CHAPTER XIII

PHYLUM—ARTHROPODA

General Characteristics. Arthropoda comprise the greatest collection of contemporary animal forms, consisting of about half a million known species. They are triploblastic Metazoa; the embryo exhibits a gastrula stage; they are bilaterally symmetrical; the digestive tract has a mouth and an anus, and has special divisions for particular functions; the coelome is limited in extent in the adult; the body is segmented and the segments bear jointed appendages. The word Arthropoda is derived from the Greek words "arthron" meaning *joint,* and "podos" meaning *foot.* Active locomotion is characteristic of many. Although all the adult body segments do not bear appendages, yet since this is mainly true of the segments of the embryo body, the opinion is maintained that the ancestors of the Arthropods, like the Annelids, possessed appendages on all the body segments. Since there appear to be fewer segments in the adult body than in the embryo, because a fusion takes place during development, it is concluded that the ancestor of the arthropod was an annelid-like creature. This idea is strengthened by the observation that many of the internal organs resemble those of Annelids. For example, there is similarity in the central nervous systems.

Three great groups of Arthropods are discussed here, first: Crustacea, which are largely aquatic and breathe by means of gills, and have two pairs of antennae; second: Insecta, air-breathing forms with one pair of antennae; and third: Arachnida, for the most part air-breathers with no antennae.

A. CLASS — CRUSTACEA

Study of a Type — Crayfish or Lobster

The crayfish is a common fresh-water crustacean, while the lobster, a salt-water form, is a familiar example (Fig. 182). The lobster is a larger animal than the crayfish, yet they both have the same general structure.

Body Regions. The body shows two main divisions: (*a*) *cephalothorax*, a combination of head and thorax, and (*b*) the *abdomen*. A horny or chitinous exoskeleton covers the soft inner organs. Although the head-thorax appears to be a single structure, yet there are embryological and other evidences indicating that it comprises thirteen segments, while the movable abdomen has six segments and an end piece called the *telson*. A groove marks the division between the head and thorax. The *carapace* is the hard dorsal cover of the cephalothorax and it is extended in front as the pointed *rostrum*. Side shields protect the lateral *gills*. Each segment bears a pair of *jointed appendages*. There is considerable variation in these, but an extended study of the appendages of crustacea indicates that in spite of differences between them in the adult condition there are evidences that modifications of an original or primitive type plan have occurred during the course of evolution. Before considering this further, let us list the appendages as they occur in the crayfish.

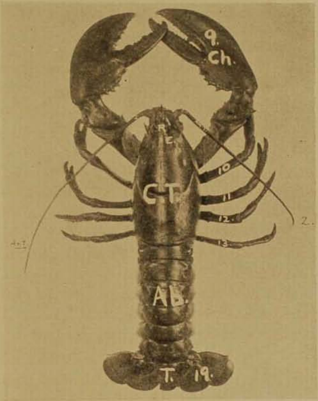

Fig. 182. — Homarus americanus — common lobster. 9. Ch. — 9th appendage (cheliped); 9-10-11-12-13. — walking legs; R. rostrum; E. eye; C. T. — cephalothorax; Ab. abdomen; T. telson; 19 — 19th appendage; Ant. 2 — Antenna. (Courtesy American Museum of Natural History.)

Appendages. 1. Antennules — most anterior possessing sense organs of touch, taste and balance.

2. Antennae — long processes, having sense organs of touch and taste.

3. Mandibles — heavy jaws for crushing food.

4. First Maxillae — very small.

5. Second Maxillae — making water currents, aerating the gills.

6. First Maxillipeds — have sense organs of touch and taste, and hold food particles.

7. Second Maxillipeds — similar in function to the preceding pair.

8. Third Maxillipeds — similar in function to the preceding pair.

9. Chelipeds — the big pincers, fighting organs; also act as walking legs, *i.e.*, first pair.

10. Second pair of walking legs, long and slender.

11. Third pair of walking legs, long and slender.

12. Fourth pair of walking legs, long and slender.

13. Fifth pair of walking legs, long and slender. They also are body cleaners.

14. First pair of swimmerets are small weak paddles in the female but stronger in the male and used to transfer sperm to seminal receptacles of female. These are first abdominal appendages.

15. Second pair of swimmerets are small weak paddles in female but in male used with first pair to transfer sperm to seminal receptacle of female.

16. Third pair of swimmerets — similar to above. These and the following fourth and fifth pairs used by female in carrying eggs until after hatching.

17. Fourth pair of swimmerets — similar to above.

18. Fifth pair of swimmerets — similar to above.

19. Sixth pair of abdominal appendages — broad flat paddles which with telson enable the animal to shoot backward quickly.

Homology. It is evident that for the most part each pair of appendages has a particular function to perform. They are not identical with each other in detail. Yet sufficient similarities are present which, considered with their embryological development and a study of appendages of various Crustacea, indicate that the primitive crustacean (as well as other Arthropods) possessed appendages composed of similar parts on all the segments and that in the course of evolution these became modified in one way or another for particular functions. It is concluded that they were similar embryonically and that even in the adult condition they show *underlying likenesses* in structure. Basic structural resemblances indicate genetic relationships and are known as *homologies.* When they occur as resemblances between parts of the same animal they are known as *serial homologies.* The appendages of the crayfish are serially homologous. Evidences of a similar condition found in other Crustacea indicate the common ancestry of all Crustacea. Homologies are considered very reliable evidence of genetic relationships of forms that seem to be unrelated. This method of reasoning is used to a great extent in Taxonomy and in tracing evolutionary lines.

For example, the fore limbs of frogs, lizards, birds and the various mammals exhibit a great variety of function and a certain amount of variety of structure, yet all show an essentially similar anatomical structural plan. All are homologous and this is regarded as an index of phylogenetic relationship.

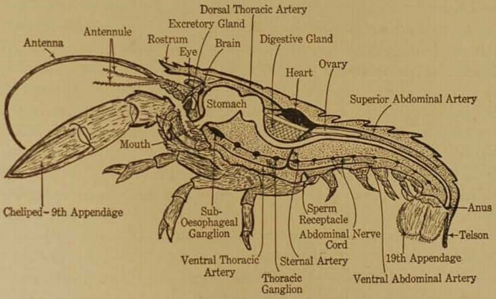

FIG. 183. — Anatomy of lobster. (Modified from Herrick — U. S. Bureau of Fisheries.)

Digestive Tract. Crayfish feed principally on animal matter. The maxillae and maxillipeds act as hands to hold the food so that the mandibles can separate it into small pieces to be swallowed (Fig. 183). The food passes through the oesophagus to the stomach. This is composed of an anterior gizzard-like first part, where the food is ground up between hard surfaces; then the fine food passes into the posterior stomach, where it is digested. It passes then into the intestine to be absorbed. Feces collect in the posterior region of the intestine to be ejected through the anus.

Circulatory System and Blood. The blood is a pale liquid containing ameboid white blood cells, phagocytic in function. Between the tissues are spaces called sinuses filled with blood bathing the adjacent tissues. In a dorsal sinus lies the heart, a tubular sac with openings on its side walls. A number of arteries extend from the heart to various organs. The contractions of the heart drive the blood out to various organs and into the sinuses, from which it finds its way back to the heart again — a crude sort of circulation compared with that of the Vertebrates. Plume-like gills lie in gill-chambers on the side of the thorax, beneath the lateral walls of the carapace. The second maxillae, just in front of the gill chamber, scoop the water forward, drawing a current through the gill-chamber from behind, aerating the gills. The blood contains a protein-copper compound called *haemocyanin*, which has the property of combining with oxygen absorbed through the gill membranes from the water outside. A compound called oxyhaemocyanin is formed. This blood compound serves to carry oxygen to the tissues. Here it breaks down, liberating oxygen which is absorbed by the cells of the tissues. Haemocyanin probably carries carbon dioxide back from the tissues to the gill membranes to be excreted.

Excretory System. Organs of excretion are two ' green glands,' located in the head, and they discharge their wastes through openings at the bases of the antennae (second pair of appendages).

Nervous System. The central nervous system is similar to that of the earthworm. Above the oesophagus is the brain or supra-oesophageal ganglion, a fusion of primitive segmental ganglia. A nerve ring connects the brain with the suboesophageal ganglion, also a fusion of primitive segmental ganglia. Five single ganglia in the thorax and six single ganglia in the abdomen are all connected with each other and with the suboesophageal ganglion by a nerve cord ventral to the intestine.

Sense Organs. The eyes are located at the end of movable stalks. Each eye is compound, being composed of a great many (2500) little eyes or *ommatidia*. Sense organs of equilibrium or position are located in the base of each antennule. Tactile and olfactory sense organs are also believed to be present.

Muscles and Skeleton. In our bodies, the skeletal muscles are attached to the outside of the bones, while in the crayfish they are attached to the inside of the chitinous exoskeleton. In both cases the result is a mechanism of movable levers.

Reproductive System. Crayfishes are dioecious. Spermatozoa formed in the bilobed testes pass through the vasa deferentia out by a pore at the base of the fifth pair of walking legs. The testes are below the heart. Copulation usually takes place in the autumn. The male transfers sperm to the female *seminal receptacle*, between the fourth and fifth pairs of walking legs. A bilobed ovary, below the heart, and a pair of oviducts are present in the female. Each oviduct opens at the base of the third walking leg. The female produces eggs in the spring, fertilizing them as they pass by the seminal receptacle. They are attached to the swimmerets at this time and so remain until after hatching. A gentle movement of the swimmerets aerates them.

Ecdysis. As the crayfish grows it periodically sheds its " shell " to provide for the increase in size, a process known as *ecdysis*, just after which the animal is soft and defenseless.

Autotomy. Crayfishes and a number of other animals possess a remarkable property of dropping off certain of their appendages, if these are injured. The break occurs at definite joints organized for this purpose. The process is known as *autotomy*. Later a new appendage is regenerated. Autotomy and the consequent regeneration constitute processes of great defense value.

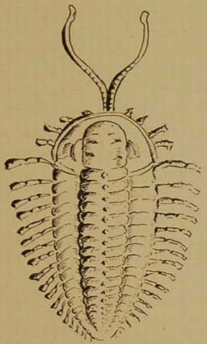

Fig. 184. — Trilobite, Triarthrus becki. (From model by Ward.)

Subclasses. There are about 16,000 species of Crustacea. A few, such as land crabs and sowbugs, live on land, but most forms are marine. They feed largely on decaying animal and plant matter.

There are two subclasses: (*a*) Entomostraca, which are very small forms and occur in great numbers in fresh and salt waters, forming no inconsiderable part of the food of the fishes of commerce. The extinct *Trilobites* (Fig. 184) belong to this class. They flourished during early Palaeozoic periods but have been extinct since the late Palaeozoic. They had a pair of antennae and many body segments all possessing appendages. (*b*) The Malacostraca are larger forms. Aristotle devised the name and he

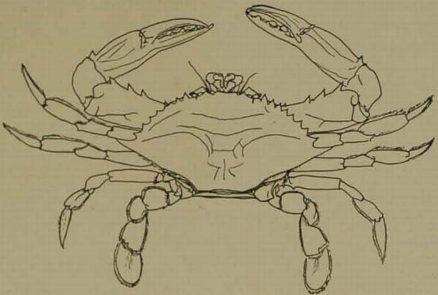

FIG. 185. — Callinectes, the Blue Crab. (U. S. Bureau of Fisheries.)

meant by it soft-shelled animals to distinguish them from hard-shelled Mollusca. The class includes lobsters, crayfishes, crabs (Fig. 185), shrimps and sowbugs (Fig. 186), land crustaceans.

Remarks. Parasitism occurs in many forms. The parasitic forms tend to lose their appendages, segmentation and sense organs, but the organs of reproduction are more highly developed. Some Crustacea live in partnership with other animals. The hermit crab (Fig. 187) lives in the cast-off shell of some sea snail, and on the shell may also be found a colony of Hydroids (*Hydractinia*) or sea-anemones. Other crabs decorate the back of the body with seaweeds. This masking serves excellently as a defense. The Japanese spider crab is probably the largest of the Crustacea. Its small central body has long jointed legs and it may measure twenty feet from tip to tip of the first pair of legs. Lobsters, shrimp and crabs are of great economic importance. The most productive regions for lobsters have been Canada, United States, Ireland and Norway. Maine has the largest lobster fisheries in the United States. Lobsters spawn

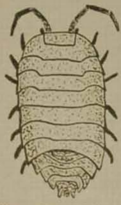

FIG. 186. — Oniscus, sowbug.

when about seven inches in length but attain sexual maturity when ten inches long. The greatest recorded length is 23.75 inches and the greatest weight thirty-four pounds.

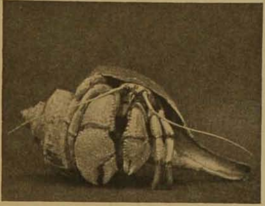

FIG. 187. — Hermit crab occupying shell of marine gastropod. (Courtesy Amer. Mus. Nat. Hist.)

B. CLASS — INSECTA

General characteristics. These Arthropods have a segmented body, jointed legs, chitinous exoskeleton, ventral chain of ganglia joined by a nerve ring with a dorsal brain. The body is divided into three regions: head, thorax and abdomen. The head has a pair of antennae in front of the mouth and a number of pairs of mouth appendages. The thorax has three segments with a pair of legs on each. It usually has also *one pair* of wings on *each* of its *two* posterior segments. There are no appendages on the abdomen.

The Morphology and Physiology of the Honey Bee

Head. The bee is a 'hairy' insect (Fig. 188). Its body is divided into a head, thorax and abdomen. The head is rather triangular in shape, seen from in front (Fig. 189). On either side above

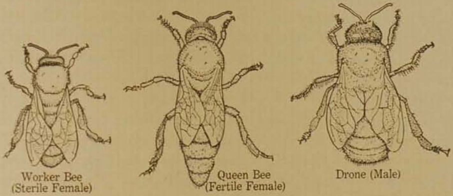

FIG. 188. — Honey bees. (From Bureau of Entomology, U. S. D. A.)

are two large compound eyes, and on top there are three small simple eyes. From near the middle of the face originate two segmented movable antennae. Below and laterally are two strong mandibles or jaws. Below the origin of the antennae and in front is a shield-like plate, the clypeus, and attached to the lower edge of this is the lip or labrum. Below the labrum, and the base of the mandibles, is the mouth. Behind the mandibles is a complicated structure called the proboscis, a very important part of it being a long flexible, hairy glossa or tongue. By means of this apparatus the bee feeds on liquids such as the nectar of flowers and on pollen.

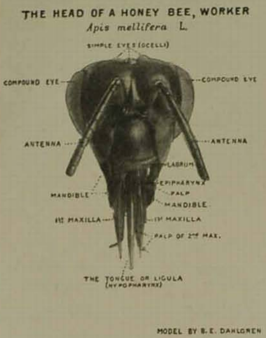

FIG. 189. — Head parts of worker bee. Photo of model. (Courtesy of Amer. Mus. Nat. Hist.)

Thorax and Appendages. The head is movably attached to the thorax by a short, narrow neck. The thorax is short and stout. It supports two pairs of wings and three pairs of legs: prothoracic, mesothoracic and metathoracic. Each leg is a jointed structure composed of the following parts (Fig. 190), beginning with the segment next the thorax: (*a*) coxa; (*b*) trochanter; (*c*) femur; (*d*) tibia and (*e*) the five-parted tarsus terminating in two claws with an adhesive organ between them. The proximal part of the tarsus is longer, broader and larger than the others and is known as the basi-tarsus or planta. The last joint of the tarsus bears two claws by means of which the bee holds to most objects in its locomotion. Between the two claws, however, is a soft pad, usually drawn up out of the way of the claws. When the bee lights on a hard or slippery surface, the claws turn out and the adhesive organ flattens down against the smooth surface, at the same time secreting a sticky substance affording a temporary hold on the surface. The wings, legs and mouth parts are organs or tools with which the worker bee collects nectar, gathers pollen, stores it in cells, makes comb and performs all the many tasks connected with the life of a honey bee community. The legs are not only organs of locomotion but possess tools for special uses. Along the anterior edge of the tibia of the fore leg is a border of little stiff hairs, the eye brush, used for cleaning the compound eyes, which may get covered with pollen from visited flowers. The basi-tarsus or planta has long hairs forming a pollen brush, used for cleaning the front part of the body and the mouth parts. At the upper end of the basi-tarsus is a circular notch or antenna cleaner. The mesothoracic legs are larger but do not have the freedom of movement of the front legs. The basi-tarsus here is larger and broader and forms an efficient pollen brush or planta. The outer end of the tibia has a stiff

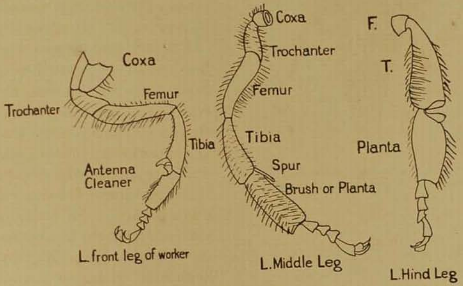

Fig. 190. — Legs of worker bee. After Casteel — U. S. Dept. Agriculture.

spur for prying off the wax produced in the wax glands of the abdomen.

The metathoracic, or hind legs, are the largest and have a more diverse range of movements than the middle legs. The inner surface of the basi-tarsus with its short hairs serves as a pollen brush and also retains pollen until it can be placed in the pollen baskets, which are on the outer surface of the lower part of each tibia and consist of fringes of long hairs bending out from either edge of the tibia.

Abdomen. The abdomen of the adult bee contains six visible segments although there were twelve in the embryo, according to Nelson. The last two disappear before hatching and the eighth, ninth and tenth become modified to form structures inclosed by the seventh which appears to be the last abdominal. The first segment becomes part of the thorax. Therefore the six visible abdominal segments are the developed second, third, fourth, fifth, sixth and seventh embryonic abdominal segments. Near the posterior end of the body of the female is the ovipositor, while in the male there are appendages used in copulation. Near the tip of the abdomen, but above, are the scent glands. It is believed that bees working about flowers rich in pollen secrete a substance from these scent glands which *marks that place* for other bees who can find it from the *odor*. On the ventral surface of the abdomen are wax glands in which wax is formed as a liquid that later hardens into little plates (Fig. 191), which the bee can pry out with the spine on the middle leg and then hand up to the mouth, where the mandibles prepare it for use in comb building. Associated with the ovipositor is the sting, a complicated piece of apparatus, part of which functions as a hypodermic needle. Liquid from the poison glands is injected into the wound, causing pain and swelling.

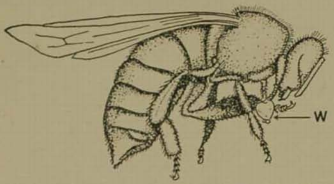

FIG. 191. — Worker bee transferring wax plate from abdomen to mouth. From Casteel — U. S. Dept. Agriculture.

The bee has a hard, chitinous exoskeleton. Segmented parts are moved by means of highly specialized muscle tissue, similar in a number of respects to the skeletal muscle of Vertebrates.

Metamerism. We have already learned that the earthworm is a segmented or metameric animal. There are many evidences of metamerism in Insects, in fact in all the Arthropoda. The head appears to be an unsegmented part of the body, and yet in the embryonic insect head there are usually six segments, most of which bear appendages. For example, the first bears the eyes; the second, the antennae; the third, appendages which early disappear and correspond to the second antennae of the crayfish; the fourth bears the mandibles. The embryonic head segments later fuse and leave no evidence, other than appendages, of the early condition of metamerism. The thorax, bearing the legs and wings, is composed of three segments, but embryonically it had four. It has already been stated that the abdomen consists of six segments derived from eleven in the embryo (or twelve if we include the first which is later part of the thorax).

Although the adult appears to be composed of only ten segments, yet we have shown that it is a modification of an embryo composed of twenty-one segments. The phenomenon of body segmentation is regarded in biology as of great theoretical interest. Many biologists regard Arthropods and Vertebrates as having been derived from segmented animals, such as the Annelids. Moreover, although the abdominal segments appear to be devoid of appendages, yet in the embryo these are present and disappear before the larva hatches from the egg.

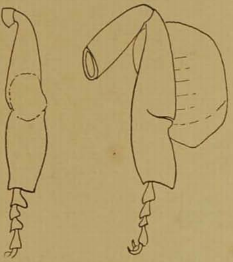

Fig. 192. — Pollen basket partly filled on leg at the left; Complete load shown in right-hand figure. From Casteel — U. S. D. A.

Pollen Collection. When bees visit flowers for pollen, they accidentally get more or less covered with it. But Casteel and Sladen have independently shown that the pollen they actually seek is scraped off and licked with the tongue and mixed with honey regurgitated from the honey stomach. The head and mouth parts get smeared with sticky pollen. It is removed by the pollen brushes of the fore legs, some of it sticking to the thorax in so doing. Now these parts are cleaned by the brushes of the middle legs. So these get filled with pollen. Then each of these in turn is taken between the brushes of both hind legs and drawn through. Let us assume that the bee has freed the planta of the left middle leg. Its pollen is now on the planta brush of the right hind leg, and then the right middle leg is cleaned next. The bee then transfers the pollen to the pollen baskets (Fig. 192).

Intestine. The alimentary canal (Fig. 193) consists of a pharynx, an oesophagus, a honey stomach or crop, a short and small proventriculus, a long and large ventriculus or true stomach and a narrow, small intestine connecting the ventriculus with the large rectum. Joined to the small intestine, at the anterior end, are about one hundred long, white, small, coiled Malpighian tubules. These are organs of excretion by which nitrogenous wastes of metabolism are removed from the blood and discharged into the intestine to be removed with the feces. The honey stomach acts as a reservoir for nectar until the bee can get back to the hive. The honey stomach also carries a supply of honey to be used in collecting pollen. The rectum is a large, thin sac forming the posterior portion of the digestive tract. Excreta and feces collect here while the bee is in the hive and retained until discharged outside. During the winter, when the bees are confined to the hive, the rectum becomes greatly distended with wastes, which are held until the first flight in spring.

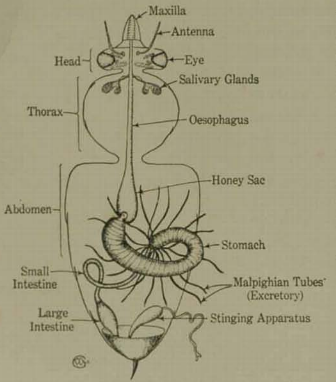

FIG. 193. — Digestive tract of bee. From Thomson (after Cheshire): *Outlines of Zoology*, D. Appleton & Co. Reprinted by permission.

Connected with the pharynx cavity are the pharyngeal glands which manufacture the brood food, — a gummy, white paste, given to the larvae in the comb cells. The queen larva is fed on this royal jelly entirely, while drone and worker larvae although given royal jelly at first have honey and pollen added on the third day and these become their main food. However, if worker larvae are fed royal jelly they become queens. It is the young workers who attend to the feeding of the larvae. Lineburg says that these young nurses pay each brood cell over 10,000 visits of feeding and inspection during the week that elapses between the time the queen lays the egg and the time the cell is capped for the pupa stage. Little is known concerning the details of digestion in the honey bee. Pollen is the primary source of protein food, while nectar and sugar given by the beekeeper are the principal carbohydrate foods. They cannot utilize *all* kinds of sugars, nor is starch digested by them. They apparently have little use for fats. Snodgrass thinks that most albuminoid absorption occurs in the small intestine.

Blood and Circulatory System. The blood is a pale, somewhat brownish fluid composed of a liquid plasma in which are ameboid wandering leucocytes functioning as scavengers of bacteria and dead cells. The blood does not contain hemoglobin. Blood fills the spaces between organs of the body cavity, and all body tissues are in a sense bathed in it. A crude sort of circulation is present (Fig. 194). A sheet-like band of muscle forms a kind of diaphragm across the upper part of the abdomen. There is another similar diaphragm ventrally. In the dorsal space or sinus formed by the dorsal diaphragm lies the long tubular heart, which extends as a fine tube through the thorax into the head. In the side walls of the larger abdominal portion of the heart are perforations communicating with the blood of the body cavity. When the ventral diaphragm pulsates, it drives the blood back and up toward the dorsal diaphragm. The contractions of this expand the sinus or space above it and so the blood is sucked into the dorsal sinus. This diaphragm pulsates, driving the blood into the heart which pumps it forward into the head, from which it flows slowly back through the thorax into the abdomen. In the process most of the tissues are bathed by moving blood and it is probable that many cells make their exchanges of food, oxygen and wastes by diffusion. It will be of interest to compare this *crude type of circulation* with that of the frog.

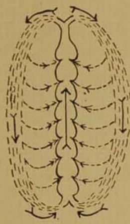

FIG. 194.—Scheme of circulation in insects. From LeConte: *Comparative Physiology and Morphology of Animals*, D. Appleton & Co. Reprinted by permission.

Respiratory System. Oxygen is delivered almost directly to the tissues through a complicated system of branching air tubes called tracheae. There are several entrances to this tracheal system from the outside. They are called spiracles, of which three pair occur on the thorax and seven on the abdomen. Associated with the tracheal tubes are large air sacs in all three parts of the body. The smallest tracheae are thin-walled tracheoles ending blindly among the tissues and permitting diffusion of oxygen and carbon dioxide. The bee exhibits respiratory movements. Inspiratory muscles expanding the abdomen cause inflow of air and expiratory muscles contracting the abdomen cause expiration of air. Some physiologists do not accept the theory that because air is thus brought so near the tissue cells, no special oxygen and CO_2 carrying compound like hemoglobin is necessary. It is known that the blood of many aquatic Invertebrates contains hemocyanin, a compound not containing iron as in hemoglobin but rather copper. Mettkowski has recently discovered the presence of copper in the "blood" of many insects also. Nevertheless, it appears as though the chief labor of delivering oxygen to tissues and removing carbon dioxide from them depends upon the tracheal system.

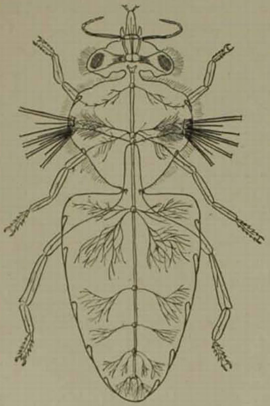

FIG. 195. — Nervous system of bee. From Thomson (after Cheshire): *Outlines of Zoology*. D. Appleton & Co., reprinted by permission.

Nervous System and Sense Organs. The nervous system (Fig. 195) resembles that of a crayfish and also that of the earthworm, though more specialized than the latter. Above the oesophagus is the large bilobed brain, a compound ganglion. This is connected by nerve cords around the oesophagus to the suboesophageal ganglion, also a compound ganglion. Behind this, in the ventral part of the body cavity, is the nerve trunk. Along its course are seven ganglia, one in the prothorax, a large compound ganglion in the thorax behind this and five smaller ganglia in the abdomen. During development, fusion of a larger number of embryonic ganglia takes place. From the ganglia, nerves go out to all parts of the body. The elements of the sensory organs, nervous system and muscles form a complexly organized adjustment system far more elaborate than is needed for a simple reflex mechanism.

The principal organs of vision are the large compound eyes. Photographs taken with the portion of an insect's eye as a lens registered as many pictures as there were facets through which vertical rays of light passed. Each little picture was slightly different from its neighbors, the facets on the right side taking more of the right side of the object, those on the left taking more of the left side of the object, etc. It is the function of the brain to *interpret* this multiple image. It is believed that insects perceive moving objects quickly; they also appear to " remember " landmarks. Bees see colors familiar to us and probably others beyond the violet end of the " human " spectrum. Observations and experiments indicate that external stimuli of various kinds arouse in the bee sensations which to us are those of vision, sound, smell, taste and feeling. Whether the insect sensation is *similar* to ours seems impossible of verification.

Although reactions of the bee to various stimuli demonstrate the above general conclusions, at the same time the exact location of many of the sense organs has not been determined. Considering the difficulties attending such investigations, the discoveries that have been made demonstrate the ingenuity of the human mind. Frisch appears to have demonstrated that the sense organ concerned in the perception of the delicate odor of flowers is located in the antennae and McIndoo has shown that sense organs stimulated by stronger odors are on other parts of the body, but Snodgrass is inclined to conclude that " there is little unanimity of opinion yet as to what function belongs to any particular set of sense organs, except the eyes."

Reproduction. The mating of a queen and a drone occurs high in the air during the so-called " nuptial flight." At this time the male copulates with the female, discharging into her vagina thousands of spermatozoa which have been formed by the testes and stored in the male seminal vesicles. After the male has discharged the sperm, secretions from the male mucous glands located near the seminal vesicles are also discharged into the vagina. These secretions coagulate preventing the loss of the sperm. In a short time the sperm pass into the spermatheca, a sac on the dorsal wall of the vagina. The queen later devotes her energies to laying eggs in the brood cells. In most of them she deposits fertilized eggs. As the eggs pass from the oviduct down the oviducts to the vagina, they pass by the orifice to the spermatheca. A sperm-pump deposits a few sperm on each egg as it passes. The fate of the fertilized eggs depends on the food furnished the larva. If entirely royal jelly, in large brood cells, queens result; if chiefly pollen and honey, in smaller brood cells, workers or infertile females develop. The queen deposits hundreds of eggs during each day of the honey season. According to Nolan, a queen observed by him kept up a daily average of 1640 eggs for twenty-six days. The sperm remain alive during the queen's entire life of four years. When the supply of eggs becomes exhausted, as may later occur, she can lay only unfertilized eggs which will develop into drones. However, Snodgrass states "So far as we know at present the working of the sperm-pump depends on the 'will' of the queen," which implies that the queen can lay unfertilized eggs although sperm still exist in the spermatheca. The development of fertilized and unfertilized eggs of the bee is later referred to in our discussion of Genetics.

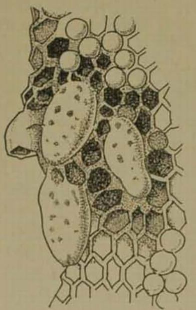

FIG. 196. — Queen cells of honey bee. From Phillips — U. S. Dept. Agriculture.

Functions of Workers. The workers, sterile females, carry on the routine work of the colony. They construct three principal types of cells. First, smaller worker cells in which workers will be raised; second, somewhat larger drone cells; and third (Fig. 196), large flask-shaped cells in which queens will be reared. In other cells honey is stored. The cells are roughly hexagonal in shape in cross-section. One group of cells is for breeding new members of the colony, and many more than these are used for storing honey to be used as food during periods when new honey cannot be made. The beekeeper takes advantage of this habit and provides *comb* both for the reserve food supply for the colony and for an extra lot of honey which he takes from the hive.

Bees drink water and carry some of it back to the hive in the honey sac, from which it is discharged into cells in which young bees are growing. The workers also get *nectar* from flowers. This is a dilute sugary solution which is swallowed and passed to the honey sac. The nectar is changed to honey in the honey sac or crop. When disgorged, it is placed in storage cells and these are not closed until it has lost part of its water. Dehydration is aided by air currents produced by the wing vibrations of many workers. This also insures a constant supply of fresh air in the hive. The workers keep the hive clean. They carry out dead bees or other insects that may have invaded the hive. The body wastes of the colony are removed. Some workers guard the entrance and prevent the admission of enemies.

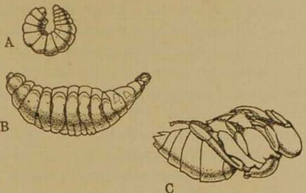

FIG. 197 *A*. — Development of bee. A. — Young larva; B. — Old larva; C. — Pupa. From Phillips — U. S. D. A.

Development. The eggs develop into larvae in the brood cells (Fig. 197 *A*). Surrounding the larva is the food placed there by the workers. When full-grown, the larval cells are capped. The larvae now form pupae. In time they leave the cells as full-fledged bees. The drones do not work, but have to find their own food. The newly formed workers at once assume duties, acting as nurses to larvae or attending to duties within the hive, but later venturing forth on food-gathering excursions. The colony gradually increases in numbers. After a drone (male) mates with a queen, the drones are disposed of.

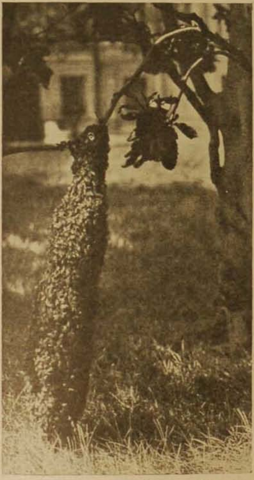

FIG. 197 *B*. — Swarm of bees. (Courtesy Amer. Mus. Nat. Hist.)

Swarming. When new young queens emerge from the queen cells, the old queen becomes restless. She attempts a combat with the new queens and endeavors to kill them. All the workers stop work and a period of unrest ensues. If the colony is in a prosperous condition, a *swarming* follows. Many of the workers prevent the old queen from attacking the new queen. Great numbers of bees leave the hive, surrounding the old queen, and fly to some hollow tree or gather on a branch (Fig. 197 *B*). The beekeeper very carefully cuts off this branch and carries the *new colony* to an empty hive which he has prepared for it. If more than one queen is left in the parent hive, the workers let the queens fight it out until but one queen is left. The young queen left in the old colony takes her " nuptial flight " with the drones. If the ruling queen dies, the workers will make large cells by tearing down the walls between three adjacent worker cells and feed the inclosed worker larva on royal food. In this way they may make several queens.

General Account of Insecta

Metamorphosis. Some insects undergo metamorphosis during their development from the fertilized egg stage, while others do not. Metamorphosis is defined as a more or less abrupt change of form during development. Two general types of metamorphosis are exhibited by insects: (*a*) Complete and (*b*) Incomplete. In

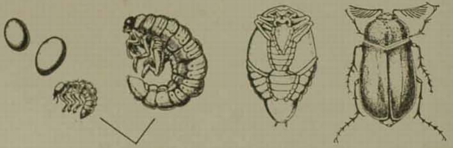

FIG. 198. — Complete metamorphosis (Beetle). Courtesy Am. Mus. Nat. Hist.

complete metamorphosis there are four stages in the life cycle, namely, *egg, larva, pupa, adult* (Fig. 198). From the egg there hatches a *larva*, sometimes called a grub, caterpillar or maggot. This is a form greatly resembling a worm and indicating the annelid ancestry of the Arthropods. Larvae feed voraciously and increase in size quickly. They soon shed the external coat (skeleton), grow further and molt again. This occurs a number of times. Finally the larva attains its mature size. It now ceases to feed and becomes quiescent in some secluded spot. Wings and appendages of the adult are formed. Internal changes occur. The insect is now a pupa. The pupa of a butterfly is called a *chrysalis*.

It is inclosed in a silken cocoon. It finally emerges as an adult or *imago*. The pupa often bears very little resemblance to the larva or imago. After emerging from the pupa stage the adults never increase in size.

Complete metamorphosis is exhibited by the honey bee, butterflies, moths, flies, ants and beetles.

In *incomplete metamorphosis* (Fig. 199), the larva develops from the egg. The larva grows and molting occurs as often as necessary. Wing pads appear and at later moltings these and other external structures increase in size until the mature condition is attained. There is no *pupa* or quiescent stage in this type

Egg Nest Moulting Adult

FIG. 199. — Incomplete metamorphosis (Grasshopper). Courtesy American Museum of Natural History.

of metamorphosis. Some forms molt three times, while others as many as twenty times in incomplete metamorphosis. The young in various stages of maturity are called *nymphs*. In many types, for example the dragon fly, the nymphs pass a longer or shorter time in water, where the eggs were laid and where the early life up to the last molting is spent. Some insects have no metamorphosis at all but are very minute replicas of the adults when they emerge from the egg. Grasshoppers, crickets, cockroaches, lice, dragon flies and may flies all exhibit incomplete metamorphosis.

Classification. Entomologists differ as to relative importance of differentiating characters that shall determine the number of *orders* into which the class *Insecta* should be divided. Some taxonomists group in *one* order many of the *orders* of other taxonomists. Considering the fact that over a half million species are recognized, one can understand the difference of opinion and also that in this brief presentation it is not feasible to consider all orders. Insects are classified (*a*) according to the type of metamorphosis they undergo; (*b*) by the mouth parts; (*c*) according to the possession or non-possession of wings and (*d*) by the wing structure. We will now consider briefly a *few* of the well-recognized orders.

Some Common Orders

1. Coleoptera. These are beetles. The front wings are hard *elytra*. These cover the more filmy posterior wings. There is complete metamorphosis. Beetles have biting mouth parts and many are carnivorous. Some beetles devour other insects harmful to crops. Other beetles are herbivorous and so destroy leaves of valuable plants. Some bore passageways through wood of trees, causing considerable damage. Fireflies are Coleoptera. The lighting is under control of the nervous system. In the flashes of fireflies, practically no heat is generated, which is in great contrast to *our* best types of illumination. The flashes of fireflies are concerned with the process of mating. The females are more or less stationary on the ground while the males dart to and fro in the air above them. It is by means of a series of answering flashes that a male locates a female and copulation takes place. Bark beetles cause millions of dollars damage to trees every year. The cotton boll weevil (Fig. 200) is an actual menace to the future of cotton growing in the South.

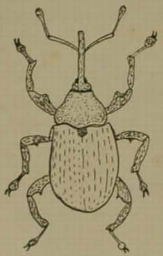

FIG. 200.—Cotton boll weevil — Anthonomis. (U. S. D. A.)

The Colorado potato beetle, *Leptinotarsa* (Fig. 201), is very destructive to potatoes, feeding voraciously on the leaves. Arsenic compounds, sprayed on the leaves of potatoes, kill the beetles, and spraying should be kept up during the growing season. The potato beetle was unknown in the eastern part of this country until the growing of potatoes reached the West where this beetle lived. It then worked its way east, following the growth of potato operations. The Japanese beetle, *Popillia japonica*, is thought to

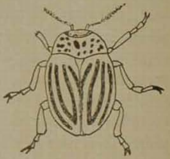

FIG. 201. — Potato beetle — Leptinotarsa. (U. S. D. A.)

have been carelessly introduced into New Jersey about 1916. Since then it has steadily increased and has spread from the center of infestation. It thrives on many kinds of fruits, flowers, crops and trees, destroying as it goes. It eats the soft tissues of leaves, as shown in the photograph (Fig. 202). If foliage is sprayed with the standard arsenate of lead, used to kill leaf-eating insects, the Japanese beetle may start feeding, but soon departs before it has received a fatal dose. The beetles appear in such enormous swarms that all known control measures are inadequate. A thoroughgoing campaign of eradication at the time of its first appearance here when the territory it occupied was small would probably have cost much less than has already been spent in attempts to destroy it and prevent its spreading. Very rigid and active quarantine measures are now in force to keep it within its present bounds.

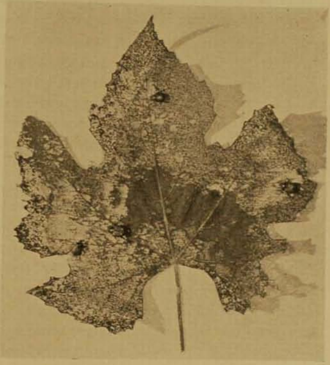

Fig. 202. — Popillia japonica destroying grapeleaf. (Courtesy Amer. Mus. Nat. Hist.)

2. **Hymenoptera.** The metamorphosis is complete. There are two pairs of filmy wings. Ants, bees, wasps and gallflies are common examples. Many of these insects live in colonies. There are a number of wild bees. In the case of the bumblebee, members of the colony, except fully developed females, die out in the fall. Each fertile female hibernates during the winter and in the spring starts a new colony which at first contains only infertile females. Later in the summer, older females lay eggs which develop into functional males and females. The digger wasps (Fig. 203) excavate a nest in the ground. In this nest they deposit live caterpillars stung in such a way as to be paralyzed and the female wasp lays eggs in the nest. The larvae of the wasp feed on these

caterpillars. Some wasps kill their prey and tear it to pieces, feeding the young on choice bits. The solitary wasps do not live in colonies. Only males and females occur. They dig in the earth and build mud nests or bore tunnels in wood. The social wasps have a colony of males, females and sterile females, or workers. The young are not provided with stored-up food, but are cared for continuously. Some wasps build enormous nests of a paper-like substance. They scrape a small bit of wood from some exposed surface, work this up with saliva and plaster it just where needed in construction of the nest. The workers build the nest. In the late summer or early fall males and females hatch from the eggs. The males "fertilize" the females and soon after die. Workers die when cold weather comes. Fertile females alone hibernate through the winter.

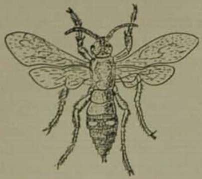

Fig. 203. — Digger wasp — Discolia. (Bur. Ento. U. S. D. A.)

The Ants (Fig. 204) form a group of Hymenoptera of which no adequate description can be given here. Among them are found architects, builders, agriculturists, masons and other types. Some have a queen, some are soldiers, some keep slaves. The workers are sterile females. Sometimes many kinds of workers are present, each type modified especially for a certain kind of work. Some ants carry pieces of leaves into the nest. These are formed into little balls on which grows a fungus, which is food for the colony. Some ant *workers* can make a honey-like secretion with which they feed the young. Some raise grass near their colonies and harvest the seed. Other ants have established profitable relationships with plant lice or Aphids. These are carefully handled by the ants, which place them where they may obtain food. Each aphid is provided with a pair of honey tubes near the tip of the abdomen. Through these a sweet liquid is exuded when the aphids are stroked in a certain way by the antennae of the ant. The ants are very fond of this

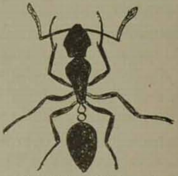

Fig. 204. — Little red ant — Monomorium. (Bur. Ento., U. S. D. A.)

food. It is stated that they carry aphids into their nests for the winter. The white, oblong bodies seen in an ant nest are pupae, being the last stage in development before the adult ant emerges.

On the whole, activities of ants are machine-like. They do not stop to consider what they do. We say their acts are instinctive. Certain observations, however, indicate that some ants at times exhibit deliberation. All the activities of the ant seem to be directed toward the welfare of the whole colony. In August, males and females from different nests of the same species undertake the nuptial flight during which mating takes place. After this the males die and the females, returning to the ground, pull off their wings and alone may start a new colony.

Most gallflies are Hymenoptera. They are small insects. The females lay their eggs under the epidermis of young leaves of oak, witch hazel, willow, some grasses and other plants. They produce an irritating substance which causes a growth to take place. This may be round like a ball and is known as a plant gall. Each type of gall insect produces a special type of gall. The larva feeds on the substance of the gall and pupates there. The mature insect eats its way out of the gall and flies away.

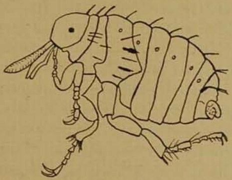

Fig. 205. — Hen flea — Sarcopysylla. (Bur. Ento., U. S. D. A.)

3. Siphonaptera. These are fleas (Fig. 205) and have no wings. They have sucking mouth parts, and metamorphosis is complete. They live among the hairs of mammals or feathers of birds. Locomotion is by leaping. One type is common to cats and dogs. The human flea has a wide distribution. The rat flea transmits the dreaded bubonic plague from rats to man.

4. Diptera. These insects have one pair of wings on the mesothorax, sucking mouth parts and complete metamorphosis. The eggs of the mosquito (Fig. 206) are laid in water in a raft-like mass. The larvae or wrigglers live in water. At the end of the abdomen is an air tube which is projected to the air above the water. The pupa lives in water also. When completely formed, they leave the water. The larvae molt a few times, and become pupae. And these in a few days come to the surface, and the adult mosquito crawls out of the skin of the pupa.

Male mosquitoes do not suck blood, but rather the juices of plants. The females suck blood. Female *Anopheles* mosquitoes transmit malaria. *Aedes* mosquitoes transmit yellow fever. The building of the Panama Canal by Americans, after the tragic failure of the French, was made possible by first ridding the region of Anopheles and Aedes mosquitoes. This was accomplished by draining swamps and spraying a thin layer of oil over waters containing wrigglers. The latter are not able to project their breathing tubes through this oil film and hence they suffocate.

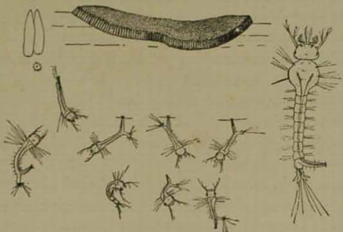

FIG. 206. — Eggs, egg mass and larvae of Culex mosquito. (Bur. Ento., U. S. D. A.)

The house fly, *Musca* (Fig. 207), is a dangerous pest. It may transmit the germs of typhoid, tuberculosis and other infectious diseases. It lays about 150 eggs in manure or garbage. The eggs become larvae or maggots. In about a day they eat voraciously, in about a week become pupae and in another week become full-fledged flies which will shortly produce another brood.

Small flies or those larger than the house fly are not the young or overgrown specimens of the house fly, but mature adults of other species. Flies do not increase in size after developing from the pupa. There are many kinds of flies and many broods are produced each summer. Plagues of house flies may be prevented by disposing of every trace of manure or animal matter on which they might breed.

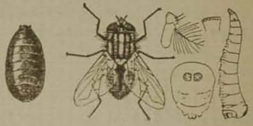

FIG. 207. — Common house fly — Musca domestica. Pupa case, adult, larva. (Bur. Ento., U. S. D. A.)

The Mediterrean Fruit Fly recently appeared in great numbers in Florida and destroyed large quantities of citrus fruit. An industry valued at many millions of dollars was threatened.

5. Orthoptera. These are the cockroaches, grasshoppers (Fig. 208), locusts, katydids, crickets and walking sticks. The cockroach (Blatella germanica) was introduced to America from Germany. Its presence indicates careless housekeeping. Walking sticks have the appearance of dried twigs, a good example of *protective resemblance*. Not only do they escape notice, but even if attacked they are of no use as food and so practically have no predatory enemies. Herrick lists six different species of grasshoppers which are injurious to crops in the United States. Linville records an observation he made in the early 1870's. A fine field of corn in the Missouri Valley was visited about noon one summer day by millions of grasshoppers. By afternoon they had eaten not only all the corn plants but every other green thing in sight. When present in such numbers their devastation is like that of a great conflagration.

FIG. 208. — Grasshopper depositing eggs. (Webster — U. S. D. A.)

6. Hemiptera. This order contains bugs, lice and scale insects which are very destructive. They have sucking mouth parts. Three species of lice infest man: the head louse, the body louse, the crab louse. Lice have no wings but claws for clinging to hairs. The mouth parts are fitted to pierce the skin and for sucking blood. One of the body lice transmits the dreaded typhus fever. Persons free of this infected louse do not get the disease. Unclean bodies and household surroundings are favorable to lice.

Tibicina septendecim (Fig. 209), known as the Seventeen-Year Locust, lives underground as a nymph for sixteen years or so. Then it emerges from the ground, crawls up tree trunks to fresh young twigs, pierces the tender bark of these and deposits eggs. The twig beyond this point dies. In six weeks the young hatch, drop to the ground, dig their way into the earth and feed on organic matter or juices of roots, grow and molt until the seventeenth year, when they emerge as before.

Aphids, or plant lice (Fig. 210), are very destructive to crops. Some live on roots of grapevines, roots and twigs of apple trees,

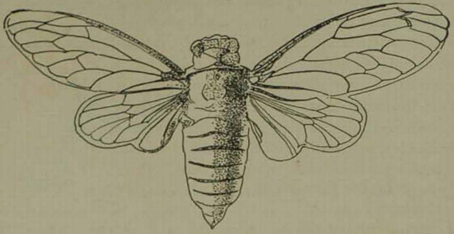

FIG. 209. — Tibicina septendecim, Seventeen-Year-Locust. (U. S. D. A.)

wheat and other cereals. Some consume leaves of such vegetable plants as the potato and turnip. During the summer the aphids are all females that lay eggs. These eggs develop into females without fertilization. This is called *parthenogenesis*. Several broods occur during the summer and an enormous number is produced.[1] In the autumn, males also appear and fertilize the eggs of the females. The last brood, thus produced, lives throughout the winter. Scale insects are extremely destructive. The San José scale (Fig. 211) came to this country from the Orient. The cottony cushion scale threatened the orange industry of California with destruction. A lady bug (beetle) (Fig. 212) from Australia was introduced to fight it. The lady bug feeds on the scale insects and thus helps to check the spread of the epidemic. It

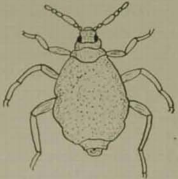

FIG. 210. — Schizoneura — Parthenogenetic female of wooly aphis of apple. (U. S. D. A.)

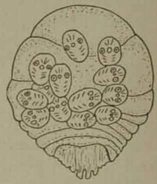

FIG. 211. — Aspidiotus — San José scale. Adult female with young. (Bur. Ento., U. S. D. A.)

[1] S. J. Hunter estimated that a single female Toxoptera is potentially capable of producing over 200,000,000,000,000,000,000 descendants in one season of six months, beginning April 1st.

has been observed many times that when a strange form is introduced into a new country where conditions are favorable for its existence and where there are no enemies, it increases rapidly for a time until its very numbers destroy its available food supply. Enemies attack it, it loses its dominant position and finally ecological equilibrium is again restored. However, this may have brought great economic loss to man.

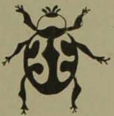

Fig. 212. — Lady bug—Novius. (Bur. Ento., U. S. D. A.)

Among the bugs should be noted the bedbug, which feeds on the blood of man and poisons him slightly each time. It multiplies rapidly in a dwelling unless vigorously attacked.

7. **Lepidoptera** consist of butterflies and moths. They have four wings covered with scales. The wings are often beautifully colored. There is a long sucking tube which is coiled under the head when not in use. It is used to suck the nectar from flowers. Some of the caterpillars are very destructive to plants. Butterflies have knobs on the ends of the antennae, moths do not possess these knobs. Moths fly by night, butterflies by day. When resting, butterflies often fold their wings vertically above the body. Moths when at rest have the wings spread out. The green caterpillars of the cabbage butterfly (*Pontia rapae*) (Fig. 213) feed on cabbages. The eggs are laid in among the leaves of the cabbage. This pest came from Europe about 1860 and spread all over this country from Canada. The gypsy moth (*Porthetria dispar*) (Fig. 214) came from Europe in 1868. Its caterpillars eat leaves and have been exceedingly destructive to trees in New England.

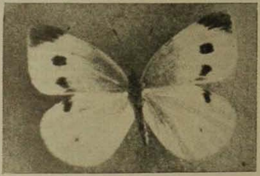

Fig. 213. — Cabbage butterfly — Pontia rapae. (Am. Mus. Nat. Hist.)

It started its depredations in this country in Cambridge, Mass. The eastern states, and especially those of New England, spend huge sums of money each year in spraying trees to combat it. The adult female of the tent caterpillar (*Clisiocampa americana*) lays her eggs on wild cherry trees. The caterpillars spin a cottony, thread-like maze of fibers, the *tents*, in which they develop. From this they emerge to strip the trees almost entirely of leaves, thus causing their death.

The army worm is the caterpillar of a moth, *Cirphis unipuncta.* The caterpillars feed on wheat, oats, corn and hay crops. Once established in a region, they march on, as an army, from field to field, destroying as they go. The codling moth or apple worm lays its eggs on young apples. The larvae eat into the apples and greatly damage or destroy the apple crop. The clothes moth is small. Its caterpillars feed on furs, woolen cloth, feathers, etc. A perfectly satisfactory method of protecting clothing from its depredations remains to be found.

FIG. 214. — Gypsy moth — Porthetria dispar. 1. — Egg masses on trunk of oak tree; 2. — Larva; 3. — Pupa; 4. — Female; 5. — Male. (Courtesy Amer. Mus. Nat. History.)

The silkworm moth (*Bombyx mori*) is thoroughly domesticated in France and Japan. Manufacture of silk fabric is one of the great industries in America, France and Japan. Moths lay their eggs on cloth or paper and the larvae are fed on mulberry leaves. In forty days the larva spins a cocoon. This is made of one very long, slender thread. It is loosely arranged on the outside, but more compact within. The pupa is killed by heating, the loose outside thread is removed, and then the inner part of the cocoon is unwound and this is woven into thread and cloth. One of the first studies engaged in by Louis Pasteur was an investigation of a protozoan disease of the silkworm and he saved the silk industry of France.

Protective Resemblance and Mimicry. Some moths are beautiful examples of *protective resemblance* (Fig. 215). The upper surface of the wings, when the insect is at rest, blends in so perfectly with the surroundings as to escape notice. Some *edible* butterflies have the same appearance as *other species* which *nauseate* birds. This is called *mimicry* (Fig. 216). The *mimics* are thus protected because they resemble the nauseating *models*. In the same way, some *harmless* flies *mimic* bees that are avoided because of their stings.

FIG. 215. — Amphidasis vetularius moth at rest on birch bark. (Protective resemblance.) (Photo by Schechter.)

CLASS C. — ARACHNIDA

Common examples of Arachnida are spiders, ticks, mites, scorpions and king crabs. They have the arthropod exoskeleton, and in many, as for example the spiders, the body is composed of a cephalo-thorax and abdomen. Spiders have six pairs of appendages attached to the cephalo-thorax. Two pairs are related to the mouth. The remaining four pairs are legs used in locomotion. The first pair of appendages are called chelicerae, the biting organs. The tip is a fang. A poison gland in the base of the chelicera secretes into a duct which opens at the tip of the fang, and by this apparatus poison is injected after the biting

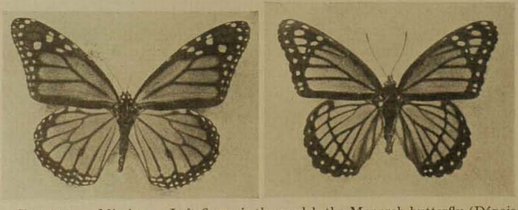

FIG. 216. — Mimicry. Left figure is the model, the Monarch butterfly (Dánais plexippus); the mimic at the right is the Viceroy (Limenitis archippus). (From photographs by Amer. Mus. Nat. Hist.)

chelicerae have pierced the skin. The poison of spiders kills their prey, which consists chiefly of insects. However, the poison of most common spiders is not virulent so far as man is concerned. On the other hand, the venom of the large Tarantulas (Fig. 217) is to be guarded against.

Fig. 217. — Tarantula, a large southern ground spider. This specimen had a body length of 2¼ inches and a spread of 7 inches. (Courtesy Amer. Mus. Nat. Hist.)

Scorpions (Fig. 218) are large, long, segmented Arachnids which capture insects with their pincer-like "hands" (*i.e.*, second pair of appendages). The first pair of appendages (chelicerae) are used with the "hands" in tearing the prey into pieces. At the hinder end of the body is a stinging apparatus supplied with a poison gland. This apparatus is used on larger animals, apparently when the scorpion is irritated. The effect on man depends both on the size of the scorpion and the size of the person. Small children are affected seriously.

The cattle tick, Boophilus (Fig. 219), clings to the skin of cattle with its mouth parts and sucks blood on which it subsists. The adult females drop to the ground, where they deposit their eggs in thousands. The cattle tick is frequently the host of a disease-producing sporozoan, Piroplasma bigeminum, causing Texas fever in cattle. If the mature female is infected, her eggs will be infected. They will continue to be infected after they hatch. It is then that they crawl up on stalks of grasses and attach themselves to cattle as the latter pass by. It was demonstrated by Theobald Smith that in this way the dread Texas fever parasite

Fig. 218. — Scorpion. (Amer. Mus. Nat. Hist.)

was transmitted. Texas fever has caused a loss of millions of dollars to the cattle industry of the United States. For many years nearly three quarters of a million acres of grazing land was quarantined against cattle raising because this territory was so tick infested. After knowledge of the life history of the sporozoan had been worked out, it was possible to undertake defense measures against it. Today in tick-infested regions, cattle are given a bath in arsenical solutions which kill any ticks that may be present.

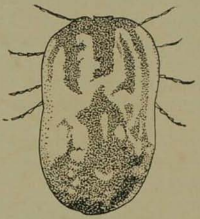

FIG. 219. — Boophilus, Texas fever cattle tick. Adult female after feeding. (U. S. D. A.)

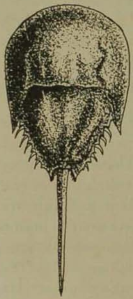

FIG. 220. — Limulus — King crab (Arachnida).

The king crab, Limulus polyphemus (Fig. 220), is found in shallow seawater on sandy bottoms along the Atlantic Coast from Maine to Central America. It is the largest living Arachnid and is unique in being a marine form. Limulus breathes by means of gills which are plate-like structures on certain appendages while there are locomotor appendages on other segments. Patten maintains that the king crab is a modern representative of the ancestors of the Vertebrates. Limulus resembles in some respects the extinct *trilobites* which were the dominant crustaceans of the Palaeozoic Era. It should be remembered that Limulus is an Arachnid and not a Crustacean. Centipedes (Fig. 221) belong to another class of the Arthropoda, *i.e.*, the Myriapoda.

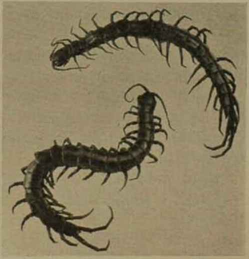

FIG. 221. — Centipedes. Class, Myriapoda. (Courtesy Am. Mus. Nat. Hist.)

Arthropod Relationships. Arthropods are related to the still more ancient Annelids because of the segmented body, with appendages borne on the segments, and because of the similarities in the nervous system. A present-day Arthropod of wide distribution exhibits many annelid affinities. It is *Peripatus* (Fig. 222), a *worm-like* form. It is considered an *Arthropod* because it has an arthropod-like heart, a limited body cavity, jointed appendages, of which one pair serve as jaws, and its organs of respiration

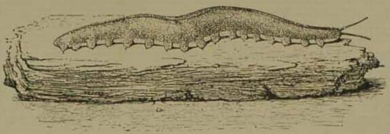

FIG. 222. — Peripatus. (After Sedgwick.) (Courtesy Amer. Mus. Nat. Hist.)

are tracheae. On the other hand, it is *annelid-like* in having a soft skin, paired nephridia, segmented body and on the whole its organs are disposed like those of Annelids.

Insects in Conflict with Man. Some authorities consider the Arthropoda to be *one terminus* of *two great lines of evolution;* the *other line terminating in the Chordata.*

In a recent contribution in the *New York Times* (February, 1929), L. O. Howard, the veteran entomologist of America, emphasizes this. Man is the dominant animal of the chordate series, while the Insecta are undoubtedly the arthropod leaders. The two forms have been, are now and will continue to be in deadly conflict with each other until one or the other dominates.

Insects today hold sway over large areas of country which would otherwise be suitable for human occupation. Man is dominant over insects in other territory. Insects constantly attempt to wrest from him the fruits of his labors and actually levy a great tax upon his labors.

Insects are in many ways admirably formed for biological success. The many-jointed body plan is adapted to ease of motion and locomotion. This is true of the Vertebrate as well. Many types of animals in the past have developed an external protective armor. In most cases this involved loss of active movement and has not proven to be protective in the long run of time. The insect armor, however, is many jointed and permits ease of movement as well as being protective. The chitinous exoskeleton of the insect is made of what is, in a certain sense, waste material and grows stronger with age. The bones of the Vertebrate require valuable food materials and they become brittle in the aged. The muscles of the insect are inside the exoskeleton and so protected while the muscles of the Vertebrate are outside the bones and more unprotected. The limb of the insect is said to be relatively three times as strong, architecturally, as the limb of a Vertebrate.

Insects are small and do not require much food to grow to the reproductive stage. Nor is much time required to attain this condition. They produce hosts of offspring and many breed more than once during a season. Great increase in numbers requires great increase in food supplies, it is true, but insects easily adapt themselves to a great variety of foods. They eat plants and animals; the living and the dead.

Insects can live in an environment that would be fatal to Vertebrates. Some, for example, live in the very alkaline waters of Great Salt Lake; some have been found in petroleum in California. Lutz has recently shown that the fruit fly, Drosophila, has survived subjection to rarefied atmospheres that would easily kill Vertebrates.

Human activities have favored the multiplication of certain insects. The Colorado potato beetle did not feed on potato leaves until settlements extended westward and carried potato fields into the range of the beetle; scale insects were not known in California until man developed the citrus fruit industry there; the cotton boll weevil would not be a topic of conversation in the south if cotton were not "king." The European corn-borer has *now* discovered unlimited fields for the expansion of *its empire* in the corn belt of America. Everyone who tries to grow vegetables, fruit or flowers is well aware of his insect enemies. It is constant war from springtime until autumn and many persons give up the fight.

Herrick expresses the opinion of experts when he says that the "losses caused by insects in the United States alone are estimated to aggregate more than a billion dollars annually." In 1919, it was reckoned that the loss amounted to about two billion dollars. In 1918 about thirty million pounds of arsenate of lead were used in spraying plants at a cost of over three million dollars. Out of seventy-three kinds of our most destructive insects, over half have been introduced from foreign countries. Abroad, they are not the agents of destruction that they become when brought here. A reason for this is, that here they do not have the natural enemies which held them in check in their native country. One method of combating them is to find the appropriate foreign enemy and introduce it here. Another source of loss is the change in food habits of native species. The Colorado potato beetle illustrates this. When planting operations extend to what has been formerly virgin territory, the domesticated plants are brought in contact with the native insects, which may find the introduced plant to be superior food as compared with the native wild plants on which it has been accustomed to feed. If the planting operatons are on a large scale, this new food is so much the more plentiful. Herrick lists fourteen species of native insects that have changed their food habits from wild to cultivated plants.

We have already called attention to the great monetary losses due to insect depredations. Dr. Howard states that we thus lose annually the labor of a million men in the United States alone. We spend millions of dollars annually on our army and navy for protection against enemies that might appear. But in the insects we have an actual, capable and utterly merciless foe, maintaining a constant warfare, destroying our property, stealing our food and killing our citizens. Why not invest in a real protection against an actual enemy? Why not mobilize, train and equip an adequate number of entomologic soldiers to wage aggressive warfare against them — an army of a size more commensurate with the great seriousness of the attack made upon us! This is entirely feasible and success is possible, for we have a weapon stronger than all the powers that they can muster. The weapon is human intelligence.

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