 112 and 113), and we only need to refer to them here as being among the most beautiful and cleanly of all the decapod hosts. As both their common and their scientific

names (*Porcellana*) indicate, their shell has the appearance of porcelain, while its bright colors and the scrupulous care with which they keep it clean adds to its beauty. In contrast to these forms are some other tropical species known as *Dromia*. They seem to delight in keeping their

FIG. 130.—A Chinese crab (*Dromia*), with a sea-anemone on its back. See page 30.

bodies covered and concealed by all sorts of foreign objects. Sometimes the back will be covered by a waving grove of hydroids or by the irregular

mass of a sponge. One species occurring in the Eastern seas always bears a large sea-anemone on its back. Doubtless this association of forms works to the advantage of all concerned.—sea-anemone, sponge, or hydroids tend to conceal the crab from its many enemies, while at the same time they obtain many a good meal from the crumbs dropped from the crab's dinner. A somewhat similar condition occurs in the genus *Hypoconcha*, the two species of which inhabit the seas of tropical America. Their backs are not hardened; but are soft like the abdomen of the hermit-crab, and hence need protection. This is effected by hiding the body beneath a shell (*hypo-concha*) of some bivalve mollusc, and this shell is borne about wherever the crab may wander. In the true hermit-crabs the coiled abdomen and its calcareous plates are well adapted to take a firm hold of the shell which protects their weak point, and in *Hypoconcha* there are means for holding the protective valve in place. The hinder part of the body is shaped to fit in the angle beneath the hinge of the shell, while two pairs of feet are bent upwards and hold the shell down in much the same way that a man holds his hat on his head in a high wind.

FIG. 131.—Spider-crab (*Inachodes hemphilli*) of the Pacific coast.

The spider-crabs receive their common name from their spider-like appearance. The body is comparatively small, while in most cases the legs are long and slender, frequently far exceeding those shown in our cut. Of the spider-crabs there is an immense series, almost all of them being inhabitants of the warmer seas. One of them (*Macrocheira*) we have already referred to as the largest of all crustaceans. It occurs in the seas surrounding the islands of Japan, and seems to be somewhat rare.

Most common along our Northern Atlantic and Pacific coasts are the species of rock-crabs and shore-crabs (*Cancer*), large, heavy forms which possess but little to interest any except the professional student except in edible qualities; but in this point they excel, as is well recognized on the Pacific coast, while on the shores of the Atlantic they are largely neglected, a fact which may be due to the abundance of other edible forms. Among these others may be mentioned the celebrated 'soft-shelled crabs' so highly esteemed by epicures. These are merely specimens of a species of swimming-crab (*Neptunus*) taken immediately after the molting, and while the

new integument is in a thin and delicate condition. At other times the shell is hard. These swimming-crabs crawl about like the others, but they are also capable of swimming freely by means of the broad, flattened paddle on the last pair of feet, shown in the figure, which represents a species from Panama. Some of these swimming-crabs live a pelagic life, being found on the surface of the ocean far from land. One small species is very abundant in the fronds of the sargasso which forms large banks in the tropical seas.

FIG. 132.—Swimming-crab (*Araneus bidens*).

In our oysters we frequently find a small, thin-shelled crab which proves a very acceptable morsel. It has the scientific name *Pinnotheres*, and 'thereby hangs a tale.' The ancients frequently found within the valves of one of the Mediterranean molluscs, *Pinna* by name, a small crab to all intents and purposes like our oyster-crab. Its presence there needed explanation, and so arose the story that it was the *Pinnotheres*, the guardian of the *Pinna*. It lived within the shell, and kept a sharp lookout for danger, and when any enemy was seen approaching, it warned the mollusc, which straightway closed its shell and rendered all safe and tight. The story contains more poetry than truth. The crab is really an intruder which seeks protection inside the valves of the mollusc, and it is a peculiar fact that it is only the female which selects this retreat. She does not eat the mollusc, but lives on whatever of food and fortune the passing currents may bring.

The fiddler-crabs are near relatives of this little form, but they lead a free and active life. They are amphibious, and one walking along a sandy shore where they abound, startles up large numbers of them, myriads hurrying and scuffling in the most amusing manner in their hurry to seek safety in the sea. As they go along, their large claw is brandished about in the most threatening manner, while the other smaller one works across it like the bow of a violin. Fiddler-crabs make attractive pets in confinement. All that is necessary is to provide them with plenty of moist sand and food suited to their demands. They will quickly construct their burrows in their new home, carrying up pellets of sand with some of their smaller legs, and dumping it as far from the burrow as the limits of their prison will admit. Their natural food is largely vegetable, and they scrape

up large quantities of the smaller algæ for food. They are not averse to decaying animal food, and in confinement when one of their number dies, all the fleshy portions are quickly devoured. I have fed them on moistened cracker, and they lived on it for months.

Once one of the old sea-captains of New England was amusing himself and me by relating the many marvels he had seen in all parts of the world. Some of his stories were not very marvellous, and yet I know that the imagination entered at least largely into them. At last he told one so strange that he thought I would doubt it, and yet I could vouch for its accuracy. In the days of the discovery of gold in California, he was taken sick while crossing 'the isthmus,' and was kindly nursed by an old negro woman. One day she said: "This is the week when the crabs go to the sea"; and sure enough, on the very next day the woods and the fields were filled with large, rapidly moving crabs, all travelling as fast as possible to the shore. What it meant or where they came from the old sailor was unable to say; but I told him that not only on the Isthmus of Panama, but in the West India Islands, there were several different kinds of land-crabs which spent their whole life in the woods and mountains, going only once a year to the ocean for reproductive purposes, and devastating the fields through which they pass. With these forms, the highest of the group, we leave the series of decapods.

As a transition between the decapods and the fourteen-footed Crustacea, may be mentioned the curious mantis-shrimps of the warmer seas. Their bodies are rather weakly put together; but their colors are unusually bright and gay. They live burrowing lives on muddy bottoms or amongst the coral sand, and unlike most crustaceans they deposit their eggs on the sea-bottom instead of carrying them about with them. To the anatomist and embryologist they afford many interesting features; but so little is known of their habits that they interest others only by their bizarre shapes.

With the sharp spines on their claws they can inflict rather severe wounds, while the tip of the abdomen is also used as an organ of offence and defence.

FIG. 133. — Sow-bug (*Porcellio*).

In comparison with the decapods in size, numbers, and interest, the fourteen-footed crustaceans occupy an inferior position. Possibly the most familiar of them are the terrestrial sow-bugs, which swarm in moist earth, in the woods, in gardens, and in cellars. They are not especially interesting,

but they have their value in that they feed on decaying vegetable matter, thus consuming much which might otherwise become offensive. Like most of the Crustacea they breathe by means of gills, which are shut in by folding-doors beneath the tip of the abdomen.

These gills, however, are adapted for breathing air in a way not usually recognized in text-books. When we come to take up the insects, we shall find that their bodies are permeated by tubes for conveying air to all the parts, and in the gills of these forms we see an outline of this structure, for they, too, contain air-tubes somewhat similar in structure to, but different in origin from, those of the insects.

It is in the water that these fourteen-footed forms acquire their greatest development. Everywhere the sea-shore teems with them, some being flattened forms much like the sow-bugs, others being laterally compressed. Of the latter group the beach-fleas, which are so abundant beneath the masses of sea-wrack thrown up by the waves, are most familiar. Their name is eminently appropriate, for they rival the true fleas in their leaping capacities. Turn over a bit of this refuse on the beach, and they will be seen in numbers, some awkwardly trying to escape by shuffling along on the side of the body, others by leaping to the most astonishing distances. Farther down, in the region which is never exposed by the retreating tide, are other forms, some interesting, some commonplace. Some play the rôle of hermits, occupying tubes which they either find or which they construct for themselves, while others live protected by other animals. Thus when one examines our large jelly-fishes, he is almost certain to find in it some of these forms which eat a home for themselves in the tissue of the disc, where they live and raise their young. It seems strange that they should escape unharmed in this home, for all around them hang the long tentacles each armed with its myriads of lasso-cells capable of killing larger forms than these parasites. Others make their home in the body of sea-anemones, passing in and out at will, and in all probability dining upon the food which the anemone, at considerable trouble, had provided for itself.

FIG. 134. — Beach-flea (*Gammarus*), enlarged.

Of the forms more nearly allied to the sow-bug, the celebrated gribble deserves mention. It is a small form scarcely a sixth of an inch in length, with sharp-cutting jaws well adapted for gnawing the hardest wood. They slowly eat their way into piles of wharves, the bottoms of boats, and all other submerged timber, their immense numbers making them extremely destructive, rivalling in this respect the ship-worm already described. There is this difference, however, between the two. The ship-worm

commits his ravages beneath the surface, and a timber apparently sound to superficial examination may be tunnelled in every direction by its tubes; the gribble, on the other hand, is confined to the surface, and one can see at a glance how far the destruction has gone on. The gribble is widely distributed; on our east coast, for some unknown reason, its damages are comparatively inconsiderable, but in Europe and on our Pacific coast it is a serious pest. Owing to its ravages the long wharves of the Central Pacific Railroad at Oakland, Cal., require constant alteration and renewal, while across the bay at San Francisco it plays similar havoc with the piers. Various attempts have been made to check the damage, and it has been found that if timber be impregnated with creosote introduced under pressure, it will be protected to a considerable extent.

FIG. 135.—Gribble (*Limnoria lignorum*), enlarged.

Others of the fourteen-footed forms live the lives of parasites. One

FIG. 136.—A 'fish-louse' or 'salve-bug' (*Egga*).

form known to the fishermen as the 'fish-louse' takes up its residence just inside the jaws of the menhaden, where, with its sharp claws it holds firmly to the roof of the mouth and samples all the food of its host even before the fish has had an opportunity to taste it. Mr. Latrobe, who first noticed this peculiarity of habitat, recalled the old tasters or *prægustators* of the Roman emperors, whose duty it was to taste every dish, so that their master should not be poisoned; and so to-day this fish-louse figures as *Cymothoa prægustator*. "The fishermen say the fish-louse is necessary to the life of the fish, and as a proof of it they observe that if the louse be taken from him, the fish will die, although thrown into the water; but it is probable that the death of the fish is not owing to the removal of the parasite, but to its being withheld too long from the water, as it is well known that this fish lives but a very short time when taken from the water."

In its general appearance the salve-bug, as the fishermen call it, is much like the preceding species. It is frequently found adhering to the skin of cod and haddock, and occasionally to other fish. It is the largest

of our east-coast species, reaching sometimes a length of two inches, but is exceeded by an allied form from the deep seas which is eleven inches long. More distantly related are the peculiar 'whale-lice,' which occur on the skin of the larger whales, sometimes in enormous quantities. They are strikingly like a spider in appearance, and are among the most aberrant of the Crustacea.

SPIDERS, MITES, AND SCORPIONS.

To many it may seem strange that the species which is introduced first under this heading is the king-crab, or horseshoe-crab, a form which in all of the text-books is placed among the Crustacea. It appears, however, that is where it really belongs. The arguments for this course are too abstruse for insertion here, as they are based on the facts of structure and development. We may, however, say that the king-crab of to-day appears to be not far different from the form from which the scorpions, and through them the spiders and mites, have descended. Every feature in which the horseshoe seems to resemble the Crustacea can have an entirely different interpretation, and one which seems far more reasonable, and which points to the conclusion indicated above.

The horseshoe-crab (*Limulus*) is distributed along our coast from Maine to Florida. None are found on our western shores or on the coasts of Europe; but other species occur on the Asiatic shores and on the east coast of Africa. This distribution seems peculiar, but it is paralleled by that of many animals and plants. Why it is so no one has yet been able to say. There is a good deal of learned talk about similarity of environment and the like, but the explanation needs to be explained.

The horseshoe has its body composed of three parts, — an anterior portion which in outline is much like the foot of a horse, a middle triangular portion, and a long caudal spine. Its color is a dirty olive-green. The front portion has a sharp edge, so that the animal can readily force itself through the mud and sand, using its feet and its pointed tail as points of resistance. It burrows along just beneath the surface, hunting for its food, which consists of clams, worms, and the like. Its method of eating is peculiar. It has no proper jaws like the

insects and crustaceans, but on the basal joints of its legs are numbers of spines which, moving against each other, serve to tear its food into shreds.

FIG. 137. — Horseshoe-crab, or king-crab (*Limulus*).

Like all Arthropods the horseshoe molts its skin; but this process differs somewhat from that in the lobster. The shell does not split down the middle, but around the sharp, front edge, thus making a large opening through which the body can be readily extracted. Along the sandy beaches where these forms abound, their cast shells can be found in great numbers, and of all sizes, some large and coarse, others small, delicate, and possessing a certain amount of beauty. The horseshoe possesses great vitality; conditions which are quickly fatal to most inhabitants of the sea affect them much more slowly. A lobster or a crab is quickly killed by immersion in fresh water; but *Limulus* will bear submersion in that strange element for several days. The eggs and the young also share this capacity for life under apparently adverse circumstances. The writer kept about a hundred embryos for three months in less than a pint of salt water, which was not changed once during that length of time. They were kept in a shallow dish, and as the water evaporated, it was replaced by water from the city hydrant. Under these circumstances the water at times must have contained two or three times the percentage of salts that it did at others, and yet this seemed not to affect the crabs in the least. Even more remarkable were the experiences of Dr. Samuel Lockwood, the first to study the development of this interesting form. The jars in which he kept his eggs and embryos passed through the winter without any special care, and several times the temperature went down to freezing; and yet the next spring some of the eggs which failed to hatch the summer before, discharged their young, just a year, lacking two weeks, from the time when they were laid!

Of all the forms living on the surface of the earth to-day, the horseshoe-crab and the brachiopods are among the oldest. Through numbers of geologic ages they have retained their forms unaltered, and some of the existing forms are close counterparts of those which lived in carboniferous or silurian times. These forms, to-day, present us with extraordinary instances of individual capacity to withstand adverse circumstances, and seem to warrant the supposition that the vitality of the race is correlated with that of the individual — that the race has survived because the individuals are able to persist through changes of condition, which would either prove fatal to or cause extensive changes in less favored forms.

The king-crab is aquatic, and breathes by means of gills; its nearest living relatives, the scorpions, are terrestrial and are adapted for aerial respiration. On the under side of the long and slender abdomen are the openings to the lung-like pouches, and it is interesting to observe that in position and structure these air-breathing lungs are closely similar to the gills of the king-crab. The body of the scorpion is long and

slender. In front is a part bearing the six pairs of appendages; one pair short and terminating in a pincer, the second much the largest, and resembling somewhat the big claws of the lobster, forceps and all, while the four remaining pairs are adapted for walking. Behind this body comes the long, cylindrical, many-jointed abdomen terminating in the sharp curved sting, which has given these animals such an unenviable reputation. This sting is tubular, and near its extremity are the outlets of the poison-glands inside the tail.

FIG. 138.—Scorpion (*Butkus*).

The scorpions are burrowing animals, excavating their holes in the earth of warm countries. They are described as preying upon small animals, which they seize in their large pincers. They then hold the unfortunate victim above the body, and, bending the tail above the back, inflict the fatal blow. It is, however, probable that fruit or fleshy plants furnish them with much of their food. The poison has a peculiar physiological action on man. It affects the corpuscles of the blood, causing them to unite in masses too large for passage through

FIG. 139.—Whip-scorpion (*Thelyphonus*).

the capillaries. The sting is rarely, if ever, fatal to human beings, but in warm climates it may produce serious constitutional derangements. The

scorpions know their power, and are consequently fearless. When stirred up, they wave their tails about in the most threatening manner, seeking an opportunity to thrust the sting into the offender.

Somewhat similar in appearance to the true scorpions are the whip-scorpions, of which we have but few. Their common name is derived from the long, jointed whip which terminates the body, replacing the sting of their relatives. What purpose this organ fulfils is not easy to see. Its presence, however, does not deprive the animals of their poisonous powers, for in the big claws are poison-glands. Little is known of their habits.

The 'daddy-long-legs,' on the other hand, are perfectly harmless forms, familiar to all, as they awkwardly walk over the grass, their long legs seeming to be constantly in the way and hardly strong enough to support the small body. They seem, however, to be of considerable use as organs of touch; and if we hold one of these animals captive for a moment, we will see it lift up and seemingly feel of objects with one or more of its feet. The farmers' boys are familiar with this peculiarity, and they regard the animal's movements as almost oracular. The 'daddy-long-legs' is caught, and then the question is asked, 'Where are my father's cows?' Up comes one of the long legs, and straightway the boy rushes off in the direction indicated, feeling confident that he will find the missing herd. The daddy-long-legs (or harvestmen, as they are often called) are carnivorous, feeding upon small insects.

FIG. 140.—Daddy-long-legs, or harvestman (*Phalangium*.)

Concerning the true spiders much more of interest is known, both from the assiduity with which they have been studied and from the really interesting habits which many of them exhibit. In the northern states we have no large forms, but farther south some monstrous loathsome species occur, which might almost seem to be the brothers of 'Dr. Grimshaw's' pet. These large species (one of which is figured on our plate, p. 159) have nothing attractive about them; on the contrary, their dull-colored hairy bodies and clumsy legs give them a repulsive appearance which is fully borne out by their habits. It has been said, contradicted, and reaffirmed that the large species of Surinam, which we figure, captures small birds, kills them with its venom, and then sucks their blood. Whether this is true or not, the animal looks ugly enough to do it, or to commit any other act.

In regard to the bird-catching habits of the bird-spider, we can do no

better than to quote from Mr. Bates. "I was attracted by a movement of the monster on a tree-trunk; it was close beneath a deep crevice in the tree, across which was spread a dense white web. The lower part of the web was broken, and two small birds, finches, were entangled in the pieces; they were about the size of the English siskin, and I judged the two to be male and female. One of them was quite dead; the other lay under the body of the spider, not quite dead, and was smeared with the filthy liquor or saliva exuded by the monster. I drove away the spider and took the birds, but the second one soon died. . . . The hairs with which [these spiders] are clothed come off when touched, and cause a peculiar and almost maddening irritation. The first specimen that I killed and prepared was handled incautiously, and I suffered terribly for three or four days afterwards. I think this is not owing to any poisonous quality residing in the hairs, but to their being short and hard, and thus getting into the fine creases of the skin. Some *Mygales* are of immense size. One day I saw the children belonging to an Indian family, who collected for me, with one of these monsters secured by a cord round its waist, by which they

were leading it about the house as they would a dog."

FIG. 141.—Trap-door spider (*Mygale hentzii*), natural size.

Other forms, structurally much like the bird-catching spider, are really interesting in their habits. These are the trap-door spiders, and Mr. Moggridge has written a very interesting book in which he details the discoveries he made about their habits. These forms live in deep holes which they excavate in the earth. To prevent discovery, these holes are closed with a trap-door with a silken hinge, and which can be tightly shut. On the inner surface the door is silken, but externally it is covered with dirt and moss, so that when it is closed one cannot detect the difference between

it and the surrounding soil. When the animal is inside, he holds the door with some of his legs, and with the others he holds the wall of the tube.

BIRD-SPIDER (*Mygale avicularia*).

thus fastening the door so tightly that it will be torn before it can be pulled open.

The trap-door spiders excavate their homes by means of the small appendages in front, carrying away the earth grain by grain. When the tube is deep enough, the door is formed. To make this, the spider spins a few threads across the top of the tube, and then covers these with earth, and then more threads and more earth are added until the whole is of the proper thickness. At first the supporting threads of the door extend across the tube in all directions; but as soon as the door is so far advanced as to be able to retain its shape, these threads are bitten away all around except where they are left for the hinge. After this the rest of the work is devoted to finishing the inside of the door.

Some of the European species studied by Moggridge lived in mossy localities, and these of course covered the doors of their tubes with moss like that around them. The question arose, was this a habit or a result of reason? To test it, our author took away all the moss from the vicinity of one of the holes, and then destroyed the door. The spider soon constructed a new door, and answered his question by bringing moss from a considerable distance to cover it. In this way the door, instead of being concealed, was the most conspicuous object in the neighborhood.

With some of the species it would seem that the protection and concealment afforded by the trap-door was not sufficient, as some construct a second door some distance inside the tube, so that one would suppose that he saw the bottom. Others make a branch to the main tube, and hang a door over the junction of the two, so that the observer would not suspect its existence. It is difficult to imagine the way in which these and other habits have arisen. Did not the animals go so far, an explanation would be easy; but so varied, so complex, are some of the features, that one cannot readily conceive a cause adequate to produce such results.

Farther north a somewhat similar habit to that of the trap-door spiders has been observed. The spider digs its hole in the sandy soil, lines it with a delicate, silken web, and surrounds the mouth of the nest with a ring of leaves and twigs fastened together with silk. Others vary it by building up the ring of twigs alone arranged like the timbers in a log-house.

We have already alluded once or twice to spider silk, but the subject demands far more attention, as spinning is highly characteristic of spiders, as the careful housewife well knows. Some spin but scattered threads, others silk, with which they form cocoons for their eggs, while still others form the familiar webs with which they capture their prey.

The spinning-organs are placed on six or eight elevations on the hinder lower surface of the abdomen. On each of these 'spinnerets' are

numbers of little two-jointed tubes, each the outlet of a silk-gland. The silk, as secreted by the glands, is fluid, but after it comes to the air it rapidly hardens. The spider has full control of its silk supply and its spinning-tubes. If it wishes, it keeps its spinnerets all separate, and then the product is numbers of distinct threads. If it brings the spinnerets together, the various threads unite as they are formed into what is often called a cable, but which is really one larger thread, and not a cable at all. When a thread is to be begun, the spider presses its abdomen against some object, and thus fastens one end, and then proceeds to draw out the rest; at other times, as when she wishes to pinion a fly, the thread is pulled out with the feet. The spider can even force out the thread without any such external aid, as is seen when they wish to 'fly.' Frequently one will see young spiders in autumn mounting to the tops of the pickets of the fences, and then elevate their abdomen until it points almost directly upward. Now a thread or a bundle of threads is forced out which catches the breeze, and is drawn out to such an extent that it buoys up the spider, which then looses his hold and goes sailing away. On some of the fine days in autumn hundreds of these flying spiders may be seen, but what their object is in traveling in this manner it is difficult to say. It may be that it is wholly for the pleasure of travel, but this is doubtful. Among the lower forms of animals, so far as we know, every act has some utilitarian end; nothing seems to have enjoyment for its sole object.

The cobwebs are the product of comparatively few species, but they differ so in their character that a study of them is very interesting. Some of them are horizontal, others nearly vertical; but even those which seem upright will be seen on more careful examination to incline a little from the perpendicular, and in all the spider walks not on the upper, but on the under side: indeed, some spiders are so constructed that they can hardly walk upright, while the claws of their feet are admirably adapted for supporting the weight of the spider in a hanging position. Some spiders, like the common house-spider, form irregular webs, the threads

FIG. 142. — Nest of *Lycosa*.

of which are apparently put together without any order. In others the webs are very regular, sometimes taking the form of domes in the grass, or of circular discs supported from the pickets of a fence. These last, which Dr. McCook calls the 'orb-webs,' are mostly the products of the common garden-spiders, which belong to the genus *Epeira*, of which we figure the male of one of the most abundant New England species, enlarged to twice the natural size. A description of one of these circular webs will have to answer for all.

FIG. 143.—Foot of garden-spider (*Epeira*), showing the hooks by which it clings to the web.

The 'orb-weavers' usually select some place for their web where they can obtain a firm support and at the same time have a crack or hole into which they can run for concealment. First they spin a long thread across the place where the web is to be, and then proceeding to the middle of this foundation line, the abdomen is depressed so that it touches the thread, and now a second thread is drawn out, the other end of which is fastened near one end of the

FIG. 144.—Garden-spider (*Epeira*).

first. So the process continues until a number of threads radiating from a common centre are formed. Then the spider begins at the centre of the web and spins a loose spiral, fastening it to each of the radii, and continuing it until a disc of the required size is formed. This spiral is but a scaffolding for the formation of the web used for catching insects. When the spider reaches the outside of the web, she retraces her steps and spins a new kind of thread. All the threads so far formed are smooth, but the new one is covered with a viscid, sticky substance, which soon runs together into drops, giving the thread a moniliform appearance under the microscope. The new thread, like the old, is arranged in a spiral, but its coils are closer, making the web much tighter than before. After this spiral is finished, the spider proceeds to construct her nest in a corner, and then stretches a string from the centre of the web to this nest.

The web is now ready for business, and the spider takes her place in the nest, with one foot upon the thread leading to the centre. When a fly touches the web, his wings and body adhere to the sticky threads, while his struggles and buzzing shake the whole web. The spider pulls in her line and lets it go again; the jar thus produced serving to bring more sticky

threads in contact with the victim. At last the spider walks out, approaches rather close to the fly, and pulling out a lot of fresh threads with her hind legs, proceeds to attach them to the fly. Finally, one wing is firmly pinioned by these silken cords, then the other is fastened, and at last he is capable of no further motion. The spider now comes closer and sinks her venomous fangs in the body of the fly, and all is over. The spider now cuts away most of the binding threads, and carries her prey to the nest, where she sits and sucks its blood.

Another form illustrated in our next cut is remarkable for the sub-aquatic nests that it makes. It crawls down the stems of the aquatic plants, and proceeds to build a balloon-shaped web, the walls of which are air-tight. When the nest is complete, the spider climbs to the surface and protrudes the tip of its abdomen, and then jerks it down quickly, crossing her legs over it as she does so. A bubble of air is caught among the hairs, and is carried down and allowed to escape into the nest. In this way she gets a supply of air to breathe while she is beneath the surface, where she spends most of her time catching aquatic insects. As the spiders descend, thus carrying air, they appear to be covered with a silver sheen.

Another use made of spider silk is to form egg-cocoons. The process of forming these is curious but complex. Some of them are scale-like, and are concealed beneath boards or stones; while others take spherical or even vase-like shapes, sometimes of considerable beauty of outline. One species carries its cocoon about with it, attached to the end of its abdomen, and the young, when hatched, ride upon the backs of the mother much like the young of the opossum.

Comparatively frequently one sees statements in the newspapers of persons suffering from the bites of spiders, which are sometimes said to be followed by fatal effects. It is extremely probable that in all these cases there is some mistake, for there are but few spiders in the northern states which possess jaws strong enough to puncture even the thinnest skin.

FIG. 145. — Water-spider (*Argyroneta*), and its sub-aquatic nest filled with air.

Several naturalists have experimented on themselves, and the worst effects following a spider's bite did not exceed those produced by the sting of a mosquito. It is probable that in all the newspaper cases the person finds a spider and has a sore, and the argument is of course of the *post hoc ergo propter hoc* type.

Our common house-spiders are rather dull-colored, but among the forms occurring out-of-doors there are many beautifully colored forms as well as bizarre shapes. Occasionally forms are found which, instead of the regular oval abdomen shown in Figure 144, have triangular hinder bodies, and this may sometimes be carried to such an extent as to produce the

FIG. 146.—Caliper-spider (*Acrosoma arcuata*).

corners of the abdomen into long horns, as shown in the figure of the caliper-spider.

Some of the spiders do not form webs, but catch their prey by agility or stratagem. The jumping spiders—usually gray or black-colored forms—are familiar examples. They may be found running about on the sides of buildings and on fences, and when alarmed jumping to a considerable distance. When they see a small insect, they creep cautiously towards it until but a small distance intervenes, and then with a sudden leap they are on its back, like a cat pouncing on a mouse. These jumping spiders are able to spin silk, but they use the thread merely as a safety cord, and each time they jump they let a thread trail out behind them to save themselves from any serious fall.

The term tarantula is commonly applied to any large spider, but it

properly belongs to a large, long-legged form living in Italy and Spain. Connected with this species there is a most peculiar superstition which has endured for ages, and which, so far as is known, has no actual foundation in fact. The story goes that the bite of this spider produces a peculiar insanity known as tarentism, which can only be cured by prolonged dancing to a peculiar style of music. In reality the bite of this maligned monster produces scarcely any effect on some persons; on others it is followed by consequences no more serious than the sting of a wasp.

FIG. 147.—*Tarantula*, natural size.

The most degraded of all the group of spider-like forms are the mites, few of which attain any considerable size. In them there is not that division of the body into the regions so prominent in the spiders and scorpions, and almost all of them live a parasitic or semi-parasitic life upon other animals or plants. Some, however, live free, and among these are a lot of aquatic forms resembling to a greater or less extent the American species figured in the adjacent cut. This form, however, lives a parasite life upon the gills of the fresh-water mussels.

Of the other forms, several must be mentioned at least by name. First there comes the itch-mite, which is the cause of the loathsome disease — the itch — now happily almost extinct. This is a very minute form which burrows just beneath the skin of man, producing a most intolerable itching. The connection between the parasite and the disease has long been known, having first been pointed out by an Arabian physician some seven hundred years ago. Closely allied to this is the form which produces the mange in dogs. Even more degraded than these forms are the so-called follicle-mites which occur in the sebaceous follicles of pigs, cattle, and occasionally in the skin of man. They are elongate, worm-like animals of minute size, which, however, betray their affinities to the mites and

FIG. 148.—*Water-mite*
(*Atax*).

spiders by their eight legs and the peculiar construction of the mouth. There is one common misconception which it may be well to correct here. People have heard of these mites occurring in the sebaceous follicles in the skin of the human nose, and hence they think that the black specks, which

FIG. 149.—Follicle-mite (*Demodex folliculorum*).

FIG. 150.—Upper and under surfaces of the European dove-tick (*Argas*), enlarged.

disfigure the skin of some persons, are these mites. In reality, these specks are but glands which have become obstructed and distended by an accumulation of their secretions.

The ticks are to be classed among the mites. Sometimes they attach themselves to men, but they are far more abundant on other animals. In the warmer countries, like Texas and South America, they seriously affect the skin of the cattle, piercing the integument and sucking the blood so that their abdomens swell up as large as, or even larger than, peas. Other forms, like that figured, occur on pigeons and other birds, and a near ally of this species, which occurs in Persia and the adjacent countries, is said to produce serious and even occasionally fatal sickness by its bite.

CENTIPEDES AND MILLIPEDES.

Both centipedes and millipedes are long worm-like forms, with numerous walking-feet, whence arises the name of the group — Myriapods (many-footed). Centipedes and millipedes differ much in appearance. The former have flattened bodies with but a single pair of feet to a segment of the body, while the latter usually have cylindrical bodies, and the majority of the segments bear two pairs of limbs. There are also many other differences between the two groups; but they need not be mentioned, excepting the fact that the former are carnivorous, while the millipedes feed largely on dead and decaying vegetable matter.

The typical centipedes — those large tropical forms whose bite is so feared by travelers in the tropics — hardly deserve the name, for it means hundred-footed, and they fall far short of that number of appendages. Some of the smaller forms, which are very abundant, even in the northern states, exceed that number, and so the term stands. The large tropical forms reach a considerable size, sometimes even a foot in length, while on either side of the head is a large strong 'jaw,' in the tip of which is the outlet of a poison-gland situated in the jaw itself. The bite of these large forms is very severe, and may be accompanied with serious consequences, yet it is probable that these effects are frequently exaggerated. Thus one species found in the West Indies bears the ominous name *Scolopendra morsitans* — deadly. It is described by Brown, a traveler of the last century, in the following words: "This insect is reckoned very venomous; the prongs of their forceps are very strong, bending and pointed, which enable them to bite very hard, and they probably emit some venomous juice also. Some who have been bit by them informed me that the parts are very painful for two or three hours, and turn frequently of a livid color. I have seen them often kill a cockroach with a single nip."

These large forms are very predaceous, and wander everywhere in search of their insect prey. It is this that brings these unwelcome visitors into the houses in the tropics, where they crawl through the thatch of the

FIG. 151. — Centipede (*Scolopendra morsitans*), half-natural size.

roof, or perchance coil up in the clothing, or even in the bed of the rightful owner. In cooler climes the smaller forms retain the same qualities. They are provided with poison-glands; but their jaws are too weak to pierce the skin of man. Still, they do a great amount of good to the agriculturist, for they kill and devour an immense quantity of injurious insects. In every damp locality you will find them abundant, and always near them are the skins of the insects on which they have dined.

The familiar galley-worm or thousand-legged worm is a familiar example of the millipods. Its shining dark-brown body, coiled in a spiral at the least disturbance, is a common object amid decaying timber. It and its allies have but little of popular interest beyond the fact that they are possessed of numerous glands opening along the sides of the body, which secrete a very powerful and offensive odor, which doubtless is protective in its character.

INSECTS.

The insects have been more often described than any other group in the whole animal kingdom, except, possibly, the birds; and yet there is always something interesting to say concerning them. Insects are found almost everywhere; even the sea has its inhabitants belonging to this group, — curious bugs which live upon the surface of the ocean, miles and miles from land. In Salt Lake, too, where the water contains a far larger proportion of salt than does the ocean, the larvæ of flies occur in large numbers.

Insects are characterized by having but three pairs of legs in the adult, and these legs are always borne on the middle of the three regions into which the body is divided.

The first of these regions is the head, and this bears the large compound eyes, so conspicuous in the flies and dragon-flies, a pair of jointed

FIG. 152.—Diagram of a grasshopper, to show the three regions—head, thorax, and abdomen—of an insect.

antennæ, and several pairs of jaws variously modified for the purposes of eating. The middle region—the thorax—has in most insects, besides the legs, one or two pairs of thin and delicate wings; while the hinder division, or abdomen, shows distinctly the segments of which it is composed.

In most of the crustacea respiration is effected by gills; but in the insects oxygen is conveyed to the tissues by means of delicate tubes, which penetrate to all parts of the body. On the sides of the thorax and abdomen of any insect, careful observation will show a series of little holes, and these are the openings through which the insect breathes. One can easily see the process of breathing by holding some naked form, like a grasshopper, in the fingers. The abdomen will be seen to expand and contract in a manner curiously like the enlargement and contraction of the human thorax when one breathes. Indeed, the phenomenon has exactly the same meaning in the two instances; when the body enlarges, air rushes in through the openings (spiracles they are called) on the side of the insect, distending the tubes and penetrating to every part of every tissue. When the abdomen contracts, the air and the carbonic acid which it has received from the animal is forced out again. Here, as in the higher forms, respiration and the combustion of tissues involved produces heat, and heat to a considerable amount. Bees at certain times breathe far

more rapidly than at others, and in this way even raise the temperature of the hives several degrees. The exertion apparently affects these insects, and it is stated that it actually produces a perspiration.

We have said that these air-tubes permeate all parts of the body; but no one except those who have studied the microscopic structure of insects can know what this means. The larger tubes are readily seen and followed by ordinary dissection; but they soon break up into smaller branches, which cannot so readily be seen. When we turn to the microscope for farther aid, we find that these minute branches still farther divide, and penetrate even to the interior of the eye, into the tissues of the viscera, and into the legs and wings.

Most wonderful of all are the metamorphoses which many insects undergo. It has been used by poets to furnish many a figure, while the theologian calls upon it for analogies to support some of his articles of faith. These changes have often been described, but no one has yet exhausted the subject. Each year as spring returns, beetle and butterfly emerge from the chrysalis to follow their short life as perfect forms, and then to die; but only after they have left behind them the eggs, which after they are gone are to go through the same wonderful changes.

These changes are most familiar in the group of butterflies, and hence we will briefly describe them there. The butterfly which flits about from flower to flower in a seemingly aimless way has really important business on hand. She has a stock of eggs to dispose of, and these she must deposit in a proper place. Keep her in confinement, and she will lay them in the box in which she is kept; but leave her to herself, and she will seek out the plant which will afford the best food for the young larvæ soon to hatch from them.

Many of these eggs seen under the microscope are objects of extreme beauty; some are colored the most delicate colors, others are ornamented with ridges, or spines, or both, sometimes arranged in the most complex yet symmetrical patterns. These eggs are laid either singly, or in large masses, or again each egg may be supported on the tip of a long and slender pedicel: in short, there is no end to the variety of insect eggs. From the egg hatches out the larva, — a long, slender, worm-like body, sometimes smooth and naked, at others clothed with various spines and hairs. In almost every instance the larva is protected to a certain extent from its ordinary enemies. Its colors may be such that it is not readily distinguished on the plant on which it feeds; or again, its fur or spines render it an object which does not please the mouth or palate of insect-feeding birds. Still others are provided with scent-glands which secrete a strong, frequently an exceedingly nauseous, odor. All these are protective. Still other larvæ

are hidden from enemies by their habits. The wood-boring beetle larva is safe from all except the strong-billed woodpecker, while not many animals care to disturb the maggot of the fly in his home in some decaying flesh.

It is the duty of the larva to eat, and eat it does. Most larvæ are furnished with powerful jaws well adapted to cutting the substances on which they feed, be it the most delicate plant of the garden or the hardest wood of the forest. The damage done by insects is perfectly enormous; the farmer has constantly to fight against their ravages, while his wife at home is wrought up to a high pitch of indignation at the discovery that the moths or the 'buffalobugs' are in her carpets. And in almost every instance it is the larva that does the damage, but not in all. The larva eats and grows, and even when he arrives at

his full size he apparently differs but little from his condition when he was much smaller. Apparently — for inside his skin marvellous changes have taken place — a new skin exists in outline inside the old, and on the sides of the body are little round patches which are eventually destined to become the wings. So with every other organ; it is being modified and changed inside the body.

Sooner or later the time for the first change comes. The larva knows it, and he crawls to some suitable place. His old skin cracks, and out of it comes a body exceedingly unlike the old. The strong jaws have disappeared, and there is not a trace of a leg; stop a bit and look a little closer, and you will see some things which will make you modify that last statement. Notice those slender lines coming from the shoulders and folding over the breast; those contain the legs; beside them are the sheaths which contain the antennæ, while outside them, on either side of the body, are two broad plates in which the wings are folded up.

In some insects the pupa stage, just figured and described, hangs freely in the open air; in others it is enveloped in a silken case, or cocoon. In the latter the larva, before it sheds its skin, begins to spin its silken threads;

FIG. 153. — Larva of *Maia* moth, with some of the defensive spines enlarged.

FIG. 154. — Chrysalis, or pupa stage, of a butterfly, showing the outlines of the various parts of the adult insect: *e*, eye; *t*, tongue; *w*, wing; 1, 2, 3, legs.

but these, unlike those of the spider, do not proceed from the end of the abdomen, but from glands opening near the mouth. The larva, in constructing its cocoon, works from the inside, and at first it presents a very gauzy appearance, as is shown just to the left of the centre of the plate opposite page 273. Through its walls the larva can be seen spinning more threads, making the net thicker and thicker, until at last the whole forms a thick, firm case formed by the winding of a single thread. Inside this cocoon, after all the silk is spun, the larva sheds its skin, and emerges a pupa much like those of its allies which are not thus protected. It may be well to state, in passing, that the pupa of the butterflies is frequently called a chrysalis.

The pupal condition usually lasts through the winter, and then, when spring comes, the dry pupal skin splits open, and out comes the perfect insect, but in what a lax and limp condition! The legs have hardly strength to support the body, while the wings appear like flabby sacs on either side. Gradually the limbs harden, while the blood flowing into the wings distends them to their full size, and in a short time the butterfly sails away to spend its few remaining days. This period of emergence from the cocoon is a critical one. Any slight obstacle will produce serious results, and one can easily obtain butterflies with deformed wings by pinching these organs before they become distended and hardened.

The moths which form cocoons have an even harder task. After they have cast off their pupal clothes, there is still the silken case before them.

FIG. 155.—Front view of the head and thorax of a *Cecropia* moth, showing at the base of the wings the hooks used in escaping from the cocoon.

It is usually stated that they secrete a fluid which softens and dissolves the silken threads, but there is often more than this. On the base of the wings of some of these moths there is a little hook with saw-like teeth, and this is used to cut the threads and pull them apart.

The duration of the life of insects varies; and as a rule exact statistics are lacking. The perfect state lasts for a shorter time than the preparatory stages; indeed, there is a whole group of insects known as the Ephemeras, because the adults live so short a time; in some instances but a single day, it is said. On the other hand, the larval and pupal stages may last for an enormous length of time. The seventeen-year cicada lays its eggs, and yet seventeen years must elapse before these will become perfect insects; in others the period is thirteen years. There is a case of longevity among the beetles which exceeds even these limits. An apple-tree was cut down, and from its timber a table was manufactured. "Many years afterwards the gnawing of an insect was heard in one of the leaves

of this table, which noise was heard for a year or two, when a long-horned beetle made its exit therefrom. Subsequently the same noise was heard again, and another insect, and afterwards a third, all of the same kind, issued from this table-leaf, — the first one coming out twenty, and the last one twenty-eight years after the tree was cut down.” How long before the tree was cut down the eggs were deposited we have no means of knowing.

BRISTLE-TAILS AND SPRING-TAILS.

In damp earth and under decaying boards, the naturalist frequently finds some minute forms, which are to him very interesting, since they are the lowest of the whole insect series. Unlike their relatives, they have no wings, and have to depend on their rapid locomotion, or upon the spring with which many are furnished, to escape from danger. This latter is a curious forked appendage, folded on the under surface of the abdomen, and capable of being suddenly straightened out, sending the insect several times its own length. Our cut does not show this spring, but it illustrates the peculiar appearance which one of the common species of the northern states presents when he is magnified. Although so small, these little forms are brightly colored; this species being yellow, shading off into brown or even purple, while others may be of almost any hue of the rainbow, or even all the colors may be present on the one specimen at the same time.

We have given the explanation of the common name spring-tails, applied to some of these forms, in

the last paragraph; the other term refers to the fact that in others of the group the abdomen terminates with two long bristles. The most familiar example of this is the ‘silver-fish,’ a little silky, gray form that is occasionally seen around books and papers. It does some damage to these as well as to carpets, clothing, and silken goods by gnawing holes in them, yet in this respect it is far exceeded by many other insects.

FIG. 157.—*Podura*.

FIG. 156.—A spring-tail (*Entomobrya*).

There is one of the spring-tails which is well known to the microscopists. This is the *Podura*, a little dark-colored form whose body is covered with minute scales. These scales have a very peculiar appearance under the microscope, and they are

used as tests of the power of definition of an objective, as it takes a really fine glass to show the true character of the ornamentation of the surface.

A little higher in the series come the earwigs, the general appearance of which is shown in our cut. The body terminates in a sort of forceps (whence the name *Forficula*, little forceps), while two pairs of short wings are present, thus making an advance above the bristle-tails which are wing-

FIG. 158. — A group of earwigs (*Forficula*).

less. In the northern United States these earwigs are comparatively rare, but in the region about the Gulf of Mexico they are rather more abundant, but still they are nowhere so common with us as they are in Europe. There they abound in the fields and gardens, hiding themselves during the day; but when evening approaches, they fly out, and begin to feed on the flowers and fruit, — habits which make them annoying pests. The name earwig alludes to a belief that these animals are fond of crawling inside the

human ear, and causing the victim the most excruciating pain, — a belief which has not the slightest foundation of fact.

COCKROACHES, CRICKETS, AND LOCUSTS.

The group of insects embracing the forms enumerated in the heading are classed by naturalists under the heading *Orthoptera*, a compound word derived from the Greek, which means straight wings. Most of the members of the group have the front wings narrow and straight, and usually of a parchment-like texture, while the hinder pair of wings are broader, and when not in use in flight, they are folded up like a fan and hidden under the first pair. Almost all the members of the group are classed among the injurious insects, from the fact that they feed on vegetation, and thus seriously interfere with the labors of the gardener and the farmer. One has but to recall the plague of grasshoppers which a few years ago devastated the farms of Kansas and Nebraska, destroying millions of dollars worth of corn and wheat, to see how injurious these forms may be. They are armed with powerful jaws, which will cut through the succulent leaf or the harder wood, while their numbers and their voracity enable them to strip a field of grain or grass in a few hours, leaving behind nothing but stubble.

This group is noticeable from the fact that its members do not pass through a metamorphosis, but gradually grow, with repeated molts, from the young as it escapes from the egg, until the adult condition is reached. Each shedding of the skin is accompanied by small changes in the form and proportions of parts.

First in order come the cockroaches, animals which, while they prove themselves nuisances everywhere, still have a most respectable ancestry so far as age is concerned: away back in paleozoic times there were cockroaches with the same flattened bodies, and the same coriaceous wings as to-day; while at the time that our beds of coal were deposited, they crawled about amongst the vegetation, and so they have continued until the present time. To-day they swarm in all our seaport and most of our inland towns, getting into houses and stores, seeming to seek the neighborhood of the water-pipes, and by their ugly shapes, dull colors, disagreeable smell, and above all their ubiquity, making themselves unmitigated nuisances.

When they once obtain entrance to a house, there is but little hope of getting rid of them. The disgusted housewife will imagine that she has exterminated them, but alas! they soon reappear in all their former numbers. Remedies that seem to kill other insects seem to have little effect on these. Persian insect powder numbs them for a while, but they

soon recover: frost kills them, but does not affect their eggs; powdered borax and cucumber peel are delusions. All that one can do is to destroy as many as possible, and stand those that remain. The fight, too, must be kept up continually. Give the roaches a respite, and they soon attain their former numbers. They lay their eggs in little cases something like the pod of a pea, and from these hatch out the little white roaches, which for a while are objects of anxious solicitude on the part of the mother.

Cockroaches are omnivorous. They eat everything which contains the least nourishment; and this renders them to a certain extent of value, for they keep all the cracks and crevices clean and free from decaying matter. When they appear in an apartment, one can extract a little consolation from the fact that they are fond of bed-bugs, and that these other pests will not

FIG. 159.—Cockroaches (*Ectobia germanica* and *E. lapponica*).

appear while the roaches abound; but this hardly begins to compensate for the damage they do. They eat the bindings of cloth-covered books, the plants in greenhouses; but above all they delight in bread and wheat flour.

The species to the left of our cut is the most widely distributed of any of the nine hundred different kinds of cockroaches; and in New York and New England it has the common name 'Croton bug,' doubtless in allusion to the rapidity with which it multiplied and spread in New York City after the introduction of Croton water. It is small in comparison with some of the forms, especially those which abound on ships and in the tropics. Fortunately all of these forms have not taken to invading our homes. The five that have done so are amply sufficient. It is noticeable that where one species of cockroach has invaded a house, no other species occurs. This is said to be due to the fact that one species is very apt to feed on the young and the eggs of the other.

The praying mantes stand higher than the cockroaches. They have

large bodies, the front parts of which are greatly elongated, while the terminal joints of the fore feet close on the preceding joint in such a way as to form a pincer, very like that of the mantis-shrimp. They receive the common name from the fact that they often assume an attitude as if deeply engaged in prayer. In their case, however, appearances are deceptive; they are on the lookout for game; for they prey upon other forms. They are most insatiate monsters, and will eat their own kind as readily as they will any other insects; and they are continually quarrelling among themselves. These qualities render them of great value to the farmer, and in the regions where they occur they will destroy more injurious insects than all the state entomologists and entomological commissioners ever appointed. Praying-mantes or rear-horses are common in our southern states, as well as in other warmer parts of the world.

Closely allied to the rear-horses are a number of species remarkable for their resemblance to the vegeta-

FIG. 160. — Walking-stick insect (*Diapheromera femorata*).

FIG. 161. — Walking leaf-insect (*Phyllium siccifolium*).

tion on which they live. Some simulate the dead branches, while others represent in the most remarkable way even the leaves of the plants. With

us the 'walking-stick,' which occurs in oak thickets, is really abundant; but its elongate body and its colors make it so like the tender shoots and the denuded midribs of the leaves, that it requires the very closest observation to see them. With the advance of the season the new twigs change their color to a grayish brown, and with this change the color of the insect also changes to the same shades. Only about half a dozen representatives of this group are found in the United States, and none of them begin to compare with the wonderful leaf-insects of the East Indies, one of which is figured above. In our cut it shows its insect characters plainly enough; but place it on a dead branch amid withered leaves, and one could scarcely see it. Its outer wings have the shape and color of a dead leaf, while even the veins resemble the nerves upon the leaf. Even the basal joints of the legs carry out the similarity; for they are flattened and leaf-like, and each is

crossed by a midrib. Our next cut shows some more of these mimicking forms from the East Indies, drawn to a smaller scale, but still showing their remarkable features.

These forms so far mentioned walk or crawl along comparatively slowly; but the rest of the group possess well-developed leaping powers. Their hind legs are large and well developed, and by suddenly straightening these the insects are able to jump long distances, sometimes many times their length. In the first forms these leaping powers are but very poorly developed. The mole-crickets are fitted for a subterranean rather than an aerial life. The terminal joints of the first pair of legs are flattened and broadened, admirably adapting them for the excavation of the large subterranean burrows in which they spend the greater part of their lives. This life under ground partially explains the apparent rarity of these forms, for they rarely leave their burrows, and then only after dark.

FIG. 162.—Examples of East Indian Orthoptera which mimic other objects.

The true crickets, on the other hand, are more common, and their persistent chirp is one of the most characteristic premonitions of the approach of autumn. As soon as the evening begins, they begin the chorus which is kept up in the most monotonous manner throughout the night. As long as these forms stay out of doors their music is endurable; but when one

obtains entrance to the bed-chamber, and, hidden in some corner, sings his love-song, sleep is impossible. Then one realizes the rasping shrillness and the penetrating powers of this note. How do they sing? They don't sing; they fiddle. Mr. Scudder has written an interesting sketch of this insect fiddling, and has even set some of the notes to music. To his pages most of the following statements are due.

FIG. 163.—Mole-crickets (*Gryllotalpa*).

The noise is all made by the male, and is produced by rubbing the wings against each other or against the legs. At one part there is a file-like ridge which corresponds to the fiddle-bow, and this is rasped against another, and this produces rapid vibrations in a broad and tense membranous portion of the wing. Each species has its own note, and the experienced student can at once recognize the form by the character of the song. The crickets sing the same tune by day as by night, but others have separate notes for the light and the dark. "On a summer's day it is curious to observe these little creatures changing from the day to the night song at the mere passing of a cloud, and returning to the old note when the sky is clear."

The existence of musical organs would indicate that the insects had the means of hearing, and so they have. Where they are in some forms is uncertain, but with regard to others not much doubt exists. Previous conceptions would lead us to look for the ears in the head, but this would be a mistake. In one group—the locusts—the ears are found one on either side of the base of the abdomen. They are large spots covered with a thin membrane, which corresponds in its functions to the tympanic membrane in the human ear, while inside are the per-

FIG. 164.—Blind cricket of Mammoth Cave (*Hadenueus cavernarum*).

ipient nervous elements. In the other group, of which the katydids may be cited as examples, the ears occur where one would scarcely think of looking for them — on the joints of the legs. There one may see the same tympanic membrane, while careful dissection reveals the same nervous elements on the inside.

FIG. 165. — Leg of a locust showing the so-called ear-drum *T*, on the tibial joint.

The house-cricket of Europe, so familiar in song and story, is a small species which has become domesticated in the eastern parts of our country. It delights in warm places, and makes its home by preference in the cracks of chimneys. In the fields we have numerous other and larger forms lurking in the grass, and during the day seeking concealment beneath boards and stones. Others are more arboreal in their habits, and among these is the common tree-cricket, a delicate form with transparent wings of a very pale green. This form is especially noticeable for its very offensive odor. The collector in handling it gets a most persistent and disgusting smell upon his fingers.

One form which inhabits the western territories stands a step higher than the familiar cricket of our fields. It is a large, clumsy species, lacking wings, which sometimes appear in large swarms, doing much damage to the crops of the farmer. At the end of the body is a large, sword-shaped organ, the ovipositor, the function of which is to pierce the earth and deposit the eggs at some distance below the surface.

FIG. 166. — Western cricket or stone-cricket (*Anabrus simplex*).

This form is essentially a vegetarian, and yet when hungry it will eat animal food, and will even devour its own kind. The farmers know this, and so they dig deep trenches around their fields, which serve as traps for the pests. Their advancing hordes tumble in, and, lacking wings, do not easily escape. Here they soon become hungry, and then they begin to attack each other, the weaker soon succumbing and furnishing food for the rest.

The katydids rival the crickets in popular esteem. The 'Autocrat' but voices the feelings of all when he writes, —

"I love to hear thine earnest voice
Wherever thou art hid,
Thou testy little dogmatist,
Thou pretty katydid;"

for the cheerful note of his green songster, with its constant repetition of 'Katy did' or 'Katy, she did'—no one was ever told what Katy did do—is in marked contrast with the monotonous, ear-rasping chirp of many other forms. During the day the katydid sits quiet; but as the shades of evening approach, he takes his place on the top of some leafy branch, and commences his ditty. We have several species of katydids, differing slightly in form and color, some having long wings and some short, but only one of these has the note which gives the name; others chirp in different syllables and different keys.

The locusts are the most numerous and most injurious of all the Orthoptera, and with us the most prominent of all is the 'hateful locust,' the grasshopper of the West, which periodically devastates the territory between the Rocky Mountains and the Mississippi. The appearance of the swarms is irregular; they will appear for three or four years together, and then the country will have a respite. In the earlier years they did but little damage to human interests, because then the farms were few and far between; but as the plains became settled, they became a serious pest, and at last their invasion during the years 1873-76 was disastrous, and in the single year of 1874 they are estimated to have destroyed crops to the amount of fifty million dollars; and in 1875, in Missouri alone, the loss to the farmers is placed at fifteen million dollars.

These ravages gave rise to a loud call for aid, and in 1877 the Congress of the United States authorized the appointment of a commission of entomologists, to devise means to check the ravages. This commission studied the subject in every aspect. They obtained a knowledge of where the animals breed, the different dates at which swarms have been recorded, descriptions of the various processes—some valuable, others utterly useless—which have been proposed to destroy the grasshoppers and their eggs. They fought the nuisances by studying their anatomy, embryology, and histology, and by preparing an extensive bibliography—and the locusts succumbed. In 1877 they did comparatively little damage, and since that time only sporadic cases have been reported.

The western grasshopper is a small species, the general appearance of which is shown in our cut. The general color is a reddish-brown, with darker spots, the wing-covers being an ashy brown dotted with darker, and the average length is about an inch and a third. It seems hardly credible

FIG. 167. — Katydid (*Cyrtophyllus concavus*).

that this small form should do the damage which is credited to it, but the vast numbers make up for the comparative insignificance of the individual. Each locust is provided with a strong pair of hard, horny jaws, and excel-

FIG. 168.—Western grasshopper
(*Caloptenus spretus*).

lent digestive powers, which enable it to eat an enormous amount; and so when a swarm of them fall on a field of wheat or corn, they soon devour every leaf; and when they leave it to seek another, it appears almost as if fire had run over it. These swarms are enormous

in size. One can hardly believe it, and yet the statement is true, that railroad trains have been stopped by their numbers, "the insects passing over the track, or basking thereon so numerously that the oil from their crushed bodies reduced the traction so as to actually stop the train, especially on an up-grade."

The permanent breeding-ground of the locust is mostly confined to the territories of Wyoming and Montana, and the British possessions lying immediately to the north. Here they may be found in considerable numbers every year, and once in a while, from climatic or other causes not understood, they migrate from these highlands, and descend in immense numbers over all the cultivated land, to the east and southeast, as far as the Mississippi. Here they breed for two or three years, but soon they begin to die out. In some way or other, the conditions of this region are unfavorable for their permanent existence there, and nature does what man cannot do. The United States Entomological Commission collected a vast amount of valuable data regarding the locusts, but their actual influence in diminishing the numbers of the pest were very inconsiderable, indeed almost infinitesimal. There is in natural as well as political affairs, a balance of power. When a species attains an enormous numerical development, as the locust does at intervals, it produces as a result a proportionate amount of enemies, and these soon check the increase in numbers and then rapidly reduce them. Of these enemies of the locusts, birds undoubtedly stand most prominent; but whether they really destroy more than some smaller and less conspicuous forms, is a question. From the moment the egg is laid until the adult condition is reached, the locust lives in constant danger from other insects. The eggs are eaten by numerous flies and beetles, while the adults are killed and devoured by many more.

The locust, like many of its relatives, with the tip of its abdomen bores deep holes in the soil, and in these deposits its packets of eggs, which pass the winter in this subterranean position. In the spring the young hatch out, — most grotesque-looking creatures, with large heads, no wings,

small body, and a most insatiate appetite. They at once begin to eat, and with the taking of food they rapidly increase in size; a fact which necessitates frequent moltings of the skin, and with each molt the proportions change, gradually approximating those of the adult, the wings appearing first like small scales, until after the sixth molt, the perfect insect appears, ready to lay its eggs, and thus begin the cycle anew.

FIG. 169. — Young of the Rocky Mountain locust (*Cataloepus spretus*).

The western locust, which we have thus described at length, is the type of numerous other forms, all injurious; but none of which with us acquire the importance of this species. In the Old World, however, allied forms have at times devastated large tracts. The prophet Joel, eight hundred years before Christ, describes their ravages and the way in which they fall upon a country, a picture perfectly applicable to the locust of the west: "A day of darkness and of gloominess, a day of clouds and of thick darkness, as the morning spread upon the mountains: a great people and a strong; there hath not been even the like, neither shall be any more after it, even to the years of many generations. A fire devoureth before them; and behind them a flame burneth: the land is as the garden of Eden before them, and behind them a desolate wilderness; yea, and nothing shall escape them. The appearance of them is as the appearance of horses; and as horsemen, so shall they run. Like the noise of chariots on the tops of mountains shall they leap, like the noise of a flame of fire that devoureth the stubble, as a strong people set in battle array. . . . They shall run like mighty men; they shall climb the wall like men of war; and they shall march every one on his ways, and they shall not break their ranks. . . . They shall run to and fro in the city; they shall run upon the wall, they shall climb up upon the houses; they shall enter in at the windows like a thief. The earth shall quake before them; the heavens shall tremble; the sun and moon shall be dark, and the stars shall withdraw their shining."

Southern Russia seems to furnish a permanent breeding-ground for the European and Asiatic migratory locusts; but doubtless others exist, for this species is said to range from Germany to northern Australia and New Zealand, and from Algiers to the Fiji Islands.

The number of species of locusts in the United States is about one hundred and forty. In their habits they are all much alike, and the description of the species, or even the most prominent ones, would prove dry reading. Some of our species attain a considerable size — three inches or more in length; but in tropical America gigantic forms with a spread of wings of eight or nine inches. Even these forms, which are among the

largest of insects, fall far short of the stories of Pliny, who tells us of locusts three feet in length, and with legs so enormous that the people in the country where they live, use them for saws! The species has apparently become extinct, for no recent naturalist has ever seen these monsters; it is possible, however, that the old author lied.

There is another aspect of locusts which needs mention, — their use as food. The Bible often refers to them in this connection, and by the Levitical law they were classed among the ‘clean’ animals. In Africa and in the East they are extensively consumed. The Arabs, for instance, “when they see a cloud of locust hovering in the air and clouding the sky, watch them anxiously, and if they descend near their *adwars*, receive them with shouts of gratitude to God and Mahomet, throw themselves on the ground, and collect them as fast as possible. Previously deprived of their heads, legs, and wings, the locusts well boiled in butter and served up with *alcuz-cuz* are considered a delicious food.” We could continue the references to the use of locusts as food by various races and tribes to a great extent, but space will prevent but one or two more. In America various persons have eaten locusts, and all declare them very palatable. Professor Riley was the pioneer in this line, and he gives the following story repeated essentially in his own words: —

Whenever occasion presented, he ate the locusts, and estimates that, prepared in various ways, he consumed several thousand of them. The first meal was partaken of with considerable repugnance, for he expected to have to overcome some disagreeable flavor, but was agreeably surprised to find that however prepared they were quite palatable. A broth made by boiling the unfledged locusts for two hours in the proper quantity of water, and seasoned with nothing but pepper and salt, is hardly to be distinguished from beef-broth, though it has a peculiar flavor and one not easily described. Fried or roasted in nothing but their own oil, with the addition of a little salt, they are by no means unpleasant eating, and have quite a nutty flavor. In fact, it is a flavor, like most peculiar and unpleasant flavors, that one can soon learn to become fond of.

“I shall not soon forget the experience of my first culinary effort in this line — so fraught with fun and so forcibly illustrating the power of example in overcoming prejudice. This attempt was made at an hotel. At first it was impossible to get any assistance from the followers of the *ars coquinaria*. They could not have more flatly refused to touch, taste, or handle, had it been a question of cooking vipers. Nor love nor money could induce them to do either, and in this respect the folks of the kitchen were all alike, without distinction of color. There was no other recourse than to turn cook myself; and operations once commenced, the interest and aid of a

brother naturalist and two intelligent ladies were soon enlisted. It was amusing to note how, as the rather savory and pleasant odor went up from the cooking dishes, the expression of horror and disgust gradually vanished from the faces of the curious lookers-on, and how, at last, the head-cook — a stout and jolly negress — took part in the operations; how, when the different dishes were neatly served upon the table, and were freely partaken of with evident relish, and many expressions of surprise and satisfaction by the ladies and gentlemen interested, this same cook was actually induced to try them, and soon grew eloquent in their favor; how, finally a prominent banker, as also one of the editors of the town, joined in the meal. The soup soon vanished and banished silly prejudice; then cakes, with batter enough to hold the locusts together, disappeared, and were pronounced good; then baked locusts, with or without condiments; and when the meal was completed with dessert of baked locusts and honey à la John the Baptist, the opinion was unanimous that that distinguished prophet no longer deserved our sympathy, and that he had not fared badly on his diet in the wilderness."

In 1863 locusts ravaged various parts of India, and Mr. C. Home, a fellow of the Zoological Society of London, experimented in locust food. His description of part of his experience is amusing. "In the evening I had asked two gentlemen to dinner, and gave them a curry and croquette of locusts. They passed for Cabul shrimps, which in flavor they much resembled; but the cook having inadvertently left a hind leg in a croquette, they were found out, to the infinite disgust of one of the party, and the amusement of the other."

There is no probability that with us locusts will ever become a staple article of diet. There is too much inborn prejudice, and too much reluctance to try experiments in the gastronomic line to be overcome; and yet the fact that locusts are edible has an important bearing. During the plague of 1874, many of the farmers were in danger of starving; while had they known it, the very forms which destroyed their crops could have been converted into a nutritious and palatable meal.

DRAGON-FLIES AND THEIR ALLIES.

This group is somewhat closely connected to the last by both structure and development; and some of the lower forms usually assigned to it seem to have as good a right to be considered as belonging to the other. Our definitions are exact, but the specimens fail to fall in position as they should: something is wrong, either in nature or in our cut-and-dried systems. It has been the custom for many years in American works to

place the dragon-flies at the base of the insect series; but they certainly are entitled to a higher rank than the cockroaches and the locusts. In European works they are always assigned their proper position.

Passing by some of the less interesting forms, the first we have to notice is the familiar little book-louse, so frequently seen running over the pages of books, especially those left in dusty places. These they sometimes damage considerably by gnawing the paper. In this form the wings are extremely rudimentary, — may almost be said to be absent, — as they form but little scales or patches of no functional importance. In England this species shares with one of the beetles the common name ‘death-watch,’ and is said to make a ticking sort of a noise, which when

FIG. 170.—*Psocus*.

heard is believed to indicate that one of the family is soon to die. Allied forms larger in size and darker in color abound on fences and trees; and these eventually have wings, and then look much like the winged plant-lice, of which we shall have more to say farther on. Our figure represents one of these winged forms, natural size, and another with its wings spread, enlarged. In the spring and early summer the unfledged larvæ abound; but later in the year,

the perfect forms appear. What they feed upon is as yet unsettled.

Closely allied to these minute forms in structure are the celebrated white ants, of which pages might be written. In their general appearance, as well as in their habits, they present a close similarity to the true ants, and to this fact they owe their common name. Their scientific name is *Termes*, and they frequently figure in books as termites, the plural form of

FIG. 171.—Male of the white ants (*Termes*).

the generic name. In reality they are not ants at all, but belong to nearly the opposite extreme of the insect series.

In these forms we find four different kinds of individuals. First come the males, which are provided with wings; and then the females, which at first resemble the males, but which later change in a remarkable way, as will be described farther on. The third are smaller individuals, with small heads and jaws, and without wings. In them the sexual organs are not

developed. These are the workers, and on them the whole labor of the colony falls. They collect the food and prepare it, excavate the mines, build the hills, care for the males and females, and take charge of the eggs and young. In these respects they closely compare to the workers among the bees and ants, except in lacking wings. Last in order come the soldiers,

FIG. 172.—Worker of the white ant.

FIG. 173.—Soldier of the white ant.

individuals with large heads and jaws, whose duty it is to guard the colony. There are usually about a hundred workers to one soldier.

For a large proportion of our facts regarding the habits of the white ants we are indebted to Smeathman, who over a century ago published a paper entitled 'Some Account of the Termites which are found in Africa and other Hot Countries.' Many of his facts have long been accepted, but others have been doubted. It turns out, however, that his accuracy was even greater than has been supposed, and later observers have confirmed almost all of his statements. To better understand the life history and economy of the termites, let us follow a colony through one cycle of its existence.

From the eggs hatch out the numerous young, which are carefully attended and fed by the workers. Some stop short in their development, and change into the workers and soldiers, while the others go on, grow the wings, and become the perfect males and females, which fly about for a short time. From these perfect insects the workers choose a king and queen, and carefully wall them up in a small clay chamber, leaving but a single, small opening through which the soldiers and workers can readily pass, but which is not large enough for the royal couple to pass. The other perfect insects not so selected soon die. Inside the regal chamber the king and queen are carefully fed by the workers, and here the royal marriage takes place. The queen now loses her wings, and with the growth of the eggs her abdomen becomes distended to an enormous size in comparison with which the head and thorax seem insignificant. Soon the egg-laying begins and continues at the rate of sixty a minute. These eggs are taken charge of by the workers as fast as they are deposited, and carried to a special chamber or nursery, where they soon hatch, and the cycle is thus complete.

We have some four or five species of termites in the United States, one of which extends as far north and east as Cambridge and Salem, Mass., but is far more abundant farther south. This form constructs its mines in

stumps and the roots of trees, or occasionally extending its ravages into the sills of houses, where it eats out all the interior, leaving but a thin, external shell, so that what to all appearance the timber remains solid it is really utterly destroyed. With us, however, the damage they do is trifling in comparison with what they occasion in the tropics. Every book of

FIG. 174. — Female white ant (*Termes*), with her abdomen distended with eggs.

travel in the warmer climes tells of the annoyance they produce, and really wonderful stories are told of their engineering abilities. Again and again has it been related that they will bore up through the floor of a house into the leg of a chair or a table, and then completely riddle the furniture by gnawing out the whole insides; and all the while the occupants of the dwelling have not the slightest suspicion of their presence, and only learn of the damage when on attempting to use the article it tumbles to pieces in their hands.

Smeathman describes the workings of an African species in the following language: "They sometimes, in carrying on this business, find, I will not pretend to say how, that the post has some weight to support, and then if it is a convenient track to the roof, or is itself a kind of wood agreeable to them, they bring their mortar and fill all or most of the cavities, leaving the necessary roads through it, and as fast as they take away the wood, replace the vacancy with that material, which being worked together by them closer than human strength or art could ram it, when the house is pulled to pieces, in order to examine if any of the posts are fit to be used again, those of the softer kinds are often found reduced almost to a shell, and all, or a greater part, transformed from wood to clay, as solid and as hard as many kinds of freestone used for building in England. It is much the same when the *Termites bellicosæ* get into a chest or trunk containing cloths or other things; if the weight above is great, or they are afraid of ants or other enemies, and have time, they carry their pipes through and replace a great part with clay, running their galleries in various directions. . . . These insects are not less expeditious in destroying the shelves, wainscoting, and other fixtures of a house, than the house itself. They are forever piercing and boring in all directions, and sometimes go out of the

broad side of one post into that of another joining to it ; but they prefer, and always destroy, the softer substances first, and are particularly fond of pine and fir boards, which they excavate and carry away with wonderful dispatch and astonishing cunning ; for, except a shelf has something standing upon it, as a book, or anything else which may tempt them, they will not perforate the surface, but artfully preserve it whole, and eat away all the inside except a few fibres, which barely keep the two sides connected together, so that a piece of inch-board, which appears solid to the eye, will not weigh more than two sheets of pasteboard of equal dimensions after these animals have been a little while in possession."

Most of the white ants live in subterranean burrows or in plants and trees, but on the western coast of Africa there is a species which builds enormous ant-hills, sometimes ten or twelve feet in height, and conical in shape. The material is clay well worked by the mandibles, and so solidly packed together that the hill will easily support the weight of a man or even, it is said, of an ox. Inside there are numbers of chambers, reminding one of the hills of true ants ; in some are the stores of the colony — wood comminuted, and formed into masses ; inside of these are the nurseries with the eggs and young ; while in the centre is the royal chamber where dwell the helpless king and queen.

One species, occurring in Java, forms huge excrescences on the trunks of trees. Says Mr. H. O. Forbes, from whom we shall frequently have occasion to quote : "It is worth while to break down a portion of their tough walls, to watch for half an hour the out-rush of the city guards, with their *pickelhaube* heads, who, with elevated antennæ, sniff round everywhere for the cause of alarm, charging about frantically, and beating their spiked frontlets against the walls in a most threatening way, till they think the danger past, when they retire and order out hordes of builders to repair the breaches, who, distinguished at once by the absence of a frontal spike, have, till then, kept away from the scene. After a general survey of the ruins, each worker retires to fetch a small squarish chip, carefully examines the exact place into which it is to be built ; then applying to that spot the tip of its abdomen, it excretes a drop of a pale glutinous substance, places in it the chip, and hammers it down by the combined application of its maxillæ and antennæ. While the building is going on, a company of soldiers stalk about the walls, guarding the workers, every now and then tapping their heads with the conscious air of a constable reminding them that his presence is their safety. Thus block after block, with amazing rapidity, is cemented together, and the sewage of the colony is piled into the odorless homogeneous walls of their dwelling."

Says Dr. A. S. Packard : "Were we to select from among the insects a

type of all that is savage, relentless, and bloodthirsty, the dragon-fly would be our choice. From the moment of its birth until its death, usually a twelve-month, it riots in bloodshed and carnage. Living beneath the waters perhaps eleven months of its life, in the larva and pupa states, it is literally a walking pitfall for luckless aquatic insects; but when transformed into a fly, ever on the wing in the pursuit of its prey, it throws off all concealment, and reveals the more unblushingly its rapacious character."

In popular estimation, the dragon-flies or 'devil's darning-needles' are horrible, and every boy in the land possesses the belief that they will sew up his ears: and even when he grows to man's estate, though this aspect be forgotten, he always has an antipathy towards these quick-flying, gayly colored forms. In this he is wrong, wholly wrong. Despite their ferocity, the dragon-flies are productive of naught but good to man; indeed, their very ferocity makes them the more his friends, for they feed wholly on mosquitoes and other insect pests. As they dart through the air, their

FIG. 175.— The metamorphoses of dragon-flies. Two larvæ are shown in the water catching insects with their 'mask': on the reed at the left is a larva skin; at the right a pupa skin, from which the adult in the centre has escaped.

burnished bodies flashing their golden green in the summer sun, they are constantly seizing and devouring; and before they reach their winged condition they had the same insect-eating lives; but so peculiar are the features of larval life, they deserve a paragraph by themselves.

From the egg there hatches out a little six-footed larva, in its general appearance like the two lower figures of our cut. On the back are shown the two little wing-pads; while below the head is a most peculiar apparatus, the so-called 'mask.' In its ordinary state this mask is folded up below the 'face,' and this aquatic monster then appears as harmless as possible;

but this is all appearance, for this mask is in reality a wonderful apparatus for seizing its prey. Some luckless insect or worm ventures near, when the mask is suddenly extended as shown in the lower figure on the left, and then the two jaws at its extremity grasp the prey. Now the mask folds up again, bringing the object caught exactly under the mouth, where the true jaws soon tear it to pieces of a suitable size for swallowing. The larva does not depend on its legs alone for locomotion; it has at the posterior end of its body a curious syringe-like apparatus. Into this the water is drawn, and then it is forcibly expelled, shooting the animal forward with considerable force.

The pupa differs from the larva in but little, except in the larger wing-pads; it continues the same predatory life, and no one who has not studied them can have any idea of the amount of life they destroy. By and by the time comes when the pupa is to change to the adult. It climbs up some plant to the surface, and then the skin of the back splits open, and from the opening emerges the perfect dragon-fly, perfect in all except that its wings and body are soft and flabby. A short exposure dries its wings, and then away it flies. The whole of these changes have been described by Tennyson in his "Two Voices":—

"To-day I saw the dragon-fly
Come from the wells where he did lie.
An inner impulse rent the veil
Of his old husk; from head to tail
Came out clear plates of sapphire mail.

"He dried his wings; like gauze they grew;
Through crofts and pastures wet with dew
A living flash of light he flew."

In early summer the water gives birth to other forms besides the dragon-flies, and among them to may-flies; insects with large front wings and small hind ones, and the body terminating in two or three long tails. The name may-flies is given from the fact that many of them appear in the month of May, while another name, day-flies, alludes to the short duration of their life as perfect insects, sometimes lasting but a few hours. They leave the water in the night, and in some places—for instance, Buffalo—in such numbers that they sometimes obscure the street-lamps. In their brief existence they lay their eggs in the water, and that is all. The larval stage is much longer, in all lasting for nearly a year, and in some forms for two or three years.

FIG. 176.—May-fly (*Poptananthus marginatus*).

The horned corydalus is one of the most formidable-looking of insects, the strong jaws, especially developed in the male, giving them a most ferocious appearance. In reality they are harmless, and the long jaws of

FIG. 177. — Female of the horned corydalus (*Corydalus cornutus*).

the male are utterly incapable of biting, but are only used for seizing the body of the female during the act of pairing. Like so many others of the forms under discussion, the larva of the corydalus is aquatic, and is well known as the favorite bait of fishermen, — the hellgrammite. In the larval state it occurs abundantly in rivers and ponds of the northern states, and there devours an immense amount of small aquatic worms and larval insects, and thus does a deal of good.

FIG. 178. — Hellgrammite, the larva of the horned corydalus.

Closely allied to these last are the ant-lions, most interesting in their larval stages. In Europe they are very abundant, but in our country they seem to be more local. The largest colony ever seen by the writer was in the sand in one of the many picturesque gorges at Ithaca, N.Y., although even larger ones have been noticed. The larval ant-lion marks out a circle some two inches in diameter in the sand, and then throws out all the sand inside this circle with its jaws. The flirt they give is so strong that the sand is thrown some five or six inches, and thus there is no ridge around the edge of the pit. Little by little the excavation goes on, until at last the limit of stability is reached. The ant-lion can dig no

further because the sand will tumble down as fast as the larva could throw it out. The ant-lion now works its body under the sand at the bottom of the hole, having only its jaws exposed. If, now, an ant wanders over the brink of the pit, the sand gives way under its feet, and it tumbles down

FIG. 179.—Adult ant-lion (*Myrmeleo*), with the pit, showing the protruding jaws of the larva.

toward the centre and the expectant jaws. The ant-lion now throws up more sand so as to aid in bringing down the prey, and at last the jaws close upon the victim. After a long life of this character, the ant-lion spins a cocoon, changes to a pupa, and at last emerges a perfect insect,

FIG. 180.—Different forms of cases of caddis-worms.

much like a dragon-fly in its general appearance, of which there is but little of general interest to record.

The larvæ of the caddis-flies or case-flies parallel, among insects, the hermit-crabs. With only a single known exception they are all aquatic,

living in streams and ponds. Each larva constructs a case to protect its soft body, and, protected by these, they crawl about over the bottom. In shape and material there is a great difference in these cases, as is shown by our figures. Some cement grains of sand together by means of a silky substance; others use sawdust, snail-shells, dead leaves, pine needles, or anything they may run across to make their cases; and one form builds a spiral case, almost the exact counterpart of the shell of a snail. Indeed, naturalists have made the mistake and described these shell-like cases as the shells of new species of molluscs. These caddis-worms are carnivorous, and live upon the smaller and even microscopic forms of animals which inhabit the same waters. The perfect insects resemble to a considerable extent some of the moths, and it may be that here is to be sought the line of descent of these higher forms.

BEETLES.

The beetles form by far the largest group of the animal kingdom, the number of species possibly equalling those of all of the other groups together. Two German students, Gemminger and Harold, published, a few years ago, a catalogue of all the described species of beetles. It contained over seventy-seven thousand names; but it of course could not be complete. Making due allowance for omissions, and for species described since the publication of the catalogue, there must be considerably over a hundred thousand species of beetles described, and there are thousands more in collections waiting to be worked up. It is only in Europe and the Eastern United States that we have any adequate knowledge of our insect forms, and even in these much-explored regions new species are continually turning up. In the United States, which is comparatively poor in species, the last catalogue (by Mr. Samuel Henshaw) enumerates 9789 species, and there are still many more to be described. In the presence of such numbers as these, one at once sees how impossible it is to have common names for all the species.

FIG. 181.—A tiger-beetle (*Tetracha*).

The beetles have strong jaws, well adapted for biting, and two pairs of wings, the first pair of which forms a hardened sheath for the other pair, which alone is of use in flight. This ensheathing has given rise to the scientific name of the group Coleoptera, which is derived from the Greek for sheath-wing. When at rest (the condition shown in most of our figures), these outer wings—elytra, they are called—are folded on the back, perfectly concealing the thinner ones, which are compactly folded below. In flight the wing-covers are held elevated over the back, while the under pair are rapidly vibrated.

In the beetles the metamorphosis is more complete than in the forms of insects already described. The larva has six pairs of feet, and strong jaws. In its external appearance it may be much like a worm, as in the case of the wire-worms and cut-worms, which are such pests to the farmers, or it may be shorter and more fleshy, like the grubs so familiar in decaying wood. The pupa is much like the perfect insect; one can readily trace in it all the features of the adult. In some there is a cocoon which may be constructed out of the surrounding material, or, in rare instances, spun by the insect itself.

From the economical standpoint beetles may be divided into three groups: those which are directly injurious to human interests from their feeding upon cultivated plants, or upon other things valued by man; second, those which have from the nature of their food but little influence upon agriculture or the like; and lastly, those which are directly beneficial from the fact that they live either upon decaying animal or vegetable matter, or upon other insects which are injurious.

First of these beneficial forms are the lady-birds, with which all are familiar. Their hemispherical, polished bodies and their bright colors and pretty markings make them favorites with all. The only plausible explanation of their common name is that it was applied out of compliment to the beauty of the insect: from this standpoint it is certainly deserved. The species of lady-birds are numerous, and may be found climbing over the leaves of plants, especially those with conspicuous flowers. They feed to some extent upon the pollen of the flowers, but

FIG. 182.—Lady-birds (a, *Coccinella trifasciata*; b, *C. 9-notata* and pupa; c, d, e, larva, pupa, and adult of *Hippodamia*; f, *Chilocorus*).

this is but an item in their diet; for they are fond of small insects, especially the plant-lice that swarm upon certain plants, and which, unless checked by these pretty beetles, would work extensive injury to the foliage. It would be a tedious task to describe our various species, nor is such a course desirable. Our cut illustrates four of the more common forms; and most of the species are essentially similar, the variations being in the number of spots, and the colors red, orange, and black predominating.

Somewhat similar in appearance to the lady-birds, but greatly different

in habits, are the leaf-eaters, mostly brightly colored, hemispherical beetles which feed exclusively upon vegetation, and some of which on this account become of considerable importance.

Possibly the best known of all the species is the celebrated Colorado potato-beetle, which a short time ago was a subject of such great dread to the farmer. The species was first made known many years ago (1824) by Thomas Say, the naturalist of Long's expedition. He found it upon the upper Missouri, where it fed upon the sand-bur. Gradually civilization spread west, carrying with it the cultivation of the potato. At last this plant reached the territory occupied by the beetle, which at once left its old food and attacked the new. At first its eastward spread was slow, not exceeding on the average fifty miles a year; but after the Mississippi was passed its rate rapidly increased, so that, in 1874, just fifteen years after it began its travels, it reached the Atlantic coast. It was a noticeable fact that its progress was most rapid on the line of the railroads. It appeared to

FIG. 183. — Eggs, larva, and adult of the Colorado beetle (*Doryphora decemlineata*).

travel on the cars, either climbing upon them or being put inside them with the freight, and thus at times it appeared in localities remote from any other district ravaged by it. In this way it rapidly spread over an area of a million and a half square miles.

At first its ravages were very considerable, — for there was nothing to check them, — and the farmers feared that the days of the potato were numbered. Gradually it was learned that certain arsenical poisons, like Paris green and London purple, could be used against the beetle; but it is doubtful if this alone would have had any considerable effect in checking the pest. Others, and far more efficacious agencies, were at work. We have already alluded to the balance in nature, and this stepped in here to avert disaster. The rapid increase in the number of potato-beetles was accompanied by an almost equally rapid development of insect-eating forms. Such an abundance of food allowed individuals to live which otherwise would have perished. Lady-birds ate the eggs and the young, flies fed on them, and bugs sucked their juices, while birds and the despised toads

picked off the adults. Nature soon established a balance, and now the potato-beetle, though still a nuisance, has far less prominence than it had a dozen years ago.

It is rather amusing to consider the alarm the spread of the potato-beetle caused in Europe. Severe penalties were imposed upon any one who should bring the pests, their eggs, or their larvæ into Germany or the British possessions. In the light of our experience with the beetle it would seem as if the scare was greater than the subject would warrant, but still there is no doubt that Europe is better off without the beetles.

One of the most interesting features connected with the spread of the potato-beetle is the change in the character of its food. In its western home it fed upon the prickly sand-bur (*Solanum rostratum*), which, though it belonged to the same genus as the potato (*S. tuberosum*), differed from it considerably in character. In the east it has varied its diet considerably; for besides the potato, bitter-sweet, and deadly night-shade (all of which belong to the same genus) it will eat thistles, pigweed, cabbage, and several other plants. This change is the more remarkable since another closely allied beetle (shown on the right of our cut), living in the southern states, there feeds on the horse-nettle (*Solanum carolinense*), a close ally of the potato, but does not attack the potato itself. These two beetles, as will be seen from the cut, are very similar in appearance; the Colorado potato-beetle has ten black lines on the wing-covers; the other has but eight.

Before the advent of the species just mentioned, the term potato-beetle was universally applied to a much smaller form, with yellow head, and three black stripes upon the wing-covers, much like the next species, but larger, and differing considerably in anatomical details. The larvæ of this species have a habit which is also found in some of the allied forms. "After making a hearty meal upon the leaves of the potato, they cover themselves with their own filth. The vent is situated upon the upper side of the last ring [of the body], so that their dung falls upon their backs, and, by motions of the body, is pushed forwards as fast as it accumulates, towards the head, until the whole of the back is entirely covered with it. This covering shelters their soft and tender bodies from the heat of the sun, and probably serves to secure them from the attacks of their enemies."

The gardener frequently has occasion to lament the loss of his young cucumber-plants. One day they will thrust their first leaves above the soil; a few days later they will be cut off and withered, the cut being made just below the surface of the earth. This is done by the larvæ of a small yellow beetle, with black head,

FIG. 184.—Cucumber-beetle (*Diabrotica vittata*).

and three black stripes on the wing-covers. It can be seen in numbers around the cucumber, squash, and other similar plants.

The flea-beetles, which derive their common name from their jumping powers, are also leaf-eaters, and one polished steel-blue species is a serious pest on the grape, eating the buds as well as the leaves; another feeds on the cucumber and potato, while a third infests fields of turnips.

Another type of leaf-eating beetles has received no common name, and so, perforce, we must use the term under which it figures in science, — *Donacia*. The species of this genus live on aquatic plants, the larvæ beneath the surface. One species which occurs in Europe has a most peculiar way of obtaining the air necessary for respiration while beneath the water. With its jaws it gnaws a hole in the stem of one of the aquatic plants, and sticks the tip of its abdomen into the opening. On the tip of the abdomen are hooks which serve to hold the larva fast; but they have another purpose as well. Each of the hooks is traversed by one of the air-tubes of the larva, and so these hooks are breathing-organs as well as anchors. In the tissues of the plant there is a considerable amount of air, and this furnishes the oxygen necessary for respiration.

There is but one of the leaf-eating beetles which has any value; and this a brilliant bronze-green species, with a very hard body, which is sometimes set in gold and used as jewelry. The species is very abundant in South America, and specimens can frequently be bought in our own markets for twenty-five cents apiece.

The long-horn beetles receive their common name from the long antennæ with which most of the species are provided. Like the leaf-cutters they

FIG. 185. — Apple-tree borer (*Leioptus*), one of the 'long-horns.'

FIG. 186. — Common apple-tree borer (*Saperda*): larva, pupa, and adult.

are to be classed among the injurious forms; but these do most of their damage by boring during the larval state in the interior of plants and trees. Many of the species are very beautiful, and the group is a favorite one with collectors.

One of the best known of the long-horns is the apple-tree borer, a nearly cylindrical beetle, about three-quarters of an inch in length. It is

a light brown, with two longitudinal white stripes on the back. The perfect insect lays her eggs in the crevices of the bark; not only of the apple, but of the pear, quince, and other trees belonging to the rose family. The grubs hatched from the egg bore into the solid wood, then they turn upwards and ascend some eight or ten inches. In the tree they remain some two or three years, and then they turn the burrow outwards, so that it ends just beneath the bark. The larva now becomes a pupa, and a month later the perfect beetle gnaws its way through the bark, and emerges into the outer world to become the parent of a new generation.

The life-history of this species is about like that of all the rest, of course making due allowance for the change of food plant. To describe these forms and their slight variations in habits, and the trees and shrubs affected by them, would be to furnish a lot of dry details, for which the reader had better refer to some of the many works on injurious insects. There are, however, one or two peculiarities which may prove of interest. One species of long-horn which lives in our southwestern states is especially fond of the printed portions of posters, and it gnaws them out, leaving the white paper untouched. The hickory-twig girdler lays its eggs in the bark of the slender twigs of the hickory and persimmon and then girdles the twig below the egg, cutting away a ring of bark with her jaws, so that the portion which contains the eggs withers and dies, thus giving the larva dead wood to feed upon. A somewhat similar habit is noticeable in a species which feeds upon the oak. The eggs are laid in the slender green twigs, and the larva then eats away the interior, so that nothing but the thin bark is left, which soon withers and dies, and the twig is soon broken off by the wind and falls to the ground. The process has been described at length by the late Dr. Fitch, and his account is so interesting that the reader will pardon some extracts.

"The worm being about half grown is now ready to cut the limb asunder. But this is a most nice and critical operation, requiring much skill and calculation; for the limb must not break and fall while he is in the act of gnawing it apart, or he will be crushed by being at the point where it bends and tears asunder, or will fall from the cavity there when it breaks and separates. To avoid such casualties, therefore, he must, after severing it, have time to withdraw himself back into his hole in the limb and plug up the opening behind him before the limb breaks and falls. . . . He accordingly severs the limb so far that it will remain in its position until a strong gust of wind strikes it, whereupon it will break off and fall.

"But the most astonishing part of this feat remains to be noticed.

FIG. 187. — The hickory-girdler (*Oncideres cingulatus*) at work.

The limb which he cuts off is sometimes only a foot in length, and is consequently quite light; sometimes ten feet long, loaded with leaves, and very heavy. A man, by carefully inspecting the length of the limb, the size of its branches, and the amount of foliage growing upon them, could judge how far it should be severed to insure its being afterwards broken by the winds. But this worm is imprisoned in a dark cell, only an inch or

FIG. 188. — The shining chestnut-borer (*Arrhopalus*), enlarged.

two long, in the interior of the limb. How is it possible, therefore, for this creature to know the length and weight of the limb, and how far it should be cut asunder? A man, moreover, on cutting a number of limbs of different lengths, so far that they will be broken by the winds, will find that he has often miscalculated, and that several of the limbs do not break off as he designed they should. This little worm, however, never makes a mistake of this kind. If the limb be short, it severs all the woody fibres, leaving it hanging only by the outer bark. If it be longer, a few of

the woody fibres on its upper side are left uncut in addition to the bark. If it be very long and heavy, not more than three-fourths of the wood will be severed . . . With such consummate skill and seemingly superterrestrial intelligence does this philosophical little carpenter vary his proceedings to meet the circumstances of his situation in each particular case!"

Some of the long-horns are peculiar in their shapes. In some the first pair of legs are greatly lengthened; in others, the antennæ may be five or six times the length of the body. Some are dull-colored, others are decked

FIG. 189. — Pine-tree borers (left, *Orthosoma cylindricum*; right, *Prionus laticollis*).

with the brightest hues, laid on in the most peculiar patterns. All possess organs for producing a noise, some of a squeaking, others of a rasping character. These noises are all produced by rubbing one part against another, much as in the crickets and locusts, already alluded to. Sometimes the wings, sometimes the legs, and sometimes the rings of the thorax, are the parts concerned, and a microscopic

examination shows that these parts are covered with fine striations, and hence the noise in its character resembles that produced by rubbing a fine file with a quill.

With us most of the weevils are small, inconspicuous forms, but in the tropics are species which rival the long-horns in size and beauty. Possibly

FIG. 190. — Long-horned weevil (*Xenoceros*).

the best known of these tropical forms is the celebrated diamond-beetle of Brazil; a brilliantly green-colored form from an inch to an inch and a quarter in length. In reality the beetle is black, and the colors are due to the scales which line the shallow pits on the surface. These scales are finely striated, and the color is produced by diffraction exactly as in the case of the pearl-oyster. There are several thousand species of weevils known, all of which are injurious to vegetation, but of all this number we can mention but two or three.

Best known of all the series are the pea and bean weevils, of which

FIG. 191. — Bean and pea weevils (*Bruchus*), enlarged; the lines at the sides of each show the natural size of the beetles.

three species are shown in our cut. It should be noticed that the figures of the insects are enlarged, while those of the plants are of the natural size. The true length of each beetle is shown by the hair-line at the side.

The form at the left of the cut is our common pea-weevil. The female of this fastens her eggs to young pods of the pea just after the flower has fallen. The larva which hatches from the egg bores its way into the peas themselves, and grows with them, and after the peas are ripe it changes to the perfect beetle. These 'buggy peas' are planted the next year, and then the beetle crawls out to lay its eggs as before. There are various ways of averting the danger. One may keep his seed-peas two years, and then they will germinate as well as ever, but the weevils will crawl out of the peas the first year and die without finding a suitable place to deposit their eggs. Or one may put the peas for a moment into hot water before planting them. This will not kill the germ, but every weevil will succumb.

Others of the weevils live between the bark and the wood of trees, and frequently one will find their peculiarly ramifying mines in the bark of pine and other trees. A German student has studied the habits of these bark-weevils, and has made some very interesting discoveries in connection with them. The male beetle excavates a copulation chamber beneath the bark, and here awaits the females. After copulation the females eat radiating passages out from this chamber, and on the sides of each they lay their eggs. If only one female comes to the male, then but one radiating passage is made; but if there are more females, the number of passages is

FIG. 192.—Mines of bark-boring beetle (*Scolytus*) in pine bark.

FIG. 193.—Bark-boring beetle (*Tomicus*), enlarged.

correspondingly increased. The larvæ in their turn eat passages at right angles to those made by their mothers, and in this way are produced the curious markings shown in our cut. Each species of these bark-beetles produces its own style of burrow, and the experienced entomologist can at once say what form has made the mines.

The weevils already mentioned have a short head; but others have the head prolonged into a sometimes enormous snout, at the very extremity of which are the small jaws, while the antennæ, as shown in the cut, take their origin from its sides. Of these forms there are many species each with its own peculiar habits. Some of them feed upon grain, some upon rice, some

upon leaves, and still others upon the pith or even on the solid wood of trees. Indeed, there are but few vegetable substances which are exempt from their ravages.

Among these forms the plum-weevil has attracted considerable attention. It is a small species, scarcely a sixth of an inch in length, which at times has seriously affected the plum crop. This weevil bores a hole in the green plum with her proboscis and deposits an egg in it; then she cuts a semicircle in the skin of the fruit around the egg, the whole making a mark much like the crescent and star of the Turkish flag, a fact which has won for this little insect the name of 'the Turk.' The infested plums soon fall to the ground, and there the beetle undergoes the rest of its development. If hogs be turned into the orchard, they will devour the infected fruit as fast as it falls, and will thus reduce the damage in the succeeding year.

The worms in chestnuts and hazel-nuts are the grubs of somewhat similar weevils, while still others affect acorns and hickory-nuts. Our cut shows one of these forms boring into the green hazel-nut to deposit its eggs, while below is a nut which has been punctured.

The oil-beetles and blister-beetles, though not conspicuous forms, present many features of interest, especially in their development.

and some are remarkable among beetles from the fact that they live a portion of their lives as parasites. Our most abundant form is the dark steel-blue oil-bottle, which is common during the summer. Its life-history is unknown, but it seems probable that like some of its allies it passes part of its life in the nests of bees. The name oil-bottle is derived from the fact that the insect when disturbed emits a disagreeable, oily fluid, which is stated to contain uric acid. An allied species from South America is remarkable for its peculiar proboscis.

FIG. 194. — Hazel-nut weevil (*Balaninus nucum*): below, a side view of the head.

FIG. 195. — Plum-weevil, or 'little Turk': *a* is the larva; *b*, the pupa; and *c*, the adult; all enlarged. At *d* is a young plum, showing the weevil at work, and one of its crescent-shaped marks; natural size.

FIG. 196. — Hazel-nut weevil, boring into the nut to deposit her eggs.

This organ is formed, like the proboscis of butterflies, by the union of the two maxillæ, each of which is hollowed out like a trough on its inner surface, and the two being pressed together thus form a tube which is used in sucking the nectar of flowers.

FIG. 197. — Palm-boring weevil.

One of the best-known members of the present group is the blistering-beetle, or Spanish fly, which has an extensive use in medicine. It is a bronze-green beetle (it is not a fly at all) about three-quarters of an inch in length, and it has its home in southern Europe and the adjacent parts of Asia. Its vesicatory

powers are due to a substance known as cantharidin which occurs in all parts of the beetle. It is not confined to this species alone, but in most of the allied forms, some containing an even greater proportion than the officinal Spanish flies. The preparation of the flies for the market is a simple affair; they are killed by heat and then dried. For producing a blister they are ground, and the powder is made into a plaster.

FIG. 198. — Spanish flies (*Lytta vesicatoria*).

Spanish flies have been extensively used in medicine for many years, and yet the life-history was not worked out until 1879. Like many of its allies it lives a parasitic life during its larval state upon a hymenopterous insect, and this habit has introduced a complex metamorphosis into its development.

The position of *Stylops* and its allies, another group of bee-parasites, is very uncertain; there is reason for believing that it is not a beetle at all, and yet from its habits it may be considered here. There is a great difference between the sexes, as is shown in our figures. The male has very large wings, capable of being folded up like a fan, but the wing-covers are little crumpled things, of no functional importance. The females,

on the other hand, are little footless grub-like forms, which no one who did not know the history would suspect were adults. The males can fly freely, but the females spend their lives as parasites in the abdomens of bees, the head alone protruding between the segments, as shown in the adjacent figure, in which the dotted outline indicates the extent of the body of the female *Stylops*. The eggs of the *Stylops* hatch inside the mother, and then escape and run freely about the hive until they have a chance to climb on to some bee-larva, and they there pupate and retain their position until the bee-larva becomes the perfect insect.

FIG. 199.—Bee-parasite (*Xenos*), male and female: a, the fore wings.

FIG. 200.—Abdomen of a bee, showing, in dotted outline, the position which the female *Stylops* occupies within the body of the host, the head alone projecting between the segments; below, the female extracted.

The so-called death-tick may be taken as the representative of another group of beetles but remotely related to those which have preceded. It receives its name from the peculiar ticking noise which it makes, which is regarded by the superstitious as foreboding death or disaster. The beetle is a small, dark-colored form scarcely a quarter of an inch in length, and it produces its noise by pounding against some object with its head. The writer once saw one upon a roll of paper, pounding away, and as this formed an excellent sounding-board, the noise was far more distinct than usual. The beetle would pound, say a dozen times, as regularly and about as rapidly as a watch ticks. then it would pause several seconds and again repeat the noise. Of course this ticking cannot have the slightest connection with human affairs;

it is rather a signal by which the insect calls for its mate.

Allied to the death-tick are any number of injurious beetles, which will feed upon substances which are usually rejected by insects. Some will eat tobacco, capsicum, and drugs of various sorts, which would quickly kill other beetles, and do not appear in the least to suffer by the strange diet. One of these forms which does considerable damage in woollen goods and in museum collections is represented in the centre of Figure 208, on a subsequent page.

One will frequently find upon flowers in the summer numbers of pretty beetles having a general resemblance to the species here figured. They

are somewhat important to the farmer, from the predaceous habits of their larvæ, some destroying the young of many injurious insects; but the species figured sometimes proves injurious, as it frequently occurs in bee-hives, where it eats the bees and spoils the honey, by making its nest in the comb.

FIG. 201.—Bee-parasite (*Trichodes*).

Far more interesting than these forms are the fire-flies, with whose appearance all are familiar; but whose light is still a puzzle to students. The luminous qualities are not confined to the adult flying beetles, but are found in the eggs and larvæ as well. One will frequently find on a damp summer evening a worm-like creature crawling in the grass, which gives off a soft phosphorescent light; this is a glow-worm, either the larva or wingless female of a fire-fly. In the adult fire-flies the luminous organs may be either on the upper or the under surface of the abdomen, but are inside the integument. These organs are rather large, and are well supplied with air-tubes, thus allowing

FIG. 202.—Glow-worms and fire-flies.

a rapid oxidation of the tissues, but what the substance is which is burned, no one has yet found out. The light has been studied with the spectro-scope, and found to consist of rays with but little thermal or actinic effect but which greatly affect the visual organs. The spectrum is continuous.

Our fire-flies are small in comparison with some of the tropical forms. In Central and South America are species which reach a length of between one and two inches, and have light-giving powers to correspond. This phosphorescent capacity is not, however, confined to the true fire-flies; but is shared by some members of the group of spring-beetles now to be taken up. One of these species, the cucuyo or cucujo, of Spanish America, reaches a length of an inch and three-quarters, and is the most highly luminous insect known. In the daytime it is not attractive in appearance, as it is a dirty brownish black; on the sides of the thorax are the oval lanterns,

while there is another on the lower surface of the abdomen where it joins the thorax. An old writer thus describes the way in which the inhabitants of the West Indies catch these beetles:—

“Who so wanteth cucuij, goeth out of the house in the first twilight of the night, carrying a burning fire-brande in his hande, and ascendeth the next hillock, that the cucuij may see it, and hee swingeth the fire-brande about, calling cucuius aloud, and beateth the ayre with often calling *cucuie, cucuie*. Many simple people suppose that the cucuij, delighted with the noise, come flying and flocking together to the bellowing sound of him that calleth them, for they come with a speedy and headlong course; but I rather thinke that the cucuij make haste to the brightness of the fire-brande, because swarms of gnattes fly into every light which the cucuij eat in the very ayre, as the martletts and swallows doe. Some cucuius followeth the fire-brande, and lighteth on the ground; then he is easily taken, as travelers may take a beetle, if they have need thereof, walking with his wings shut. In sport and merri-ment, or to the intent to terrify such as are affrayed of every shadow, they say that many wanton wild fellowes sometimes rubbed their faces by night with the flesh of a cucuius, being killed, with purpose to meet their neighbors with a flaming countenance, as with us wanton young men, putting a gaping vizard over their face, endeavor to terrify children or women who are easily frightened.”

A much later writer gives another account which the reader will certainly excuse us for quoting. After describing several insects of Cuba, the present insect is taken up as follows: “But a really beautiful and interesting insect is the cucujo, or famous fire-fly of the West Indies, two of which I now have on my table in an impromptu cage, where they have been domesticated for a week. Very docile are they in my hands, to whose touch they seem to have become pleasantly accustomed, taking kindly to a diet of moist sugar in lieu of sugar-cane, which is their appropriate aliment, and accepting a semi-daily bath in my wash-basin with great apparent enjoyment, floating about in the water for several minutes, and then spreading out their legs and feelers as a sign that they are ready to come out. They are a sufficiently unattractive bug in their unilluminated state, being of a dingy earth-brown color, and about the shape and size of a large cockroach; but they become so glorified by the irradiance of those wondrous orbs of phosphorescent light which they carry about on their shoulders, that the children scream with delight at the sight of them, and ladies make pets of them as I do, and even use them as ornaments

FIG. 203. — Cneujo, one of the phosphorescent snapping-beetles.

on some occasions. I saw a lady at the 'Retreta' once, with a coronet and stomacher of them; and all the crown jewels of Spain could not have made her so resplendent. The light is not a flash, seen but a moment and then gone, like our fire-fly's light, but it is emitted in a brilliant, steady ray, at will, and is of extreme beauty of tint, being of a slightly greenish yellow viewed in some positions, and of pale red viewed in others." To the foregoing it only needs to be added that the phosphorescence is completely under control: while the beetle is eating or sleeping no light is emitted; but if they be given a warm bath, it is greatly stimulated. The perfect beetles live from April to July or August.

The cucujo, as was said above, is a member of the group of snapping-beetles, all of which, during their larval stages, live upon vegetable substances, some on the soft and succulent plants, others boring in the wood of the harder trees. The common name is derived from the curious way these insects have of snapping or springing to a considerable height when placed upon their backs. On the under side of the thorax there is a spring; the insect bends backwards as far as possible, and then releases the spring, which suddenly bends the body in the opposite direction, thus throwing the beetle into the air. We have many species of these spring-beetles, almost all of them dull, inconspicuous forms with but little of general interest aside from the spring about them.

FIG. 204. — Elater, or snap-beetle, with its larva, commonly called a wire-worm.

Every traveler to Egypt brings back with him little stone or pottery beetles (either genuine or manufactured in England) the Scarabæi of the ancient Egyptians. In all the countries around the Mediterranean the beetle which formed the model exists to-day, and is regarded as the type of a large group which is called Scarabæus, individuals of which, some of great size, are found in all parts of the world, the species described amounting to over seven thousand.

The Scarabæus proper is shown in the lower centre of our cut, engaged in a most characteristic operation. It gathers up particles of the dung of various mammals, and in the centre a single egg is laid. The dung is now pushed along with the head and the hind legs, until the rolling converts it into a round, hard ball nearly two inches in diameter, which they proceed to bury in a hole which they excavate to the depth of a foot or more. So far the history was known to the ancient Egyptians, but they supposed that all the beetles were males. From these facts and suppositions this beetle was held sacred and invested with a symbolism of deep significance. It was the type "of the world, as P. Valerianus supposes,

on account of the orbicular form of its pellets of dung, and the notion of their being rolled from sunrise to sunset; of the sun, because of the angular projections from its head resembling rays, and the thirty joints of the six tarsi of its feet answering to the days of the month; and of a warrior, from the idea of manly courage being connected with the supposed birth from a male alone. It was as symbolical of this last that its image was engraved on the signets of the Roman soldiers; and as typical of the sun, the source of fertility, it is yet, as Dr. Clarke informs us, eaten by the women to render them prolific."

FIG. 205.— Egyptian Scarabæi; in the centre, two of the beetles (*Ateuchus*) which formed the original.

We now know more about these insects than did the old Egyptians. We know that there are females as well as males, and that the burial of the ball of dung is not a symbol of anything, but merely a provision for the larvæ of the next generation. Buried far beneath the surface the egg hatches out, and the resulting larva feeds for a time upon the substance of the pellet, and eventually changes to a pupa, and then to the adult, which makes its way to the surface to perform the same curious operation.

We have several species in the United States with habits similar to those of the *Scarabæus*, while others differ considerably in this respect. Without doubt our best-known species of these latter are the familiar

June-bugs, so familiar in early summer. In all stages of existence they are nuisances. As perfect beetles they gnaw the leaves of various trees,

FIG. 206. — June-bug (*Lachnosterna fusca*), with larva and pupa.

sometimes stripping them of all their foliage, while the larvæ are even more injurious to the roots of the grass of meadows and lawns. On digging up a bit of turf one frequently finds a fat, white grub — the larva of the June-bug — which is busily engaged in feeding upon the roots about it. In Europe there is a similar species; but as it appears a month earlier, it is called the May-beetle. Its history has been worked out very thoroughly, and it is said that it requires from three to four years for it to complete its metamorphoses. For this

reason it is somewhat periodical in its appearance.

A little less familiar is a slightly larger beetle of similar shape, but of a bright lemon-yellow color. It is the goldsmith-beetle. Dr. Samuel Lockwood has studied its habits, and from his pages the following account is extracted. For five years he sought the larvæ, but in vain. "The next step was to examine very thoroughly every larva of a Coleopterous kind found in proximity with the imagoes. This led to the discovery that cer-

FIG. 207. — Goldsmith-beetle (*Cotalpa lanigera*) and larva.

tain large whitish grubs about an inch and three-quarters long and over half an inch thick, had a yellowish brown scale on the part corresponding to the thorax, and it was thought that it might ripen into the red golden hue of the thorax of the perfect insect. This decided my course. Like Scholasticus, who, having heard that the crow lived a hundred years, at once went to the market, bought a young one, and resolved he would see,

I filled a deep glass jar with earth and placed six large grubs on the top. It was interesting to observe how quickly these soft creatures burrowed out of sight." In the following spring five goldsmith-beetles emerged from the earth, one of the larvæ having died. What the larvæ feed upon is yet unknown; the adult eats the leaves of various trees.

With this brief mention we must dismiss our native *Scarabæus*, but

HERCULES BEETLE (*Dynastes hercules*).

there are certain tropical forms which demand attention from their enormous size. These are the Goliath, Hercules, and elephant beetles of popular parlance. Our plate shows the male and female of a Central American Hercules beetle, natural size. The differences between the two sexes are very considerable, the male being provided with a most strange forceps, produced by the forward growth of the top of the head and the thorax. These are not jaws, as is frequently supposed, and have nothing to do with eating. The Goliath beetles of western Africa are not quite so large, and yet specimens have a length of four inches and a breadth of two. For years these forms were among the greatest rarities in the entomologists' collection, and specimens brought enormous prices — fifty pounds or more. A missionary who spent many years on the Gaboon coast has told the writer of his experience in collecting these forms. He would go out in the morning with two or three negro boys, and carefully search the bushes for these beetles. When one was found, he would place it on the head of one of the boys, and the spiny legs becoming entangled in the wool, the insect was held a safe captive until the return from the search. Then the hair to which the insect was fastened was cut off, and the beetle was killed.

Our next group contains some small forms which make up for their diminutive size by the amount of destruction they are able to accomplish.

FIG. 208.—Museum pests: *a*, *Anthrenus*; *b*, *Ptinus*; *c*, *Dermestes*, the bacon-beetle; *d*, *Attagenus*.

Indeed, they are among the most serious nuisances among the whole of the beetles. Our cut represents three of the species, as well as a fourth form referred to on a preceding page (p. 205). At the left, near the shank of the rabbit's foot, is the museum-beetle whose ravages cause so much annoyance in every collection; and when it once gets entrance to a museum.

it is almost impossible to get rid of it. It lays its eggs on specimens of every sort, and the larvæ soon riddle them. Nothing of organic nature seems to be proof against them, for they bore through the hardest horn as easily as through the skin of a bird. They and their allies make the curator's life a burden. He is continually resorting to benzine, bisulphide of carbon, and other insecticides; but the best he can do is to check, not eradicate, the evil.

In this work the museum-beetle is frequently aided by the larger bacon-beetle, shown in the foreground of Figure 208. This attacks other things besides museum collections, and not infrequently proves an almost intolerable nuisance in storehouses; the species to the right is almost equally destructive, but is not quite so abundant, and has not received any common name.

All these species, however, pale before the first cousin of the museum-beetle, the much-dreaded carpet-beetle or buffalo-bug, of which the next illustration shows both the larva and the adult. This, like many of our most injurious insects, has been imported from Europe. In the Old World it fed upon flowers frequently, varying its diet with dried meats and similar substances. In 1874 it first be-

FIG. 209.—Larva, pupa, and adult of the carpet-beetle or 'buffalo-bug' (*Anthrenus scrophulariæ*).

came prominent in the United States with changed appetite. It neglects its former food and shows a marked predilection for carpets, woolen goods, and furs. It possesses great vitality; ordinary insecticides are of no avail against it; it laughs at tobacco, pyrethrums, camphor, and the like, and no one has yet found a way to kill it off. When it once gets entrance to a house, the only course to prevent its damage is to dispense with carpets entirely, and to use in their place rugs, which can be easily taken up and beaten.

The carrion-beetles must be regarded as friends of man, for they and their larvæ feed largely upon decaying animal matter. They have the sense of smell well developed, and as soon as a rat or mole or any larger animal begins to decay, they come flying to it, seeking a place to lay their eggs. Some of them are dull colored, but others are prettily marked with

red and black arranged in cross-bars across the body. Still, no matter how prettily marked they may be, they are not attractive, for they usually

FIG. 210. — Carrion-beetles (*Necrophorus*) engaged in burying a mouse.

smell strongly of the carrion ; and, as if this were not enough, many species have the power of secreting a fluid of most nauseous odor.

There are several groups of water-beetles, most of them of value to mankind from their habit of preying upon the larvæ of other insects.

FIG. 211. — Water-beetles (*Hydrophilus*) ; at the left a larva ; attached to the leaf is a case of eggs.

Both the larvæ and the adults may be found in almost every pool of water ; the larvæ are not able to leave the water, but the adults frequently fly ; and

the larger species, when attracted by a light at night, will occasion considerable alarm in a quiet household. The largest species of these water-beetles belong to the same genus as the species figured. In these large forms there are several interesting features. First is the peculiar egg-nest or cocoon shown in our cut. In this cocoon the female places a considerable number of eggs and then fastens it to some object floating on the surface of the water. When the larvæ hatch, they at first play the part of cannibals, feeding upon their brothers and sisters in the same cocoon, but after they escape from the egg-nest they eat other forms. In their eating their habits are very peculiar. The larva of the species figured takes the insect which it has caught and holds it above the surface of the water. It now crushes it, and lets the juices drop down into its mouth, which is held just above the surface.

The adults of all the water-beetles breathe air, and during their sojourn below the surface of the water they depend on a supply which they take down with them, either entangled in the hairs which cover the body or held beneath the wing-covers.

The next group of beetles — the carabids of science, the running beetles of the Germans — contains over ten thousand species of active, predaceous insects, the majority of which are to be regarded as of very beneficial character. Some are small, others reach a very large size, and most of them are eminently terrestrial, living on the ground, where they seek their food.

The bombardier beetles, of which there are some hundred and fifty species, are interesting from their peculiar defensive apparatus which has given them their name. On either side of the vent is a gland which

FIG. 212. — Water-beetle (*Dytiscus*).

FIG. 213. — Carabid beetles (*Calosoma*, *Pasimachus*, *Harpalus*).

secretes a strong-smelling acrid liquid, which is converted into a gas as soon as it comes in contact with the air. When the beetle is alarmed, as is the

case when one lifts the stone under which it is concealed, it shoots off a portion of this liquid with a slight popping noise, and the liquid, as it turns to vapor, produces the effect of smoke, thus making the comparison to a cannon almost complete. The novice at collecting is pretty apt to drop his first specimen when it shoots off its gun in his face.

Another genus which occurs in Mammoth Cave is remarkable from the fact that it has no eyes, either in the larval or adult stages, a fact indicated in the scientific name — *Anophthalmus* — which is applied to it. Its nearest relatives are well provided in this respect. Concerning the other species of the group there is but little of general interest to relate, as all are greatly similar in their habits.

The tiger-beetles, the last group of the Coleoptera, are even more predaceous than the carabids, and it is to their carnivorous habits that they owe their common name. Many of them are brightly colored, the metallic green wings of some of our most abundant species being common objects on the sunny paths in summer. As one walks along, they rise and fly a few feet to settle down until alarmed again. Other species occur on the

sea-shore, and these have their bodies of a color which harmonizes well with the surroundings, and is evidently protective in

FIG. 214. — Tiger-beetles (*Cicindela*).

its nature. The larvæ of the tiger-beetles are as predaceous as the adults; they live in burrows in the earth and climb up and down by means of two large hooks upon the back of the abdomen. They lay in wait at the mouth of their burrows, with only the head and large jaws exposed, and when a fly or ant comes near them, it is quickly seized and taken to the bottom of the hole, where it is devoured. The

perfect beetles are very handsome, but these larvæ are hideous, misshapen monsters, the hooks on the back, their round shoulders, and their ugly faces making one think of such characters as Quilp.

ANTS, WASPS, AND BEES.

In scientific works the ants, wasps, bees, and their numerous allies figure under the name Hymenoptera, a term which alludes to the membranous character of the wings, the second pair of which are always smaller than the first. It is to be noticed, however, that there are individuals which never acquire wings. This is true of the neuters, or workers among the ants, while in other forms one sex may be winged, while the other lacks organs of flight. In all the insects noticed in the preceding pages the mouth parts are adapted for biting alone; but in the present group they

may be fitted for both biting and sucking. This is well shown in the adjacent cut of the head of a bee, where the two hard horny jaws (*f*) are the biting-organs. Below these extend the long and slender tongue and accessory jaws, which are separated in the drawing to show the shape of each; but which in nature are placed side by side, so that they form a tube through which the insect can sip the nectar of flowers.

There is no group of insects which presents more interesting forms than the Hymenoptera, and we must ascend to some distance in the vertebrate series before we meet a greater amount of intelligence than here. Everywhere else among the invertebrates the acts at first sight seem to be governed by a blind instinct; but here we find reasoning powers well developed. In other insects one fixed course is followed, but here a change of conditions is immediately followed by a corresponding change in the actions, thus giving great plausibility to the view that animals are not guided solely by inherited habits, but that they carefully think out the proper course to be pursued.

These reasoning powers are best developed in the bees and ants; but before we take them up we must first consider some of the lower forms of Hymenoptera, like the saw-flies, ichneumon-flies, etc. In these forms the intellect seems to be less developed, and there is nothing of that social instinct which we shall find to be so characteristic of the higher forms; we also notice in them a lack of the sting and its accessory apparatus which makes a familiar call from an ant or wasp so painful.

The saw-flies and horn-tails are to be regarded among injurious insects, for they live exclusively upon vegetation, and in this and many other respects they seem to form a connecting link between the Hymenoptera and the butterflies and moths. Our cut shows the male and female of a saw-fly or horn-tail, the latter at the right hand. At the posterior end of the female abdomen will be noticed a long horn, the possession of which gives rise to one of the common names. This is an apparatus for the deposition of its eggs. Under a microscope this horn is seen to be furnished with teeth like a saw, and by means of these the insect can bore or saw a hole into the wood of some tree. When the hole has been bored to the proper depth, the eggs are passed down through the interior of the horn, and deposited at the bottom of the burrow. There they hatch, and the resulting grubs bore through the wood, thus causing considerable damage.

FIG. 215.—Head of a bee, showing the various parts which go to make up the proboscis.

Occasionally the shade-trees of our streets are seriously injured or even killed by the ravages of some of these saw-flies.

FIG. 216. — Male and female saw-flies (*Sirex*).

Next in order come the gall-flies, mostly small forms whose products are familiar to all. On the leaves of the oak one frequently finds large, round, brown bodies, — oak-apples, they are called, — which are produced by one species of gall-fly; the peculiar swellings on the stems of golden-rods are the product of another. It would make a long list to enumerate the various forms of galls, and the plants on which they occur, and yet the experienced entomologist on seeing one of these abnormal formations, can say at once what species of gall-fly was concerned in its production.

FIG. 217. — Rose-gall, and an enlarged view of the insect (*Rhodites rosæ*) which produces it.

Yet while naturalists know so much about galls, there is another aspect of the subject on which they are profoundly ignorant. The female gall-fly stings the leaf or plant, and in the opening she makes she deposits an egg. The injury this puncture produces is but very slight; and if we were to run a needle into the plant in the same way no effects would follow. The egg, however, makes a great change in the plant, but in what way it produces this change is a problem as yet unsolved. It may be that some poison accompanies the egg, but this is certainly not the case in every instance. Now mark the result. The plant, as soon as the

egg is deposited, may begin an extraordinary production of cellular tissue around the egg, soon resulting in a marked alteration of the corresponding part of the plant. On the other hand, the gall may not begin to be formed until after the hatching of the egg. Stranger still is the fact that if two different species sting the same plant, the resulting galls will be entirely different in their character; while if the species stings two different kinds of plants, the galls will be much alike.

Inside the gall the larva feeds and grows, and it may remain inside it until it attains the perfect condition, or it may bore its way out, descend

FIG. 218.—*a*, sumac-gall; *b*, willow-gall; *c*, cabbage-willow gall.

to the ground, and there undergo the rest of its changes. In connection with this growth some interesting features have recently been discovered in Europe. From one form of oak-leaf gall a gall-fly hatches out, which immediately proceeds to deposit its eggs, not in the leaf as did its parent, but in the buds, and the resulting galls are very unlike those of the preceding generation. Now, when the proper time comes, from this second generation of galls a fly hatches which does not in the least resemble its parent, but which, until its history was known, was classed in an entirely distinct genus. This in its turn lays eggs, which develop into the first form. As the reader will see, this is an alternation of generations, recalling those detailed in the earlier pages of this volume. There is still another fact to be noticed in this connection. The individuals of one generation will all be females, while in the next both males and females will occur. In still other forms, like the rose-gall fly, shown in Figure 217, several generations will occur without the appearance of males.

The ichneumon-flies are to be classed as beneficial forms ; for they are true parasites, passing their larval lives inside the bodies of other insects,

FIG. 219. — Ichneumon-fly (*Macrocentrus*).

and in this way they destroy a host of forms which otherwise might cause great damage to the farmer. Of these ichneumon-flies there are many thousand species, a few large, but the great majority small. In all the habits are much the same, and a description of one will answer for all, with the prefatory remarks that there is scarcely a species of insects which is free from their attacks, and that some affect the eggs, while others begin with the larvæ or even the adult hosts. In some the eggs are placed within the host, in others they are placed on the larvæ, and then the grubs which hatch out bore their way through the skin, where they begin to feed on the tissues. There is a wonderful relation between these parasites and their hosts. Both

grow, but the parasite is careful not to attack any vital part. It is necessary for his existence that the larva on which he feeds should continue alive so as to furnish him food, and hence it is only when the parasites emerge that the host dies. Our figure shows one of the adult ichneumon-flies greatly enlarged, and by its side a caterpillar from which the ichneumon larvæ are emerging.

FIG. 220. — A caterpillar covered with the larvæ of an ichneumon-fly (*Microgaster*) which have hatched from eggs laid by the perfect insect, represented at the right.

It is no uncommon sight with the collector to find caterpillars thus covered, and the only wonder is that the host can so long endure with so many parasites feeding upon its tissues.

On a preceding page allusion was made to a balance of nature, and this is well exemplified in the case of the ichneumon-flies. When any insect appears, like the army-worm or the Rocky Mountain locust, in vast swarms, there soon appears a corresponding number of these parasitic

insects, and these soon check the increase of these pests, and next they reduce their numbers so that they no longer can produce great damage; and then, having nothing to feed upon, the ichneumon-flies themselves begin to disappear, and the balance is again restored. It is in this way that these inconspicuous forms are of more avail in reducing the numbers of noxious insects than any act of man can be.

The ants are by far the most interesting of all the insects, and to their consideration we shall have to devote considerably more space than to any of the other forms. All are familiar with the general appearance of these animals, and hence no illustrations will be necessary. The ants are eminently social animals, forming large colonies, between the various numbers of which there is apparently the most perfect agreement, every individual working for the good of the whole. To carry out their domestic economy, there is, besides the males and females (whose sole duties are the perpetuation of the species), a vast number of workers, who perform all the labor of the colony. The males and females are winged, but the workers — the forms most familiar to us — are without wings. These last may differ considerably among themselves; for while in some species only one kind of worker occurs, in others there may be larger workers, or 'soldiers,' which at once recall the soldiers among the white ants. Indeed, in many features of their economy these two groups, although structurally so diverse, closely parallel each other. In the sauba ant of tropical America the complexity is carried still further, as there are here three kinds of workers, but it is not yet known what are the functions of the two larger kinds.

Among bees, as is well known, there is but a single female, or queen, to a colony or hive; but among ants there may be several, while on the other hand, a colony of ants may exist without a queen. At certain seasons of the year the newly fledged males and females will come out from the nests in enormous numbers and take their 'marriage flight,' the male and female flying away together. In other cases, they fly separately, the pairing taking place before or after the flight. The rest of the history is involved in uncertainty. The females on alighting immediately begin to dig their burrows in the earth, using their mandibles for the purpose; but it seems probable that they are not able in all cases to found a new colony, although in some instances it has been shown that they can. In digging, the queen finds her large wings an incumbrance, and so she bites them off with her mandibles, assisting the operation by contortions of the body. Her subsequent life is to be underground, and she is merely casting off useless incumbrances.

Occasionally a queen has been seen to be adopted by a colony. Dr.

McCook, a prominent American student of these forms, introduced several workers to an artificial nest containing a solitary queen. "One of these soon found the queen, exhibited much excitement, but no hostility, and immediately ran to her sister-workers, all of whom were presently clustered upon the queen. As other workers were gradually introduced, they joined their comrades, until the body of the queen (who is much larger than the workers) was nearly covered with them. They appeared to be holding on by their mandibles to the delicate hairs upon the female's body, and continually moved their antennæ caressingly. This sort of attention continued until the queen, escorted by workers, disappeared in one of the galleries. She was entirely adopted, and thereafter was often seen moving freely, or attended by guards, about the nest, at times engaged in attending the larvæ and nymphs which had been introduced with the workers of the strange colony."

Sir John Lubbock, to whose careful observations of the habits of ants we owe the greater part of our knowledge of these forms, says: "I have found that when I put a queen with a few ants from a strange nest, they did not attack her, and by adding others gradually, I succeeded in securing the throne for her." He farther says: "In no case, however, when I have put a queen into one of my nests has she been accepted. Possibly the reason for the difference may be that the ants on which I experimented had been long living in a republic; for, I am informed, that if bees have been long without a queen, it is impossible to induce them to accept another."

In the nest the ants exhibit the greatest solicitude for the safety of the queen, keeping her constantly surrounded by a body-guard, which seeks to direct her every motion. When the time for oviposition comes, they carefully take away the eggs to the breeding-chambers.

The nests themselves vary considerably. Some are formed above the surface of the earth, by piling up all sorts of refuse, while the greater majority are situated beneath the surface. With us the nests are usually of moderate size; but occasionally very large ones are seen. It is in the tropics, however, that the most enormous colonies occur, and Mr. Bates "mentions that while he was in Parà, an attempt was made to destroy a nest of the sauba ants, by blowing into it the fumes of sulphur, and he saw the smoke issue from a great number of holes, some of them not less than seventy yards apart." The most remarkable ants' nest is one which is found in the Malay Islands. It was first discovered by Professor H. N. Mosely, the naturalist of the 'Challenger' Expedition, and has been more recently studied by Mr. H. O. Forbes. This gentleman was collecting a lot of epiphytic orchids from a tree in Java, when "I was totally overrun, during

the short momentary contact of my hand with the bunch, with myriads of a minute species of ant (*Pheidole javana*), whose every bite was a sting of fire. Beating a precipitous retreat from the spot, I stripped with the haste of desperation, but, like pepper-dust over me, they were writhing and twisting their envenomed jaws in my skin. each little abdomen spitefully quivering with every thrust it made. Going back, when once I had rid myself of my tormentors, to secure the specimens I had gathered, I discovered in the centre of the bunch a singular plant I had never seen before, which I perceived to be the central attraction of the ants. . . . I was overjoyed with the revelation, that a slice struck off by my knife made of an intricate, honey-combed structure, swarming with minute ants,—a living formicarium.” The plant consisted of a large spiny bulb, surmounted by an axis bearing the leaves and the minute flowers; the inside of the bulb being ramified with galleries in all directions to form a home for the ants. What is most strange is that the plant itself forms these galleries without the slightest assistance from the ants, and they are produced as well when no ants are present as at other times.

FIG. 221.—Young plant of *Hydno-phyton*, showing the bulb occupied by ants.

Inside the nests the labors of the ants are somewhat specialized. The care of the eggs, larvæ, and pupæ devolves upon the young and tender workers, and they are kept pretty busy feeding their charges, and carrying them from higher to lower levels and back again, according to the variations in temperature and moisture, and the imminence or absence of danger. The foraging and fighting, on the other hand, fall upon the older workers with thicker skins, and it would appear from Mr. Lubbock's observations, that foraging parties are regularly detailed to attend to the food of the colony. He found, by marking them with paint, that the same individuals came out after the honey every day for many weeks in succession. As this might be laid to greediness on their part, he confined them one day, and then others came out to take their place.

The food of ants consists largely of insects, but they are also fond of sweet substances, like honey, sugar, and fruit, as well as animal matter of any sort; while, as we shall have occasion to remark farther on, this diet is varied by other substances. The important part they play in destroying insects can hardly be appreciated. “Forel found in one large nest that more than twenty-eight dead insects were brought in per minute, which would give, during the period of greatest energy, more than one hundred thousand insects destroyed in a day by the inhabitants of one nest alone.”

There is a great difference in the foraging habits of the ants in cold and warm climates. In the north each ant goes off by itself, but in tropical America and Africa they hunt in vast armies. Most noted of these tropical forms are the driver-ants of western Africa. They are jet-black and vary from a third to three-quarters of an inch in length. According to Dr. G. A. Perkins, "They do not appear to have any fixed habitations . . . but excavate the earth from between the roots of trees, and in the cavity thus formed lay their eggs and rear their young, and from which they issue in incredible numbers (literally millions of millions) to go on their raids.

"The night is chosen for their foraging expeditions. In the midst of social enjoyment the stirring announcement is made, 'Here are the drivers!' and instantly, as by an electric shock, all are on the alert to escape a personal attack. Lanterns and bamboo torches are lighted, and a search made about the house to learn the direction taken by the assailants; and if in their usual numbers, the house is often left to them entirely for hours. . . . 'All hands' are awaked from their slumbers, and the whole yard lighted; the animals are released from confinement and left to take care of themselves; the fowls removed to a place of safety if one is to be found; but if neglected and left without the chance of escape, their destruction is sure.

"The drivers are alike the enemy of man and beast, though there are times when their visits are most welcome. On their approach every kind of vermin is seized with consternation and seeks safety in flight. Centipedes, cockroaches, scorpions, etc., etc., leave their hiding-places, and are seen seeking places of greater security, only to fall at last into the clutches of their relentless foe, from whom there is no escape.

"An invading army could not exhibit a higher state of discipline than is seen in the movements of these insects. They enter a house, usually at one point, where a strong guard is left to defend the pass; they then branch off right and left, and again divide and subdivide, till the whole ground is completely covered; not an inch is left unexplored, and every crack and cranny is entered, giving but little hope of escape to any creature that may be found secreted there. Attacking their prey, they plunge their forceps into it, regardless of the size or strength of their antagonist. Nothing will cause them to relax their hold. The animal or insect writhes and twists under the pain, but his case is rendered more hopeless every moment by additions to the number of his assailants; at length, when completely exhausted by struggling, he yields to his fate, and is despatched at the victors' leisure. . . . It is interesting to see a band of these midnight marauders returning home from the scene of plunder on the approach of day. Issuing from the same place they entered, they are each seen

bearing away some trophy with them; a joint of a cockroach's leg, the body of a spider, or the larvæ of some insects, etc., are the various spoils. As the laborers pass on with their loads, they are guarded by a large body of soldiers, which are stationed along the sides of their path; or, if they are to pass through a place of uncommon exposure, these soldiers form a covered passage, by standing upon each other's back and hooking their forceps together, and through the arch thus formed the laborers pass in safety."

These drivers are blind, and they try to avoid the light of the sun. They only appear in the daytime on dark days, and then keep in the shade of the thick woods and deep grass. In their journeys they go in ranks of from four to eight abreast, and progress at the rate of about two yards a minute. Says Dr. Perkins: "I have seen a stream of drivers crossing an open path at six o'clock in the morning, and at six at night their number was undiminished. How long they had been passing before I saw them, or how long they continued, I am unable to say. Their path, from constant travel, became quite worn and smooth." These ants, according to Dr. Savage, will destroy even the largest animal if it be confined so that it cannot escape. "Indeed, it is said that they have been known to destroy the great python when gorged with food and powerless. The natives even believe that the python, after crushing its victim, does not venture to swallow it, until it has made a search, and is satisfied that there are no drivers in the vicinity!"

In their habits, the foraging ants (*Eciton*) of South America are closely similar to the drivers of tropical Africa, but in structure they differ considerably. Mr. Bates saw ten different species of them, and his account is so interesting that the reader will certainly pardon somewhat extensive extracts. All hunt in vast organized armies, but each has its own method of hunting.

"The *Eciton* *legionis* lives in open places, and was seen only on the sandy campos of Santarem. The movements of its hosts were, therefore, much more easy to observe than those of all other kinds which inhabit solely the densest thickets; its bite and sting were also less formidable than those of other species. The armies . . . consist of many thousands of individuals, and move in rather broad columns. They are just as quick to break line on being disturbed, and attack hurriedly and furiously any intruding object, as the other *Ecitons*. . . . The first time I saw an army was one evening near sunset. The column consisted of two trains of ants, moving in opposite directions; one train empty-handed, the other laden with the mangled remains of insects, chiefly larvæ and pupæ of other ants. . . .

"On the following morning no trace of ants could be found near the place where I had seen them the preceding day, nor were there signs of

insects of any description in the thickets; but at the distance of eighty or a hundred yards I came upon the same army, engaged evidently on a razia of a similar kind to that of the previous evening; but requiring other resources of their instinct, owing to the nature of the ground. They were eagerly occupied on the face of an inclined bank of light earth in excavating mines, whence, from a depth of eight or ten inches, they were extracting the bodies of a bulky species of ant of the genus *Formica*. It was curious to see them crowding around the orifices of the mines, some assisting their comrades to lift out the bodies of the *Formicæ*, and others tearing them in pieces, on account of their weight being too great for a single *Eciton*; a number of carriers seizing each a fragment, and carrying it off down the slope. On digging into the earth with a small trowel near the entrances of the mines, I found the nests of the *Formicæ*, with grubs and cocoons, which the *Ecitons* were thus invading, at a depth of about eight inches from the surface. The eager freebooters rushed in as fast as I excavated, and seized the ants in my fingers as I picked them out, so that I had some difficulty in rescuing a few entire for specimens. In digging the numerous mines to get at their prey, the little *Ecitons* seemed to be divided into two parties, one set excavating, and another set carrying away the grains of sand. When the shafts became rather deep, the mining parties had to climb up the sides each time they wished to cast out a pellet of earth; but their work was lightened for them by comrades, who stationed themselves at the mouth of the shaft, and relieved them of their burdens, carrying the particles, with an appearance of foresight which quite staggered me, a sufficient distance from the edge of the hole to prevent them from rolling in again. . . .” Referring to two other species, he continues as follows:—

“When the pedestrian falls in with a train of these ants, the first signal given him is a twittering and restless movements of small flocks of plain-colored birds (ant-thrushes) in the jungle. If this be disregarded until he advances a few steps farther, he is sure to fall into trouble, and find himself suddenly attacked by numbers of the ferocious little creatures. They swarm up his legs with incredible rapidity, each one driving its pincer-like jaws into the skin, and with the purchase thus obtained, doubling its tail, and stinging with all its might. There is no course left but to run for it; if he is accompanied by natives, they will be sure to give the alarm, crying, ‘*Tauóca!*’ and scampering at full speed to the other end of the column of ants. The tenacious creatures who have secured themselves to his legs then have to be plucked off one by one, a task which is generally not accomplished without pulling them in twain, and leaving heads and jaws sticking in the wounds.

“The errand of the vast ant-armies is plunder. . . . Wherever they

move, the whole animal world is set in commotion, and every creature tries to get out of their way. But it is especially the various tribes of wingless insects that have cause for fear, such as heavy-bodied spiders, ants of other species, maggots, caterpillars, larvæ of cockroaches, and so forth, all of which live under fallen leaves or in decaying wood. The Ecitons do not mount very high on trees, and therefore the nestlings of birds are not much incommoded by them. The mode of operation of these armies, which I ascertained only after long-continued observation, is as follows: the main column, from four to six deep, moves forward in a given direction, clearing the ground of all animal matter, dead or alive, and throwing off here and there a thinner column to forage for a short time on the flanks of the main army; and re-enter it again after their task is accomplished. If some very rich place be encountered anywhere near the line of march,—for example, a mass of rotten wood abounding in insect larvæ,—a delay takes place, and a very strong force of ants is concentrated upon it. The excited creatures search every cranny, and tear in pieces all the large grubs they drag to light. It is curious to see them attack wasps' nests, which are sometimes built on low shrubs. They gnaw away the papery covering to get at the larvæ, pupæ, and newly hatched wasps, and cut everything to tatters regardless of the infuriated owners which are flying about them. In bearing off their spoil in fragments, the pieces are apportioned to the carriers with some degree of regard to fairness of load, the dwarfs taking the smallest pieces, and the strongest fellows with small heads the heaviest portions. Sometimes two ants join together in carrying one piece, but the worker-majors, with their unwieldy and distorted jaws, are incapacitated from taking any part in the labor. The armies never march far on a beaten path, but seem to prefer the entangled thickets where it is seldom possible to follow them. I have traced an army sometimes for half a mile or more, but was never able to find one that had finished its day's course and returned to its hive. Indeed, I never met with a hive; whenever the Ecitons were seen, they were always on the march.

“I thought, one day at Villa Nova, that I had come upon a migratory horde of this indefatigable ant. The place was a tract of open ground near the riverside, just outside the edge of the forest, and surrounded by rocks and shrubbery. A dense column of Ecitons was seen extending from the rocks on one side of the little haven, traversing the open space, and ascending the opposite declivity. The length of the procession was from sixty to seventy yards, and yet neither van nor rear was visible. All were moving in one and the same direction, except a few individuals on the outside of the column, which were running rearward, trotting along for a

short distance, and then turning again to follow the same course as the main body. But these rearward movements were going on continually from one end to the other of the line, and there was every appearance of this being a means of keeping up a common understanding amongst all the members of the army, for the retrograding ants stopped very often for a moment to touch one or another of their onward-moving comrades with their antennæ, a proceeding which has been noticed in other ants, and is supposed to be their mode of conveying intelligence. When I interfered with the column or abstracted an individual from it, news of the disturbance was very quickly communicated to a distance of several yards toward the rear, and the column at that point commenced retreating. . . .

“The position of the large-headed individuals in the marching column was rather curious. There was about one of these extraordinary fellows to about a score of the small class; none of them carried anything in their mouths, but all trotted along empty-handed, and outside the column at pretty regular intervals from each other, like subaltern officers in a marching regiment of soldiers. It was easy to be tolerably exact in this observation, for their shining white heads made them very conspicuous among the rest, bobbing up and down as the column passed over the inequalities of the road. I did not see them change their position or take any notice of their small-headed comrades marching in the column; and when I disturbed the line, they did not prance forth or show fight so eagerly as the others. These large-headed members of the community have been considered by some authors as a soldier-class, like the similarly armed caste in the termites; but I found no proof of this, at least in the present species, as they always seemed to be less pugnacious than the worker-minors, and their distorted jaws disable them from fastening on a plane surface like the skin of an attacking animal. I am inclined, however, to think that they may act, in a less direct way, as protectors of the community; namely, as indigestible morsels to the flocks of ant-thrushes which follow the marching columns of these *Ecitons*, and are the most formidable enemies of the species. It is possible that the hooked and twisted jaws of the large-headed class may be effective weapons of annoyance when in the gizzards or stomachs of these birds, but I unfortunately omitted to ascertain whether this was really the fact.”

Some of these foraging ants were blind, and between these and the eyed species the gradations could readily be traced. First are forms in which the eyes are sunk in deep sockets; next come those with the sockets, but with the eyes gone; and lastly, those in which both eyes and sockets have disappeared, only a faint ring remaining to show the place where they should be. These blind forms travel in covered ways which are con-

structed out of grains of earth. Among the termites on a preceding page we met similar covered ways, but there the particles were cemented together. Here they are constructed, in the most surprising manner, of earth without a particle of cement.

These foraging ants are not always bent on plunder. At times Mr. Bates saw them when they appeared as if smitten with sudden laziness, and like ants of our own climes, they engaged in cleaning themselves and their fellows, brushing the antennæ with the fore feet, and cleaning the legs with the jaws and tongue. "Here and there an ant was seen stretching forth first one leg and then another to be brushed and washed by one or more of its comrades, who performed the task by passing the limb between the jaws and tongue, finishing by giving the antennæ a friendly wipe." Dr. McCook has observed similar toilet habits among the ants of Pennsylvania.

The roads which some species of ants construct are marvels of engineering. Some of them are above ground, while others partake of the nature of tunnels which are continued for prodigious distances. The Rev. Hamlet Clark tells us that a planter in Brazil had great difficulty in protecting his trees from the ravages of one species. "Sometimes in a single night it will strip an orange or lemon tree of all its leaves; a ditch of water around his garden, which quite keeps out all other ants, is of no use. This species carries a mine under its bed without any difficulty. Indeed, I have been assured again and again by sensible men that it has undermined, in its progress through the country, the great river Paraiba. At any rate, without anything like a natural or an artificial bridge, it appears on the other side and continues its course." This is, as Mr. Lubbock remarks, not absolute proof that this species actually tunnels under the river, but the view gains plausibility from the observations of Mr. Linneceum on an allied species occurring in Texas. His account, as presented in abstract by Mr. Norton, runs as follows:—

"He states that they often carry their subterranean roads for several hundred yards in grassy districts where the grass would prove an impediment to their progress. On one occasion, to secure access to a gentleman's garden, where they were cutting the vegetables to pieces, they tunnelled beneath a creek, which was at that place fifteen or twenty feet deep, and from bank to bank about thirty feet."

Of the surface roads, those made by the agricultural ant of Texas are among the most remarkable. They are constructed by carefully clearing away all grass and other obstacles, which is a labor of considerable extent in the semi-tropical climate and rank vegetation of Texas. The longest road measured by Dr. McCook could be traced distinctly for sixty feet;

“but Lincecum describes one over three hundred feet long, which traversed sixty feet of thick weeds, underran heavy beds of crop-grass one hundred and eighty feet, and then through the weeds growing in the locks of a heavy rail fence sixty feet more. Throughout its whole extent this road was very smooth and even, and varied from a straight line only so far as to lose some thirty feet of distance in passing from the pavement to the outer terminus. The width was from two to two and a half inches.”

Some of the ants are provided with stings, situated like those of the bees at the tip of the abdomen; in others these stings are rudimentary, and of no functional importance, and yet these have well-developed poison-glands, and some are capable of projecting the poison, according to Lubbock, to a distance of eighteen inches. The jaws, however, are the most important organs of offence and defence; and no one who has not watched a battle between two colonies can have any idea of the more than bulldog-like pertinacity with which the grip will be maintained. Frequently one will see a head entirely severed from the body, and yet the jaws are clasped tightly around the victim. These battles are most interesting to watch, and it will be noticed that each species has its own characteristic manner of attack. Some attack singly, while others advance in regular armies, and still others attempt to terrify rather than to kill. Some of these battles are due to the hatred which one species seems to bear towards another, or even to an animosity existing between two colonies of the same species. Others are undertaken for the purpose of making slaves of the victims, and this opens up a most interesting side of ant-economy.

There are many of these slave-making ants, and among them we find that slavery is not an unmixed good. The slave-makers on their expeditions bring back the pupæ of their victims, and from these are reared the slaves, who have to partake in the domestic duties of the colony of their captors. In some they are assisted in this by the victors; but others, like the Amazons, “present a striking lesson of the degrading tendency of slavery, for these ants have become entirely dependent upon their slaves. Even their bodily structure has undergone a change; the mandibles have lost their teeth, and have become mere nippers, deadly weapons indeed, but useless except in war. They have lost the greater part of their instincts; their art, that is the power of building; their domestic habits, for they show no care for their own young, all this being done by slaves; their industry, — they take no part in providing the daily supplies: if the colony change the situation of the nest, the masters are all carried on the backs of the slaves to the new one; nay, they have even lost the habit of feeding. Huber placed thirty of them with some larvæ and pupæ and a supply of honey in a box. ‘At first,’ he says, ‘they appeared to pay some little

attention to the larvæ; they carried them here and there, but presently replaced them. More than half of the Amazons died of hunger in less than two days. They had not even traced out a dwelling, and the few ants still in existence were languid and without strength. I commiserated their condition, and gave them one of their black companions. This individual, unassisted, established order, formed a chamber in the earth, gathered together the larvæ, extricated several young ants that were ready to quit the condition of pupæ, and preserved the life of the remaining Amazons.'” What an example is this to set before the sluggard!

In the case of other forms the degeneration has proceeded still farther — has almost reached the condition of parasitism; for the slave-owners are far weaker than their slaves, and how they obtain these useful servants is an unsolved problem. Their strength is gone, their jaws have lost their use as offensive weapons, and even the whole group of workers has disappeared.

Some ants keep cattle as well as slaves; cattle we may call them, from the way in which they have been domesticated and the use to which they are put. Most numerous of these domesticated animals are the plant-lice (*Aphids*), but there are several others which are kept in the same way and for the same purposes. The plant-lice have the power of secreting a sweetish substance, — honey-dew, it is called, — which exudes through two short tubes near the hinder end of the body. The flow of the honey-dew is under control of the aphid, and the careful observer may see the ants

FIG. 222. — Plant-lice feeding on a twig, below is an ant caressing an aphid with her antennæ preparatory to sucking the honey-dew.

caressing their cattle and then sipping the sweets that flow in response. With some ants this association with the aphids seems more or less accidental, but with others it is evidently intentional. They build regular roads to the trees on which the plant-lice feed, or in other instances they keep the aphids in their nests, where they can suck the juices of the roots of plants. Still farther, they care for the young and the eggs of the plant-lice with as much solicitude as for their own, and this not only with the forms living in the nests, but with those which live outside on trees and shrubs. Were the eggs left where they were laid, they would be exposed to numberless dangers, so the ants carry them to their subterranean burrows and there care for them during the winter, and then when the spring comes, the young are carefully taken out and placed upon the plant best adapted to their needs.

With some of the animals kept in the nests of ants the problem is more difficult. They secrete no honey-dew, they do not guard the colony, and what part they play is not easily seen. Mr. Lubbock has hazarded the suggestion that they may be the pets of the ants, taking, among these intelligent insects, the place of our cats and dogs.

The subjects of recognition and communication among ants are also imperfectly known. Ants, without doubt, are able to recognize the members of their own colony, not only readily distinguishing them from those belonging to other nests, but even from other individuals from the same nest. How they do it we don't know, and all attempted explanations are but guesses. Ants are also able to tell their fellows of certain things. Thus when one finds a choice object, too large for her to carry alone, she quickly returns to the nest and marches out with several associates to aid her. This much is a matter of common observation, but Mr. Lubbock wished to ascertain if more than the fact that such objects existed was communicated, and to this end he made many very careful experiments, almost all of which had negative results. It even appeared that the ant could not even tell her associates the way to the treasure.

Closely connected with these two subjects is that of intelligence, and it is placed beyond a doubt that the ants really possess considerable intelligence and reasoning powers of no mean order, although this side of their life has often been exaggerated. When we once begin to tell the marvelous stories of the habits of ants, there is no knowing where to stop. We have the best of evidence that they perform many wonderful feats which would imply that they reasoned out exactly the proper course to pursue, and yet when ants in confinement are tested by closely similar conditions, they frequently fail lamentably.

The number of species of ants considerably exceeds one thousand, and

of these we can mention but two or three of the most interesting, in addition to the few incidentally introduced in the foregoing pages.

Among the strangest of all the ants are the honey-ants, of which there are several species occurring in various parts of the world; but none of them are better known than the honey-ant of our western territories, whose habits have been extensively studied by Dr. H. C. McCook. They build small nests or hills of gravel some two or three inches high and some six in diameter. In the inside of the nest are galleries much as in other ant-hills, but in the chambers are workers which are in reality but stores for honey, — living honey-jars they might be termed.

The ordinary workers make their expeditions to the dwarf-oaks of the neighborhood and collect a sweet substance which exudes from the galls on the branches. This they carry home and feed to the other workers, who store it in their crops until these become swollen out into immense sacs as large or even larger than a currant. This increase in size of course distends the abdomen until at last it becomes a large globe, on which can be seen a few cross-bars, the remains of the normal integument. It has been said that the intestine was wholly obliterated by this operation; this is not true, but the pressure forces it up against one side and effectually closes it so that nothing can pass through it. The amount which one of these honey-jars will contain almost surpasses belief; it is said that they increase their weight by this honey a hundred fold, and even that the distention occasionally terminates with a rupture of the walls: the ants actually burst.

These honey-bearers do not digest the sweets fed to them; they are rather to be regarded as storehouses, where the honey is kept until a time of need, and then it is poured out for the benefit of the community. At these times they regurgitate the honey, and the other ants stand round, each swallowing the drops as they come up. "The honey has an agreeable taste, slightly acid in summer from a trace of formic acid, but perfectly neutral in autumn and winter; it contains a little more water than the honey of bees, and has, therefore, somewhat greater limpidity. The Mexicans press the animals, and use the gathered honey at their meals; others prepare by fermentation an alcoholic liquor from it." They also "apply it to bruised and swollen limbs, ascribing to it great healing properties."

The cutting or parasol-ant is an inhabitant of Texas, which builds

FIG. 223. — Honey-ant of Texas, with the abdomen distended with honey, enlarged.

large hills, one of which measured twenty-one feet long and four feet high. The normal mound much resembles the "American spittoon in shape." Dr. McCook thought at first he had pitched his camp near a deserted mound. There was not a sign of life. "As the evening began to fall, the scene was wholly changed. Hosts of ants of various sizes were hurrying out of the open gates into the neighboring jungle, and two long double columns were stretched from the bottom to the top of the large overhanging live-oak. The ants in the descending columns all carried above their heads portions of green leaves, which waved to and fro and glanced in the lantern light, giving to the moving column a weird look, as it moved along. It seemed like a procession of Lilliputian Sabbath-school children bearing aloft their banners. It is this habit which has given this insect in some quarters the popular name of parasol-ant."

The leaves were cut with the sharp mandibles, and after being taken inside the nest were manipulated so that they could be made into cells strongly recalling the honey-comb of bees. It would also appear that, before building the comb, the juices of the leaves serve as food. They have gates to their nests composed of sticks and leaves, between which are placed gravel and grains of sand. In the evening, when the gates are to be opened, the smallest workers appear first, carrying away the smaller particles and depositing them two or three inches from the mouth of the burrow, and then later, the larger workers come out and take away the other rubbish. Near morning when the gates are closed the process is reversed, the same particles being used to close the openings as were carried away in the evening. The larger sticks and leaves are used first, and "the last touches are carefully and delicately made by the minims, who in small squads fill in the remaining interstices with minute grains of sand; and finally, the last laborer steals in behind some bit of a leaf, and the gate is closed."

Still more wonderful are the large chambers and the long tunnels excavated by these parasol-ants. Some of "these holes were nearly as large as the cellar for a small house. One such excavation, about three miles from Austin, was twelve feet in diameter and fifteen feet deep." This nest was six hundred and sixty-nine feet from a tree which the ants had stripped, and between the two was a tunnel which pursued an almost straight course, while two branch tunnels went to a peach orchard, one hundred and twenty feet distant. All this excavation was done by the smaller workers. It hardly needs to be said that these ants are regarded as serious pests by the inhabitants.

The only other species which we can mention is the agricultural ant of Texas, which offers quite a contrast to the last, in that its work is done

in the day-time, avoiding, however, the middle of the day and occasionally working at night. These ants carefully clear away all the grass from around their nests, biting it off with their jaws, and then later grubbing up the stumps. The discs thus cleared are either kept entirely clean, or only 'ant-rice' (a species of grass of the genus *Aristida*) is allowed to grow on them. From the disc paths radiate in various directions to the harvest fields. In the centre of the disc are the gates to the nest, and these may be surrounded by a mound, or be even with the surrounding surface, some of the mounds being twenty or more feet across and half a foot high.

The name agricultural ants is given in allusion to the habits. They gather the seeds of the ant-rice, and convey it to their underground abodes, where it serves as food. They carefully clean the grains of their husks, and one author even says that the ants actually plant the seeds of the ant-rice each October, although confirmation of this fact has not been obtained. In their storerooms (which, of course, are underground), the seeds are apt to sprout when moistened by the rains, and at such times they bring the grain out to dry, and thus check the damage.

Other harvesting or agricultural ants are found in other parts of the world. One in Florida feeds on the seeds of a species of millet; but the longest known species is that occurring in the region around the Mediterranean, and which is described in the book of Proverbs: "Go to the ant, thou sluggard; consider her ways and be wise: which having no guide, overseer, or ruler, provideth her meat in the summer, and gathereth her food in the harvest." This advice, as will be seen from the preceding pages, is good if one only takes care that he model his acts upon one of the better sort of ants, and not upon one of the slave-making forms.

The digger-wasps are solitary forms, the females of which dig nests either in the ground or in wood, in which to rear their young; while others make cells of mud in which they lay their eggs. Our cut shows several forms, and incidentally illustrates several interesting features in their economy. At the left is shown a large wasp in the act of stinging a spider. This is a habit common to many of these forms; the sting sometimes kills the spider, but more usually it merely numbs it without killing it. The spider is then placed in the nest with the eggs, and then when the wasp-larva hatches out, it has a supply of food at hand. Were the spider dead, it would quickly decay or dry up; but when merely paralyzed, it will keep for a long time. At the right of the cut is shown a wasp-larva feeding on the abdomen of a spider.

Some of these digger-wasps are called sand-wasps, from their habit of

digging in sandy places; while others are known as mud-daubers, because they make little mud-cells, more or less like those shown in the centre of the figure, each of which is charged with an egg and provision for the young; and the forms which excavate their burrows in wood are commonly known as wood-wasps. It is not to be understood that all these forms store up

FIG. 224.— The life of wasps. At the left, a large wasp is stinging a spider; at the right, the larva of another wasp is feeding upon a spider, which has been paralyzed by a sting.

spiders as food for their young; each species has its own favorite, and some take flies, others caterpillars; and so on through almost the whole catalogue of insects.

With the social wasps we again take up forms which live in communities, and whose habits, so far as we know them, are as interesting as those of the ants or the honey-bees. But our knowledge on these points is somewhat limited, for the investigation is not an easy one, since each individual is armed with a sting, the merits and capacities of which are familiar to all. Bees will allow one to come around them without manifesting any especial alarm, but a wasp or a hornet is about as irritable as an insect well can be.

FIG. 225.— White-faced wasp (*Vespa maculata*).

As with all social insects, there are males, females, and workers among the wasps, and the nests are adapted for communal life. These nests are familiar to all, hanging from the timbers of a barn, or the branches of a tree in the forest; they are large oval structures, built of paper, and having the entrance below. Long before the introduction of wood-pulp, the wasps knew how to make paper from wood. On the warm days of spring

and summer, one may see the wasps alight on the gray weathered boards of fences and barns, and a close examination will show that they are tearing off bits of the partially decayed surface with their jaws. These bits they chew up into a pulp, and from this the paper of the nests is made, and the peculiar ashy color is due to the source from which the material is made.

Inside the nest is a 'comb,' with hexagonal cells like those of the honey-bee; but these cells, instead of being made of wax, are constructed of paper. In each cell an egg is laid, and the young which hatches from it is carefully fed and attended by the workers of the colony. These cells are vertical, not horizontal like those of the bees, the mouth being below; and to prevent the young from falling out, there is a sort of glutinous substance in the cell: when the larva becomes older, its head grows so large that it cannot pass out through the mouth of the cell. After the larva becomes transformed to the adult, the cell it occupied is carefully cleaned out, and thus serves again as a home for another, the process being repeated again and again, as the wasps and hornets have several broods in a season.

Besides our common honey-bees, there are many other insects grouped together as bees. Some of these live solitary lives, while others are social in their habits; and here we again notice the existence of workers associated with a communal life. Many of the solitary forms construct the burrow for rearing their young, much as do the digging-wasps, provisioning the cells in much the same manner, except that instead of insects they use the pollen of plants, which they mix into a sort of paste.

Frederick Smith, an English entomologist, who has paid especial attention to the bees, writes: "If I were asked which genus of bees would afford the most abundant materials for an essay on the diversity of instinct, I would without hesitation point out the genus *Osmia*," the mason-bees. The name mason-bees refers to their fondness for mud in the construction of their cells, some of which are dug out of hard wood, others in the earth, while still others are plastered on the under sides of boards and stones. In short, there is hardly any situa-

FIG. 226.—Nest of the burrowing-bee (*Andrena*).

tion which they may not occupy, and with each variation in condition, the mode of procedure also varies.

Even more interesting are the leaf-cutting or upholsterer bees, which are well shown in our cut. At the left are shown the male and female, considerably enlarged, while in the lower centre a bee is represented in the act which has gained for these forms the first-mentioned common name. Seated on a leaf, it quickly cuts out a bit with its sharp jaws, the piece varying in size and shape according to the position it is to occupy in the cell. Other leaves show the places from which bits have been cut. With

FIG. 227.—Male and female of the leaf-cutter bee (*Megachile*), with examples of their work.

these pieces of leaf she lines her cells, which may be excavated in the earth or even in solid wood, as shown at the right of the cut. The bottom of each cell is formed of a circular patch, while the sides are ‘upholstered’ with larger oblong pieces. In each cell an egg is laid, and a quantity of food for the larva is placed beside it.

The carpenter-bees have much the same habits as the mason and leaf-cutting bees in boring into timber, but they do not use leaves or mud in making their cells. Instead they employ the chips and sawdust produced in the excavation. Their holes first go inwards across the grain to the depth of half an inch or more, and then turn to follow the grain of the wood for a foot or even eighteen inches. When we consider the hardness of the timber and the comparatively insignificant means which they have for digging their holes, it is seen that they make pretty good progress, for

they advance their tunnels at the rate of about half an inch a day. Little by little the jaws cut and tear away the wood, and at last when the hole is large enough it is stocked with eggs and pollen.

The bumble or humble bees are social forms whose large bright yellow and black bodies and droning hum are familiar to all. This hum is a true voice. On a preceding page mention was made of the mechanism of breathing of insects, and in the bees the act of breathing also makes the note. Each of the little apertures on the side of the body through which the air for respiratory purposes passes has a membrane which vibrates in the current just as do the vocal cords of man, and like them it is subject to the control of the insect.

One of the most interesting fields of natural history is that which shows the relations of insects to plants. Of late years it has been cultivated most assiduously chiefly by Darwin and Hermann Müller, and in our own country by Professor William Trelease. It has been conclusively shown that many flowers will not ripen seeds unless pollen be brought them from some other flower. This transfer of pollen is accomplished by insects which, in their search for honey, visit flower after flower and plant after plant, and oft-repeated experiments have shown that if a plant be covered with gauze so that no insect can visit it, no seed will be produced. These relations of plants and insects have produced many wonderful modifications, in each the sole purpose of which is that the pollen will be deposited on such a part of the insect that on visiting another flower it will be brushed against the proper part for fertilizing the seed.

The bumble-bees are the insects most effective in fertilizing the clover-blossoms. Now no bumble-bees occur as natives in Australia and New Zealand, and so when the colonists tried to raise clover, their endeavors did not meet with success. The seeds germinated, grew, and blossomed, but no seed was ripened, and so the stock died out. Again and again the attempt was made, and with the same result, until at last the experiment was tried of introducing bumble-bees from Europe. This was the one thing needful. The bees thrived and multiplied, and the clover now seeds itself just as it does with us.

The bumble-bees make their nests beneath the surface of the ground. If the queen can find some deserted hole, like the burrow of a mole, she occupies it; but if not, she excavates one for herself. In this she deposits a mass of pollen and honey, and in this places some eggs. As soon as one brood is thus provided for, another is started in the same way, and so on throughout the summer. The larvæ, on hatching from the egg, feed on the provisions at hand, and bore in all directions in the mass. At last the time comes for the change to a pupa. The larva then spins a silken

cocoon wherever it may be, and then the adults build around it a wall of wax. This fact accounts for the irregularity in the comb. The first broods are composed solely of workers, and the males and females do not appear until late in the season.

The hive or honey bee is, without doubt, by far the most valuable of all the insects, and is now distributed over the whole world through the agency of man. It was introduced into America by the early settlers in the seventeenth century, and now the bee industry has a great importance with us, it being estimated that there are a hundred thousand bee-keepers in the United States.

The importance of the honey-bee has made it the subject of careful study by numbers of investigators, and to-day we know more of its habits and history than of any other insect. One of the most careful observers was Huber, who, strange to say, was blind, and conducted his studies by means of intelligent servants, who followed his directions; while in America, Langstroth, a native of Philadelphia, and Quinby, have greatly advanced our knowledge of the economic side of the life of the bee, and of keeping them for pecuniary profit.

Still, much as we know about the bee, certain points are as yet involved in obscurity. The two economic products, wax and honey, are formed no one knows how. The bee feeds upon the nectar of flowers, and this is acted upon by the saliva of the insect, changing its chemical nature and converting it into honey, after which it is regurgitated and placed in the honey-cells. The wax is the product of certain glands on the under surface of the abdomen, but farther than this we know almost nothing.

The wax is used by the bees for building the cells, some of which are stored with honey, while others are utilized for rearing the young. It was formerly thought that the cells of the honey-comb were perfect hexagonal prisms, and this idea, though overthrown twenty years ago, still survives. Page after page has been written to show what a wonderful instinct it is that leads the bees to construct cells which are of such a shape as to afford the greatest economy of material, and whose sides and angles are fixed and invariable.

In fact, this is all nonsense. The hexagonal shape results not from any intention on the part of the bee, but from the fact that a number of cylinders, placed side by side and pressed together, will take a hexagonal shape, and the economy of material results not from a desire on the part of the bee, but as a mathematical necessity. The bee, in building the cell, places herself in the proper position and then raises the walls around her; and so when two bees work side by side, the intervening wall will be flat and not rounded as it is when it is free.

The history of a colony of bees runs somewhat as follows: In the spring the queen lays the eggs in the cells which are to produce workers and drones, or males. Later in the season the eggs for the queens of the new brood are deposited. When these latter have gone through their metamorphoses, the 'swarming' occurs. First, scouts are sent out to find a proper location, and then the old queen, accompanied by a portion of the workers, sets forth to found the new colony. Their first act is to thoroughly clean the new home, and then the various labors begin. In the meantime the young queen takes a 'marriage flight' with one of the drones, and then returns to manage affairs at the new hive. Again and again this process is repeated so long as queens continue to come forth; but when all are gone, the workers fall upon the drones and kill them all.

If the queen of a hive should die, the workers are able to raise up a new queen. The larval bees are fed upon 'bee-bread,' which is produced

FIG. 228. — Queen, workers, and drone of the honey-bee; above are front views of the heads.

by chewing pollen and mixing it with certain juices of the digestive tract. The larvæ which are destined to produce workers are fed a different quality of bee-bread from those which are to become queens; and so, if the queen die, the workers select a worker-larva, enlarge its cell, and feed it with the queen food, and the result is that the worker-larva develops into a queen. This, however, is not so strange, when we consider that the workers are in reality undeveloped females. On the other hand, hives of bees exist sometimes without queens, living under what may be termed a republican form of government, and it is rather interesting to note that a hive which has lived for some time in this way cannot be induced to accept a new queen.

Bee-keepers have introduced many ingenious inventions to facilitate the honey-storing capacities of the bees. There are patterns of hives beyond number, while they aid the bees by placing in the hives sheets of wax pressed so as to form a foundation for the comb. They even go so

far as to adulterate the honey in a most ingenious manner. They feed the bees with glucose, thus saving them long journeys to the flowers, but glucose does not make good honey. Some of the honey is sent to the market in the comb, while the rest is 'extracted,' the comb being used again in the hive, or is melted up and sold as wax. The uses of beeswax are many; indeed, it would take pages to enumerate them all. Possibly the largest amount is used to make the candles consumed in Catholic countries.

Among bees, as among cattle and other domesticated animals, there are various breeds, each of which has its peculiar features and its advocates. Some want Egyptian, while others are satisfied with Italian or Syrian queens, and so on through the list. The plants on which the bees feed influence the quality of honey. That produced by feeding on white clover is considered the best, that from buckwheat standing next. California is the great honey-producing state, the shipments in 1878 having aggregated 1,773,700 pounds; and in 1880, 1,011,856 pounds.

Besides our common honey-bee there are many others which gather honey, especially in the tropics. Some of this honey is good, while some is bitter or otherwise disagreeable to the taste. Mr. Wallace has given an account of one of these wild bees' nests occurring in the island of Timor. "In the valley where I used to collect insects I one day saw three or four Timorese men and boys under a high tree, and, on looking up, saw on a very lofty, horizontal branch three large bees' combs. The tree was straight and smooth-barked and without a branch, till at seventy or eighty feet from the ground it gave out the limb which the bees had chosen for their home. As the men were evidently looking after the bees, I wanted to watch their operations. One of them first produced a long piece of wood, apparently the stem of a small tree or creeper, which he had brought with him, and began splitting it through in several directions, which showed that it was very tough and stringy. He then wrapped it in palm-leaves, which were secured by twisting a slender creeper round them. He then fastened his cloth tightly round his loins, and, producing another cloth, wrapped it round his head, neck, and body, and tied it firmly round his neck, leaving his face, arms, and legs completely bare. Slung to his girdle he carried a long, thin coil of cord; and while he had been making these preparations one of his companions had cut a strong creeper, or bush-rope, eight or ten yards long, to one end of which the wood-torch was fastened, and lighted at the bottom, emitting a steady stream of smoke. Just above the torch a chopping-knife was fastened by a short cord.

"The bee-hunter now took hold of the bush-rope just above the torch, and passed the other end round the trunk of the tree, holding one end in

each hand. Jerking it up the tree a little above his head, he set his foot against the trunk, and, leaning back, began walking up it. It was wonderful to see the skill with which he took advantage of the slightest irregularities of the bark or obliquity of the stem to aid his ascent, jerking the stiff creeper a few feet higher when he had found a firm hold for his bare foot. It almost made me giddy to look at him as he rapidly got up—thirty, forty, fifty feet above the ground, and I kept wondering how he could possibly mount the next few feet of straight, smooth trunk. Still, however, he kept on with as much coolness and apparent certainty as if he were going up a ladder, till he got within ten or fifteen feet of the bees. Then he stopped a moment, and took care to swing the torch (which hung just at his feet) a little towards these dangerous insects, so as to send up the stream of smoke between him and them. Still going on, he brought himself under the limb, and, in a manner quite unintelligible to me, seeing that both hands were occupied in supporting himself by the creeper, managed to get upon it.

“By this time the bees began to be alarmed, and formed a dense, buzzing swarm just over him, but he brought the torch up closer to him, and coolly brushed away those that settled on his arms or legs. Then stretching himself along the limb, he crept toward the nearest comb and swung the torch just under it. The moment the smoke touched it, its color changed in a most curious manner from black to white, the myriads of bees that had covered it flying off and forming a dense cloud above and around. The man then lay at full length along the limb, and brushed off the remaining bees with his hand, and then drawing his knife cut off the comb at one slice close to the tree, and attaching the thin cord to it, let it down to his companions below. He was all this time enveloped in a crowd of angry bees, and how he bore their stings so coolly, and went on with his work at that giddy height so deliberately, was more than I could understand. The bees were not evidently stupefied by the smoke or driven away far by it, and it was impossible that the small stream from the torch could protect his whole body when at work.” These bees were not stingless, like so many tropical bees, as Mr. Wallace found out by sad experience, as after the combs had been let down, the bees became numerous below, and some of them stung him severely.

Of the stingless bees there are many species in South America. Mr. Bates alone obtained forty-five. But though these forms cannot sting, they can bite severely. One noticeable peculiarity in many of these forms is their habit of gathering clay. They first scrape it up with their jaws, and then the mass is passed back from one pair of feet to another, until at last it rests on the broad joints of the hind pair of legs in the place where most

bees carry pollen. These bees build their nests in hollow trees, and the clay is used to build up a wall closing the crevice, all except the opening for their entrance and exit. Another allied species uses sticks and dried leaves instead of mud to stop the hole, cementing them together with a gum which it gathers from one of the forest trees.

BUGS.

The term bug is used in different senses by naturalists and by the general public. In England it is generally restricted to one species—the form which is so apt to infest beds in uncleanly houses, while with us almost any insect or larva may be called a bug. The naturalist, however, restricts the term to a certain group of insects which in the more precise terminology of science are termed Hemiptera. The bugs are characterized by having the mouth parts adapted for sucking and piercing. As shown in the cut, they form a needle-like tube which is kept between the legs when at rest, but which can be directed in almost any way when the occasion offers. The wings also differ from those of other insects. In all they have a peculiar type of arrangement of the little nerves or veins which strengthen them, while the first pair may be to a certain degree modified into wing-covers corresponding to the elytra of the beetles. In the group of bugs most studied these wing-covers are hardened at their base, while the half more remote from the body is membranous, and it is to this fact that the term Hemiptera (half-winged) applies. It is to be noticed in passing that some of the bugs are without wings, but still in all the rest of their structure they

FIG. 229.—Under surface of a cicada, showing the piercing and sucking beak extending back between the legs.

agree with the others.

In number of species the bugs rank next to the beetles and flies, Mr. Uhler estimating them at fully fifty thousand. Still, mere numbers do not make a group interesting, and so little have the habits of these forms been studied that we shall dismiss them with but brief mention.

At the bottom of the series of bugs come some forms which live as parasites on various mammals, and which are known as lice. Their habits have, indeed, extensive modifications of structure. The wings have been lost while the feet have been modified for holding on to the hair, so that they resemble the pipe-tongs which the gas-fitter uses and are admi-

FIG. 230.—Head-lice (*Pediculus capitis*).

rably adapted for grasping the round hair. Lice, however, are disagreeable to contemplate, and we gladly leave them to take up other, if not more pleasing, still more interesting forms.

First of these are the so-called scale-insects, which are familiar to all as small scales on the trunks of trees, on the leaves, or on the fruit. Those on the apple-tree are well known, and resemble somewhat the shell of an oyster. These are the females, greatly changed in structure, and in reality forming but protective covers over the eggs and young. These scale-insects occasionally do considerable injury, but some of them, on the other hand, contribute to man's needs. One of these beneficial forms is the lac-insect. This punctures the skin of the twigs of various East Indian trees, and the exuding juice, drying on the exterior, forms the lac of commerce, which, however, needs some treatment before it is ready for the market. As broken from the tree it forms stick lac. This is soaked in water to remove the coloring-matters, to be mentioned farther on. It now has a granular appearance, and is called seed lac. The next process is to melt it, after which it may either be allowed to cool in large masses (lump lac), or it is strained through cloth and allowed to form a thin layer on a flat board, where it soon hardens and breaks up into small scales, and is then the familiar shell-lac, the most common form in trade. It is used as the basis of an alcoholic varnish, in sealing-wax, cements, and many other substances used in the arts.

FIG. 231. — Apple-bark covered with the scale-insects; at the left, enlarged views of the young, the scale, and the adult female.

The coloring-matter in the stick lac, to which allusion has just been made, is composed of the bodies of the dead insects, and the bodies of the females are colored a brilliant red. The aqueous extract referred to is evaporated, and the residue, formed into lumps or cakes, forms the basis of carmine lake, a pigment which rivals the carmine of the cochineal in brightness and durability. The addition of various substances, like the salts of alumina or tin, change the hue, and thus gives rise to quite a range of red or reddish pigments. An allied species of insects living on the oaks in the region around the Mediterranean affords the dye kermes, and these two, it is supposed, were the basis of the rich crimson of the ancients as well as of the later red dyes of Holland and Belgium whose permanence is so well known.

Since America was discovered, the kermes and the lac-insect have lost in rank, for the cochineal has to a large extent replaced them. When the Spaniards conquered Mexico, the Indians knew of the value of the cochineal, and assiduously cultivated the cactus for its food. Every year cer-

FIG. 232.—Male pine scale-insect, enlarged, and a branch of pine-needles affected with the scale.

tain districts were expected to give a certain amount of the insects as tribute to the ruling chief. The general appearance of the insects is shown in our figures, which show both the male and the female considerably enlarged. The female alone is of value, and in life, as she feeds on the

FIG. 233.—a, a portion of the nopal cactus, with powdery patches produced by the cochineal insect (*Coccus cacti*), natural size. At b and c, the male and female insects, enlarged,

leaves of the cactus, her body is covered with a thick downy pubescence (see figures on the left), which completely changes her appearance, and conceals her from her enemies.

The management of a cochineal plantation is not an easy task. Just

before the rainy season sets in, branches of the cactus covered with females are cut off and taken under shelter. These form what might be called the 'seed' for the next year's crop. Then in October, when the rain is over, the plantation is stocked again with insects, by placing several of these insects on each plant. There they rapidly multiply, each female producing over a thousand eggs. After the resulting progeny becomes full grown, the insects are carefully picked off by hand, there being several pickings before the return of the rainy season. The picking is very slow and tedious, and an Indian can pick in a day only enough to make two ounces of dried cochineal. According to the way in which the insects are killed, the cochineal varies in appearance, though there is not much difference in the quality of the carmine. If they are boiled, they have a brownish red color, and lose most of their down; these are the 'foxy' insects. If baked in a hot oven, they retain the down, and are then known in the trade as 'silver grains'; while if heated on plates of hot iron, they turn black, and are then 'black grains.' It is said that it takes some seventy thousand insects to make a pound of dried cochineal; and when we consider that all these must be picked by hand, we see that the temptation to adulterate must be great. Adulteration is most easily practised with the silver grains, by rolling them in powdered talc or white lead, which sticks to their bodies to a certain extent, and very materially alters their weight.

From the cochineal comes a long series of carmine colors, the preparation of which is a matter of considerable complexity, and need not be described here. It consists of making an infusion of the dried insects in water, mixing this with salts of alumina, and allowing the color to be precipitated. The finest qualities can be prepared only on bright sunshiny days; and it is related that an English manufacturer paid a thousand pounds to learn that the reason why he could not make as good a quality of carmine as the French, was on account of the lack of bright days in England.

In America, the great centre of the cochineal industry is in the province of Oaxaca. In 1844 the French introduced the nopal cactus and the cochineal into Algiers, and the Dutch, at a later date, into Java, and now these countries produce considerable amounts, that of Algiers being said to excel that of Mexico.

The insect which produces the manna of the shops is another allied species, but it hardly needs to be said that this manna does not correspond to the description of the miraculous food which supported the Israelites in their long journey through the small Sinaitic peninsula. It is rather to be classed with the lac mentioned above, as it is an exudation from the tamarix-tree. The Arabs collect the resulting grains, boil and purify

them, and then use them as food. In the Mediterranean region other trees are punctured, and the resulting manna is sold for its medicinal qualities.

Still another species of economic importance is the wax-insect of China, concerning which we extract the following from the pages of Mr. C. C. Cooper: "On the third day we entered the white wax country, so named from its producing the famous white wax of Szechuen, which has been erroneously called vegetable wax. This district was less undulating than that of the tea-gardens, and presented to the eye a view of extensive plains surrounded by low hills. The plains were all under wax and rice cultivation, the wax-trees being planted round the embankments of the small paddy-fields, which were at most thirty yards square. The country thus presented to the passing traveler the appearance of extensive groves of tree-stumps, each as thick as a man's thigh, and all uniformly cut down to a height of about eight feet, without a single branch. The cultivation of wax is a source of great wealth to the province of Szechuen, and ranks in importance second only to that of silk. Its production is not attended with much labor or risk to the cultivator. The eggs of the insect which produces the wax are annually imported from . . . Yunnan (where the culture of the eggs forms a special occupation) by merchants who deal in nothing else but pa-la-tan,—white wax eggs. The egg-clusters, which were described to me as about the size of a pea, are transported, carefully packed in baskets of the leaves of the pa-la-shu—white wax tree—which resembles a privet-shrub, and arrive in Szechuen in March, where they are purchased at about twenty taels per basket. The trees by the middle of March have thrown out a number of long, tender shoots and leaves, and then the clusters of eggs enclosed in balls of the young leaves are suspended from the shoots by strings. About the end of the month the larvæ make their appearance, feed on the branches and leaves, and soon attain the size of a small caterpillar, or rather a wingless house-fly, apparently covered with white down, with a delicate plume-like appendage, curving from the tail over the back. So numerous are they that, as seen by me in Yunnan, the branches of the trees are whitened by them, and appear as if covered with feathery snow. The grub proceeds in July to take the chrysalis form, burying itself in a white wax secretion, just as a silk-worm wraps itself in its cocoon of silk. All the branches of the trees are thus completely coated with wax an inch thick, and in the beginning of August are lopped off close to the trunk, and cut into small lengths, and carried to the boiling-houses, where they are transferred without further preparation to large caldrons of water, and boiled until every particle of the wax rises to the surface. The wax is skimmed off and run

into moulds, in which shape it is exported to all parts of the empire." It is used for candles and also as medicine. It would seem that the natives of the central provinces did not find it profitable to reserve a portion of the insects to use in starting the next year's crop, but find it cheaper to import them from the southeastern districts. The wax is crystalline and dazzling white, and in its chemical nature it is a cerotic ether.

The plant-lice, or aphides, which swarm upon vegetation, come a step higher in the scale, and in their habits there are several points of interest. We have already alluded to them as being the cows of the ants, and Linnaeus speaks of '*Aphis vacca formicarum*'—aphis the cow of the ants. They have two slender tubes projecting from near the tip of the abdomen through which they can secrete at will a sweet juice—the honey-dew of which the ants are so fond.

FIG. 234.—Winged stage of the plant-louse (*Aphis*). Compare with the wingless forms shown in Figure 222.

As usually seen, the plant-lice are fleshy, wingless forms (Fig. 222) which slowly wander over the plants, puncturing the tissue here and there, and greatly weakening its vitality, if not completely destroying it. At times, however, winged forms are seen, and these facts have a peculiar explanation. The elucidation of the story is due to Bonnet, a Swiss naturalist who lived in the last century. He separated one of these wingless forms, and carefully watched it for months, noting its every change, and recording every molt. One day it surprised him by giving birth not to an egg, but to a living young; the next day it was the same, and so on—some days, one young, some days, several—until at last the total number amounted to ninety-five. These young grew up, and in their turn became mothers, and this without the intervention of any males. So it went on through the summer; generation after generation appeared, and it was not until the autumn that the perfect insects—male and female, the former winged—appeared. These laid eggs, which were to remain through the winter, and then in the spring reproduce the species.

One of these aphid-like forms, the Phylloxera, is to be enumerated among the extremely injurious insects. It first acquired prominence in the vine-growing regions of France, where, for several years, the vines had been injured and killed, no one knew by what. At last the government took the matter in hand and offered rewards for practicable remedies, and in 1868 it was shown that the Phylloxera was the cause. This was a step, for one must know the cause before he can intelligently apply the remedy. It was found that there were two types of the insects,—one

affecting the roots, and the others making galls upon the leaves. Those which attacked the roots made swellings, and the more tender the roots, the more quickly the plants succumb to the attacks. While these discoveries were being made, the pest increased to an alarming extent, and whole districts were obliged to give up the vineyards. It was soon found that certain American stocks had immunity from the insects, and so

FIG. 235.—The grape-Phylloxera, enlarged, with roots of the vine damaged by its ravages.

grafting on American plants was resorted to extensively and with good results. Insecticides were also used, but the expense is too great. Another remedy is submerging the vineyard with water for twenty-five or thirty days in the autumn or a longer period in winter.

The Phylloxera is a native of America, but most of our vines are not subject to their attacks to any great extent. Attempts have often been made to introduce European grape-vines into this country, but without any great success; and the inference is that the Phylloxera is the cause of

A GROUP OF TROPICAL HEMIPTERA.

the failure. Exactly why the 'Concords' and 'Clintons' are not seriously damaged is difficult to say, but it is a fact that there is always a "certain harmony between the indigenous fauna and flora of a country"; and our native vines are such as, from their inherent peculiarities, have best withstood the attacks of the insect. Again, with us, enemies of the Phylloxera are numerous, while they are lacking in Europe.

Another group of bugs are represented by a number of forms common in our latitudes, and known under the vulgar name 'stink-bugs,' from the most disagreeable smell and taste which they have, and which must be familiar to all from their habit of wandering over field-fruits and communicating to them some of their own disagreeable odor. Many of them take the most bizarre shapes, the thorax being frequently prolonged into horns and spines like the common form shown in our cut. In the tropics these forms are even more strange, and some of these are shown near the top of the plate facing page 250.

Much larger than these are the cicadas, one of which is represented as seen from beneath in Figure 215, while below in the plate just referred to

FIG. 237.—The seventeen-year locust (*Cicada septimdecem*); above are shown at *c* the eggs, which are deposited in the holes (*d*) in a twig; *a* is a pupa; *b*, a pupa-case from which the adult cicada (*c*) has escaped.

a complicated manner, and the air being produced the note.

A first cousin to the harvest-fly is the celebrated seventeen-year locust,

which really is not a locust at all. It derives its common name from the fact that its swarms make their appearance once in seventeen years. The larvæ spend this long time underneath the earth, where they feed upon the roots of various trees. At last the time comes for emergence, and then the clumsy-looking but rather active pupæ bore up out of the soil and make their way to trees, where, clinging to the bark, they undergo the last molt, and the perfect insect appears.

There are two distinct broods of the seventeen-year locust, in one of which the locusts emerge once in seventeen years, while in the other the period has been changed to thirteen years. In different regions each brood has its own times of emergence, and hence we may hear of swarms of these insects almost every year in some part of the country; but in each region the seventeen or thirteen year period is invariable. These insects do considerable damage, not only when in the preparatory stages by gnawing the roots of trees and shrubs, but as adults by their punctures of the bark, and by the way in which they deposit their eggs. They select small branches of the trees, and with their ovipositor they bore into them to the pith, and then deposit their eggs in the hole thus made. The branches thus injured (which may contain as many as fifty packets of eggs) soon die and are broken off by the wind. In this way the young, as soon as they hatch, are able to immediately burrow into the earth; but occasionally it occurs that the branch does not break off, and then the larvæ are said to precipitate themselves to the ground, and then to make their way to some tender and succulent root.

The lantern-flies and candle-flies are tropical species occurring in both hemispheres. They are peculiar in shape, the front of the head being prolonged into a long horn, or 'lantern,' like that shown near the centre of the plate opposite page 250. By some this lantern is said to be phosphorescent, while others deny it any luminous properties, and say that these insects fly only in the day-time, when any such light would be useless.

Every one has noticed on the grass of our fields and lawns small masses of what is apparently spittle, and no doubt the question often arises. How came it there when there is not a trace of a person having been near? The answer is, that the mass is not spittle at all, but is the product of a little larval bug which sits fastened to the grass, with its beak perforating the

FIG. 238.—Earthen tubes made by the seventeen-year locust just before assuming the adult condition.

leaf or spear on which the animal rests. It sucks in the juices of the grass, and after having absorbed the nutriment from them it expels the water together with a considerable quantity of air, thus producing the peculiar frothy appearance.

The general shape of these small, inconspicuous bugs is shown by the adjacent cut, which represents a little form which at times proves very injurious to the grape-vine. The colors of this, as well as of the allied species, are very variable, and but little dependence can be placed upon them in the description of any form. Yet many of these small species, when viewed by a common hand-lens, will be seen to be exceedingly beautiful, their colors being bright and harmonizing and laid on in pretty patterns.

FIG. 239. — Grape-vine hopper (*Erythroneura vitis*).

All the forms of bugs so far enumerated belong to one group, which have the first pair of wings of homogeneous texture throughout, while those which remain to be enumerated have them half coriaceous, half membranous, as was mentioned on a preceding page. Of these latter forms — the true Hemiptera — we find forms which are beneficial and forms which are injurious to vegetation, although none of them have any commercial importance to be compared with that of the lac-insect or cochineal.

First of them are a number of aquatic, rapacious forms which rival the water-beetles in their predaceous habits. Some of them swim in the normal position, while others, also natatory in habit, always go upon their backs; some creep about the bottom; others are adapted for walking on the surface. Some of them are very large, and their long and strong beaks are capable of inflicting a very severe wound. Fishes are their

FIG. 240. — Spiny-bug (*Boydium*).

FIG. 241. — 'Water-scorpion' (*Zetonia*); dorsal and ventral views of two different species.

especial prey, and they kill them by inserting this long beak and then sucking the blood. Distantly allied to some of these species of our ponds and brooks is a group remarkable from the fact that it lives and breeds upon the surface of the ocean hundreds and even a thousand miles from land, and thus has introduced some

modifications of structure exceedingly interesting to the scientist.

The remaining forms are terrestrial, and a large proportion of them are of value to mankind from the fact that they prey upon other insects, piercing either the larva or the adult with their sharp beaks. Of these

forms we need to say but little, but of the injurious forms a few words are necessary.

First in order comes the universally distributed bed-bug, the terror of all cleanly housekeepers. It is a thin, flat, foul-smelling form, in which the wings are not at all developed. Where the bed-bug started is unknown, but it has been distributed over most parts of the world.

The chinch-bug, well-known for its ravages in fields of grain, and the larger, strong-smelling squash-bug are the most familiar representatives of the forms with wings. The damage they cause is sometimes considerable, but still neither of them acquire that prominence which at times characterizes the Rocky Mountain locust or the grasshopper.

FIG. 243. — *Milyas cinctus*.

Many of the allied forms are interesting from their colors or strange shapes: some may be black and rounded, so that they resemble a black bead; others, flattened nearly as thin as a sheet of paper, and colored exactly like the bark beneath which they dwell. Some are as brightly painted as any butterfly, while others are as unpretentious as a Quaker. Again,

some may have the antennæ flattened out into broad leaf-like membranes, while others, like one figured on the plate opposite page 250, have the legs modified in a similar way. To enumerate all these variations would take pages and volumes, and so we leave the bugs with the remark that, as objects of beauty they deserve more than the contempt with which they are usually treated.

FIG. 242. — Squash-bug (*Anasa tristis*).

FIG. 244. — *Podisus spinosus*, with one wing extended.

FLIES.

The flies are two-winged insects (whence the name Diptera), whose typical form, the common house-fly, is familiar to all. The mouth parts are wholly fitted for sucking, and in some cases, as in the familiar mosquito and black-fly, they are at the same time piercing-organs of no mean capacities. On the other hand, in some forms they are not adapted for piercing; but only for taking liquid food, although they can at times eat solids by first forcing out a small amount of saliva, which softens and dissolves them so that they may be drawn up by means of a peculiar muscular 'sucking-stomach,' which plays the part of a pump. The larvæ of the flies are footless, worm-like forms, familiar to all under the name of maggots. They live some in animal and some in vegetable matter, and

undergo a complete metamorphosis in passing into the pupal and adult conditions.

In number of species, the flies stand second only to the beetles; and although only about twenty-five thousand species have been described from the whole world, the probabilities are that the total number of species is between seventy-five and a hundred thousand. In number of individuals, the flies surpass probably every other group of insects. While beetles, butterflies, and bugs usually occur in solitary individuals, one has but to recall the immense numbers of some species of flies to see how greatly they outnumber all the rest.

FIG. 245. — Hessian-fly with a bit of wheat straw, showing the place occupied by the 'flaxseed' stage of the insect; *a* and *b* represent the larvæ and pupa: all enlarged.

Some of the flies, like some of the Hymenoptera already mentioned, produce galls on plants, and one of these species, the celebrated 'Hessian-fly,' has acquired a great economic importance. The name Hessian was applied to it under the belief that they were introduced with straw by the Hessian mercenaries during the Revolutionary War. This view is probably erroneous. No one has

yet found in Germany any fly like our pest, and besides, there is good reason to believe that the Hessian-fly committed damage in this country before the Revolution. It is far more probable that the insect was a native American species which suddenly changed its food plant as so many other forms have done within more recent times.

The earliest recorded ravages of the Hessian-fly were in the neighborhood of New York, and from there they have spread over the whole country. The fly is but about an eighth of an inch in length, and yet in certain years their numbers are so enormous that the damage they cause extends up into the millions of dollars. The fly lays its eggs on the young shoots of the wheat, and the larvæ on hatching out bore their way into the centre of the stalk, where they feed on the sap of the growing plant. In this way they rob the kernels of part of their food supply, causing them to fill imperfectly; and they also weaken the stalk, so that it is easily beaten down by the wind and rain. The first brood of eggs hatches out in August, from the spring wheat; and then the females lay their eggs in the winter wheat, and these in turn hatch out in the spring.

Other allied species feed upon the cranberry and the heads of the wheat; but none of them have acquired anything like the prominence of the Hessian-fly.

Every traveler, at certain times of the year, in our northern woods, becomes well acquainted with that pest, the black-fly. It is a small insect, with black body and transparent wings; but the torment that it can cause bears no relation to its size. Still, it can hardly compare with some of its relatives in warmer countries. Thus in the region of the Black Sea there is a species which frequently kills cattle by the inflammation ensuing from its bites, while in our southern states the allied 'buffalo-gnat' is almost equally destructive. Its bite produces an inflammation, and death frequently follows, accompanied with severe cramps and convulsions. The larvæ of these various black-flies are like those of the mosquito, in the fact that they live in the water, though they differ in many points of structure.

FIG. 246. — Black-fly (*Simulium molestor*), enlarged; at the left, a still more enlarged view of the aquatic young.

The mosquitos, of which there are many species, are too well known in their adult condition to need any extended description. The females lay their eggs in small masses on the surface of stagnant water, each mass resembling somewhat in shape the peel of a quarter of an orange. The eggs are arranged at right angles to the surface of this float, and when they hatch the larvæ escape from the lower ends of the eggs directly into the water. Here they feed upon the abundant decaying vegetable matter, and soon become large enough to be readily seen, and from the peculiarities of their motions they have received the appropriate name of wrigglers. They make their way quickly through the water by the contortions of their body, and then they will remain quiet for a few moments, when the buoyancy of their bodies brings them, tail uppermost, to the surface of the water. At the extremity of the body there is a small tube, fringed with hairs, and through this the larva breathes air when at the surface. A few moments are sufficient to obtain a sufficient supply, and then the larva wriggles its way to the bottom again.

With growth the larva molts two or three times, and then changes to the pupal condition, which differs in several respects from the larva, as is shown in the cut. The breathing-tubes have changed to the sides of the thoracic region, and so now, when it comes to the surface for respiratory purposes, it comes

FIG. 247. — 'Wrigglers,' the young of the mosquito. A, larva; B, pupa; C and D indicate the openings through which the air for respiratory purposes is taken.

with the anterior part of the back upwards. At last the time for the emergence of the perfect insect arrives. The pupa now rises to the surface of the water, and at last floats upon it. The skin now splits down the back, and from the opening thus formed the mosquito draws its body, legs, and wings; and then, standing upright in the old pupal case, as one would in a boat or canoe, it allows the flabby wings to dry. This period is fraught with great danger to the young mosquito, for the slightest wind will upset the boat in which he stands, and an immersion in the water will quickly result in the death of the delicate form.

As is well known, summer and autumn are the seasons when these insects most abound, and at times they occur in enormous swarms. At other seasons of the year they may occur, and the writer once remembers visiting a house which was afflicted with them in the month of February. A little examination showed the cause. A number of hyacinth glasses standing in the window formed the breeding-grounds, and in them wrigglers were to be seen in great numbers. The glasses were emptied, and the plague ceased until the next season.

The horse-flies are considerably different from the mosquitos, but they have one feature in common with them,—it is the female which bites. They will fly round and round a horse, with a dull, droning note, seeking some unprotected spot on which to alight, and suck their fill of blood. Their larvæ, too, are carnivorous, and prey upon insects and snails, thus partially repaying the farmer for the torments they cause his live-stock.

FIG. 248. — Horse-fly (*Tabanus*).

The robber-flies are also large, strong forms, which do a considerable amount of good by their predaceous habits. They fly strongly and quickly, resting on some bush or on the ground until they see some insect, when they dart after it, grasp it with their strong feet, and run their beak through it. Our figure shows a species which in this way does considerable good by destroying injurious insects, while its larva feeds upon the eggs of the western locust.

FIG. 249. — Robber-fly (*Eraz*).

The bot-flies, on the other hand, are to be regarded as unmitigated nuisances, from their parasitical habits in the preparatory stages. There are some sixty species known, all of which prey upon the vertebrates, and all but one upon mammals. In the habits of the various species there are considerable differences to be noted.

First to be mentioned is the bot-fly of the horse, very familiar to all who have much to do with these useful animals. It is a brownish species

with spotted wings, and is well shown in our cut. The adults live but a short time, and never take any food. The whole energies of the female are devoted to obtaining an opportunity to lay her eggs in the proper place. In the choice of this the different species affecting the horse vary somewhat, that figured preferring the region about the knees easily reached by the lips of the horse, while a closely allied form deposits them upon the lips themselves. Each egg is deposited singly, and is fastened by a sticky secretion to one of the hairs.

FIG. 250. — Horse bot-fly (*Gastrophilus equi*) and larva.

In this choice of a position for the eggs there is a due regard, for the life of the larva to be hatched from these depends upon their being placed where they can be taken into the mouth of the horse. The larvæ escape from the egg in a few days, and when the horse is nipping the place where they are laid, they find their way into the mouth and thence to the stomach. Here they fasten themselves to the lining walls by means of the little hooks shown at the upper end of the left-hand cut of Figure 250. The result is that they produce sores in the stomach, and, when there are many present, the resulting pain almost drives the animals frantic, and the inflammation ensuing may result in death.

When full-grown the larvæ loose themselves from the walls of the stomach and pass into the intestines along with the food, and are then carried out with the excrement. They now burrow into the earth, pupate, and at length emerge as the perfect fly with which we started. The bot-fly which lays its eggs on the lips of the horse differs from the form just described in that the larvæ burrow into the wall of the intestine instead of the stomach.

The bot-flies of cattle differ considerably in their habits from those of the horse. The eggs are laid as

FIG. 251. — Cattle bot-fly (*Hypoderma bovis*), larva, and pupa, enlarged.

before upon the hair or skin of ruminants, especially in the neighborhood of the neck, shoulders, and groin. The larvæ on hatching burrow their

way into the skin and produce suppurative sores, which of course damage the hide for leather. Here they grow until, at last, they attain a length of about an inch, when they escape, fall to the ground, and burrowing beneath the surface, undergo the rest of their changes. These larvæ are called 'grubs' by the cattlemen, while the sores they cause are designated as 'womils' or 'wurmals,' which is evidently a derivative of worm-holes.

A third form of bot is that which infects sheep, and which has habits distinct from those already described. This fly brings forth its larvæ alive, and deposits them in the nostrils of sheep; the larvæ then quickly crawl up the air-passages of the head, until they reach the large cavities known as the frontal sinuses, where they pass the rest of their larval life in a

manner analogous to that already described for the other species. This period lasts for about nine months, and then they crawl out and drop to the ground, where they pupate and change to the imago as before.

When a sheep is afflicted by but one or two of these parasites, the effect is but slight, but the presence of large numbers produce the disease known as 'staggers,' the principal symp-

FIG. 252. — Sheep bot-fly (*Estrus ovis*), larva, and pupa, enlarged.

tom of which is indicated by the name. At first there is a discharge from the nose, and later the sheep moves about in a dizzy, staggering manner, and in many cases death may finally ensue.

It is curious to notice the way in which different animals at once recognize the presence of bot-flies. The deposition of the eggs cannot pain them, and hence this cannot be the cause of their excitement. It must be something connected with their buzzing note, or more probably some peculiar smell which warns the horse, cow, or sheep of their proximity. The sheep will crowd together and hide their noses in the dust, cattle run about in the wildest way, while the horses will often become unmanageable in their presence.

Our common flies, typified by our common house-fly and blow-fly or 'blue-bottle,' represent a very large group only a few of which need mention. The house-fly is too well known to need description, and although regarded as a nuisance, still does an immense amount of good by its habit of feeding in the larval stage upon decaying substances of all sorts, — offal, carrion, manure, in short, almost any offensive matter which

might otherwise prove dangerous to the health of mankind. The blow-flies are especially fond of depositing their eggs upon meat or cheese, and are regarded as even more of a nuisance than the smaller house-flies.

The celebrated tse-tse fly of tropical Africa is something like the blue-bottle in shape and size, but it is a far more dreadful pest than any insect among us. Its mouth parts (shown on the left of our cut) are strong, sharp, piercing instruments with a poison-gland at the base, and the punctures of this are followed by death in the case of cattle, horses, sheep, and dogs, but in the case of man and many other animals they are harmless, or productive of no more severe consequences than the bite of a mosquito. In the case of an ox, for instance, there is no immediate effect; but in the course of a week a sore forms around the puncture, and then the nose begins to run, and swellings

FIG. 253.—Blow-fly (*Calliphora vomitoria*), enlarged twice.

FIG. 254.—Tse-tse fly (*Glossina morsitans*), enlarged, with magnified views of the head and antenna.

occur under the jaw. The animal now grows thin and weak, and in the course of a few months dies, sometimes with staggering and blindness, as if the poison affected the brain.

If a swarm of these animals attack a horse at once, the death is more speedy, sometimes occurring within a week. After death almost every tissue in the body shows signs of disease; and as yet there is nothing known which will avert a fatal result in case any of the animals mentioned above be bitten. By some the tse-tse is identified as the fly which caused the fourth of the plagues of Egypt, but the evidence on this point is far from conclusive.

The cheese-mite, or skipper, is a familiar form, the larva of a small fly. The larvæ jump about in the most lively manner, although they have no

feet. The leaping or 'skipping' is accomplished by doubling the body and then suddenly straightening it, thus throwing the body some four or five inches. An allied form is the wine-fly, which passes its larval stages in the lees of wine, the alcohol which is present seeming not to affect them in any way unless beneficially.

A similar immunity to what would appear to be adverse conditions is seen in the case of the larvæ of the brine-flies. In some cases the larvæ live in the ocean, in others in the far stronger brine of Great Salt Lake, and the neighboring alkaline waters of Utah and Nevada. In Great Salt Lake these larvæ are sometimes cast up in long windrows along the shore, while in Mono Lake they occur in as great numbers. Professor W. H. Brewer has the following notes upon the larvæ occurring in the latter lake:—

"The numbers and quantities of these flies and larvæ are absolutely incredible. They drift up in heaps along the shore, and hundreds of bushels could be collected! They only grow at certain seasons of the year, and then Indians come from far and near to gather them for food. The worms are dried in the sun, the shell rubbed off by hand, when a yellowish kernel remains, like a small, yellowish grain of rice. This is oily, very nutritious, and not unpleasant to the taste, and under the name of *koo-chah-bee* (so pronounced) forms a very important article of food. The Indians gave me some of it; it does not taste bad, and if one were ignorant of its origin, it would make nice soup. It tastes more like patent meat biscuit than anything else I can compare it with. . . .

"The waves cast these larvæ in little windrows on the shore; the quantity is large; the chief difficulty in collecting is to get it as free from sand as is possible, and then it is dried on clothing or blankets. My guide, an old hunter there, told me that everything fattens in the season of the *koo-chah-bee*; that ducks get very fat, but their flesh tastes unpleasantly from it, and that the Indians get fat and sleek. . . . The flies settle on twigs, spires of grass, etc., until nothing of the perch can be seen, merely a wand of closely clinging flies. They also at times rest on the water in great numbers."

This use of these larvæ as food is paralleled by the use of the eggs of a similar species in Mexico. Among the Mexicans this is called a mosquito, but in reality it is a far different species. It lays its eggs in large numbers on the grass surrounding some of the lakes of Mexico, and in some places the Indians prepare bunches of sedges for their deposit. At times these bundles are taken up and beaten, and the eggs which fall off are gathered, dried, and ground into flour called Ahuatl. This flour is mixed into small cakes by the aid of hens' eggs, and these are then fried. It is held that as these contain no flesh, they are legitimate food on the

fast days of the church. Americans who have eaten them describe them as far from palatable.

Last among the true flies come a small group which spend their adult lives as external parasites on birds and mammals. In some cases, as that of the horse-tick figured here, this life has not continued long enough to greatly affect the insect, but in other cases it has resulted in the complete disappearance of the wings. One form is remarkable for being provided with wings, and living on birds during a portion of its existence, and then migrating to the hair of some mammal, and there dropping its organs of flight.

FIG. 255. — Horse-tick (*Hippobosca equina*), enlarged.

FIG. 256. — Bat-tick (*Nycteribia*), an example of a wingless fly.

Some entomologists regard the fleas as extremely modified flies, while others think that they have nothing to do with the two-winged forms which we have just left. These, however, are abstruse questions and need not be discussed here, but the weight of authority now seems to be in favor of the latter view.

The general appearance of the fleas is well shown in our cut. They are wingless forms, the hind legs of which form well-developed leaping-organs, while the mouth parts are modified into an admirable piercing and sucking organ whose capacities are known to all. There are several species of fleas, some of which will breed upon the human body, while others will torment man, but require for their development the flesh and blood of some other animal. Most noted among the fleas is the celebrated jigger-flea of tropical America. It is known under a variety of names, such as chigoe, chique, pique, all of which are readily seen to be modifications of one fundamental word. The larva of the jigger is much like that of the more familiar form. It lives in the earth and there undergoes its transformations. The adult female displays a marked preference for the human feet, and when occasion offers, she quickly burrows beneath the skin and there matures her eggs. Of these there are an enormous number, and their growth soon swells the abdomen out into a spherical sac, to which the rest of the body bears about the same proportions as in the case of the female white ant already described. This growth soon produces a severe sore, and unless the parasite be removed a dangerous ulcer results. Next the eggs

FIG. 257. — Flea (*Pulex*), enlarged.

are deposited in the flesh, and the member is quickly filled with multitudes of young jiggers, and then serious consequences which may even demand amputation ensue.

Mr. W. H. Dall has described the actions of the so-called educated fleas which periodically are exhibited in all of our leading cities. These minute animals in their natural state are, as is well known, excessively inclined to jump; but in these exhibitions this tendency has been checked, and the insects draw miniature coaches, trains of cars, and the like, as steadily and demurely as any old family horse. The bottoms of the exhibition cases are lined with blotting-paper, which gives a good foothold for the hooks on the feet of the flea; and when the exhibition of any particular flea was over, he, together with his load was turned wrong side up, so that there would be no exhaustion from unnecessary labor.

“The most amusing, and at first incomprehensible, of the various performances, is that of the dancing fleas. The orchestra are placed above a little music-box, whose vibrations cause them to gesticulate violently for a few moments, fastened as they are to their posts. Below them are several pairs of fleas (fastened by a little bar to each other in pairs, those of each couple just so far apart that they cannot touch each other) apparently waltzing; an inspection shows that the two composing each pair are pointed in opposite ways; each tries to run away, the ‘parallelogram of forces’ is produced; the forward intention, converted to a rotary motion, ludicrously imitating the habits of certain higher vertebrates.”

Mr. Dall concludes that the insects are not ‘educated,’ and that as in the case of the dancing, every feature of the exhibition can be explained by the desire and earnest efforts of the insects to escape, but there yet remains to be explained the reason why the fleas exhibited no longer jump, but adopt another style of locomotion. It may be, as Mr. Dall suggests, that the legs have been tampered with, or that the load placed upon their back is the inducing cause. The proprietor of the exhibition said in substance that it was effected as follows: “The wild flea is put into a small pill-box with a glass top and bottom, revolving on an axis like a lottery wheel and forming a miniature tread-mill. After a few days’ confinement herein the flea, which in a state of nature is, as we know, excessively inclined to jump, becomes broken of the habit. It is said that the constant raps which it receives when attempting to jump, and thereby hitting the sides of its prison, incline it to walk.”

BUTTERFLIES AND MOTHS.

Last, and in structure the most differentiated of all the insects, come the moths and butterflies; the Lepidoptera of science. This name — Lepidoptera — means scaly-winged, and alludes to the fact that the wings are covered with minute scales, laid like the shingles on a roof. If we handle one of these insects, these scales are rubbed off, and cover the fingers with a powder, in reality the scales themselves. The colors of moths and butterflies are frequently very bright; but they are due not to the general integument, but rather to these scales; and the beautiful patterns existing on some of these insects are to be regarded as mosaics, scales of different colors producing the effect in exactly the same way that the Florentine artist does with his bits of stone.

The metamorphosis of the Lepidoptera are 'complete'; that is, the larval, pupal, and perfect stages are all distinct. The larva, or caterpillar, almost invariably is a vegetable feeder, and is provided with strong jaws for gnawing the leaves or stems of plants. The pupa, or chrysalis, is incapable of locomotion, while the adult with its strong wings completes the cycle. In the adult there are no strong jaws; but instead, all the mouth parts are fused into a long tube adapted for reaching the bottom of the flowers and sucking up the nectar secreted there. This tube is sometimes of enormous length, and when not in use is coiled under the head like a watch-spring: in Figure 275 it is shown partially uncoiled.

There are many differences between moths and butterflies; but we need mention only a few of the most apparent. In the moths the antennæ are either feathery or hair-like; while in the butterflies they terminate in a hook or knot; when at rest the moths hold their wings flat, while the butterflies fold them vertically over the back; lastly, the butterflies fly by day, while most of the moths keep themselves concealed until the shades of evening, when they appear in large numbers, and are attracted by every light.

When the word 'moth' is mentioned, every good housewife at once recalls the small insect which makes life a burden, — the clothes-moth or carpet-moth, as it is variously termed. It is a small, inconspicuous insect, not a third of an inch long, dull yellow in color, which flies about in the early evening in the most aggravating way. Now it is perfectly visible; but the moment one tries to catch it, it disap-

FIG. 258. — Clothes-moth, with enlarged views of (a) larva, (b) pupa, and (c) pupa-case, the latter constructed from the fibres of the fabric on which the larva feeds.

appears as if provided with the cap of invisibility. This moth is searching for a place to lay its eggs, and prefers for this purpose articles of wool or feathers. The moth itself is utterly incapable of doing any damage; but the larva which hatches from the eggs works havoc with our carpets and clothing. It eats the wool, and then when ready to change to the pupal condition, one form makes a cocoon of the fibres, and in this it goes through its changes, emerging as the perfect insect from June to August.

An allied moth, the grain-moth, is illustrated in our next cut. Like the preceding it is a native of Europe; but it has followed man to all parts of the earth. Its history is but little different from that already detailed, except that it feeds on wheat stored in granaries, as well as in the field.

FIG. 259. — Grain-moth (*Tine granella*); below, eggs, infested grain, and pupæ, enlarged.

FIG. 260. — Willow-leaves, rolled and held by a caterpillar, in order to form a nest for pupating.

Wormy apples are caused by a different style of moth, scarcely larger than that just mentioned, but differing in many points of structure. This form, the coddling-moth, is a small gray insect, which lays its eggs on the young apples just as they are beginning to form. The larva eats its way to the core, and there waxes and grows fat. Its ravages usually cause the fruit to ripen prematurely and to fall to the ground, where the larva crawls out, and, seeking some sheltered place, spins its cocoon, where it spends the winter, emerging in the spring as the perfect insect, ready for the new crop of apples. If cattle or hogs are allowed to roam in the orchard, they will eat the wormy apples as fast as they fall, and as a result the fruit the next year will be comparatively free from worms.

The coddling-moth is a member of a group of moths which are called tortricids, from the habit which many of the larvæ have of rolling or twisting up leaves to provide protection for their cocoons. Of these leaf-twisters each species has its peculiar way of doing this, and the entomologist, on seeing one of the nests, knows at once the moth which later will emerge

from it. Our figure shows the leaves of the willow thus curled and bound together with silken threads.

Travelers from Mexico frequently bring with them, among the curious products of that land, 'jumping-seeds.' When held in the hand, the warmth causes the seed to jump, in the most unaccountable manner, to a considerable distance — half an inch or even more. If the seed be cut open it is found to contain a fat, white grub, the cause of the peculiarity in the motion. It bends its body, and then suddenly pounds with its head and jaws, and in this way causes the seed to rise in the air. If kept in confinement, at last there hatches from the seed a small moth, which is first cousin to the coddling-moth of our own latitudes.

Other similar jumping-seeds and galls are known, and while on the subject, the following account of a jumping-gall produced by one of the gall-flies may be of interest. Mr. Riley says: "It is a little, spherical, seed-like gall, produced in large numbers on the under side of the leaves of the post and other oaks of the white-oak group. This gall drops in large quantities to the ground, and the insect within can make it bound twenty times its own length, the ground under an infested tree being sometimes fairly alive with the mysterious moving bodies. The noise made often resembles the pattering of rain."

The honey-moth is a pest to the bee-raiser in Europe, but fortunately it does not occur to any great extent in America. Where it occurs it some-

FIG. 261. — Honey-moth (*Galleria*), with larvæ and infested comb.

times almost completely fills the comb with its larvæ, to the great injury or the total destruction of the product. The larvæ feed upon the wax, and spin their delicate silken webs over the wax, or run tunnels lined with silk in all directions through the comb.

Forms allied to this attack almost every sort of vegetable product.

Some feed on grass, some affect cucumbers, others bury their eggs in the gooseberry, and still others eat flour and meal. One of these forms, which is a serious pest in the hop-raising regions of central New York, is illustrated here. Not content with doing all the damage it can, it has two broods a year, thus doubling the amount of destruction it is capable of causing; but, as with most other insects, there is a periodicity in its abundance, some years there being many of them, while in others they are extremely few.

FIG. 262. — Hop-vine moth (*Hypæna humuli*).

As now understood, the word geometry means the science of theorems and propositions, straight lines, circles, pyramids, spheres, and angles. It formerly meant the measurement of the earth's surface; and so, when mankind wanted a name for the measuring-worms, which loop themselves up and straighten themselves out as if they were going to find out just how many miles it is around our globe, what should be more natural than to call them geometrids? They stretch themselves out as far as possible, and then, taking hold with the legs just behind the head, bring the rest of the body up in a loop, so that the legs at the hinder portion can grasp the surface just behind the anterior members, and the body then can be extended as before. Other names are 'inch-worm,' 'span-worm,' and 'loop-worm.'

FIG. 263. — Currant-worm, pupa, and moth which proceeds from the latter. One of the larvæ is letting himself down to the earth by a silken thread, previous to pupation.

The geometrids are all injurious, the amount of injury they do being limited chiefly by the comparative rarity or abundance of the individuals. Probably the best known of all are the canker-worms, which play such havoc with the foliage of our fruit and shade trees. Yet we can easily control these on account of a peculiarity immediately to be described. The larvæ let themselves down from the trees by a silken thread, and burrow into the ground, from which they emerge later as perfect insects. The male is winged like most moths, but the female is utterly without wings, and so the only way in which she can get to the leaves to lay her eggs is to

climb the trunk of the tree. If now we put a girdle of printer's ink, coal-tar, or oil around the tree, she cannot pass it, and the leaves consequently will not be eaten by the larvæ.

Other geometrids affect other plants, and at times do a great amount of damage. To enumerate the species and the plants they feed on is beyond our scope; such accounts should be sought in the works on economic entomology. There is, however, another side of the life of the geometrids to which we may refer. All through the line of insects we meet with cases of 'protective resemblance,' instances where one form so mimics other objects as not to be readily distinguished: at

FIG. 264. — Gooseberry span-worm and moth (*Abraxas*).

FIG. 265. — Juniper-moth (*Dresjanodes*) and larvæ upon a juniper-twig. In life the larvæ, when upon their food plant, are even more difficult to detect than in the cut.

times one insect will curiously copy another in its shape and color; again, as we saw in the case of the walking-stick and the walking-leaf, it takes a part of a plant as its copy. Some of the geometrid larvæ give us excellent examples of this; for instance, there is a measuring-worm which feeds on the juniper, and which, as it hold itself stiff and rigid for hours at a time, would hardly be noticed, so closely does it resemble one of the twigs which has been divested of its leaves, leaving nothing but the scales behind. There can be no doubt but that in all these cases the resemblance is for the benefit of the animal; for they are less readily seen, and hence are far more likely to escape the notice of insect-eating birds and other predaceous forms.

The largest family of moths is that known as the Noctuidæ, a name given in allusion to their nocturnal habits—habits which, however, are shared by the great majority of other moths. When the lamps are lighted on a summer evening, these forms come in large numbers, seemingly intoxi-

cated by the light, and with their eyes glowing like coals of bright red fire. Why they are thus attracted it is difficult to say, since in the day-time they keep themselves concealed in dark corners, and in every way try to escape the glare of the sun.

Entomologists are well aware of this habit of noctuids and other moths, and so one of the favorite methods of catching them is to go with a lantern

FIG. 266.—*Agrotis* and *Plusia*, two moths; the latter in side view with folded wings.

to some favorable locality, and with a net catch them as they fly round the light. All, however, are not attracted in this way, and so other expedients are adopted. One is sugaring. Just at dusk the collector goes to the woods and paints the trunks of the trees with patches of a mixture of sugar and beer, or rum, and then awaits the advent of the moths. Soon they begin to appear, and all night long they come, attracted by the savory smell. All the collector has to do is to capture them as they come.

Most striking of all the noctuids are the large forms known as ‘underwings,’ of which we have some eighty species in the United States. Seen

FIG. 267.—Underwing (*Catocala*) and larva.

at rest with their wings closed they are of a sombre color, usually such as to match the trees which they frequent; but when their wings are expanded, as in the cut, their beauty appears, their lower wings, banded with red or orange and black, being visible.

The underwings are comparatively uncommon, and hence do but little damage. On the other hand, the army-worm is often a serious pest. “At

irregular intervals it sweeps through our meadows and grain-fields about the time that wheat is beginning to ripen, often rendering it unfit for the mower or harvest-machine. It proves injurious from Maine to Texas, and from the Atlantic to the 100th meridian." It receives its name from the armies it forms when on the march from one field to another. Very similar in appearance is the cotton-worm moth of the southern states, which feeds upon the leaves of the cotton, causing an immense amount of damage, estimated in some years at thirty million dollars.

In the silk-worm family we meet almost the only moths of value to mankind, and even here all would be regarded as injurious were it not for the silk that some of them produce. Silk is spun by every moth that makes a cocoon, but in the great majority it does not possess the qualities requisite for a textile fibre; it is not strong enough, or it is not easily unwound, while in others the worms are not easily raised; so that few have economic value.

The true silk-worm moth is represented in the upper left-hand corner of our plate. It is an inconspicuous cream-colored or light lemon-yellow species which would hardly be suspected as of great value, and yet it undoubtedly stands first among all the insects. It is a native of China, and neither history nor tradition goes back to the time when it was not reared for its silk; and to-day the moth or the worm is not known in the wild state.

As this insect is so important, it may be well to follow it more at length than we have done with the other moths. First, there are numerous varieties, each of which have their merits and peculiarities. The eggs, or 'seed,' may be fastened to the leaves of the mulberry or some other object, or they may be free in some of the varieties. These eggs have a commercial value, and China and Europe import large numbers of them. They are sold by weight; each moth lays from three to four hundred eggs, and it takes on the average forty thousand eggs to weigh an ounce.

The silk-worm which hatches from the egg is black or dark gray. It feeds voraciously on the leaves of the mulberry, and rapidly grows until it becomes necessary to change its skin; it then molts, and repeats the operation three or four times before it is full grown. It now grows lighter, becomes a translucent pink or amber color, and begins to spin its silken threads. It is now allowed to crawl to the 'spinning-arches,'—bent twigs interlaced with broom-corn or dried brush,—where it begins to spin its cocoon. The temperature is now kept at about 80°, and the worm first

FIG. 268.—Cotton-worm, egg, and moth.

SILK-WORM MOTHS.

1, True silk-worm, eggs, and moth; 2, Yama-mai moth; 3, Cecropia moth; 4, Ailanthus moth.

throws out some threads for a framework, and then commences the cocoon proper. The first portion is loose, and is known as floss; but soon the inner, more dense portion is begun, the spinning going on as described on page 172. The threads are not coiled round and round, but are rather laid in loops like the figure eight.

If the cocoon be desired for silk, it is taken about eight days after the beginning of the spinning, and the chrysalis inside killed either by dry heat or by steam, the latter being the preferable course. In warm countries two or three days' exposure to the direct rays of the sun are all that are necessary for killing the animals. Now the silk is ready to be reeled. This is done in most places by hand, but in France steam-machinery has been introduced. In each reel is a basin of water kept near the boiling-point by a fire beneath or by steam, and into this the cocoons are plunged to soften the gum which holds the threads together. After this is accomplished the attendant beats the cocoons with a small brush on which the threads become entangled. "After beating a short time, the operator gets all the cocoons fastened, and taking the bundle of threads, shakes the cocoons till each hangs by a single one. She now takes up five or more threads, according to the quality of the silk wanted," and joins them into strands. This is repeated with another lot, and the threads thus formed are rolled on a reel, after having passed through various parts, the object of which is to make the threads smooth and even, and to keep them from sticking together. As soon as one of the threads begins to give out, the attendant supplies a new one, bending it on with her fingers, and so keeping the strand of uniform size. Each cocoon will yield about a thousand feet of silk.

If it be desired to keep the cocoons for breeding purposes, they are fastened to cardboard, or strung on a string, so that the moths may emerge more readily. When they come out, the mating is carefully attended to, and then the females are placed in trays lined with smooth woollen cloth, on which the eggs are almost immediately deposited. The eggs are kept through the winter in some place where they will not be exposed to extremes of heat or cold. If it be desirable to separate them afterward from the cloth, all that is necessary is to immerse them for a short time in warm water, and then remove them with a knife.

In the spring the eggs are put in a warm place, and as they approach the time of hatching, mosquito-net is spread over them, and on this are placed leaves of the mulberry, and then when the worms escape from the egg they crawl up through, and at once begin to feed. As they increase in size, a net with a larger mesh is placed over them, and on it again is placed fresh food.

Silk-worms are subject to several diseases, among which muscardine and pébrine are the most prominent. Muscardine is caused by a fungus "of precisely the same nature as the fungus which so frequently kills the common house-fly, and which sheds a halo of spores, readily seen upon the window-pane, around its victim." Pébrine, on the other hand, is the result of a parasitic protozoan, and in its action presents a strange analogy to cholera in man, except that it is hereditary.

As we have said, the silk-worm is a native of China, and for centuries it was not known outside of that country. The Chinese knew its value

FIG. 269. — Ailanthus silk-worm, moth, and pupa (*Philosamia cynthia*).

and enacted severe penalties for taking it out of the country; death, even, was the reward of the culprit, if found. At last—so the story goes—two monks carried the eggs, concealed in the hollows of their canes, to Constantinople, from whence the worm gradually spread over the whole of southern Europe. To-day France and Italy are great silk countries, rivaling China and Japan. At various times the people of the United States have had the silk-raising fever: mulberry-trees have been planted, eggs imported, and worms raised; but, except with a few, the result has been a total loss. Some, however, have been successful. They have obtained from six to eight dollars an ounce for their eggs; and in 1877 France paid

\$338,000 for silk-worm eggs raised in the United States. Cocoons are also sent to southern Europe for reeling, and bring from fifty cents, fresh, to two dollars and a quarter, killed, a pound. North Carolina and Kansas are the great silk-raising states, the silk produced in the former equalling the best of the French.

Another silk-worm, the *Ailanthus* silk-worm, represented in the cut, has recently been introduced along with its food plant. Owing to the greater facility with which it is raised, its greater immunity from disease, and its greater power of standing cold, considerable expectations have been based upon it; but, although it can be reared in the open air, it has not the slightest chance of rivalling the long-familiar form. The general color of the moth is a rusty green, on which are spots and bands of white and pale lilac. The larva is a light bluish green.

We have in the United States several species which spin silk of value, one of which, the *Cecropia* moth, is represented in the upper centre of our plate. This is one of the largest moths, and is common in almost every collection. Its rich brown colors and the brightly colored eyes and bands make it very beautiful. Its larva feeds on a large number of plants, and were there some way of reeling the silk easily, the species might be of some economic importance.

More valuable of our native forms as a silk-producer is the *Polyphemus* moth, a form which rivals the last in size and beauty. Mr. Trouvelot has experimented with this species as a silk-producer. As it is a native of our northern states, it stands our climate well, and passes through our cold winters without injury, and the silk is strong and glossy, thus making it of value as a commercial product. Mr. Trouvelot began his experiments in 1860, and, as he had to learn everything, he at first met with ill success, but in 1865 he had become expert in cultivating them, and "in that year not less than a million could be seen feeding in the open air upon bushes covered with a net; five acres of woodland were swarming with caterpillar life."

FIG. 270. — American silk-worm (*Polyphemus*).

The growth of the larva is astonishingly rapid. On hatching it weighs but a twentieth of a grain; in fifty-six days it increases its weight over

four thousand times, or to over two hundred grains, having eaten in that time three-quarters of a pound of oak-leaves. If it were not for numerous enemies, how quickly these would strip our forests of their leaves.

One experiment tried by Mr. Trouvelot was very interesting. Every naturalist receives numerous parcels of insects, the boxes being perforated to allow the animals to breathe. How needless this is, is seen from the following: "Having observed how clear and air-tight the cocoon of the *Polyphemus* seemed to be, I could not conceive that air was necessary for it to breathe. Desirous of ascertaining whether my idea was correct, I took three cocoons, and at

FIG. 271.—Cocoon of the American silk-worm.

two different times I covered them carefully with a thick coating of starch, allowing the first coating to dry before putting on the second one. After this the cocoons were covered at three different times with a heavy coating of shellac varnish; thus the cocoons were made perfectly air-tight. They were kept in a cold dry room all winter. In July the moths came out perfectly healthy, the fluid they discharge through the mouth having dissolved the starch and varnish. So these insects had been nine months with no air, except the very small volume enclosed in the cocoon, and they had accomplished their transformation just as well as if the air had been allowed to come into the cocoon."

The pale green luna-moth is the only other species of native silk-worm that we need mention, and, in the writer's opinion, is far the most beautiful member of the group. The hind wings are produced into long and slender tails, while the delicate green of these organs of flight is enlivened by eye-like spots — transparent in the centre, and margined with white, yellow,

FIG. 272.—Io moth (*Hyperchiria io*).

red, and black — one spot in each wing. The larva of this beauty is fond of the leaves of the walnut and hickory.

Allied to these silk-worm moths are a large number of other showy forms; to even catalogue them would take more space than we can afford. Some are very common, flying

about at dusk on summer evenings; while others are so rare that they are

regarded as among the treasures of the entomological cabinet. In naming them the calendar of mythology has been extensively called upon, and we have Io, Maia, and Prometheus moths in addition to those already attended to. Here also come the tiger-moths, the tussock-moths, and the bag-worms, — forms too numerous to mention.

A little moth shown in our next cut is a good representative of a group of injurious species which attack currant-bushes, peach and pear trees, and grape-vines. They are elegant and gayly colored, and a large part of the wings are without scales and transparent. Indeed, the shape of the body and wings, together with this transparence, make them resemble so closely some of the wasps that sometimes even experienced entomologists are deceived; and if their keen eyes are at fault, why should we not suppose that the birds, who know nothing of the technical characters separating Lepidoptera and Hymenoptera, will let these forms severely alone for fear of taking a stinging insect into their mouths?

FIG. 273.—Currant-borer (*Egeria ti-puliforme*).

Rivalling the silk-worm moths in numbers and beauty, but not in value, are the swift-flying, narrow-winged hawk-moths. In scientific works they figure under the name Sphinx, given, it is said, in allusion to a habit which the larvæ have of holding the head elevated and the body motionless for hours at a time in the way that the monster of Egypt was supposed to do. The resemblance, it must be admitted, is rather remote. Another common name — humming-bird moths — is far more appropriate, for in the dusk of evening one may

FIG. 274.—Tobacco-worm (*Phlegethontias carolinensis*).

see some of them hovering before the flowers just as do the humming-birds, the wings in the most rapid vibration producing a humming noise, and the long proboscis probing the blossoms in search of nectar.

Apropos of the name humming-bird moth the following from the pages of Bates' 'Naturalist on the Amazons' is interesting: "Several times I shot by mistake a humming-bird hawk-moth instead of a bird. This moth (*Macroglossa titan*) is somewhat smaller than humming-birds generally are, but its manner of flight and the way it poises itself before a flower whilst probing it with its proboscis are precisely like the same actions of humming-birds. It was only after several days' experience that I learned to distinguish one from the other when on the wing. This resemblance has attracted the notice of the natives, all of whom, even educated whites, firmly believe that one is transmutable into the other. They have observed

the metamorphoses of caterpillars into butterflies, and think it not at all more wonderful that a moth should change into a humming-bird. The resemblance between this hawk-moth and a humming-bird is certainly very curious, and strikes one even when both are examined in the hand. Holding them sideways the shape of the head and the position of the eyes in the moth are seen to be nearly the same as in the bird, the extended proboscis representing the long beak. At the tip of the moth's body there is a brush of long, hair-like scales resembling feathers, which, being expanded, looks very much like a bird's tail. But of course all these points of resemblance are merely superficial. The negroes and the Indians tried to convince me that the two were of the same species. 'Look at their feathers,' they said; 'their eyes are the same, and so are the tails.'

As a typical member of the group, we figure all the stages of the tobacco-worm. The moth is a large, grayish species, well represented in

FIG. 275. — Tobacco-moth.

our cut. Like the rest of the hawk-moths, it has the body large and stout and the wings narrow, the anterior pair being pointed and much larger than the hinder pair. Noticeable in our illustration is the long proboscis, partially uncoiled, through which the nectar is sucked. Usually this is kept closely coiled, like a watch-spring, below the head. This species is the most injurious of any of our native hawk-moths, and its larvæ feed

upon tobacco, tomato, and potato plants, sometimes in such numbers as to seriously injure the crops. It is interesting to note that, different as the products are, these three plants are closely allied in structure.

The pupa or chrysalis of this hawk-moth is also noticeable from its peculiar shape. One might almost call it a classic jar or urn, with a handle on one side. This handle of course has its cause. On a preceding page we figured a chrysalis of a butterfly, pointing out the part which served as the case for the proboscis; in the present form this case is distinct, and forms the handle.

The tongue of this hawk-moth is very long, but still it is greatly exceeded in some forms. For instance, there is a species occurring in Madagascar in which this organ is over nine inches long. At first sight it would seem that such length could not be needed, but when we study the flora of that peculiar island the cause at once appears. This moth sucks the honey from one species of orchid, and the flowers of this are of such a size that a shorter tube would not reach the nectar. This relation between this moth and the orchid is even more intimate, since the

FIG. 277. — Owlet-moth (*Cucullia*).

moth is needed in order to fertilize the seed. The stamens and pistil are so arranged that this moth, and only this one, is adapted to carry the pollen from one blossom and deposit it in the proper place in another flower.

We have already given the superficial characters separating the moths from the butterflies, and hence need not repeat them here. Butterflies embrace the most beautiful of all the insects, and none of the cases of a museum are more attractive than those filled with these forms. On the other hand, butterflies are stupid animals, and we find little in their habits which are interesting.

Among the lower forms are the skippers, usually dull-colored butterflies which in many ways show an affinity to the moths. They may be at once recognized by the hooked form of the antennæ. We have about one hundred and fifty species of them in the United States. Almost equally large in number of species is another group of smaller forms known as 'blues,' 'coppers,' and 'hair-streaks.' The derivation of the first two is obvious, and refers to the colors of the wings; the hair-streaks are orna-

FIG. 276. — Chrysalis of tobacco-moth.

mented with one or two fine light lines on the dark under surface of the wings. It is in the tropics that these forms attain their greatest prominence, and there their wings are among the most brilliant objects, some shining like burnished gold, others of metallic blues or greens which no artist's pencil can duplicate.

Larger and still more beautiful are the swallow-tails and their allies. Every one is familiar with the large yellow and black turnus butterfly, its hind wings prolonged into a slender 'tail,' whence the name 'swallow-tail.' Almost equally abundant is the asterias, a black species with yellow spots, whose larva feeds upon parsnips, carraway, celery, etc. These, however beautiful they may be, are far excelled by some of the tropical forms. For instance, there is an African species, rich brown in color, which spreads eight inches—an enormous butterfly. One specimen of this is said to have been sold for one hundred and fifty pounds on account of its great rarity.

Allied to the swallow-tails are the large bird-wing butterflies of the tropics, the grandest of the whole butterfly group. Collectors grow crazy over them, exhibiting an excitement in their presence which one cannot understand unless he sees their magnificent colors and enormous size. Listen to Mr. Wallace as he describes one of his experiences in the Malay Archipelago:—

"During my very first walk into the forest at Batchian I had seen, sitting on a leaf out of reach, an immense butterfly of a dark color, marked with white and yellow spots. I could not capture it, as it flew away high up into the forest, but I at once saw that it was a female of a new species of *Ornithoptera*, or 'bird-winged butterfly,' the pride of the Eastern tropics. I was very anxious to get it and to find the male, which in this genus is always of extreme beauty. During the two succeeding months I only saw it once again, and shortly afterward saw the male flying high in the air at the mining village. I had begun to despair of ever getting a specimen, as it seemed so rare and wild, till one day, about the beginning of January, I found a beautiful shrub with large, white, leafy bracts and yellow flowers . . . and saw one of these noble insects hovering over it; but it was too quick for me, and flew away. The next day I went again to the same shrub and succeeded in catching a female, and the day after a fine male. I found it to be, as I had expected, a perfectly new and most magnificent species, and one of the most gorgeously colored butterflies in the world. Fine specimens of the male are more than seven inches across the wings, which are velvety black and fiery orange, the latter color replacing the green of the allied species. The beauty and brilliancy of this insect are indescribable, and none but a naturalist can understand the intense excite-

ment I experienced when I at length captured it. On taking it out of my net and opening the glorious wings, my heart began to beat violently, the blood rushed to my head, and I felt more like fainting than I have done when in apprehension of immediate death. I had a headache the rest of the day, so great was the excitement produced by what will appear to most people a very inadequate cause."

FIG. 273. — Exotic butterflies: right, bird-wing (*Ornithoptera amphrysus*), with larva and chrysalis; left, calliper-butterfly (*Leptocercus curius*).

In the same cut with our figure of a bird-winged butterfly, is another form with the hind wings prolonged into extremely long tails. This feature has given rise to its scientific name—it has no common name—*Leptocercus*, slender-tailed. It is an East Indian genus, and Mr. Forbes found a species in Sumatra which mimics the dragon-fly in the most curious manner. "It flits over the top of the water, fluttering its tail, jerking up and down just as dragon-flies do when flocking the water with

the tips of their abdomens. When it settles on the ground, it is difficult to see, as it vibrates in constant motion its tail and wings, so that a mere haze, as it were, exists where it rests.

The cabbage-butterflies and their allies are distinguished by the prevalence of some shade of yellow, or even pure white. For many years our gardeners were troubled by the depredations of a green worm, which ate the leaves of the cabbages and turnips, at times causing a considerable loss. This was the larva of our native cabbage-butterfly, a white insect shaded with scales of dark brown. But a greater evil was to come. Europe furnished us with a new foe to the cabbage, which soon cast the native form into the shade. It is supposed that about the year 1857, the larvæ of the European cabbage-butterfly were introduced into Quebec, and from this centre they have spread all over the northern United States. The larva makes its way to the centre of the cabbage, where it is out of the way of foes and insecticides, and its presence is liable to be unsuspected until the cabbage is cooked.

In times long past, the whole northern United States was covered with a vast ice-sheet or continental glacier. Its thickness is estimated at nearly

FIG. 279.—Native cabbage-butterfly (*Pontia oleracea*); its larva below.

FIG. 280.—Imported cabbage-butterfly (*Pieris rapæ*): male, larva, pupa, and female.

a mile in northern New England. Its southern border has been traced by means of the 'terminal moraine'—exactly like those of the glaciers of the Alps—from the Atlantic to the Mississippi, and there are abundant traces of it farther west. It crossed Cape Cod, followed the length of Long Island, crossed the northern part of New Jersey and Pennsylvania, and so on through southern Ohio, Indiana, and Illinois. Gradually the climate changed and became warmer, and the glacier melted away; its margin retreated further and further to the north, until at last it entirely disap-

peared. The presence of this immense ice-sheet, of course, had its influence on the climate, and thus on the animals and plants. When the glacier had its greatest southern extent, arctic forms dwelt along its border; and when the sheet retreated, these species followed it.

FIG. 281. — White Mountain butterfly (*Chionobas semidea*).

An illustration of this is afforded by the distribution of the White Mountain butterfly and its allies. This form belongs to the genus *Chionobas*, which is represented in the United States east of the Mississippi River, only on two or three of the highest peaks of the White Mountains. The nearest points where the same genus is found are Labrador and Colorado. It is supposed, to account for this peculiarity in the distribution (which is paralleled by some plants), that the White Mountain colony is composed of strag-

glers left behind on the retreat of the glacier, and that only on these elevated peaks did they find a temperature and a climate adapted to their needs. On any other hypothesis their distribution is inexplicable.

The genus *Morpho* (again no common name) is one of the beauties of the tropics, and, strange to say, its members are limited to South America and the islands of the eastern seas, none being found between. The explanation of this is difficult: for here it is not possible to invoke the aid of glaciers in explanation. There are some thirty-five species known, those of the East presenting some marked differences from those of Brazil. In the latter country most of the species are a metallic blue above, shading off into black, while the under surface of the wings is a rich brown, ornamented with eye-like spots. Some of them are very large, measuring seven inches across the outspread wings:

FIG. 282. — Neoptolemus butterfly (*Morpho neoptolemus*).

and their lazy flight, large size, and beautiful colors make them a prominent feature in all descriptions of the tropics.

FIG. 283.—Io butterfly (*Vanessa io*), above; Janira butterfly (*Epinephile janira*), below.

Another group of tropical forms (one of which just enters the United States — into Florida) is the *Heleconias*. The outlines are shown in the plate opposite page 158. and one has only to imagine the black of the cut to be a deep velvety black, and the lighter spots either green, red, yellow, or white, to see how beautiful they are.

The *Vanessa* butterflies are beautiful forms occurring in the temperate regions of both Europe and America. Our cut shows a deep red form occurring in Europe, the eye-spots on the wings being marked with yellow, purple, black, and rose. Another species, which has an almost world-wide distribution, is the 'Camberwell beauty.' It is a deep purple, or purplish brown, the wings being margined with a yellow or cream-colored band. This is our earliest butterfly, appearing in the warm days of spring, sometimes when the snow is hardly off the ground, much to the astonishment of most people. This early appearance is to be attributed, not to any early escape from the chrysalis, but to the fact that the individuals have spent the winter in some sheltered spot.

FIG. 284.—Progne butterfly (*Grapta progné*); the right side shows the lower surface of the wing.

The *Graptas* are also very beautiful, especially when we consider the rich brown and gray marblings of the under side of the wings (shown at the right of our cut), and in the centre of the hind wing there is a gold or silver mark, varying in shape with the different species, and giving rise to the names *comma*, *interrogationis*, *c-album*, and the like, as

specific designations. The species of *Argynnis* have one or two silver spots on the under side of the hind wings which adds greatly to their beauty.

One of the most wonderful cases of insect mimicry is furnished by a butterfly occurring in Sumatra, and which even excels that afforded by the walking-sticks and leaf-insects described on a preceding page. It is called *Kallima paralecta*, and is described so well by Mr. Wallace that we cannot forbear quoting his account in full. "Its upper surface is of a rich purple, variously tinged with ash-color,

and across the fore wings there is a broad bar of deep orange, so that when on the wing it is very conspicuous. This species was not uncommon in dry woods and thickets, and I often endeavored to capture it without success; for after flying a short distance it would enter a bush among dry or dead leaves, and however carefully I crept up to the spot I could never discover it till it would suddenly start out again, and then disappear in a similar place. At length I was fortunate enough to see

FIG. 285. — Leaf-butterfly (*Kallima paralecta*) of Sumatra. In the centre a specimen is shown at rest on a twig.

the exact spot where the butterfly settled, and though I lost sight of it for some time, I at length discovered that it was close before my eyes, but that in its position of repose it so closely resembled a dead leaf attached to a twig as almost certainly to deceive the eye even when gazing full upon it. I captured several specimens on the wing, and was able fully to understand the way in which this wonderful resemblance is produced.

"The end of the upper wings terminates in a fine point, just as the leaves of many tropical shrubs and trees are pointed, while the lower wings are somewhat more obtuse, and are lengthened out into a short, thick tail. Between these two points there runs (on the under surface) a dark

curved line, exactly resembling the midrib of a leaf, and from this radiate on each side a few oblique marks which well imitate the lateral veins. These marks are more clearly seen on the outer portion of the base of the wings, and on the inner side toward the middle and apex, and they are produced by striæ and markings which are very common in allied species, but which are here modified and strengthened so as to imitate more exactly the venation of a leaf. The tint of the under surface varies much, but it is always some ashy brown or reddish color, which matches well with those of dead leaves. The habit of this species is always to rest on a twig and among dead or dry leaves, and in this position, with the wings closely pressed together, their outline is exactly that of a moderately sized leaf, slightly curved or shrivelled. The tail of the hind wings forms a perfect stalk, and touches the stick while the insect is supported by the middle pair of legs, which are not noticed among the twigs and fibres that surround it. The head and antennæ are drawn back between the wings so as to be quite concealed, and there is a little notch hollowed out at the very base of the wings, which allows the head to be retracted sufficiently. All these varied details combine to produce a disguise that is so complete and marvellous as to astonish every one who observes it; and the habits of the insects are such as to utilize all these peculiarities and render them available in such a manner as to remove all doubt of the purpose of this singular case of mimicry, which is undoubtedly a protection to the insect. Its strong and swift flight is sufficient to save it from its enemies when on the wing; but if it were equally conspicuous when at rest, it could not long escape extinction, owing to the attacks of the insectivorous birds and reptiles that abound in the tropical forests."

In tropical America occurs a butterfly remarkable for making a noise

FIG. 286. — *Limenitis dissippus*.

when in flight. Mr. Darwin, years ago, described this habit as he observed it on his celebrated voyage around the world in the 'Beagle.' He says, after mentioning some other peculiarities of *Ageronia feronia*: "A far more singular fact is the power which this insect possesses of making a noise. Several times when a pair, probably male and female, were chasing

each other in an irregular course, they passed within a few yards of me, and I distinctly heard a clicking noise, similar to that produced by a toothed wheel passing under a spring catch. The noise was continued at

short intervals, and could be distinguished at about twenty yards' distance." Later observers have discovered the mechanism producing the noise; it is a drum-like organ in the base of the fore wings. Some of our own species also produce a noise, but not nearly so loud as in the case mentioned.

One of our most common butterflies, a dark red species marked with black, is represented in Figure 286. Its larva feeds upon various trees, as the apple, plum, oak and willow, but is not abundant enough to do much damage. It is remarkable among our insects for the case of mimicry it presents, as in its general appearance—colors and style of ornamentation—it closely resembles the common milkweed-butterfly, which structurally is greatly different from it.

SOME DOUBTFUL FORMS.

Before we close our account of the great group of Arthropods, we must mention, at least by name, some forms concerning whose affinities naturalists are in doubt. It is easy enough to find them assigned to some position in the cut-and-dried systems of books; but the trouble is, they will not fit where they should.

First of these comes a worm-like form, — *Peripatus* by name, — which every one regarded as a true worm, until Professor Moseley showed that it breathed in much the same manner as do the higher insects. Immediately was this discovery made, the form took a very high rank from a scientific standpoint; for it had so many peculiar features that it was at once thought that here was the key to many deep problems concerning the exact way in which the insects arose. Alas for these hopes! *Peripatus* has not solved the question it was expected to solve; and in the writer's opinion it has little or nothing to do with it, but possibly belongs among the worms, near where it was formerly assigned. Still, the study directed in this way has been of great value, for by it much light has been thrown upon many other questions concerning which naturalists were all at sea.

A second group are the water-bears, — minute aquatic animals with eight legs, and quite a bear-like appearance, which occasionally appear in the collections of microscopists. Usually they are placed among the spiders, merely because they have eight legs, but beyond this there is but little to warrant such assignment. Specimens are rare, and should be sought in the wet moss of swamps, where they occur along with the *amœba*, described in the early pages of this volume.

The last forms to be mentioned are the sea-spiders, which are found in abundance in every sea. They are small-bodied, slender-legged forms, which wander about over the hydroids in a lazy manner. Their young live as parasites in the hydroids, forming swellings where they occur. Like the last they are usually classed with the spiders, and for the same reason; but this step is one of doubtful propriety. Most of these forms along our shores are small; but the deep-sea dredgings have revealed specimens of enormous size, some measuring nearly two feet across the extended legs, and the body so small that it appears almost like a knot tying the string-like legs together.

VERTEBRATES.

It has become quite a standing joke among naturalists that no one knows exactly what a vertebrate is. Turn to your dictionaries and the school text-books, and you will find some very exact and clear definitions, which, at first sight, would seem to set the question at rest; but they do not. They lack one thing; nature will not accommodate itself to them. They were all very well in the early days of science, but to-day they (or nature) are all wrong. When we knew of nothing but the structure of the adult animals (and but little of that), classification was an easy matter; but when we came to learn the steps of growth, the problem became more complicated. It was then seen that there were various relationships of animals; that they could not be arranged in a straight line, but that one needed the geometry of three dimensions to show the position of any one form with regard to its fellows. Still in a popular book we do not need to go into that detail which would be necessary in a manual of science, and hence we can give all the definition which is necessary for our purposes, without paying any attention to the numerous exceptions.

Vertebrates, then, comprise these forms familiar to all under the names of fishes, reptiles, birds, and mammals. They are characterized by a jointed backbone, or in its place a simple cartilaginous rod; they breathe either by gills or by lungs, according as they live on the land or in the water. Their whole central nervous system is situated above the alimentary tract, and the heart is below, while in most forms two pairs of appendages—the paired fins of fishes, the legs of mammals and reptiles, and the legs and wings of birds—are readily discernible.

So far as intelligence goes, many of them stand below the higher forms which we have passed, while in structure they exhibit but little complication. Others, on the other hand, are decidedly specialized, and one member—man—towers far above all the rest of the animal kingdom, in intellectual capacity.

THE TUNICATES AND THE LANCELET.

The union of the two groups represented in our heading is indefensible on scientific grounds; they are widely different in structure, as we shall see; but they are here considered together since they agree in and differ from all the rest in lacking the jointed backbone or series of vertebrae common to all other vertebrates.

The tunicates are marine forms, which are but little known to any but the man of science, although some of them attain considerable size. In the older works on zoology they were classed with the molluscs, with which, however, they really have not the slightest affinity, although they exhibit many analogies. Their true relationships were not suspected until their development was studied, and then it was seen that their young were strikingly like tadpoles in appearance. And farther, they had a very similiar internal structure. Both breathed by gills, and the water to aerate the blood was drawn in the mouth, and then was forced out through slits on the sides of the throat, exactly as occurs in the adult

FIG. 287.—A simple tunicate (*Phallusia*).

fish; farther, both have a cartilaginous rod (the notochord) in a position which exactly corresponds to the centre of the vertebral column of the frog, but which entirely disappears in the adult tunicate. Farther than

this it is not necessary to go into the anatomy and development of these forms.

The tunicates are both simple and compound; that is, some of them live a solitary life, while others are united into large masses with a common integument, and some of these organs also serving for all the colony, a condition recalling that occurring in some of the hydroids, described in an early part of this volume.

The general appearance of one of the simple forms is shown in our cut. There are two openings to the body: into one of them the water streams, carrying with it food and oxygen, while from the other flows the water which has fulfilled its purposes and with it the waste products of the body. A common name for these animals is sea-squirts, from the fact that when touched they contract as far as possible, forcing the water out of the openings. Some of the species are also known as 'sea-peaches' and 'sea-pears,' in allusion to their shapes and colors.

The compound forms are, as a rule, smaller than the simple ones. The form figured is very common on sea-weed and rock-weed all along the shores of the ocean, different species occurring in different seas. As will be seen, the animal has a somewhat star-like appearance; the rays of the stars are each the incurrent opening to the body, comparable to that of the simple form, while the spot in the centre is the excurrent orifice, used in common by all the members of the colony.

One of these compound forms, *Pyrosoma* (fire-body), needs special mention. It is an inhabitant of the tropical seas, and reaches a length of two or three feet. In these the individuals are arranged so as to form a large cylindrical tube, the cavity of which forms the excurrent orifice of the colony. Most remarkable about these forms is their phosphorescence, which is described as very great. They move slowly through the water, appearing on dark nights like a mass of fire, and the story runs that one naturalist wrote a description of the beautiful appearance they present, and then read his account by the light which the animal itself afforded.

Strangest of all are the *Salpas*, delicate, transparent forms which throng the warmer seas. Sometimes they occur singly, sometimes in long chains of individuals adhering together, and it has been found out that these two

FIG. 288.—A compound tunicate (*Botryllus*) upon a piece of sea-weed.

conditions represent alternating generations. The chain Salpæ give rise to the solitary forms, and these in turn to the chain generation. This fact was first discovered by the German poet-naturalist, who accompanied Count Romanzoff in his voyage around the world. This was the first known instance of alternation of generations, — a condition which, as we have seen, is very common among the lower invertebrates.

The lancelet, or *Amphioxus*, is a small form hardly known outside the museums and laboratories, but there it occupies a foremost place on account of its many interesting anatomical and developmental peculiarities, all of which point to its being a near representative of the group from which the vertebrates have sprung. Its general appearance and size are shown in

FIG. 289. — Lancelet, or *Amphioxus* (*Amphioxus lanceolatus*), natural size. Below, several united in a chain.

our cut, the animal being translucent. It is a vertebrate which lacks vertebræ, having only that rod of cartilage which we mentioned just above; it has no heart, but several of the blood-vessels pulsate; it has no real brain, the anterior end of the nervous system being smaller than the rest of the spinal cord; in short, it is a very strange animal, and has at various times been regarded as a worm and as a mollusc.

It lives on sandy shores, now darting up and swimming about for a moment, and then settling down to conceal itself in the sand. On our American shores it occurs as far north as Virginia, while other forms are found all over the world. So simple are they, and so great a lack of ordinary characters do they exhibit, that the question is not yet settled whether there be one species or several. One author thinks that there are five species.

LAMPREYS AND HAG-FISHES.

The lampreys and hag-fishes stand on a higher level than do the forms just mentioned. They are larger, eel-like animals which live principally in the sea, although the lamprey goes into the rivers to lay its eggs, and in some cases it may live in fresh water all its life.

The lampreys, or lamprey-eels, of which there are several species, differ from the true eels in many important points, only two of the superficial

FIG. 290. — Lampreys (*Petromyzon*).

ones needing mention here. In the true eels the jaws are armed with a row of teeth implanted in sockets, while the lamprey lacks true jaws, but has a circular sucking-mouth, the whole inside of which is lined with horny hooked teeth, each of which is planted on a little elevation of the skin. The lampreys, again, have not a single gill-opening on either side of the neck, but instead seven openings, as can be seen from our cut. In the hag-fishes the number of gill-openings may vary from one to several.

and even in the same specimen the numbers may differ on opposite sides of the body.

The lampreys derive their common name from the Latin word *lampetra*, which means 'stone-sucker, an allusion to the habit these animals have of attaching themselves to stones, for which their sucking-mouth is well adapted. It is not to stones alone that they attach themselves, for their normal manner of life is to adhere to fishes. Then the sharp teeth rasp and abrade the skin, and the blood which flows from the wound forms their food. The hag-fish goes a step farther in this parasitic life; for it carries the gnawing so far that it makes a hole into the body cavity of the fish, and then it enters and lives there an internal parasite until its host dies.

Every spring the lampreys ascend the streams in large numbers, seeking a place to lay their eggs. These migrations are mostly made at night, and at the time of the run the people in certain localities catch large quantities of them for food, while in other places they are entirely neglected. Those that escape deposit their eggs, and then die.

SHARKS AND SKATES.

The sharks, at least by reputation, are known to all. Their name has been taken as a synonym for rapacity and cruelty, and their character warrants it. They are admirably adapted for a predatory life. They are provided with an awful array of teeth, and the arrangement of these could not be bettered. They are placed on the jaws, row behind row, and each tooth is triangular, and is itself minutely toothed on its edges. One row is in active use at a time, while the others, inside the mouth, point backwards or down the throat, and these are effective in preventing the escape of any prey after once it has obtained entrance to the mouth. Then there is but one way in which it can go — towards the capacious gullet. When the teeth of one row fall out or are lost by any injury, those of the next succeeding row move up to take their place.

The sharks are strong swimmers, and their bodies are capable of bending to an enormous degree. They have no true bones, the whole skeleton being cartilaginous, thus admitting of great flexibility. The tail is not like that of ordinary fishes, but is composed of two unequal lobes, the backbone being continued into the upper and larger lobe, a feature paralleled elsewhere only among the sturgeons and gar-pikes. On the back is a strong dorsal fin, which frequently shows above the surface of the water and gives the bather or sailor warning that one of these monsters is at hand.

Sharks breathe by means of gills; they take water into the mouth (which is situated on the under side of the head), and pass it back and out through gill-clefts on the sides of the neck, where the fine filamentary gills extract the oxygen from it. In ordinary fishes there is but one external aperture for the escape of the water after it has passed the gills, but in the sharks each gill-cleft (there are usually five) has its own aperture on the side of the neck, as may be seen in all of our figures. In their digestive apparatus they have a peculiar structure for increasing the surface, and thus affording more facilities for assimilation. In the intestine, folds go inward from the wall, and these are coiled in a spiral, which may either be like a screw or more after the fashion of a very wide watch-spring.

The economic importance of the sharks is very slight. Their flesh is of but slight value as food, but still in certain places the fishing for this purpose is carried on to a considerable extent. On this point Dr. Günther says: "In China and Japan, and many other eastern countries, the smaller kinds of sharks are eaten. Sharks' fins form in India and China a very important article of trade, the Chinese preparing from them gelatine, and using the better sorts for culinary purposes. The fins are obtained, not

exclusively from sharks, but also from rays, and assorted in two kinds; viz. 'white and black.' The white consists exclusively of the dorsal fins, which are on both sides of the same uniform light color, and reputed to yield more gelatine than the other fins." Kurachee, on the west coast of India,

FIG. 291.—Common dog-fish (*Squalus acanthias*), above; sea-hound (*Mustelus canis*), below.

is the great seat of the shark-fishing industry, and the annual catch amounts to some forty thousand.

The skin of sharks is covered with small hard scales, each of which is spined. This makes the surface very rough, and the skin when taken off and dried figures in trade as shagreen, and formerly had an extensive use by carpenters and cabinet-makers in smoothing their work; but to-day sandpaper has driven it entirely out of the market, on account of its greater cheapness.

Another valuable product of the sharks is oil, and for this alone they are taken on our shores. The principal shark taken along the New England coast for this purpose is the dog-fish, which is extensively fished for and easily caught. They swim in immense schools, following the mackerel and other migratory fishes along the coast; and are universally hated by the fishermen on account of their habits. The amount that they will eat is almost incredible, and if surrounded in a mackerel-seine, their sharp teeth make quick work with the net, allowing large numbers of fish to escape. In fishing for them, a hook is usually used, fastened to a bit of chain or wire, for their sharp teeth would instantly cut any cord. When taken they are almost immediately cut open, the liver taken out, and the body flung back into the sea. This injury of course proves fatal, but is not immediately so; for the dog-fish thus mutilated does not seem to mind it seriously, but at once begins to feed on anything there may be around, and death intervenes only after a considerable time. Sometimes in extracting the liver, the stomach is cut completely through: but this fact does not interfere with their voracity; for, on being thrown back, they eat even more than before, regardless of the fact, that, like Munchausen's horse, everything taken into the mouth soon falls out behind.

The livers contain the oil, and are worth half a cent apiece; and low as this price may seem, the catching of dog-fish is really profitable, so abundant are they. To extract the oil the old way (and that still practised in the British provinces), is to place the livers in water, and allow the mass to stand in the sun for several days, until the oil rises to the surface. Then it is skimmed off. This, however, takes too much time to satisfy modern ideas, and so now they are boiled or 'tried' with water. This latter method is much quicker, and besides produces a much larger quantity of oil. On the other hand, the quality is much inferior, so that, time excepted, there is not much to choose between the two processes. It takes about a thousand dog-fish livers to make a barrel of oil. The oil is used to adulterate the cod-liver oil or 'cod oil,' used by curriers in dressing leather.

Our common dog-fish is of a gray color, thoroughly shark-like in its appearance; but its small size makes it of little danger to man. It reaches at the most a length of about three feet, and a weight of fifteen or twenty pounds. Like many other sharks, it brings forth its young alive, and the eggs as taken from the mother are strange-looking objects. In each female there are two horny capsules of an amber color, and each capsule contains from two to four eggs. Through the walls of the capsule one can see the developing embryo, at certain stages a most interesting object, even to the non-scientific.

In the same cut with our common dog-fish is shown (the lower figure) the smooth-hound, also an American species, but one which has none of the voracity of its fellow. Indeed, it is not fitted for such a rapacious life, for its teeth are of an entirely different character from those of most sharks. Instead of being sharp and of a cutting nature, they rather resemble the pavements of our streets. When we consider the nature of the food, we see at once how well these teeth are adapted to their purpose. These smooth-hounds feed upon crabs and shell-fishes, and these teeth, like the jaws of a stone-crusher, are admirably adapted to breaking the shells of these animals, thus rendering them in a condition suitable for digestion.

The series of sharks is a rather long one, there being about a hundred and fifty species known; and our space will admit of mention of but a few of the more interesting forms. All are marine with one exception,—a small form found in Lake^s Nicaragua. The largest known form is the whale-shark of the Pacific, which attains a length of fifty, and it is said even of seventy feet, a size which well entitles it to its common name. It is, however, not a dangerous form; for its teeth are very small, and the animal is said to feed on sea-weed, a statement which, however, needs confirmation.

Strangest in appearance is the huge hammer-headed shark, which may attain a length of fifteen feet. Its most striking feature is its head, which is queerly drawn out on either side into a shape very like a hammer, the eyes being placed on the ends of the lobes. This species is one of the forms that attack man when occasion offers; and it is fortunate that it appears but seldom on our northern coasts. In the tropical seas it is very abundant, and the voyager frequently sees them rising from the depths in large numbers, the school presenting the appearance of a cloud.

This habit, if habit it may be called, of man-eating is common to several species of the larger sharks, so that the term 'man-eater' is rather indefinite. Most prominent among these detested forms are the great blue and white sharks, the former reaching a length of twenty-five, the latter of thirty-seven, feet. Still another but less common species is sometimes found forty feet long. The story has often been told of the way in which these sharks will follow a ship, sometimes for days, eating everything that is thrown or falls overboard. The catalogue of things which have been found in their stomachs is enormous, and shows the most omnivorous appetite, or rather, an incontrollable desire to swallow everything that comes in their way. According to Ruysch, the whole body of a man encased in armor was found in a white shark; while Bluemenbach records the occurrence of a horse in the stomach of another individual of the same species.

It is no wonder that sharks following a ship day after day arouse the

ire of the superstitious sailors. They watch him as he swims around, and realize that should they tumble overboard, a quick death and a living tomb is their fate. Nothing seems to them too bad for the insatiate monster, and when shark-fishing is proposed, they heartily enter in. A large hook is obtained and made fast to a few fathoms of chain, and this in turn to a rope. The hook is now baited with a large piece of pork or 'salt horse' and thrown overboard. Like a flash the shark swims towards it, turns on his back so as to bring the mouth in the proper position; a single gulp, and

FIG. 292. — Hammer-head shark (*Sphyrna zygaena*).

the monster is hooked. A block and tackle is now rigged, a noose is cast around the tail, and the shark, twisting and squirming, is hauled on the deck, where he lashes about in the wildest fashion. He is not conquered yet; for his teeth are still formidable, and so is his tail. A sailor darts quickly in, strikes a terrible blow at the base of the tail with a broad-axe, and all danger from the hinder part of the body is over. The task of killing the rest is quickly accomplished.

Sometimes the course of procedure is not so humane as that already detailed. The sailors can show no pity for a monster whom they know

would show none for them; but they adopt the most cruel methods they can devise for ridding the ship of its escort. A recent writer has thus told how he rid his vessel of a shark which had been following it for days, and arousing the most superstitious ideas in the minds of his crew, each one of whom felt that he was marked out for a victim:—

“Looking over the bulwarks of the schooner, I saw one of these watchful monsters winding lazily backward and forward like a long meteor; sometimes rising till his nose disturbed the surface, and a gushing sound like a deep breath rose through the breakers; at others, resting motionless on the water as if listening to our voices and thirsting for our blood. As we were watching the motions of this monster, Bruce . . . suggested the possibility of destroying it. This was, briefly, to heat a fire-brick in the stove, wrap it up hastily in some old greasy cloths as a sort of disguise, and then to heave it overboard. This was the work of a few minutes; and the effect was triumphant. The monster followed after the hissing prey. We saw it dart at the brick like a flash of lightning, and gorge it instantaneously. The shark rose to the surface almost immediately, and his uneasy motions soon betrayed the success of the manœuvre. His agonies became terrible; the waters appeared as if disturbed by a violent squall, and the spray was driven over the taffrail where we stood, while the gleaming body of the fish repeatedly burst through the dark waves as if writhing with fierce and terrible convulsions. . . . His fury, however, was soon exhausted, and the agitation of the sea subsided. The shark had given himself up to the tides, and was unable to struggle against the approach of death.”

Near relatives of the sharks are the rays and skates, and a number of forms almost bridge the gap between them. The general appearance of one of the typical forms is shown in the upper figure of our cut,—a broad flat body, not separated from the head, and a long tail much more slender in its appearance. Most of them are bottom-feeders, moving lazily along by gentle undulations of the sides of the body, and stopping now and then to devour some flounder or oyster lying on the mud. They lack the sharp teeth of most of the sharks, but instead, have the pavement-like teeth described as characteristic of the smooth-hound.

Best known of all the ray-like forms are the saw-fishes, which in the shape of body are more like the sharks than they are to the typical rays. The strangest part of their structure is the long saw, with teeth implanted in its edges, which projects from the tip of the snout. This terrible organ is at once an organ of offence and defence. The saw itself sometimes reaches a length of six feet, and the teeth, two inches apart, project an inch or more from its sides. With this strange organ the saw-fish slashes

about him in the most vicious manner, and the result is that large pieces are torn or cut from its prey. It is especially fond of attacking whales, round which it swims with great facility, cutting here and there, and sometimes ripping open its huge antagonist. Were it not for the saw this animal would be in a bad way for obtaining food, for its mouth is

FIG. 293.—Skate (*Raia*), above; Torpedo, or cramp-fish (*Torpedo*), below.

poorly armed with teeth; but the pieces the saw tears away are eagerly swallowed.

The torpedo, or cramp-fish, is another interesting form in which the organs of defence take a most peculiar character. Underneath the skin, on either side of the head, is a large galvanic battery, the exact nature of which is not perfectly understood. Each battery consists of a large number of cells, the whole closely resembling in appearance a bit of honey-

comb. These cells are filled with a jelly-like substance, and under the control of the animal these batteries can give a very severe electrical shock. The exact way in which the electricity is generated no one knows, but its physical and chemical effects have been studied. The dorsal surface of the torpedo is positive, and the ventral negative, and by connecting the two by means of wires with suitable apparatus a spark may be obtained and some chemical compounds may be decomposed.

The appropriateness of the names torpedo and cramp-fish is very evident, for bathers who have stepped upon them have been disabled by the discharge. On our shores these forms are comparatively rare, and nowhere do they appear to be very abundant. About fifteen species are known from the whole world, three occurring in the waters of the United States.

The sting-rays, from their greater abundance, are a much more serious annoyance to bathers. They have on the base of the tail a number of spines, which, when trodden upon, will severely lacerate and wound the foot. No one has yet been able to find any poison connected with these spines, and yet the sores they cause are frequently very serious, the surrounding surface becoming inflamed and swollen, the whole being very painful and sometimes lasting for a long time. These sting-rays are not all confined to the ocean; they are also found in the fresh waters of Central and South America, and Bates records their presence a thousand miles up the Amazon, where they frequently injured the bathers.

Largest and most feared of all the rays are the eagle-rays and sea-devils of the tropics. They are huge monsters fifteen and twenty feet across, which haunt the bottom, and feed upon everything found there. They have a curious pair of fins growing out from the side of the head, and these almost take the place of hands. With them they scoop up shells and crabs and pass them to the mouth, and it is said that they occasionally clasp the anchors of small boats with these fins, and drag boat and all out to sea. On the west coast of America, especially at the pearl-fisheries of Panama and farther south, these animals are dreaded far more than sharks by the divers. These men say that the sea-devils swoop down upon them, and envelop them with their broad bodies as with a blanket, and then devour their victims at leisure.

As showing the size of these devil-fishes we may be allowed to introduce the measurements of one, the capture of which was described by Le Vaillant. It was taken with harpoons, and was the smallest of three which were seen. It was twenty-eight feet in length from the tips of the horns to the end of the tail. Its mouth was large enough to take in a man with perfect ease. It was covered with the sucking-fish, or remoras,

to be described later in this volume, and Le Vaillant records the old (utterly false) opinion of the sailors that these served to direct the movements of the monster.

The sea-devils, like the great majority of the rays, bring forth their young alive—one being said to be the usual number at a birth. The young accompany the mothers for a time, and during this period the old ones are especially dangerous. The young are of considerable size when they come into this world. One cut from the mother is now in the British Museum. It had a weight of twenty pounds, and was five feet wide. The mother was fifteen feet wide, and between three and four feet in thickness.

As has just been said, most of the rays give birth to living young, but those which lay eggs have very curious egg-capsules. They are quadrangular in outline, each corner being prolonged into a long tendril which is coiled around the stems of sea-weeds or corals. When the time comes for the young to hatch, one end of the capsule splits open and allows the escape of the ray. These skates' eggs are very common cast upon the beach all along the shore, and they have received the common names of 'sea-purses' and 'sailor-purses.' In England they are called 'skate-barrows'—an admission of their origin, and a comparison with the hand-barrows which the fishermen use in carrying their fish to and from the drying-racks.

THE TRUE FISHES.

One of the most marked peculiarities of science is the way in which the meaning of terms is changed, and their use restricted with our advances of knowledge. In years gone by the term fishes was used to indicate almost everything living in the sea, and even to-day the terms shell-fish and star-fish remain in our vocabulary, although every one knows that they are not *fishes* at all in the proper sense of the word. More lately the same term has undergone a still farther restriction by scientific men; for while some forms, like the lampreys, are as fish-like in appearance as are the eels, in their structure and mode of growth they are as different from a codfish or a perch as these latter are from a snake or turtle. So to-day the term is restricted to the forms enumerated here and their immediate

relatives; it may be in the future that still further modifications may be introduced with our advance of knowledge.

FIG. 294.—Fish, showing the various fins: *d*, dorsal; *c*, caudal; *a*, anal; *v*, ventral; *p*, pectoral.

The typical form of a fish hardly needs description. It is long and slender, with various fins and a gill-cover on either side of the neck. The fins

which correspond to our arms are called the pectorals; those to our legs, the ventrals; while those in the median line are the dorsal, above; anal, below; and the caudal or tail-fin, at the end of the body. These terms are rather more technical than most that we have used, but they are so necessary in the description of fishes that we have introduced them here.

STURGEONS AND GAR-PIKES.

There are two groups of true fishes, one embracing almost all our common forms; the other, represented by the sturgeons, gar-pikes, and a few other existing forms, seems on the road to extinction. Its members were very numerous in geological time, and the term 'age of fishes,' applied to the Devonian period of the earth's history, was due to the prevalence of these forms in those ancient seas. To-day forty species embrace the

STURGEONS.

whole number in the world. Some of these ancient forms were very large—twenty and thirty feet long, a size which is only approximated by the huso sturgeon of to-day, which sometimes weighs three thousand pounds, and measures twenty to twenty-five feet from the tip of the snout to the end of the tail.

There are about twenty different kinds of sturgeons in the world, seven occurring in the waters of the United States. Their bodies are protected by five rows of large bony scales or plates, and their mouths, on the under side of the head, are toothless. Still, though they lack teeth, these fishes are carnivorous. They have the power of moving or protruding the jaws to some distance, while the size of the gape renders it easy to swallow a large fish entire. The other general features of the external appearance can be gathered from our plates. The peculiarities of the anatomy need not be alluded to.

There exists as much difference in regard to the esteem in which the flesh of the sturgeon is held as was noted in the case of the lampreys. In some places their reddish-colored flesh is highly esteemed as food, while in others it is regarded as of no account. The sturgeons are migratory fishes, ascending the rivers to lay their eggs, and at such times they are taken in large quantities. It is, however, in Europe and western Asia that these fishes acquire their greatest importance, and on the rivers flowing into the Black and Caspian seas the various kinds of sturgeon (sterlet, huso, osseter, and bielaga) are extensively fished. Before the ice leaves in the spring the fishermen drive a row of stakes across the river, thus forming a sort of fence, or weir, the object of which is to lead the sturgeon to a 'pot' or 'trap,' which can be lifted up and the contents readily taken. This sturgeon-weir is V-shaped, the apex of the V being turned up stream, and right at the point is placed the trap. The sturgeon, on leaving the sea in the early spring, to lay their eggs in the rivers, come to these weirs, and, led by the converging sides, soon make their way to the trap, where the fisherman is warned of their presence by the bobbing of certain floats. All hands are now called, and by means of large ropes the trap—a huge lattice cage—is raised to the surface, and the fish killed.

It is not only for the flesh that the sturgeon is fished; it also furnishes isinglass and caviare. The isinglass, which is used as a thickening for soups and a basis for jellies, is merely the swimming-bladder of the sturgeon split open and dried. Caviare is celebrated. Some esteem it highly, while others think it one of the most nauseous substances ever taken into the human mouth. The taste for it has to be acquired, and besides there is a great difference between the various qualities, owing to differences in the modes of preparation and the care taken with it. To prepare it, the

roe, or mass of eggs, is taken from the female sturgeon, soaked in vinegar for a time, and then this is poured off, salt is stirred in, and the whole dried, either in the sun or over a fire. The different kinds of sturgeon produce caviare of different qualities, and to suit some palates, the eggs are allowed to begin to decompose before the preparation is begun. The caviare from the sterlet is the most highly esteemed, and all from that species produced in Russia is sent to the imperial tables. The amount annually produced from all the species of sturgeon is enormous, the amount which has been exported from the Caspian fisheries having been estimated at four hundred thousand pounds in a single year.

Among the near relatives of the true sturgeons, may be mentioned the shovel-nosed sturgeons, and the spoon-bills or paddle-bills of the Mississippi basin. The first of these has the front of the head long and spade-like, while the second has it produced into a broad, flat paddle, which may equal a third the total length of the fish. It is a most peculiar organ, and its use is to stir up the mud at the bottom, so that the contained animals may be more easily obtained. A spoon-bill occurring in China reaches a length of eighteen feet; but our native form barely reaches a third of that size.

The gar-pikes form another group highly interesting to the naturalist, which to-day is confined to the American continent. There are but three or four species, and these have the whole body covered with a compact armor of hard, bony scales. These fishes occur all through the United States, from Lake Champlain to Texas; they reach a length of about five feet, but have but a very limited use as food. The Indians used to catch them for a most peculiar purpose. They extracted the teeth, and, according to Charlevoix, a French traveler of a hundred and fifty years ago, they pretended that these "are a sovereign remedy against the toothache, and that by pricking the part most affected with one of these teeth, the pain vanishes that instant."

FIG. 295.—Gar-pike (*Lepidosteus osseus*).

Another form, still more like the true fishes, which occurs in our western streams, must be mentioned at least by name, or rather by its several names. It is the bow-fin, mud-fish, dog-fish, brindle or grindle of the fisherman; sometimes it is personified and given the more complete name of 'John A. Grindle.' It has no value as food.

THE BONY FISHES.

First among the bony fishes,—the group which contains all of our most familiar forms, which have the skeleton, not cartilaginous, but composed of hardened bones,—come the eels, familiar to all. These are long, cylindrical fishes, occurring in both salt and fresh water. They are carnivorous, eating almost everything of a size suitable to be swallowed; and when living prey is not handy, they play the part of scavengers, as all readers of the ‘*Ingoldsby Legends*’ will readily recall.

Until a very recent date the whole life-history of the eel was involved in mystery, and even now there are many undecided points. Still, the following account is probably correct, so far as it goes. The same species of eels are found in both salt and fresh water. In the spring immense numbers of small individuals make their way up the rivers and streams. When they start on these migrations, they are little beauties, an inch and a half or two inches in length, and so transparent that every feature of their internal anatomy can be seen and studied through the body walls. One can see the heart beat, and the blood stream through the gills and blood-vessels: they seem as if made of glass. Arrived at their destination, they rapidly wax and grow fat. They prowl about, mostly at night, burrowing in the mud in search of worms and cray-fish, or lurk behind some stone, to pounce upon some unlucky fish which may venture too near.

At last, after several years, they become adult, and again are seized with a migratory impulse, but this time their course is towards the sea. In the autumn they set out, traveling mostly by night on their long journey, sometimes hundreds of miles, to the salt water; for in the ocean alone will they reproduce. The fishermen tell, with every appearance of truth, of the immense numbers of eels which congregate in the shallow bays in the months of October and November. They coil themselves in large masses, sometimes several feet in diameter; and the existence of these masses seems to be in some way communicated to all the others within a considerable distance; for as soon as a bunch begins to be formed, they come from every direction. The fishermen take advantage of these congregations; stationing themselves near one, they spear the eels as they come swimming towards the spot; but they carefully refrain from disturbing the bunch, since the minute it is alarmed the individuals scatter instantly in every direction. It would appear that this bunching is connected with the laying of the eggs, but on this point nothing certain is known.

We have said that the eels will not reproduce in fresh water; the evi-

dence on this point is wholly circumstantial, but it is nevertheless conclusive. When eels are placed in land-locked ponds, they grow large, but their numbers never increase. This, of course, points to the conclusion that all the eels of fresh waters must have been born in the sea, and it farther explains the fact that until the completion of the Welland Canal no eels were found in the great lakes above Niagara Falls. The young in their

FIG. 296. — Common eels (*Anguilla vulgaris*).

upward migrations reach this barrier, but cannot pass it. Says Professor S. F. Baird: "In the spring and summer the visitor who enters under the sheet of water at the foot of the falls will be astonished at the enormous numbers of young eels crawling over the slippery rocks, and squirming in the seething whirlpools. An estimate of hundreds of wagon-loads, as seen in the course of the perilous journey referred to, would hardly be con-

sidered excessive by those who have visited the spot at a suitable season of the year."

The common eel, contrary to the common opinion, is provided with small scales, but the true sea-eels or conger-eels are without them. These latter forms never leave the sea. They are comparatively rare on our coasts, but in Europe they are taken in large quantities for the markets.

Queerest of all the queer fish brought up from the great depths of the seas by the recent exploring expeditions are the pelican-fishes. They are

FIG. 297.—Pelican-fish (*Eurypharynx pelecyanoides*).

all mouth and tail. the most curious creatures that can be imagined. Of their habits nothing is known, but the probability is that they swim along open-mouthed, near the bottom, their immense gape serving as a net, and their first discoverer thought that digestion might be partially accomplished in the large pouch between the halves of the lower jaw, which in its appearance recalls that of the pelicans. But very few specimens are known, the first being found in 1882.

The cat-fishes and horned pouts occur mostly in the fresh waters, but a considerable number of them live in the sea. In our northern waters,

especially in semi-stagnant ponds, the horned pouts — bull-heads, the boys call them — are especially abundant. They lie concealed during the day, but as night comes on, they start out in their search for food, and then is the fisherman's opportunity. They bite most voraciously, and usually the angler is not content with hook and line. He makes 'bobs' by sewing together large numbers of angle-worms on the threads, and these are used in

FIG. 238. — Burbot (*Lota lota*), above; sheat-fish (*Silurus glanis*), below.

fishing. The teeth of the fish become entangled in the loops of the thread, and thus the pouts are hauled to the surface and shaken off into the boat. This method of fishing, besides being more expeditious, has another advantage. These fish have the fins supported by a strong and sharp spine, and, unless one be careful, he is very apt to get these spines run into the hand, where they produce a painful but not serious sore. There is good reason

to believe that in some species there is a poison-gland situated behind the pectoral fin and connected with these spines, but the subject has never been adequately investigated.

Most of the horned pouts are of moderate size, but their flesh is highly esteemed by many people. In the Great Lakes and in the Mississippi basin larger species (cat-fish) occur, which may reach a weight of one or two hundred pounds. The sheat-fish of Europe is even larger, and specimens of three and even four hundred pounds are sometimes taken, thus making it the largest fresh-water fish, the sturgeons excepted, of that continent. All the cat-fishes are characterized by the presence of slender filaments, or 'barbels,' around the mouth, which doubtless serve as organs of touch.

It is in South America, and especially in the Amazon and its tributaries, that the cat-fishes acquire their greatest and strongest development. In our northern waters these fish are smooth-skinned, but there they are covered with bony scales, or large plates, and are so wonderfully protected that one on seeing them at once recalls the knights of the Middle Ages, clad in full armor—helmet, beaver, hauberk, gauntlets, greaves, and all. Our northern cat-fishes will live for a considerable time removed from their element, but they are excelled in this respect by their tropical relations. When the pools in which they live begin to get low in the dry season, some species will leave them and travel overland to a larger pool, sometimes occupying whole nights on the journey. The flesh of these forms is rather dry, but very palatable, and the Indians catch them in enormous quantities.

In the Nile a species occurs which has electric powers, like those of the torpedo already mentioned; but the electric organ is distributed all over the body, instead of being localized as in the other form.

Among the most celebrated of all fishes are the electric eels of South America. Mr. Bates gives the following account of their habits as he found them on the upper Amazon: "We walked over moderately elevated and dry ground for about a mile, and then descended (three or four feet only) to the dry bed of another creek. This was pierced in the same way as the former watercourse, with round holes full of muddy water. They occurred at intervals of a few yards, and had the appearance of having been made by the hand of man. The smallest were about two feet, the largest seven or eight feet, in diameter. As we approached the most extensive of the larger ones, I was startled at seeing a number of large serpent-like heads bobbing above the surface. They proved to be those of electric eels, and it now occurred to me that the round holes were made by these animals working constantly round and round in the moist, muddy soil. Their depth (some of them were at least eight feet deep)

was doubtless due also to the movements of the eels in the soft soil, and accounted for their not drying up, in the fine season, with the rest of the creek. Thus, whilst alligators and turtles in this great inundated forest region retire to the larger pools during the dry season, the electric eels make for themselves little ponds in which to pass the season of drought.

"My companions now cut each a stout pole, and proceeded to eject the eels in order to get at the other fishes, with which they had discovered the ponds to abound. I amused them all very much by showing how the

FIG. 299.—Electrical eel (*Gymnotus electricus*).

electric shock from the eels could pass from one person to another. We joined hands in a line whilst I touched the biggest and freshest of the animals on the head with the point of my hunting-knife. We found that this experiment did not succeed more than three times with the same eel when out of water; for the fourth time the shock was scarcely perceptible." The other fish in the pools all proved to be one of the armored horned pouts already alluded to.

A friend of the writer told his experience with one of these eels. He had been on a collecting expedition to the Amazon and was trying to bring

one of these creatures alive to Cambridge. He kept it in a bucket on the deck of the ship, and a sailor, seeing it coiled up on the bottom, mistook it for a large bar of soap, and straightway proceeded to wash his hands with it, when the shock and the surprise knocked him flat upon the deck. The story is often told that the natives capture these forms by driving horses into the pools occupied by them, and thus exhausting their electric powers, but it would appear that this is rarely if ever the case.

The shock given by the electric eel is stronger than that from the torpedo or electric cat-fish; but still it is not sufficient to numb and disable horses and men, as the story alluded to would have it. These electric eels reach a length of about six feet; they have two pairs of batteries, one above, the other below, the tail, and the nerves supplying them are very large and numerous. Structurally they are greatly different from the electric cat-fish already mentioned.

The carp family is of enormous extent, there being nearly two thousand species in the rivers of the world, about two hundred and sixty being recognized in North America. South America and Australia have none. They are mostly small forms of but little economic importance, and many of its members are familiar under the common names chub, shiner, minnow, dace, and roach. Our cut illustrates a few of the more interesting or important forms.

At the top of the figure is the carp. Originally a native of China, it has been introduced into Europe and America, where it is valued as the best food fish of the family. It multiplies with astonishing rapidity, and is really a valuable accession to the fished-out ponds of the eastern states. Still, we would not advise one to try them cooked in the German fashion: "Stewed in water first, afterward in a gravy made of brown bread, a small portion of sugar or of molasses is added, and then they put in enough of brown beer to make gravy sufficient to cover the fish."

Long domestication has resulted here as elsewhere in the production of a large number of varieties. The 'leather-carp' has lost its scales, while in the 'mirror-carp' (shown at the right centre of Figure 300) some of the scales are enormously developed.

A near relative of the carp is the goldfish, shown in the same figure, and like it, coming from China. It is a familiar but most uninteresting pet as it swims about, its body undergoing innumerable distortions from the magnifying effect of the globe of water in which it is kept. Its sole claim to prominence lies in the golden color of its scales, and this is a result of domestication. In its wild state the scales are green, and fish which escape from confinement soon return to the natural color.

The suckers are more distantly related to the carp, and may be dis-

missed with bare mention, for they are almost perfectly worthless. Once in a while there is found some man who relishes their dry, muddy flesh, but actual starvation would be necessary to make any one with well-developed taste eat them. They are mostly fresh-water forms of the United

FIG. 300. — Carp: above, the common carp (*Cyprinus carpio*); at the right centre, the mirror-carp; left centre, goldfish (*Carassius auratus*); below, the barbel (*Barbus barbus*).

States. Some sixty species are known, some of which reach a length of three feet. The name sucker has reference to the way in which they obtain their food.

The group now to be taken up is of vastly more importance, from an economic standpoint, than any already mentioned, and its first member, the herring, whose smoke-dried bodies 'two for a cent' figure in every

grocery store, ranks an easy first among food fishes. It spreads over the whole north Atlantic, south to New York and the Bay of Biscay, and is even more extensively fished for in Europe than upon our own shores; and the total annual catch is estimated at 1,500,000,000 pounds, with the probability that even this enormous amount is too low. The herring move in vast schools, some of which cover many square miles. Concerning their

FIG. 301.—Herring (*Clupea harengus*).

migrations there is great uncertainty. All the investigations of naturalists and fishermen have not yet solved the problem; and yet they are doubtless sub-

ject to certain laws of nature. For years they will appear each season at a certain spot, and then the next year there will not be a single one. This irregularity is far more marked on the European than on our shores. The shoals apparently come from the north to the more southern shores to lay their eggs. These immense schools feed upon what would at first sight appear inadequate,—the minute microscopic crustaceans and embryo molluscs. Yet these are so abundant that they really furnish an abundance of food for all the herring, and millions upon millions of other fish besides. These the herring strain from the water. They swim, open-mouthed, and the water which passes the lips goes out through the gills; but not so these almost microscopic animals. These are retained by little spines which arise from the arches of the gills, and form a small sieve, or lattice work, the meshes of which are too small to allow even these atoms to pass.

With us the herring is of far less consequence than it is in Europe. Our annual catch is estimated at 43,000,000 pounds, while our provincial neighbors take 200,000,000. In Europe they are preserved in many ways, while with us only two are prominent. Of smoked herring eastern Maine produces 370,000 boxes each year, while the young, packed in boxes with French and Italian labels, are sold as sardines to the amount of nearly 2,500,000 pounds. An immense number are also used as bait in the cod and other fisheries.

Equally or even more abundant on our coasts and reaching farther to the south is the menhaden or pogey, which is farther blessed with about thirty additional common names. Where they spend the winter is unknown. The probability is that they live in the deep and warmer water off the

coast, coming to the shores at the approach of warm weather. Says Mr. Goode: "The arrival of the menhaden is announced by their appearance at the top of the water. They swim in immense schools, their heads close to the surface, packed side by side, and often tier above tier, almost as closely as sardines in a box. A gentle ripple indicates their position, and this may be seen at a distance of nearly a mile by the lookout at the masthead of a fishing-vessel, and is of great assistance to the seiners in setting their nets. At the slightest alarm the school sinks towards the bottom, often escaping its pursuers. Sailing over a body of menhaden swimming at a short distance below the surface, one may see their glittering backs beneath, and the boat seems gliding over a floor inlaid with blocks of silver."

The greatest use of menhaden is in the manufacture of 'pogy oil'. The fish are principally caught by seining, and then they are cooked in salt water by means of steam, which separates a large part of the oil, the rest being extracted by hydraulic pressure. The flesh and bones are then made into artificial fertilizers to be used as manure. Some fish are used as food, either fresh or pickled, while the young (shadines) are packed in oil, and sold sometimes as sardines, sometimes as 'American sardines.'

The alewives are allied forms which ascend the rivers to lay their eggs, and in some localities they have become 'land-locked'; that is, they never return to the sea. The shad is more important as a food fish, and is the largest of the herring-like forms. Some esteem it highly as a food fish, and indeed were it not for the seeming superabundance of bones, it would rank among the best. The shad, too, go up the rivers to spawn. The gizzard-shad or mud-shad (Fig. 294) is a far less valuable form, which has become land-locked in various places.

The true sardine is an European species, the fishery of which is of vast importance. These fish are best broiled, but we are obliged to put up with their bodies boiled in oil and packed in small tin boxes. The small size of the bones, and the little lime which they obtain make it possible to eat sardines, bones, and all.

At this point must be mentioned some deep-sea forms and some of their surface-swimming allies. In these, one of the most interesting features is the existence of luminous organs,—small spots which give off light. These spots are usually ranged along the sides of the body. Strangest of these is a species "obtained at depths ranging between sixteen hundred and twenty-one hundred and fifty fathoms, off the coast of Brazil, near Tristan d'Acunha, and north of Celebes." The head is broad and flat, and the eye has undergone a most wonderful change; it occupies the whole upper surface of the

snout, is divided into two halves, right and left, and, says Dr. Günther, "seems to have lost its function of vision, and assumed that of producing light." In regard to all these forms there remains yet much to be learned. Our figure shows one very peculiar species from the deep seas.

The largest strictly fresh-water fish known is the periecu of the Amazon and its tributaries. It is said to reach a length of fifteen feet, and a weight of over four hundred pounds. It is very important in the region where it occurs, and is stated to form the main article of animal food for half the

FIG. 302. — Deep-sea fish.

inhabitants of the province of Para. Observations upon its habits are few. Mr. W. H. Edwards speaks of it as follows: "Not long after noon we stopped at a house (on the Amazon), where a number of Indians were collected about a periecu, which they had just caught. This was the fish whose dried slabs had been our main diet for the last few weeks, and we embraced the opportunity to take a good look at so useful a species. He was about six feet long, with a large head and wide mouth, and his thick scales, large as dollars, were beautifully shaded with flesh-color. These fish often attain a greater size, and, at certain seasons, are very abundant,

especially in the lakes. They are taken with lances, cut into slabs of half an inch in thickness, and dried in the sun after having been properly salted."

The smelt, or frost-fish, of the United States, and the smelt, or sparling, of England, are very nearly alike. Our smelt enters the rivers in the winter and early spring for the purpose of spawning, and at such times they are taken in large numbers. Josselyn, in 1677, wrote "the frost-fish is a little

FIG. 303. — Pericu (*Arapaima gigas*).

bigger than a gudgeon, and are taken in fresh brooks: where the waters are frozen, they make a hole in the ice about half a yard or a yard wide, to which the fish repair in great numbers, where, with small nets bound to a hoop about the bigness of a firkin-hoop, with a staff fastened to it, they take them out of the hole." Their habits and the mode of fishing are the same to-day. Some esteem the smelts highly; but to others their sweetish taste is very disagreeable.

The salmon family, containing the salmon, trout, charr, whitefish, etc.,

is a very interesting and important group, and therefore will occupy a considerable space in our pages. Both as food fishes, and as affording 'sport' for the fisherman, they rank highest of all the fishes. Every amateur angler details his experience in fishing for these forms, and still the oft-told story is as interesting as at first. Every detail has its fascination, — the preparation of the fly, the digging the worms, the description of the stream and lake, the struggle with the fish, and the fish which one saw but didn't catch, are all laid down in the veracious narrative.

How many trout and salmon we have is a question on which there is much dispute. In 1873 forty-three North American species were enumerated. Ten years later this number was reduced to eighteen, by uniting forms before considered distinct, and it is possible that the number may be still farther reduced.

Best and longest known is the salmon of the Atlantic, which ascends the rivers of Europe as well as those of our east coast. In former times this fish was very abundant as far south as Connecticut, and Hendrick Hudson saw a 'great store' of them in the river which bears his name. To-day the fisherman must go to the rivers of Maine and the British provinces for this fish. Their former abundance almost surpasses belief. Years ago the apprentices of Connecticut set forth their grievances and their ultimatum, much as do the wage-workers of to-day. Among the things they resolved, was not to eat salmon more frequently than twice a week.

There are land-locked salmon in Europe as well as in America; but the great majority spend at least half their life in the salt water. The time at which the adults enter the fresh water for spawning varies with the locality, and would seem to be dependent upon the temperature. Thus on the southern coast of New England they come in April and May, while in the Penobscot, June and July are the great months. When they first enter the rivers they are fat and plump, and their flesh has that peculiar pinkish hue known as salmon-colored. This color is said to be due to the shrimps and other crustaceans on which they feed. They stay in the rivers two or three months before the spawning time comes, and as this approaches they become lean and ugly, and their bright colors disappear, while the lower jaw of the male develops a powerful hook, which he uses to good effect in his battles with his rivals. The spawn is deposited in the gravel near the sources of the streams, and the young fish usually appear in May. They stay in the fresh water for two or three years before the descent to the sea. As long as they stay in the rivers (sometimes until seven or eight inches long) they are called 'parr,' and are spotted with red, and banded across the back. Next comes a silvery coat, and the fish is now a 'smolt,' the next stage is a 'grilse,' and the last is the adult salmon. In some places the

'grilse' returns to the fresh water, as in Canada and Europe; but it does not usually in the United States.

Says Norris, in his 'American Angler': "There is nothing in the water that surpasses a grilse in its symmetrical beauty, its brilliancy, its agility, and its pluck. I have had one of four pounds to leap from the water ten times, and higher and farther than a salmon. Woe to the angler who

FIG. 304. — Above, the salmon (*Salmo salar*); below, the sea-trout or salmon-trout (*Salmo trutta*).

attempts, without giving line, to hold one even of three pounds! He does it at the risk of his casting-line, or his agile opponent tears a piece from its jaw or snout in its desperate effort to escape."

The fishing for the salmon is rightly ranked as the highest sport of the angler — not that fishing which employs nets and seines, but that struggle between man and fish which calls into play every muscle and a consummate

skill. Who can describe it, and the enthusiasm (and appetite) it breeds? There is the cast of the fly, the strike of the fish, and then his struggles, all of which must be met. until, at last, he is safe in the landing-net. The pen of a Walton only is equal to the task.

The largest salmon on record was brought to London in 1821; it weighed eighty-three pounds. The largest taken in America was a fish of sixty pounds. Salmon weighing forty pounds are more common, but in the rivers of Maine the majority weigh but ten or twelve.

The salmon of the Pacific differ so in their characters from the Atlantic species, that they are arranged under a different head, and yet in their flesh they are almost identical. Both have the same rich, oily, pink flesh, and both cloy the appetite much sooner than some of their relatives, and after one has had enough he no longer wonders at the protest of the Connecticut youth already alluded to. There are five species of Pacific salmon

FIG. 305. — Quinnat salmon, young.

known under an immense number of names, some of Indian, some of Russian, and others of American origin; but none especially euphonious, although most are more or less descriptive. Of these, but one needs to be mentioned; it is the quinnat, king, chinook, or tchawytcha (choweecha) salmon, which ranges from Monterey to Alaska, and is the predominating form in the Columbia and Sacramento rivers.

The young of the Pacific as of the Atlantic salmon are hatched in the fresh water. At first they are of a very retiring disposition, hiding among the pebbles at the bottom; but with growth they acquire courage, and when from four to six inches long they seek the sea. As soon as they pass from the river their life is unknown until, when full-grown, they return probably to the same river that gave them birth. What they do in the sea or where they spend the time, are as deep mysteries as is that instinct which at last forces them to return to the rivers. Still there is evidence which tends to show that the deep sea is the place of their sojourn. At last the time

comes for that strange return to the scenes of their youth: it is literally a going home to die. Up the rivers they come until, at last, the head of the tide is reached, and here they stop for awhile and play about at the boundary line between the salt water and the fresh. At last, the line is crossed, and with this passage of the Rubicon a change occurs in their habits. They no longer eat. "They begin," as Mr. Stone expresses it, "a journey which is a long fast, and ends only in death. If they could be credited with a knowledge of what lies before them, none of the martyrs of Christendom could claim greater merit than these devoted salmon that march on unflinchingly to inevitable death."

They press on in the most persevering manner towards the head-waters, and nothing can stop them except some insurmountable obstacle, like a fall or high dam. On and on they go to the head-waters of the rivers, where the water is so shallow that it does not cover their backs, until at last a suitable place is found for the eggs. Now a hole is dug in the gravel, the spawn placed in it, and the whole carefully covered up by the aid of the noses and tails of the parent fish. These now seem to think their life-work is done. In the Atlantic species after spawning there is a return to the sea, but not so here; "they hover about the vicinity of their spawning-ground, growing weaker, more emaciated, and diseased every day, till death comes to their relief." It must be said that possibly some which spawn near the sea may return, but those which go some distance never do.

What an interesting, what a surprising, history this is! What can be the nature of the instinct that impels these fishes to seek the fresh waters at such a time? We may call it instinct, but this means nothing. Instinct is but a word used to express or conceal our ignorance. As soon as the salt water is left behind, the flesh begins to deteriorate, and in a few weeks it is useless for food, and after spawning "their downward progress is rapid. They grow less comely in appearance, more slimy to the touch, more unsymmetrical in form; parasites collect by thousands in their gills and under their fins; the tails and fins fray off: a white and loathsome fungus gathers over all parts of them, frequently destroying their eyesight; and swarms of suckers—the carrion birds among fishes—wait about them to feed upon their lifeless bodies when they die. For some strange and unknown reason the salmon in the higher tributaries do not hasten back to the salt water which would cleanse their bodies of the parasites and fungus, and restore their appetite, and with it the health and vigor: but they linger, with strange indifference to their fate, around the spots where they have deposited their eggs, waiting patiently for the only possible relief from their wretchedness, which is death." What a parallel is this for the preacher!

On their course from the sea they have to run the gauntlet of the fishermen, who take them by the million. The immense canning factories of the Columbia are well known, but a few statistics may prove interesting.

In 1880 the amount packed was nearly five hundred and fifty thousand cases, each of which contained forty-eight pounds of fish. In 1886 the twine for the nets cost nearly \$250,000, and the tin consumed for cans amounted to over sixty thousand boxes.

As representatives of a third group of the salmons may be cited the lake-trout and the brook-trout. The lake-trout, otherwise known as salmon-trout and Mackinaw-trout, may attain a weight of a hundred and twenty pounds. In its different localities it shows great variations. It is important as a food fish, and is caught chiefly in nets in the Great Lakes.

The brook-trout, on the other hand, but rarely reaches a weight of twelve or fourteen pounds, and then only when it lives in some deep pool where it has plenty of food. In its colors and appearance it is exceedingly variable, and were ichthyologists to follow the example the students of the shells set them, we should have species innumerable. Except in the tributaries to the Great Lakes it does not occur more than three hundred miles from the coast. It is one of the most attractive fishes for the angler. It is so cautious about biting if there be anything suspicious to be seen, and yet when it takes hold, it is in earnest. It darts out from beneath the root where it has been lying in concealment and has no toying with the bait, but at once seizes it, and is then quickly packed away in the basket.

More important, if less gamy, is a representative of still another group of salmon-like forms, — the lake white-fish, which sometimes attains a weight of over twenty pounds. A remarkable, and as yet not certainly explained fact, is the regular migrations it makes in summer to the shore, which cannot be for spawning, for that occurs at another time. They will but rarely take the hook, but are mostly taken in nets, the fall being the best fishing-time. The fish are sold in the fresh state, and are also packed in salt. In the winter large quantities are shipped in a frozen condition to all the region within two or three hundred miles of the lakes.

The pikes and pickerel and their allies are scattered over most of the earth, excepting our western territories and the islands of the South Seas. Prominent among them comes the large muskellunge of our great lakes, a fish which may weigh from sixty to eighty pounds. It is a gamy fish, and when one takes the hook, the angler may be assured of an abundance of sport. The pike and pickerel, of which we have four, are smaller species abounding through the whole United States. Though their flesh is good, they are not desirable inhabitants of the streams, on account of their almost

unparalleled voracity. Everything in the water is food for them. They will swallow snakes and frogs, and even the swift trout often furnishes them a meal. Fishing for pickerel is exciting sport. In the bright, warm days of autumn the fisherman goes to the lake or some still reach of the river, and trolls his spoon-hook through the lily-pads. There is a silvery gleam in the water, a sudden dash, and a pickerel is hooked.

A few of the relatives of the pike and pickerel must be mentioned. Among them is the mud-minnow of the northern states, a small fish which delights in muddy and swampy streams, but is not of the slightest economical importance. A South American ally, *Anableps*, is far more interesting from the peculiar structure of its eyes. It swims at the surface of tropical streams, with part of its head above and part below the water, and its eyes are divided into two parts, one being fitted for vision in the air, the other being like that of ordinary fishes. Corresponding to this double eye are two pupils, and the lenses have different curvatures in the two parts. These fish attain a length of about a foot.

FIG. 306. — Mud-minnow (*Umbra limba*).

The blind-fishes also are interesting, but in this case the interest centres in the rudimentary condition of the eyes. Five species are known, but the most celebrated is the form which lives in Mammoth and Wyandotte caves, while others are found in Cuba, and in the streams running through the rice-fields of the south. In these but the rudiments of the eye exist, and

FIG. 307. — Blind-fish of Mammoth Cave (*Amblyopsis sp.*).

the optic nerve, usually so well developed, is reduced to a mere thread. Living as they do in subterranean streams, eyes are of no use to them. In the perfect darkness which exists in the underground caverns, the strongest of eyes could distinguish nothing, and so nature wastes no energy in preserving an organ absolutely useless. Their sense of hearing, on the other hand, is acutely developed, and it is as difficult to catch them as any of their relatives with eyes. "It requires the greatest caution to bring the

net beneath them without driving them away. At the slightest motion of the water they dart off a short distance and usually stop. Then is the time to follow them rapidly with a net, and lift them out of water. They are mostly found near stones or rocks which lie on the bottom."

In addition to the sense of hearing they have that of touch highly developed. The head is destitute of scales, and on either side of the body there are numerous transverse ridges (shown in our cut), each of which is made up of a row of little papillæ, and to each papilla there runs a nerve. In this way highly specialized organs of touch are distributed over the whole body. The Mammoth Cave blind-fish is perfectly white, and reaches a length of four inches and a half, or even five inches. Says Mr. Putnam, "The largest specimen captured of late years is said to have been taken during the summer of 1871, and sold for ten dollars to a person who was so desirous of securing the precious morsel that he had it cooked for his supper."

There are two very distinct groups of flying-fishes: one, the true flying-fish; the other, the flying-gurnards. The first of these only is to be considered here; the other will be mentioned later. Of the true flying-fish there are some forty or fifty species; but with the distinctions between them we need not concern ourselves, merely saying that nine occur on the eastern coast of the United States. They are characterized by the excessive development of the pectoral fins (see page 327). Aside from their value as food, the whole interest in them centres in the 'flight'; but about this there are the most contradictory statements. Says Professor D. S. Jordan, a perfectly competent authority, the flying-fish of California "known to the Italians and Spaniards of the Pacific coast as the 'volutor,' reaches a length of eighteen inches, and a weight of one and a half pounds, being one of the largest flying-fishes. . . . This fish flies for a distance, sometimes, of nearly a quarter of a mile, usually not rising more than three or four feet. Its motions in the water are extremely rapid, and its motive power is certainly the movement of its powerful tail in the water. On rising from the water the movements of the tail are continued for some seconds, until the whole body is out of the water. While the tail is in motion, the pectorals are in a state of very rapid vibration, and the ventrals are folded. When the action of the tail ceases, the pectorals and ventrals are spread, and, as far as we can see, held at rest. When the fish begins to fall, the tail touches the water and the motions of the pectorals recommences, and it is able to continue its flight, which it finally finishes by falling into the water with a splash. While on the wing, it resembles a large dragon-fly. The motion is very swift; at first it is in a straight

line, but this becomes deflected to a curve, the pectoral on the inner side of the arc being bent downward. It is able to some extent to turn its course to shy off from a vessel. The motion seems to have no reference to the direction of the wind."

On the other hand, Karl Möbius arrives at some different conclusions. He does not admit that they can change their course, and claims that the curve is due to their flying across the direction of the wind. He also says

FIG. 308. — Flying-fish (*Exocoetus*).

that the length of their flight exceeds five hundred feet, and it is more rapid than the motion of a ship going at the rate of ten miles an hour.

The skip-jack, or bill-fish, of the Atlantic, though differing greatly from the flying-fishes, are closely related to them in structure. The name bill-fish relates to the long, sharp beak which terminates the head; while the other name, skip-jack, has reference to their mode of swimming. Their chief value is in the part they play in the food supply of cod, tunny, and other fishes. "The methods it adopts to escape from their pursuit," says Mr. Couch, "are peculiar. . . . Multitudes then mount to the surface, and crowd on each other as they press forward. When still more closely

pursued. they spring to the height of several feet, leap over each other in singular confusion, and again sink beneath. Still further urged, they rush along the surface by repeated starts for more than one hundred feet, without once dipping beneath, or scarcely seeming to touch the water."

The belones, needle-fishes, or gar-fishes have the same long beak as the bill-fish, and a striking peculiarity of all is that their bones are green in color, a fact which prejudices many against using them as food, though Mr. Goode pronounces our common species "exceedingly palatable." Some of the species of the tropical seas reach a considerable size, and their sharp beaks make them an object of danger to bathers in the eastern seas. According to Professor Moseley they rush blindly about when alarmed, and strike any object haphazard. He was told that in the Pacific islands the natives were in this way not infrequently speared by these fishes, and that death sometimes ensued from the peritonitis which resulted.

The barracudas of the warmer seas (one of which is represented in the upper part of our cut) are even more dreaded by bathers, but from a different reason. They grow to a large size, frequently weighing forty pounds, and their carnivorous habits and the powerful armature of their jaws render them feared almost as much as the larger sharks, as they are ready to attack man, and are capable of inflicting serious if not fatal wounds. The flesh of the barracudas is highly esteemed in most places, but in Cuba it is under the ban because there have been instances of severe sickness caused by eating it. These may have been caused by some peculiarity in the food; indeed, Günther states that it results from their feeding on smaller poisonous fishes.

The term mullet is applied to various fishes, among them the mullet of the ancient Romans as well as to some of the suckers. With us, however, except away from the sea, it is restricted to a group most of the members of which are fond of brackish water. There are about seventy species known, but with us but two attain any importance. They are possibly the most abundant species along the Atlantic and Gulf coasts of the United States. They furnish an abundant supply of food. "During the fall," says Mr. Stearns, "they move in such immense schools that the noise of their splashing resembles distant thunder; and to persons living near the river or bay their noise, kept up day and night, becomes very annoying. . . . When one fish finds a spot rich in their desired food, its companions immediately flock around in a manner that reminds one of barnyard fowls feeding from one dish." Their food consists almost solely of the microscopic forms found in the mud on the bottoms, and the throat is so constructed that no large particles can pass down it.

The living-fishes or walking-fishes of the fresh waters of southeastern Asia are somewhat like the mullets, and yet there are differences which make their position very uncertain. Most peculiar about them is their power to withstand drought. Their ponds or tanks may dry up, and still they will exist in a semi-torpid condition beneath the dried mud.

FIG. 309. — Barracuda (*Sphyraena spet*), above; goose-fish or fishing-frog (*Lophius piscatorius*), below.

Indeed, they are adapted for breathing air, and can be drowned by a too long submergence beneath the water. They are used as food, and in China it is said that they are carried about in tubs for sale, and slices are cut from the living fish according to the desires of the customer. Thirty-one species are known, the largest of which may grow to be forty feet long.

The largest series of fishes is that whose most prominent characteristic is the possession of spines in the dorsal, and frequently in other fins. This alone would not separate the group from many others provided with the same structures, but there are many other characters, the details of which are beyond our scope, which mark them off from all others with similar fins. Of this spiny-finned series only the most important and most interesting need to be mentioned here.

The first species to be considered is the celebrated blue-fish, which ranges through almost all of the warmer seas of the world. It is a model of voracity; an animated chopping-machine, it has been called. It requires an enormous amount to supply the demands of its stomach, but still worse, it destroys far more than it eats. The blue-fish go in immense schools, chasing the menhaden, mackerel, and squid, and committing sad havoc in

FIG. 310. — Living-fish (*Ophiocephalus*).

their ranks. Indeed, it is said that they seem to eat for the mere pleasure of swallowing the food, and that when completely filled, they disgorge all that they have swallowed, and then begin again. The amount of destruction they cause is perfectly enormous, and we cannot forbear quoting the estimate of Professor S. F. Baird upon this point.

“The capture of blue-fish from New Jersey to Monomoy, during the season, amounts to not less than one million individuals, averaging five or six pounds each. Those, however, who have seen the blue-fish in his native waters, and realized the immense numbers there existing, will be quite willing to admit that probably not one fish in a thousand is ever taken by man. If, therefore, we have an actual capture of one million, we may allow one thousand millions as occurring in the extent of our coasts referred to, even neglecting the smaller ones, which, perhaps, should

also be taken into account. An allowance of ten fish per day to each blue-fish is not excessive; . . . this gives ten thousand millions of fish destroyed per day. And as the period of the stay of the blue-fish on the New England coast is at least one hundred and twenty days, we have in round numbers twelve hundred million millions of fish devoured in the course of a season. Again, if each blue-fish averaging five pounds devours or even destroys half its own weight of other fish per day (and I am not sure that the estimate of some witnesses of twice this weight is not more nearly correct), we will have, during the same period, a daily loss of twenty-five hundred million pounds, equal to three hundred thousand millions for the season."

Still, this voracity, to a certain extent, has its compensations, for when they reduce the number of the mackerel, the lobsters are noticed to increase in numbers. And besides, the blue-fish is most excellent eating, and yet it is considered unfit for food in the southern states as far north as Washington. It is one of the gamiest of salt-water fishes, and its capture is regarded as among the finest sport of the angler. The usual way of fishing for it is by trolling from a sail-boat, but on the New Jersey coast large numbers are taken from the shore by throwing the hook out as far as possible into the surf, and then hauling it in. The hook must be fastened to a bit of wire, for the sharp teeth of the fish would quickly sever a cord.

The scad, moss-bunkers, pompanos, and the like must be dismissed with the mere remark that they are good for food. The pilot-fish demands a few words more on account of the interest surrounding its habits. It has been known from the most ancient times, and in the times of yore it was thought to lead the sailor, and to announce the vicinity of land by its sudden disappearance. It really does keep company with ships and large sharks, and strange to say, it is never attacked by the latter. This form is not very common, and one quotation will give about all that is known of it. Dr. Meyen in his 'Voyage around the World' states that "the pilot swims constantly in front of the shark; we ourselves have seen three instances in which the shark was led by the pilot. When the shark neared the ship, the pilot swam close to the snout, or near one of the pectoral fins of the animal. Sometimes he darted rapidly forwards or sideways as if looking for something, and constantly went back again to the shark. When we threw overboard a piece of bacon fastened on a great hook, the shark was about twenty paces from the ship. With the quickness of lightning the pilot came up, smelt at the dainty, and instantly swam back to the shark, swimming many times around his snout, and splashing, as if to give him exact information as to the bacon. The shark now began to put himself in motion, the pilot showing him the way, and in a moment

he was fast upon the hook. . . . It seems probable that the pilot feeds on the shark's excrements, keeps his company for that purpose, and directs his operations solely from this selfish view."

Very different in importance is the mackerel, which formerly each spring made its appearance in immense numbers on our coasts. Where it spends the winter is unknown. Some claim that it hibernates in the mud; but others, with more probability, believe that it retires to deep water during the cold months. As soon as it appears, the fishing begins; at first, to the

FIG. 311. — Mackerel (*Scomber scomber*).

south, and then it gradually works north. The methods of fishing are by seines and by hooks. The seines are large nets, the largest being a quarter of a mile long, and twenty fathoms deep. Its

upper edge is buoyed with corks, or glass floats; while the lower is weighted with lead.

Far more exciting is the hooking, and the favorite bait is made from the silvery skin of the mackerel itself. When the mackerel begins to bite well, the excitement runs high. Each fisherman wants to rank first, and he works with all his might. He manages ten or twelve lines, and as fast as he catches the fish, he slings them into a barrel. The work is very hard, and the novice, kept up by excitement for a while, with tired muscles and blistered hands, at last has to give in. Not so the fisherman; he works as long as the mackerel bites, and in some cases a single fisherman has caught ten or fifteen barrels in a day, each of which will hold from a hundred and fifty to two hundred fish.

The fish are largely sold in the markets in the fresh condition, while still more are packed in salt for shipment to the interior, where the barrels and 'kits' form a feature in every grocery store. The fish to be salted are split open, cleaned of the viscera, and then thrown into tubs of water and washed, and then are packed in barrels with salt, — one barrel of salt to every four barrels of fish. Later they are selected into 'grades,' according to size and condition. The disappearance of the mackerel for several years past has no explanation.

A near relative of the mackerel is the tunny of Europe, the horse-mackerel of the American shores. It is one of the largest of fishes, attaining a weight of fifteen hundred pounds. In America its dark flesh is despised, and the fish is caught only for the oil, of which it may yield over twenty gallons. In the countries bordering on the Mediterranean it is held in high esteem.

They are caught in large traps, much like some of those in use in America, but of enormous extent, the walls in some instances being three miles in extent, and leading to a pot with a netting floor, which can be raised and lowered as desired by means of rope. The fish are driven through all the mazes of the net, and at last find the way into this pot. The bottom is now lifted, bringing all the fish near the surface, when they are stabbed and hooked by cruel instruments of iron, and each fish as it is killed is drawn into the boats. In a single haul of the pot, nearly a thousand fish have been obtained, worth at least forty-three thousand francs.

The Spanish mackerel, too, must be mentioned, since it is one of the most highly esteemed of our fishes, and since it is becoming more abundant

FIG. 312.—Tunny, or horse-mackerel (*Orcynus thynnus*).

than in the past, it promises to play a more important part than it now does in supplying us with food.

The sword-fishes and sail-fishes are also important forms, and are, besides, interesting from the peculiar 'sword' in which the head terminates: the sail-fishes having the dorsal fin greatly larger than in the true sword-fish. The latter is by far the more important of the two, and some account of it may prove interesting. In Holland's 'Pliny' of 1601 occurs the following: "The Sword-fish, called in the Greeke Xiphias, that is to say in Latin Gladius, a sword, hath a beake or bill sharp-pointed, wherewith he will drive through the sides and planks of a ship, and bounge them so, that they shall sinke withal. The experience whereof is scene in the oceane neare to a place in Mauritania called Gotta, which is not far from the river Lixos." We do not need to go so far for the proof of the old tale, for it has often been authenticated even on our own shores. One

more reference to old times must be permitted. Mr. Goode tells us that, in Siena, Columbus deposited mementos of his first voyage, which resulted in the discovery of a New World. The objects are still in the old collegiate church, and consist of the helmet, armor, and weapons he wore when he first planted his feet on American soil, "and the weapon of a warrior killed by his party when approaching the American coast — the sword of a sword-fish."

The sword-fish is exceedingly pugnacious, and it would seem that all its ire is aroused at the sight of a whale. It fights, as a warrior should,

FIG. 313. — Sail-fish (*Histiophorus gladius*).

with its trusty blade, and the stroke of this weapon has a fearful force. It uses the sword to kill the fish it eats, and instances are numerous where it has been driven through the sides of ships. In one instance cited by Mr. Goode the sword "had been driven through the copper sheathing, an inch board undersheathing, a three-inch plank of hard wood, the solid white-oak timber twelve inches thick, then through another half-inch hard oak ceiling, and lastly penetrated the head of an oil-cask, where it stuck, not a drop of the oil having escaped." The force with which the fish must have struck can hardly be imagined.

Sword-fish are extensively fished for food, and the annual catch on the New England coast is about one million five hundred thousand pounds. Some like the flesh, but in the writer's opinion it is about as poor as possible. The fish are caught by harpooning.

In almost every popular work on natural history reference is made to the wonderful archer-fishes of the East Indies, sometimes with wonderful details. Yet the basis of the story is furnished by Bloch, a naturalist of the last century, in words which, when translated, were much as follows: "Observe how this fish ensnares the flies it discovers on the marine plants which project above the water. It approaches within five or six feet of the insect, and then squirts water upon it with such force that it never fails to bring it down and make it its prey." Upon this slender basis what marvellous superstructures have been raised, and what faithful pictures have been drawn! And yet the whole story is probably a myth, which arose, nobody knows how. No recent traveler has seen the operation, and Bleeker (a thorough student of fishes, who lived many years in the Dutch Indies, where these fishes abound) never saw an instance of it, nor even heard it mentioned in Batavia. Still, the archers and coral-fishes are most attractive, even if the old story is destroyed, for they are among the most brilliantly colored of all fishes, and are exceeding savory withal.

The surgeons or doctors are also remarkable for a sharp lancet-like spine on either side of the tail, which can be erected or depressed at will. They are very pugnacious, and when aroused they flirt the tail around in the most vicious manner, inflicting severe wounds.

Of the perch-like forms the first to be mentioned is the weak-fish or squeteague, which derives the first-mentioned name from the weakness of its jaws. It is of comparatively little value as food. A relative of it is the drum-fish, shown in our cut; it is one of the largest of our food fishes, but is little used north of Maryland. They are bottom-feeding fishes, and are provided with hard and heavy pavement-like teeth, which well adapt them to feeding on crabs and molluscs. They go in large schools, and when they appear on an oyster-bed, the amount of damage they do frequently amounts to thousands of dollars. They fill their mouths with the molluscs, crush the shells, and swallow what they need; but it seems that they do not eat half what they destroy, but seem to go over a bed crushing the shells and dropping the fragments untasted on the bottom. The size of the schools is shown by three quotations from Mr. Ingersoll. In one haul 218 were caught, weighing between 8000 to 9000 pounds. Another haul took 719, weighing on the average over fifty pounds each; while the largest on record occurred in 1804. One haul of the seine drew on shore "12,250 fish, the average weight of which was found to be thirty-three

pounds, making in the aggregate 202 tons 250 pounds." The name drum-fish alludes to the drumming sound which they make at the spawning season. How they do it is not certainly known. Some attribute it to the grinding action of the pharyngeal bones, while others think it is produced by the passage of air from one part of the air-bladder to the other. Several other fishes have the same power; among them is the fresh-water drum, or, to take another expressive name, the thunder-pumper of the Great Lakes and the Mississippi basin. The salt-water drum must not be dismissed without alluding to the fact that its scales are used in making the

FIG. 314. — Drum-fish (*Pogonias chromis*).

fish-scale jewelry, which a few years ago was so extensively manufactured in Florida.

The scup, scuppaug, or porgy, is a valuable food fish, occurring in the summer on the whole coast south of Cape Cod. It, however, is far excelled by the sheepshead of the same waters, which receives its name from the shape of the head, and also from the way in which it browses on the barnacles and shell-fish. It is one of the choicest of food fishes, and is chiefly caught with a hook. Somewhat near it in the system of classification comes the celebrated red grouper of the south, the monstrous Jew-fish, which may weigh four or five hundred pounds, and the striped bass, or rock-fish, which is so highly esteemed for the table. The common yellow perch of fresh water is an allied species.

The black bass of fresh water, of which we have two species. — large- and small-mouthed, — are among the gamiest of fishes, and some anglers go fairly crazy over them. Their flesh is equal to that of a trout, but their pluck is far superior.

The pumpkin-seeds, or sun-fishes, which bite so freely, and come up so hard, making the boy angler think he has caught a 'ten-pounder,' must also be mentioned. They are mostly brilliantly colored forms, but their beauties only come out when, drawn from the water, they begin to die. Then the play of colors is magnificent, and the far-famed dolphin can hardly surpass the display. The pumpkin-seeds are all much alike in shape, and of but very little value for food or anything else, except as they afford sport for boys.

Quite a different fish is a small species living in the valley of the Jordan, which, like some of its relatives, has curious reproductive habits. The female deposits the eggs in a little hollow in the bottom of the stream, and then the male takes them into

FIG. 315. — Pumpkin-seed, or bream.

his mouth, and keeps them there until after they hatch. "The little ones rapidly increase in size, and appear to be much incommoded in their narrow prison. They remain in great numbers, pressed one against another, like the grains of a ripe pomegranate. The mouth of the father-nurse now becomes so distended by his progeny that his jaws cannot meet. The cheeks are swollen, and the animal presents the strangest appearance." Some of the young remain until they are four inches long.

Most of the hundred species of parrot-fishes (*Scarus*) live in the tropical seas, where they browse on the coral forests, and some are furnished with an apparatus by which they can hold themselves in position in even the strongest breakers. One species living in the eastern seas requires to be prepared with the greatest care, since the contents of the gall-bladder, if allowed to escape, will poison the flesh. Mr. Forbes, speaking of the form found in the Keeling Islands, says: "Several fatal cases had occurred in the settlement, especially among children, who almost immediately after partaking of the flesh were seized with giddiness and stupor followed by death, with a dropsical state of the body, within two or three hours. The effect of the application of the bile externally produced simply a bad fever. A woman, while cleaning such a fish by the shore, on one occasion threw

out the entrails on the water, when a frigate-bird, which had been hovering over her, swooping down picked up the tempting morsel ; but it had only risen some thirty feet in the air when it fell back on the water lifeless."

Our American tautog and the closely allied cunner are common about rocks along the coasts of our northern states. The tautog is much the

FIG. 316. — Climbing-fish (*Anabas scandens*).

larger ; but the cunner, which weighs on the average about half a pound, is much the better flavored of the two. Around Boston cunners are eaten in large quantities, but farther to the south they are despised ; why, no one can tell.

On the Californian coast are a number of small fishes — surf-fishes is the best name for them — which are remarkable from the fact that they bring forth their young alive. These were for a while the only known

viviparous fishes, and created no little excitement in the scientific world, but now there are several others which are known to have the same peculiarity. The surf-fishes have but little value as food, and the largest never weighs more than five pounds.

Still more remarkable are a number of fishes belonging to the eastern hemisphere, and especially to India. The most celebrated among them is the climbing-fish, or climbing-perch, which has been known to science for nearly a hundred years. The story was then told that this fish ascended

FIG. 317.—Gourami (*Osphromenus gourami*).

trees, but soon the tale fell into disrepute. Now it would appear to be fully authenticated. As seen in the figure, the gill-covers are furnished with long spines, and these, together with the tail, seem to be the means employed. The reason for the climbing is not easily seen; it may result from the desire to make their way up any stream, and the rain tickling down the trunks of the trees may arouse all the ambition of the fish. A remarkable feature in its anatomy, and one which is common to it and the species to be mentioned next, is the structure of its gills and the gill-accessories. Above the gills there is a large labyrinthine chamber richly supplied with blood-vessels. This was formerly believed to be a reservoir for

water, but now it would seem to be more probable that it is for breathing air direct. Indeed, experiments show that this fish can be drowned if kept so that it has not access to the air.

In the tropical gourami the same structure prevails; but there is not found associated with it such terrestrial habits. The celebrity of the gourami lies in its flesh, and it is esteemed among the best of all food fishes. Tales are told of specimens which weighed a hundred and fifty pounds; but one of twelve or fifteen pounds is regarded as large. Attempts have been made to introduce it into France, but not with any great success; the climate is too cold for it.

The mullet of ancient Rome, which formerly was so highly esteemed, and brought such extravagant prices from epicures, belongs here. It was brought to the table alive, and the guests watched the changing colors as it died. To-day it is still held in high esteem; but it does not begin to hold the rank it formerly did.

Among the strangest of fish histories is that of the tile-fish. First as to the name. The fish was absolutely unknown until 1879, when fishermen caught the first specimens. Science immediately christened it *Lopholatilus*, and as it had no common name, one was formed for it from a part of the scientific one. In 1880 it was found to be extremely abundant south of New England; and as it was a large fish and of good flavor, it promised to become of considerable importance. Specimens weighing fifty pounds were not uncommon, and the average size was perhaps ten or twelve pounds. In March, 1882, there was a very severe gale, and after it the surface of the sea was covered with millions upon millions of dead fish. Agents of the United States Fish Commission sailed over the ground, and

FIG. 318.—Spine and poison-sac of *Syngnathus*.

found that for a distance of three hundred miles north and south, and fifty east and west, the water was covered with them. It was estimated that fifteen hundred millions were destroyed. What the cause was is still uncertain; but it is probable that the destruction resulted from a mixing of waters, either too cold or too warm for the fish. Since that time, although numerous attempts have been made, not a single specimen could be obtained, although before it bit freely. It is possible that the species was exterminated.

Mention must also be made of the wonderful black swallower of the deep seas. It is well named, for, paradoxical as it may seem, it is capable of swallowing a fish larger than itself. Its jaws are loosely jointed, and thus will admit of the passage of a large fish, while the skin and stomach could not be more distensible were they made of rubber, and this is the apparatus which

allows it to swallow a fish, in some instances, six times its own bulk. It makes one think of the bag which 'Jack the giant-killer' wore doing his famous gastronomic duel with the giant.

Except for baiting fish-nets and lobster-traps, the sculpins are about as useless as they are ugly. They have an enormous head, small body, and large pectoral fins. One remarkable peculiarity about them is their habit

FIG. 319. — Walking-fish (*Periophthalmus*).

of swallowing air as soon as they are drawn from the water. In this way they will swell up like a balloon, and then, when thrown back, they float helplessly about on the surface, utterly unable for a time to descend to the bottom where they ordinarily dwell.

The European weaver-fishes can cut and sting severely with the spines of their fins and gill-covers, but in the tropical seas of the east are far more

dangerous forms (*Synanceia*); for in these there is a poison-gland (Fig. 318) on each of the dorsal spines, and this may cause a wound always as painful as that of a scorpion, and sometimes followed with fatal effects. In still other related fishes the gill-covers, in addition, have poison-organs.

Our figure on the preceding page shows a strange fish,—strange both in appearance and in habits. It has no common name, and so the scientific *Periophthalmus* must suffice. This name has reference to the large eyes, which are exceedingly movable, and can be thrust far out of their sockets or retracted at will. The fishes live almost as well out of water as in it, and they are fond of wandering about on the mud-flats, hopping freely by means of their strong fins and tail. They feed on the shore life,—the beach-fleas and molluscs,—and their rapid motions enable them to escape any ordinary enemy. With one exception all belong to the shores of the Indian Ocean.

True parasites are exceedingly uncommon among fishes, but there is one instance, not exactly of true parasites, which is very interesting from the peculiar homes that it seeks. In the Mediterranean it lives, like a hermit in its cave, inside the body of the sea-cucumbers. It makes its entrance through the anal opening, and with its head toward the vent watches for its food.

The suck-fish, or stay-ship, are strange fish, five species of which occur on our coasts. Their peculiarity lies in the fact that the first dorsal fin loses its character of a fin, and is converted into a sucking-organ, placed on the top of the head and extending a short distance on the back. With this sucker it attaches itself to any floating object, especially sharks and sword-fish, and thus gaining a free ride. But what advantage this is to the fish it is not easy to see; for they are strong swimmers, and it would hardly seem necessary that they should require such a peculiar style of locomotion. Besides fish, they sometimes adhere to other objects, and the sailors are fully persuaded that when they fasten themselves to the hull of a ship, her progress will be greatly retarded, no matter how strong the breeze.

It is stated that this peculiarity is in some places made of use in fishing for turtles. One of the earliest references to this is transcribed from the pages of Mr. Goode, who in turn takes Ogilby's 'America' of 1671, where it is accompanied by a very curious figure of an Indian fishing.

"*Columbus*, from hence [from Cuba] proceeding on further Westward, discover'd a fruitful Coast, verging on the Mouth of a River, whose Water runs Boyling into the Sea. Somewhat further he saw very strange fishes, especially of the *Guaican*, not unlike an Eel, but with an extraordinary

great Head, over which hangs a Skin like a Bag. This Fish is the Natives Fisher; for having a Line or handsom Cord fastned about him, so soon as a Turtel, or any other of his Prey, comes above Water, they give him Line; whereupon the *Guaican*, like an Arrow out of a Bowe, shoots towards the other Fish, and then gathering the Mouth of the Bag on his Head like a Purse-net holds them so fast, that he lets not loose till ha'd up out of the Water."

FIG. 320. — Suck-fish (*Remora*).

While in Europe the herring is the most important of fishes, with us the family of cods must take that rank. No other group can begin to equal it. First and foremost of the family comes the cod itself, a fish so familiar as not to need description. It is a circumpolar species, which descends on our coast in abundance to south of Cape Cod, and in lesser numbers as far as Cape Hatteras. The great fisheries, however, are farther to the north, North of Cape Cod, away to beyond the Arctic Circle, it can be caught almost anywhere; but there are certain spots where it is especially abundant. These are shoal places on 'banks' in the ocean, and of them the Grand Banks of Newfoundland and the Georges Banks south of Nova Scotia are doubtless the best known. The Grand Banks have been fished

upon for centuries. No one knows when they were first discovered; but there is much reason to believe that the hardy Basque fishermen visited them regularly long before the discovery of Columbus, and that from them or the sailors of Bristol he may have got his idea of an India to the west.

The cod is a bottom-feeding fish, with an almost insatiable appetite. Anything not too large is swallowed by it, sometimes when without the slightest nutritious qualities. Other fish, perhaps, form the bulk of the food; but worms and molluscs are eaten in large quantities, and before the days of dredging the naturalist had to depend upon the stomachs of cod and other similar fishes for his shells from deep water. No wonder was it that the enthusiastic conchologist, poking over the piles of fish 'gurry,' was thought to be crazy, and no wonder that one was stoned as a lunatic by the boys of that quaint old town, Marblehead!

Cod-fishing is a profitable, and at the same time a dangerous business. The fishing-smacks are small, and the men in setting the trawls have to

FIG. 321.—Cod (*Gadus morrhua*).

venture out in open boats, and then if the fog sets in, they have nothing to guide them back to the vessel. They may drift about for days, and perhaps never get back to the schooner. Gloucester, Mass., is the great fishing-centre, and in some years the casualties from that city exceed one hundred: not a year passes in which few lives are lost.

The fishing is done in the ordinary way with hook and line, as well as by trawls. For bait, other fish or squid, or even clams, are used, squid ranking among the best. Some of the fish are sent to the market fresh; but the great majority are salted and dried in different ways, and the place where the cod are drying in the sun does not have an appetizing smell.

A near relative of the cod is the haddock, which has much the same habits, and is caught in the same way. Its flesh, except for chowders, is not so good as that of the cod, and it commands a lower price. The differences between the two may be seen from our figures, and in buying the dried fish one may be sure of what he is getting by noticing the shape of

the tail, as well as whether the line along the side is white or black. In the newly introduced 'boneless cod' this is not possible, as the 'blocks' are divested of their skin. Packed in this way enormous quantities are sold, each dealer having his own band. Some of the names employed seem rather peculiar; there are 'fern-leaf,' 'lily,' 'white-swan,' and twenty other names placed upon the boxes of cod, none of which seem to have the least quality of the element of appropriateness. Dried cod will smell as strongly when called 'lily,' as when by any other name.

The pollock and the hake are two other cod-like fishes of great importance, although they fall far behind the cod and haddock in this respect.

One of the cods enters fresh water. This is the burbot, which occurs in the northern parts of both the Old and the New worlds. It is shown in Figure 298 on a preceding page. Opinions differ as to its palatability; some esteeming it highly, while others regard it as unfit for food. In the

FIG. 322. — Haddock (*Melanogrammus aeglefinus*).

Hudson Bay territory, and far to the northwest, it is really an important element in the food supply, and the roe, either alone or mixed with a little flour, is baked into bread. The average size is about five pounds, but it occasionally reaches a weight of sixty pounds.

The flat-fishes have a strange development. They start out in life like any other well-behaved fish, but soon they exhibit a tendency to lie upon one side. Stronger and stronger grows this tendency, until at last this becomes the normal position. Were the structure to remain as it is in other fishes, the result would be that one eye would be constantly directed upwards, while the other was turned downwards and could see nothing but the mud. This, however, does not occur, for with the change of position of the body the lower eye also begins to change, until at last it twists the bones of the skull and comes to lie on the same side of the head as does its fellow. The fish thus strikingly resembles the profiles meant for the

human head, which children draw, and in which both eyes are represented on the same side of the face. With this turning of the body comes a difference in the colors of the two sides. That which is constantly directed downward remains white, while the other assumes a dark hue.

Largest of the flat-fishes is the halibut, whose white steaks are familiar to all. The female affords the best meat, and her average weight is about a hundred or a hundred and twenty-five pounds. The largest known was caught in Sweden and weighed seven hundred and twenty pounds; and the next largest of which a record is accessible is a doubtful instance of one of six hundred pounds, and the next weighed four hundred and one pounds. The large fish are coarse-fleshed and much inferior to the smaller specimens.

Our plate shows three European species of flat-fish, all of which have considerable celebrity. The largest is the turbot, which has a very high reputation as a food fish, and always commands a high price. The next in size (the dark fish to the right) is the plaice, quite a different fish from the American form called by the same name. In the left foreground is the sole, which takes a rank next to the turbot.

Speaking of the American plaice, Mr. Goode, after referring to its use in various places to the south, says, "In Boston, and indeed throughout the greater part of New England, this, with all other flounders, is considered unfit to eat." This is a strange statement, for in New England the flounders are highly esteemed, and in every sea-shore town they are eaten in great quantities.

All of the flat-fishes are bottom-feeders. They either swim leisurely along, just above the sand or mud, or lie buried beneath the surface, with only the jaws and eyes exposed. They are voracious and will bite at almost anything.

The little sticklebacks, with a varying number of spines upon their backs, are familiar to every loiterer beside our streams and along the wharves of our harbors. Exceeding busy fishes are they, of little economic importance (except as they eat the fry of other fishes), but very interesting on account of their habits. When the spawning season comes round comes the nest-building, which is performed by the male alone. The operation has been so charmingly described by Mr. John Keast Lord in his 'Naturalist in Vancouver Island and British Columbia' that we cannot refrain from quoting his account nearly in full.

"The site is generally among the stems of aquatic plants, where the water always flows, but not too swiftly. He first begins by carrying small bits of green material, which he nips off the stalks, and tugs from the bot-

Side.

FLAT-FISHES.

Top.

Bottom.

tom and sides of the banks ; these he attaches by some glutinous material, that he clearly has the power of secreting, to the different stems destined as pillars for his building. During the operation he swims against the work already done, splashes about, and seems to test its durability and strength ; rubs himself against the tiny kind of a platform ; scrapes the slimy mucus from his sides to mix with and act as mortar for his vegetable bricks. Then he thrusts his nose into the sand at the bottom, and, bringing up a mouthful, scatters it over the foundation ; this is repeated until enough has been thrown on to weight the slender fabric down, and give it substance and stability. Then more twists, turns, and splashings to test the firm adherence of all the materials that are intended to constitute the foundation of the house that has yet to be erected on it. The nest, a nursery, when completed, is a hollow, somewhat rounded, barrel-shaped structure, worked together in much the same way as the platform fastened to the water-plants, the whole firmly glued together by the viscous secretion scraped from off the body. The inside is made as smooth as possible by a kind of plastering system ; the little architect continually goes in, then, turning round and round, works the mucus from his body on to the inner sides of the nest, where it hardens like tough varnish. There are two apertures, smooth and symmetrical as the hole leading into a wren's nest, and not unlike it.

"All this laborious work is done entirely by the male fish, and when completed he goes a-wooing. Watch him as he swims towards a group of the fair sex, enjoying themselves amidst the water-plants, arrayed in his best and brightest livery, all smiles and amiability ; steadily and in the most approved style of stickleback love-making, this young and wealthy bachelor approaches the object of his affections, most likely tells her all about his house and its comforts, hints delicately at his readiness and ability to defend her children against every enemy, vows unfailing fidelity, and, in lover-fashion, promises as much in a few moments as would take a lifetime to fulfil. Of course she listens to his suit ; personal beauty, indomitable courage, backed by the substantial recommendations of a house ready-built and fitted for immediate occupation, are gifts not to be lightly regarded.

"Throwing herself on her side, the captive lady shows her appreciation, and by sundry queer contortions, declares herself his true and devoted spouse. Then the twain return to the nest, into which the female at once betakes herself, and therein deposits her eggs, emerging, when the operation is completed, by the opposite hole. During the time she is in the nest (about six minutes) the male swims round and round, butts and rubs his nose against it, and altogether appears to be in a state of defiant excite-

ment. On the female leaving, he immediately enters, deposits the milt on the eggs, taking his departure through the back door. So far, his conduct is strictly pure; but I am afraid that morality in stickleback society is of a rather lax order. No sooner has this lady, his first love, taken her departure, than he at once seeks another, introduces her as he did the first, and so

FIG. 323.—Sea-stickleback (*Spinachia spinachia*), above; and three-spined stickleback (*Gasterosteus aculeatus*), below.

on, wife after wife, until the nest is filled with eggs, layer upon layer, milt being carefully deposited betwixt each stratum of ova. As it is necessary there should be two holes by which ingress and egress can be readily accomplished, so it is equally essential in another point of view. To fertilise fish-eggs, running water is the first necessity: and as the holes are invariably placed in the direction of the current, a steady stream of water is thus directed over them."

To this account but a few words need to be added. The mucus is secreted not by the sides of the body, as was thought by Mr. Lord, but by a special gland which opens just in front of the vent. During the mating season some of our east-coast forms change their colors with great rapidity.

The sea-horses and pipe-fishes are queer forms, covered with a bony armor, but beyond this they differ considerably in appearance. The pipe-fishes are long and slender, and in them the fish shape is almost lost; while

FIG. 324. — Left, pipe-fish (*Syngnathus*); right, sea-horse (*Hippocampus*).

in the sea-horses the body is stouter, while the shape is the most bizarre of any of the fishes. There is absolutely nothing in the sea to which it can be compared, and, as may be seen by the cut, the comparison to a horse is very appropriate. One sees the equine head, and the long and gracefully curving neck; but there the resemblance stops, for the rest of the body of the fish is composed of the long and curling tail. In the reproduction of both pipe-fishes and sea-horses there is a feature to be noticed. As soon as the female lays the eggs, the male takes them and transfers them to a pouch beneath the tail, where they hatch, and at last escape. Dr. Lock-

wood has described the whole operation, and his picture after the young had been set free is too good to be lost in the pages of a scientific magazine.

"The scene that followed was one of singular and lively interest. I was nervous with delight, and wished that every naturalist could see it for himself. I am sure there is no student of nature but will excuse the enthusiasm which prompted me to write at once to a friend that 'he must not set the minister down as a horse-jockey, on being informed that he was now the proud possessor of the most numerous drove of colts ever owned by one man the whole wide world over.' Using my best judgment, — for, owing to the mazy motion of this tiny throng, counting was out of the question, — I set the number as not far from a thousand. . . . We might suppose it would require a few days for the young Hippo to find out the remarkable monkey-like endowment of its tail. Not so. Only look at what my own eyes beheld many a time, when a 'stampede' of these little colts was going on, although they were but a day old. There come two little Hippos, each swimming in a direction at right angles to that of the other. Just at the point of passing, one, lasso-like, whips his caudal extremity round that of his fellow, who, of course, in like manner, returns the caudal compliment, which, to speak technically, acts as a 'double lock.' Of course both pull, and by a natural law, the force is exerted in exactly opposite directions, and the right angle is resolved into a straight line. It is but poor headway they make, nor does it mend the matter much, that a third little fellow comes giddily on, and, switching his tail, takes a hitch at that precise point in space where the other two met. Now a triple force is exerted, and the effect is, with two straight lines to project three obtuse angles. And so the three toil on, obtusely laboring *in statu quo*. But a droller sight is that of yonder colt, who seems to be of somewhat belligerent proclivities, as he is leading by the nose a weaker member of his own species, having with his caudal extremity noosed him on the snout."

Both the sea-horse and the pipe-fishes are fond of lurking in the eel-grass and rock-weed near the shores. Our native species of sea-horse is much plainer than that figured, and lacks the long filamentary spines on the head and back. In an Australian species, on the other hand, these run to the other extremity, and project from all parts of the head and body, extending to a great length. Thus arranged, the animal is to a great extent safe from his enemies, as these streaming ribbons make him look almost exactly like the bit of sea-weed round which he twists his tail.

The trunk-fishes, though used to a limited extent as food in the tropics, have their sole interest in their strange shapes. The whole body is enveloped in a firm and unyielding case, composed of large plates, and which

usually has a triangular shape, the belly being flat, and the back acute. Specimens are very common in every museum and seaside town.

Distantly related to them are the peculiar swell-fish, mostly tropical, which, when captured, inflate the body with air so that another of their names, balloon-fish, is very appropriate. They have not the slightest economic value, but might almost seem to be constructed for the purpose of serving as curiosities. Of both these and the trunk-fishes there are several

FIG. 325. — Swell-fish, or balloon-fish (*Tetodon fahaka*).

species in the tropical seas; some occurring occasionally as far north as New England.

As useless as it is strange, is the large sea sun-fish which is found in all the northern seas, the Pacific as well as the Atlantic. Descriptive powers fail when one attempts to picture in words this ichthyic oddity. It is all head, and is chopped off square behind, where, on either side, arise the dorsal and anal fins. The tail-fin bears no resemblance to the ordinary tail of fishes, but seems rather a frill to relieve the otherwise utterly absurd appearance of the fish.

In our northern waters one occasionally sees these forms basking at the surface, with the dorsal-fin, like that of a shark, extending above the waves. At times it would almost seem as if they were asleep in this position, as they take not the slightest notice until the boat is close upon them. If one wishes a drenching this is his opportunity; for if he strike the fin, say with an oar,

he will know by the quantity of water which is instantly splashed over him, that the fish below is a large one. Indeed, they may weigh as much as seven or eight hundred pounds. Of their history as good as nothing is known.

The last of the true fishes to be mentioned bears a superfluity of names. In continental Europe it has about fifty, while in England and America

FIG. 326. — Fishing-frog (*Lophius piscatorius*), below; barracuda, above.

there are over fifteen more. Most common with us is fishing-frog, or angler, but the vulgar 'all-mouth' is far more descriptive, for the mouth certainly reaches 'from ear to ear.' It is the most wonderful of all mouths in existence. The figure does not begin to do justice to it. One can only realize its extent when a specimen lies on the wharf, its jaws propped open by a stick.

Many are the stories, some wonderful, all strange, which have clustered around this fish. Authors will tell you that it hops friskily about on the beach when left stranded, and that the peculiar tufted spine on the head is a veritable fishing-rod. The little fish, they say, cluster round it in the belief that some choice morsel is there, and that suddenly it strikes them, and knocks them into the cavernous mouth yawning below. In these stories, we are afraid that there is more fiction than fact.

Another tale, almost as fanciful, is that related by Mr. Kent. He regards the fishing-frog as one of the most perfect mimics in the whole realm of nature; but the present writer, although he has seen many of these fish alive and under the most favorable circumstances, has failed to see such remarkable features as the Englishman points out. Certainly his resemblances are strained, but still we must let him speak for himself. "The fish," says he, "while quietly reclining on the bottom of its tank, presented a most astonishing resemblance to a piece of inert rock, the rugose prominences in the neighborhood of the head lending additional strength to this likeness. This resemblance being recognized, it was found on a little closer inspection that the fish constituted, in connection with its color ornamentations, and manifold organs and appendages, the most perfect facsimile of a submerged rock, with that natural clothing of sedentary animal and vegetable growths common to boulders lying beneath the water, in what is known as the Laminarian Zone. In this manner the numerous, simple or lobulated membranous structures dependent from the lower jaw, and developed as a fringe along the lateral line of the body, imitate with great fidelity the little, flat, calcareous sponges, small, compound ascidians, and other low-organized zoophytic growths that hang in profusion from favorably situated sub-marine stones. That famous structure known as the angler's 'rod and bait,' finds its precise counterpart in the early growing phase of certain sea-plants, such as the oar-weed, while the more posterior dorsal fin rays, having short lateral branchlets, counterfeit in a like manner the plant-like hydroid zoophytes. One of the most extraordinary mimetic adaptations was, however, found in connection with the eyes, structures which, however perfectly the surrounding details may be concealed, serve, as a rule, to betray the animal's presence to a close observer. In the case of the angler, the eyes, during life, are raised on conical elevations, the sides of which are separated by darker longitudinal stripes into symmetrical regions, the structure, as a whole, with its truncated summit on which the pupil opens, reproducing, with the most wonderful minuteness, the multivalve shell of a rock-barnacle. To complete the simile, the entire exposed surface of the body of the fish is mapped out by darker, punctated lines into irregular, polygonal areas, whose pattern is at once

recognized by the student of marine zoology, as corresponding with that of the flat, cushion-like expansions of the compound truncate *Botryllus*. Thus disguised at every point, the angler has merely to lie prone, as is its wont, among the stones and debris at the bottom of the sea, and to wait for the advent of its unsuspecting prey, which, approaching to browse from what it takes to be a flat rock — differing in no respect from that off which it obtained the last appetizing morsel of weed or worm — finds itself suddenly engulfed beyond recall within the merciless jaws of this marine impostor."

The fishing-frog attains a very considerable size, and is common on our New England coast. It spawns in the summer, and a mass of its eggs is a truly beautiful object. The eggs, each with a drop of pink oil, are enveloped in a gelatinous ribbon, a foot or more wide and fifty, or even seventy, feet long. As seen floating in the sea the whole is a tissue of a slightly

FIG. 327. — Young fishing-frog as it escapes from the egg.

pinkish hue, more beautiful, and seemingly more delicate, than any product of the looms of man. The eggs hatch soon, and the young fish, on escaping from the egg, bears no resemblance to the adult fish. The mouth is small and delicate, and their ventral fins are long and rod-like, and for the first few days they increase rapidly in length, until they become half as long as the fish itself. Of the subsequent history nothing is known.

LUNG-FISHES.

A very few forms from tropical countries are grouped together as lung-fishes, since they have the air-bladder modified into a lung-like organ. Sometimes there is but one of these lungs, and in other forms there are two, as in the higher vertebrates. Though highly interesting to the naturalist, these forms have but little to attract the ordinary person; or perhaps it would be better to say that we know but little about their habits.

FIG. 328. — Lung-fish (*Protopterus annectans*).

Of the one-lunged forms there are two living species in Australia, known to the natives as barrmunda, while the colonists call them flat-heads. The flesh is good, but the fishes do not seem to be very abundant.

One of the two-lunged forms comes from Brazil, but it is among the rarest of all fishes. The other type is African, and is much better known. It is the doko, or komtok, of the natives, and the *Protopterus* of science. Its general appearance is shown in our cut. It lives in rivers and ponds.

and when these dry up in the hot season, they burrow beneath the mud at the bottom, where they form balls or cocoons in which they spend the time of drought in a semi-torpid condition. Dumeril, a French naturalist, has studied the way in which these cocoons are formed with fishes carried to France. He finds that the fish, on burrowing into the mud, secretes an immense quantity of slime, which fastens the mud together into a hard ball. These balls are occasionally dug out of the earth and carried to civilized countries, where a short immersion in water serves to release the fish, which swims as freely, with an eel-like motion, as in its native waters. Then it breathes by its gills; but when the water is dried up, the lungs are called into play.

The great interest for the naturalist in these forms is found in the fact that they occupy a position intermediate between the gar-pike and sturgeon on the one hand, and the frogs and salamanders on the other.

BATRACHIA.

The frogs, toads, salamanders, and the like are called either Batrachia or Amphibia; the former being derived from the Greek word for frog, while the latter has reference to the half-aquatic, half-terrestrial mode of life of many of the forms. In the older works the Amphibia were grouped with the reptiles; but now it is known that they are totally distinct. One marked peculiarity of these animals is the metamorphosis which many of them undergo. All of them, at least at one period of their life, breathe by

FIG. 329.—*Menobrachius* (*Necturus maculatus*).

means of gills, just as do the fishes, and some of the species retain this mode of respiration throughout the whole of their existence; while in others, the gills are absorbed, the gill-clefts close up, and then the lungs and skin are the organs in which the blood obtains its supply of oxygen. In the higher forms there are many other features introduced, which will be alluded to farther on.

One of the forms which retains its gills through life is that represented in our first figure. So far as the writer is aware, it has no common name,

unless it occasionally shares some of those belonging to other species to be mentioned further on. Its body is exceedingly fish-like, except that it is provided with four feet instead of fins; while the gills, instead of being placed in chambers at the sides of the throat, project from the sides of the neck like large plumes. This animal — *Necturus*, it is called — is found through a large part of the northeastern United States; but it does not occur in New England. Its only relatives are some white, nearly blind forms which live in certain caves in Austria.

A little higher in structure comes the ‘mud-eel’ of the southern states, and which is said to be comparatively common in the ditches in the rice-swamps of South Carolina and Georgia. It is exceedingly like an eel in its appearance, except that it has the same gills, only smaller, of the last-mentioned species, and a single pair of short legs. The negroes regard it with a sort of superstitious horror, considering it as extremely poisonous, and possessed of many other evil powers. In this respect the animal is greatly maligned; for it is a perfectly harmless form, whose sole object in life seems to be to get an abundant supply of worms and other food.

SALAMANDERS.

In the salamanders the external gills, so prominent in the other forms, disappear with growth. Less than a hundred are known from the whole world, and of these, fifty are found in North America. Largest of all our species is the ‘hell-bender’ of the Mississippi basin, which is especially abundant in the Ohio and its tributaries. It is an ugly, disagreeable-looking form, which occasionally grows to be two feet long. It is remarkably voracious, eating anything not too large to be swallowed. In this way it becomes a serious pest to the sportsman; for frequently these writhing and squirming creatures seize the bait, and are drawn to the surface, where they secrete a large amount of slime. Few fishermen will touch them; but will cut the line rather than try to release them from the hook. Their vitality is wonderful. Says Mr. Frear: “One specimen, about eighteen inches in length, which had lain on the ground exposed to a summer sun for forty-eight hours, was brought to the museum, and was left lying a day longer before it was placed in alcohol. The day following, desiring to note a few points of structure, I removed it from the alcohol in which it had been completely submerged for at least twenty hours, and no sooner placed it on the table before it began to open its big mouth, vigorously swayed its tail to and fro, and gave other undoubted signs of vitality. This form, large as it is, is surpassed by the giant salamander of Japan, which reaches a length of three feet.

Of all the salamanders but few are more famous than the axolotl of Mexico. It lives in the lakes surrounding the city, and is taken extensively and used as food. The flesh is stated to be excellent, and indeed there is no reason why it should not be; but most people from the United States regard it with feelings of aversion. This form is remarkable for the fact that it breeds in the larval stage, and the perfect form is as yet unknown. It is true that it is occasionally stated that it does reach the perfect state in Europe; but these observations are stated by Professor Cope (the highest authority on the subject) to be founded on error.

FIG. 330. — Hell-bender, or water-dog (*Protonopsis horrida*).

We figure here the form which really does change, and which has been confused with the axolotl; the differences between the two are so slight that for all ordinary purposes the cut will do as well for one form as for the other. At certain periods of the year these aquatic forms begin to breathe air, and at the same time the fringe-like gills begin to decrease. Then the fin-like fold upon the tail is absorbed, and at last the animal takes on the appearance shown in the next cut.

These axolotl-like forms are very interesting when kept in an aquarium. They exhibit hardly a trace of intellect, but are very voracious. It is amusing to feed a worm or a long, stringy bit of meat to them, allowing

FIG. 331. — Axolotl (the larval condition of *Amblystoma tigrinum*).

FIG. 332. — Adult of the axolotl (*Amblystoma tigrinum*).

one to take one end, and the other the other extremity. Each swallows its portion until at last the noses meet, and then begins a wonderful gymnastic exhibition. They tug and pull and turn one another over and over; the advantage now rests with one, and again the star of the other is in the ascendant. So it goes on, sometimes for hours, until at last the meat gives way, or one of the animals succeeds in pulling the strip from the mouth and stomach of its fellow.

Interesting from another point of view is the capacity these forms have of repairing injuries. One may cut off the entire foot, and in a short time it will be reproduced in miniature, and after a longer lapse of time it will

FIG. 333. — *Pleurodeles*, showing the ribs perforating the skin.

acquire the size of its fellow. It is even said that a partial extirpation of the eye will be repaired in the same way.

Of our more common salamanders but little need be said. Some of them live in the water (these are commonly called tritons, newts, or efts — corrupted into evets), and some in moist places on the land. By common superstition many, if not all, are regarded as poisonous, but this is erroneous. One of the European species, a large, yellow-spotted form, is celebrated from the story, older than the Christian era, that it can withstand fire. Thousands and thousands have been immolated to test the truth of the tale, and just so many times has its falsity been exposed. Still the story lives, and the writer once heard a man deliberately affirm

that he had seen one of these animals thrown into a coal fire, and then when the fire went out, it was found alive and lively in the ashes!

In Europe there is another curious species found, but its peculiarity lies in another direction. Our cut shows the form, and along the sides of the body may be seen some spines. These are really the extremities of the ribs protruding through the skin. What the function of this can be it is not easy to see. It may be that these spines render the salamander less liable to be swallowed by birds and other animals, and thus aid in the preservation of the species.

FROGS AND TOADS.

There are eight hundred different species of frogs and toads in the whole world, and sixty in the United States. They reach the extreme of forward batrachian development, and in their growth from the egg they parallel the succession of forms already mentioned. Most of the species lay their eggs in the water, and from them hatch out 'tadpoles,' which in their early condition have gills and a tail, and thus resemble somewhat in miniature the *Necturus* figured on a preceding page. As they increase in size, the gills are absorbed, and then the tadpoles to a certain extent are salamander-like. They differ, however, so far in the life from both the forms mentioned, in lacking legs, and hence they have to wriggle their way along by the vibration of the tail. Now the legs begin to grow out, the hinder pair appearing first as small buds, the front pair following a little later. It is commonly said that the tail now drops off. This would be a waste of just so much material, and nature is economical. The tail does not drop off, but is gradually absorbed, growing smaller day by day, until at last the tadpole becomes a frog or toad.

The tadpole is a vegetarian; his jaws are armed with horny plates suitable for scraping and gnawing all sorts of aquatic plants: and his intestine is very long, and coiled like a watch-spring in the body. When the perfect condition is reached, all this is changed. He now lives on flesh, and the intestine is proportionately greatly shorter. Some of the frogs and toads go through these changes in a single season, or even in a few weeks, but others require a year; while by keeping tadpoles in a cool, poorly lighted place, like a cellar, they can be retarded for several years.

All of the frogs and toads do not go through all these changes, and not all the eggs are laid in the water. In the West Indies there is a tree-toad which fastens its eggs to the leaves of trees, or hides them under stones; and in this case the perfect frog emerges from the egg. In another species of tree-toad occurring in Peru there is a pouch on the

back in which the eggs are kept, until the tadpoles are hatched, and then these escape into the water.

Most remarkable of all in its reproductive habits is the Surinam toad. This is a large form living in northern South America, with webbed hind feet, and the fingers of the fore legs terminating in most curious lobes. When the proper season comes round, the female lays her eggs, and the male takes them and places them on her back. The eggs are surrounded

FIG. 334.—Surinam toad (*Pipa americana*), with the young in the pits on the back.

with a glutinous secretion which makes them adhere; but this is not necessary long; for immediately the skin around each egg begins to thicken up, thus enclosing it as in a cup, until finally a lid is developed which closes the cup and keeps the egg from the air. Inside these cups the eggs undergo their development, having first gills, and then appearing like tadpoles with a well-developed tail; and lastly, on reaching the frog stage, forcing up the lids and escaping, as shown in the cut.

Among the most useful animals to the gardener and agriculturist are the oft-despised toads. The amount of noxious insects they will devour

every twenty-four hours is almost beyond belief. They seem so slow and clumsy in their hopping gait that unless one has watched them, it seems hardly possible that they can catch forms so active as most insects. And yet a few moments' watching will show how they do it. Look at some old fat toad as he sits blinking his eyes in the shade of a grape-vine. He seems utterly oblivious of everything; but wait until some fly lights near him. With the quickness of light his long tongue is thrust out, the fly sticks on the end of it, and is drawn into the mouth before you are aware of it, and there sits the toad as stolidly as before. Occasionally he captures a form, like a grasshopper or earthworm, too large to be swallowed at a single gulp; then he puts up one of his paws and tries to hold it down, or, slowly hopping to some stick or stone, tries to "butt" the insect down, by knocking it against the object.

In the early spring the toad is one of the first forms to be heard in the ponds and puddles. It takes a long breath, and then expanding a vocal sac beneath the throat, it utters its rolling musical note. This is its love-song, and if one visits the pond at this time, he will find it filled with toads. A week later and the song has stopped in the pond, and not a toad is to be seen there; but from some retired spot you can occasionally hear the same 'urr-r-r-r-r,' and there the toad is to be found.

One of the most peculiar of the North American toads is the spadefoot toad, which receives its name from a projection on the foot used in digging. These forms, while really quite abundant, are but rarely seen, from the fact that they live subterranean lives, only coming to the surface for breeding purposes in the month of April, and then after a few weeks suddenly disappearing. Dr. C. C. Abbott has written a long account of these forms, and a few extracts from his paper will illustrate the peculiar features of their economy. His observations were made near Trenton, N.J., in 1884. "During the night of June 25-26, a violent northeast storm arose, and the rain fell in torrents. The sink-hole which for weeks had been nearly dry, was again flooded, and on the afternoon of the 26th was literally alive with these rare toads. Sitting on every projecting stick or tuft of grass, or swimming with their heads above the surface of the water, were spadefoots by the hundred, and every one apparently uttering those shrill, ear-piercing groans which only these batrachians can utter. Not only during the day, but all night their cries were kept up. The following day there was no abatement, but during the night the sound decreased. On the morning of the 28th not an individual was to be seen or heard."

In these two days they had laid their eggs and returned to the underground burrows. The eggs hatched out, the tadpoles changed to frogs, and a month later every individual of the new brood had disappeared.

Some of the young, kept in confinement, dug their oval oblique holes in the sand, almost all of them disappearing below the surface in twenty minutes. Concerning the note made by this species Dr. Abbott says in another place: "So unlike the cries of any other of our batrachians were their utterances that all who heard them were attracted to the spot, and wondered, when they saw the animals, that so great a volume of sound could proceed from so small a creature. One need not wonder, however, on this point, if they will examine the development of the animal's vocal cords. The machinery for producing sounds equal to an ordinary steam-whistle is apparently contained in the throat of this rare and curious batrachian."

The tree-toads are elegant forms adapted for an arboreal life. The ends of their fingers and toes are expanded into broad discs, to the better enable them to adhere to the leaves and branches of trees, while their colors are such as to conceal them from observation. Indeed, they have the power to change their colors to a considerable extent in order to agree

FIG. 335.—Tree-toad (*Acris gryllus*).

more closely with their surroundings; and our commonest species will be dark brown or ashy gray when on the trunk of a tree, but when found among the leaves it is green. The tree-toads are strong and usually pleasing singers, some of them furnishing the shrill 'pee-wee' of the early spring, while others are heard later in the year, or indeed during the whole season, until the time for hibernation comes round.

There occurs in the Malayan Islands a very peculiar frog which is called the flying-frog. Mr. Wallace, its discoverer, describes it as follows: "One of the most curious and interesting reptiles which I met with in Borneo was a large tree-frog, which was brought me by one of the Chinese workmen. He assured me that he had seen it come down, in a slanting direction, from a high tree, as if it flew. On examining it I found the toes very long, and fully webbed to their very extremity, so that when expanded they offered a surface much larger than the body. The five legs were also bordered by

a membrane, and the body was capable of considerable inflation. The back and the limbs were of a very deep shining green color, the under surface and the inner toes yellow, while the webs were black, rayed with yellow. The body was almost four inches long, while the webs of each hind foot, when fully expanded, covered a surface of four square inches, and the webs of all the feet together about twelve square inches. As the extremities of the toes have dilated discs for adhesion, showing the creature to be a true tree-frog, it is difficult to imagine that this immense

FIG. 336. — Flying-frog (*Rhacophorus*).

membrane of the toes can be for the purpose of swimming only, and the account of the Chinaman, that it flew down from the tree, becomes more credible. This is, I believe, the first instance known of a flying-frog.

Of the true frogs the species are numerous, there being considerably over a hundred known. We usually associate a frog with water, but there are large numbers which only go near the water to lay their eggs, and some of these may be terrestrial, while others live in trees in exactly the same way that do the tree-toads. Still it is to the aquatic forms that we must go for our typical frogs. Best known of these with us is the large bull-frog, which occasionally reaches a length, legs included, of eighteen or

twenty inches. These large specimens are not common, and usually but one or two will be found in possession of a pond. Their note is very aptly compared to the bellowing of a bull; for, with the exception of the spadefoot toad, the bull-frog is the loudest voiced of any of our amphibians. During the day he keeps quiet or utters only an occasional croak, but at dusk, especially in early summer, his loud metallic voice drowns all the other choristers of the pond.

The bull-frog lays its large masses of eggs, enveloped in a gelatinous matrix, in the spring; the tadpoles soon hatch out and eat everything which comes in their way. With their horny jaws they attack decaying animals and plants, scraping away the soft parts little by little, until at last but the hard, indigestible portions remain. The anatomist frequently takes advantage of this and sinks the animal of which he desires the skeleton in a pond filled with tadpoles of various sorts. In a short time every particle of flesh has been torn and gnawed away, leaving naught but the bones and ligaments behind, but these in perfect condition. While the tadpoles of most frogs go through their changes in a single season, those of the bull-frog last through the winter, and through the ice one can see them wriggling about and following the same life as in the warm days of summer.

It is beyond our province to describe the various species of our common frogs, — the green frog, marsh-frog, leopard-frog, and the like. Each has its favorite habitat, and each utters its own peculiar note. All are carnivorous, and anything — insects, fishes, tadpoles, or worms — that comes in their way is eagerly devoured. All are edible, and nothing is more palatable than a mess of frogs' legs, properly cooked.

CÆCILIANs.

Strangest of all the amphibians are the worm-like Cæcilians of tropical countries. The casual observer would not in the least suspect that they have the slightest relationship to the frogs and salamanders, but would rather regard them either as worms or as snakes. They have long and worm-like bodies, and are without any traces of limbs. Their eyes are rudimentary, or these animals may be entirely blind, a fact alluded to in the name given them, which is derived from the Latin *cæcum*, blind. And yet in all their anatomy they show resemblances to the salamanders. Even in their growth they pass through similar stages, having at one time gills; these organs being like the fringes of the *Necturus*, or the mud-eel, or axolotl, in the walls of which the blood-vessels ramify. In the adult condition they breathe by lungs, like any frog or salamander. The species

BULL-FROGS (*Rana catesbeiana*).

of Cæcilians are few, and specimens are rare. Most of the forms occur in tropical America, but others are found in Ceylon, Siam, etc. In their habits they are somewhat like earthworms, as they live in holes in the damp earth, and feed on insects and other forms which they may capture.

FIG. 337.— Blind-worm (*Cæcilia*).

According to the Brothers Sarasin, who studied them in Ceylon, they lay their eggs in long strings, and instead of depositing them in the water, the mother incubates them. A similar condition occurs in the mud or Congo eel of the southern states (p. 359); an additional proof of the view of Professor Cope that the Cæcilians have descended from *Amphiuma*-like forms.

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