MODULE #12: Phylum Arthropoda

Class Insecta

We now come to the largest class in creation, class Insecta. There are over a million known species of insects, and the number grows each year as new species are found and classified. In fact, insect species make up more than three-fourths of the species in the animal kingdom. They have the following characteristics that separate them from other members of phylum Arthropoda:

ØThree pairs of walking (or jumping) legs
ØUsually have wings at some stage of their life
ØOne pair of antennae
ØThree segments: head, thorax, and abdomen

Although these characteristics are common to all insects, there is amazing variability in these and other characteristics within this huge class.

Insect Legs

Most insects use their legs for walking. As you would expect for arthropods, insect legs are jointed. They typically connect to the thorax of the insect, and the variety throughout class Insecta can be illustrated by the many different kinds of insect legs. For example, the front pair of legs on a praying mantis isn't just for walking. Each leg has a powerful claw that the mantis uses to capture prey. Flies, on the other hand, use all of their legs for walking, but the legs come equipped with sticky pads that allow them to walk up walls and even upside down on ceilings! The grasshopper uses its two most powerful legs for making great leaps, while the water strider has legs that are bristled at the end, allowing it to actually walk on water. Other insects use their legs to make sounds, while still others use them as a means to store food. This should give you a glimpse of the variety that exists in this class.

Insect Wings

Although most insects have two pairs of wings, some have only one pair, and a very few have none at all. There are four basic types of wings in class Insecta:

Membranous wings
Scaled wings
Leather-like wings
Horny wings

Membranous wings are thin, transparent, and have a detailed network of veins that are visible. A fly's wings, for example, are membranous. Scaled wings have delicate scales that cover the wings. As a result, they are not transparent. The scales are easy to rub off, as if they were made of powder. Moths and butterflies have scaled wings. Leather-like wings are wings that appear to be a part of the exoskeleton. They are typically laid over a second, membranous pair of wings so as to protect them. Grasshoppers have one pair of membranous wings under one pair of leather-like wings. Horny wings are often hard to distinguish from leather-like wings. They also are used to cover and protect membranous wings. They are tougher than leather-like wings, however, and they typically cover almost the entire insect, rather than just the membranous wings as in the case of leather-like wings. Beetles, such as ladybugs, tend to have horny wings.

The Basic Anatomy of an Insect

Since there is so much variety in class Insecta, it is hard to pull out a “representative” insect to study. Nevertheless, we will go ahead and use the grasshopper as our representative insect. The figure below contains sketches of the outside and inside of a grasshopper.

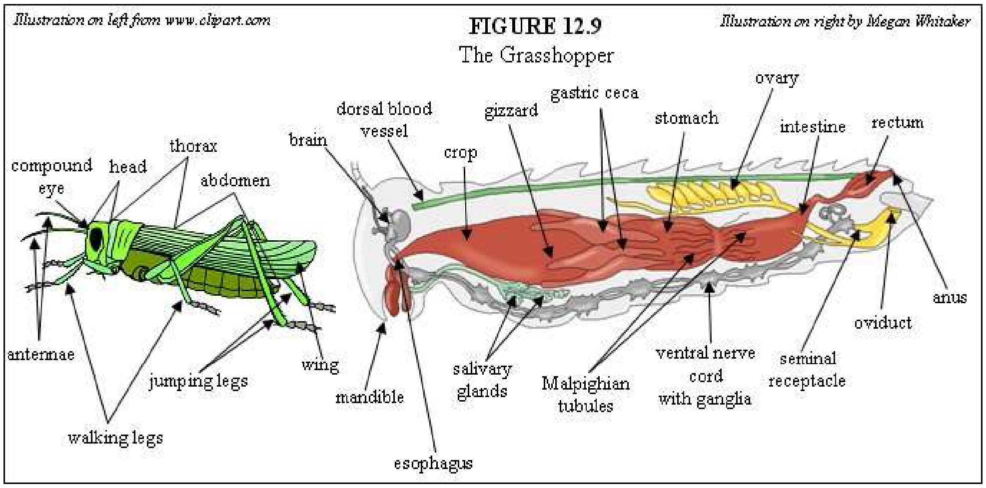

FIGURE 12.9
The Grasshopper

Respiration and Circulation in Insects

One of the most interesting aspects of insects is the fact that even though they have no respiratory system, they get plenty of oxygen. How is this possible? Well, insects have an elaborate system of interconnecting tubes called tracheas (tray key' uhs). These tubes are connected to the outside through a series of small holes in the exoskeleton called spiracles. The network of tracheas is so complex and thorough that air runs throughout the body, providing oxygen to all tissues! That's why you see no lungs in Figure 12.9. Air goes directly to the tissues, where oxygen and carbon dioxide are directly exchanged with the cells.

If insects have no respiratory system, why do they have a circulatory system, as is evidenced by a dorsal blood vessel? Well, cells need more than just oxygen to survive, and they need to expel more than just carbon dioxide. Thus, as the blood flows over the tissue (remember, this is an open circulatory system), it picks up other cellular waste products and delivers vital substances other than oxygen (such as food). Where do the waste products go? Well, insects don't have green glands, but they do have Malpighian (mal pig' hee ahn) tubules, which reside in the vicinity of the intersection between the stomach and the intestine. When blood flows over the Malpighian tubules, it is cleaned of the waste products, and they are put into the intestine for elimination through the anus.

Another interesting aspect of insects is that many of them have both simple and compound eyes as a part of their nervous system. Typically, the compound eyes actually provide vision, while the simple eyes just look for the presence of light. The signals from both sets of eyes are fed into the brain, which is attached to the ventral nerve cord. This makes up the “backbone” of the nervous system. Besides the eyes, the nervous system also gets information from tactile hairs that provide touch, taste, and smell information. Some insects even have a sense of hearing, but the mechanism for detecting sound is not where you would expect. In a grasshopper, for example, there is a vibrating membrane (called the tympanic membrane) attached to the ventral nerve cord. The vibrations of this membrane provide a sense of hearing. Rather than being on the head, however, it is actually in the first segment of the abdomen!

The Feeding Habits of Insects

The grasshopper has a mandible which is designed for chewing. Although this is the case for the majority of insects, there are many different mouth structures in the insect world. This is because there are many different feeding habits apparent in class Insecta. Mosquitoes, for example, do not have mandibles. Instead, they have mouthparts designed to puncture and then suck. Flies, on the other hand, have an almost spongelike mouth that is used to absorb food. Finally, because butterflies primarily eat nectar from flowers, they have a mouth designed to siphon.

Once food has entered the mouth, however, most of the differences between insects disappear. The food is mixed with secretions from the salivary glands. Enzymes and water in these secretions begin breaking down the starches that the insect has ingested. The food then passes through the esophagus and goes on to the crop, where it might be stored for later use. Once the food is needed, it is sent to the gizzard, where it is ground into fine particles. The gizzard empties into the stomach, where it is mixed with digestive enzymes which come from the gastric ceca (see' kuh). Undigested food then passes through the intestine, to the rectum, and out the anus.

Reproduction and Development in Insects

Perhaps the most extraordinary thing about insects is the means by which they develop from a fertilized egg into an adult. As is the case for almost all arthropods, the female and male sexes are completely separate in class Insecta. Females receive sperm from males during mating but, like the crayfish, store it in seminal receptacles for a time. When the female lays her eggs, they are fertilized by the stored sperm. We call this stage of the new insect's development the egg stage. Once the egg hatches, things get really interesting.

When they hatch, most insect young are in a stage called the larva stage. In this stage, the young insect, regardless of its species, tends to resemble a segmented worm. It eats and molts over and over again, eventually entering the pupa stage. In this stage, the insect forms some sort of case around itself. The case might be formed of exoskeleton, or it might be woven from filaments. During this stage, everything changes. The organs are rearranged and reshaped, body structures are dismantled and reformed, and an amazing transformation occurs. When the transformation is complete, the insect breaks out of its case and enters the adult stage of life. In the adult stage, the insect has all of the features and organs that are normally associated with its species.

Now, of course, you should have heard about this process before. It is called metamorphosis (met uh mor' fuh sis) and is usually discussed in terms of the butterfly. When a butterfly's eggs hatch, the young are called caterpillars. They resemble segmented worms at this point. This, then, is the larva stage for the butterfly. Eventually, the caterpillar weaves a chrysalis (krih' suh lis). This is the casing that forms in the pupa stage. When the insect emerges from the chrysalis, it is an adult butterfly. Moths also go through a very similar form of metamorphosis, but the larva of a moth typically forms a cocoon rather than a chrysalis. What you might not have been aware of until now is that the vast majority of insects go through this transformation process. Flies, for example, go through the same process. When they are in their larva stage, they are called maggots, and when they are in their pupa stage they do not use a cocoon or chrysalis but rather a shell of exoskeleton.

In fact, if an insect does not go through the metamorphosis process described above, it goes through a similar one that involves only three stages. Thus, biologists classify the development of an insect as either complete metamorphosis or incomplete metamorphosis.

Complete metamorphosis - Insect development consisting of four stages: egg, larva, pupa, and adult

Incomplete metamorphosis - Insect development consisting of three stages: egg, nymph, and adult

When an insect develops through incomplete metamorphosis, it hatches from its egg stage into its nymph stage. In this stage, the insect looks like a miniature version of its adult form, but the proportions seem wrong. It lacks wings and reproductive organs. It molts several times during the nymph stage and, when it finally develops wings and reproductive organs, it is considered an adult. Examples of both types of metamorphosis are given in the figure below.

Praying mantis nymph photo © Corbis, Inc.
Caterpillar photo © Michael Ledray
Chrysalis photo © Photodisc, Inc.

FIGURE 12.10
Complete and Incomplete Metamorphosis

Praying mantis photo © Brian Palmer
Butterfly photo © Heather Ringler

A praying mantis exhibits incomplete metamorphosis. The egg hatches a nymph (left), which becomes an adult (right).

A monarch butterfly exhibits complete metamorphosis. The egg hatches a larva (left), which forms a chrysalis to become a pupa (middle). The adult (right) emerges from the chrysalis.

Now please realize that there is nothing "incomplete" about incomplete metamorphosis. It is a full life cycle in which each stage of life is exquisitely designed. We simply use the term "incomplete" to signify that it has fewer stages than the other type of metamorphosis that is seen in class Insecta.

A Few Orders in Class Insecta

Class Insecta contains many different orders. Obviously, then, there is simply no way to go through them all. Nevertheless, to give you some feel for the diversity of life in this class, we need to at least touch on some of the major orders.

Order Lepidoptera: The Butterflies and Moths

Since we were just discussing the developmental process in insects, and since that process is usually associated with butterflies, we might as well start our insect order discussion with order Lepidoptera (lep uh dahp' tur uh). As we mentioned before, butterflies and moths (in their adult stage) have scaled wings. This is the major characteristic that sets them apart from most other orders in class Insecta.

Do you know the difference between a butterfly and a moth? Well, there are differences, but they are rather subtle. In its adult stage, the antennae of a moth usually look feathery, while the antennae of a butterfly look like straight stalks with knobs on the end. Also, the body of the adult is much slimmer in butterflies than it is in moths. Finally, when butterflies rest on the ground or sit on top of a plant, they typically hold their wings up vertically. Moths, on the other hand, tend to hold their wings out horizontally when resting.

Although butterflies and moths can be quite beautiful, they are not always the most desirable things to have around. Many butterflies eat ravenously while in their larva stage. Some have been known to cause millions of dollars' worth of crop damage every year. Also, if certain types of moth lay their eggs in your closet, the larvae that hatch can destroy the clothes stored there. That's why many people put mothballs in their closets. Mothballs are small samples of a chemical called napthalene. They emit an odor that repels moths so that when they are placed in a closet, moths will not enter the area and lay eggs.

Order Hymenoptera: Ants, Bees, and Wasps

Scaled wings, of course, are not the only kinds of wings in class Insecta. Members of order Hymenoptera (hi muh nahp' tur uh) have membranous wings. In fact, “hymen” means “membrane” and “ptera” means “wings” in Greek. Now that statement might confuse you in light of the fact that the title of this subsection includes ants as being a part of order Hymenoptera. Ants don't have wings, do they? Well, it turns out that they do, but you rarely see them. You'll learn why in a moment. Members of this order usually have stingers, too.

All species within order Hymenoptera are what biologists call social insects, which sets them apart from all other orders except Isoptera, which contains the termites. They exist within a society in which they have very particular functions. The best example of this is bees. In a hive, bees belong to one of three groups: queen, drone, or worker. The vast majority of bees in the hive are worker bees. They are actually female bees that do not have reproductive capabilities. Instead, their egg-laying organ, the ovipositor, is a barbed stinger. When they sting an enemy, they release a poison with the stinger. The barb in the stinger, however, lodges in the victim, making it impossible for a bee to remove its stinger. Thus, the bee will rip off its last abdominal segment, leaving the stinger behind. This increases the effect of the poison, but it kills the bee. As their name implies, worker bees do all of the work. They build and maintain the hive, collect food for the hive, care for the eggs, care for the larvae once the eggs hatch, and protect the queen.

The queen bee is the only female with reproductive capabilities. Because she can lay eggs, however, her stinger is not barbed. Thus, she can sting as many times as she wants. A given hive has only one queen, so workers protect her at all times. If the queen dies, the hive is out of luck, right? Wrong. You see, while the queen is alive, she produces a chemical that biologists call “queen substance.” This substance is transferred to all workers, and it attracts workers to her. When the queen dies, the workers notice that they are no longer being given that substance, so they feed some of the developing larvae a special high-protein food that they secrete. This causes those larvae to develop reproductive organs. The first one to enter adult stage is the new queen, and the rest are killed.

The drone bees are the only males in the hive. They are useless for all situations except mating. Their mouths are not designed to gather nectar from flowers, so they cannot make honey. They also do not help maintain the hive. They simply wait their turn to mate with the queen. Since drones are good only for reproductive purposes, worker bees have been observed killing them or pushing them out of the hive when food becomes scarce!

As you no doubt are aware, bees make honey. What is honey and why do they make it? Honey is partially digested nectar that the bees have sucked out of flowers. It serves as food for the queen and the drones, and it is also a backup supply of food for the workers when they cannot find nectar. The honey is stored in honeycombs, hexagonal storage chambers made out of wax that is secreted by (you guessed it) the workers. The workers then fan the nectar with their wings in order to evaporate excess water, concentrating the partially digested nectar until it becomes honey. It turns out that no engineer could have designed a better system for the storage of honey. The hexagonal shape of the storage chambers allows them to store a large amount of honey with a minimal amount of wax. The wax that the bees use to make these storage chambers is so strong that two pounds of wax can hold 50 pounds of honey! Bees are so industrious that they make far more honey than they need under normal conditions, so people (and some animals) take advantage of this by using the honey for themselves.

Now stop and think about this for a moment. The queen controls her “subjects” with a special chemical. When that chemical is no longer supplied, the workers “know” that they need a new queen, so they produce another substance that, when fed to the developing larvae, forms a new queen. At the same time, these workers store honey in a structure that science tells us is perfectly engineered for the task. If honey runs short, the workers also somehow “know” who among them (the drones) are expendable. Isn't that amazing? This is just one more of the incredibly designed systems in creation that simply shout out the glory of God!

We still haven't told you why you don't see wings on ants, have we? Well, you needed to understand the concept of social groups in insects first. The ants that you see most of the time are worker ants, which do not have reproductive capabilities. These ants do not have wings. Only ants that can reproduce have wings. They never venture out of the anthill, so you never see them. Even if you were to see them, you might still not see wings. The male ant dies shortly after mating, and the female ant loses her wings once she mates. Thus, only a small portion of any given ant species has wings, and those individuals either don't live long or don't keep their wings long. No wonder you never see them!

Order Coleoptera: The Beetles

No, we're not going to discuss the “Fab Four” here. (If you don't know who the “Fab Four” are, ask your parents.) Instead, we are going to discuss the largest order within class Insecta (indeed, the largest order in the animal kingdom), order Coleoptera (ko lee ahp' tur uh). The name of this order literally means “sheath wing” in Greek. That is a very adequate description of what sets it apart from most other orders. All members of this order have horny wings. These wings are thick, sometimes colorful, and they typically cover the creature's entire body, protecting the membranous wings underneath. The horny wings make beetles look like little war machines, and that look is often enhanced by horns on their head or extended mandibles that can viciously cut through their enemies.

Beetles have a voracious appetite. Sometimes that is a good thing, and sometimes it is a bad thing. Many beetles feed on insects that damage crops. The ladybug, for example, feeds exclusively upon aphids and other crop-destroying insects. The fact that the ladybug has a huge appetite works out all the better for farmers. There are some beetles, however, (the Japanese beetle and the rice weevil, for example) that destroy crops themselves. The fact that they have a huge appetite is not good for farmers!

One particularly interesting beetle that we want to discuss is called the bombardier beetle. This ugly little beetle has one of the most beautiful defense mechanisms in all of creation: a fully equipped chemical weapon. This weapon begins with storage vessels that contain a mixture of two chemicals: hydroquinone and hydrogen peroxide. Under normal conditions, these chemicals would react, but while stored in the bombardier beetle's vessels, they are kept from reacting by the presence of a third chemical which inhibits the reaction. When the bombardier beetle feels threatened, however, it fills an empty reaction chamber in its body with the chemicals. Two other chemicals, catalase and peroxidase, are then added. These chemicals cause the hydrogen peroxide and hydroquinone to react violently. The violent reaction produces a great amount of heat and pressure in the reaction vessel. The beetle then points its tail in the direction of trouble and opens a valve between the reaction vessel and the tail. A jet of steam that has a temperature of roughly 200°F shoots out the tail in the direction of danger. Any potential predator is immediately burned and frightened away! The bombardier beetle can perform this feat up to 20 times per day! The bombardier beetle is just another in the long list of organisms on this planet that tell us over and over again that this world was designed.

Order Diptera: Flies, Gnats, and Mosquitoes

We now come to the order with the most annoying creatures, order Diptera (dip' tur uh). All organisms in this order have a pair of membranous wings that they use to fly. Their second pair of wings is much smaller and is used as stabilizers during flight. Some research indicates that they might be used to determine the insect's air speed as well. Members of this order have no other defense mechanism except the ability to get away quickly. Their exoskeleton is rather weak; they have no stingers; and their mouths are designed to either pierce or suck, not to bite. Thus the only way that these creatures stay alive is to fly away. Given the fact that they are so prevalent on warm, sticky days, they obviously are good at it!

Flies are pests, but they can actually be quite dangerous. The average housefly carries millions of bacteria and viruses in its intestinal tract and on its body. When a fly lands on a food source, it eats by secreting digestive juices onto the food and then sponging it back up. Many of the microorganisms and viruses it carries are transferred to the food in that process. Thus, if a fly lands on your food and begins to eat it, you run the risk of being infected by those microorganisms and viruses, some of which are pathogenic to humans.

Mosquitoes also carry potentially pathogenic microorganisms and viruses. In Module #3 we studied how the Plasmodium sporozoan, which causes malaria, is carried by the mosquito. Mosquitoes also carry some types of parasitic worms and the yellow fever virus. These creatures are quite effective at infecting you, because they feed on your blood. Their mouthparts are perfectly designed to taper into four needles that easily pierce the skin. Since your blood tries to clot in order to prevent bleeding, the mosquito then injects a chemical that counteracts the blood's clotting mechanism. This keeps the blood flowing freely, allowing the mosquito to get all that it wants. The problem is, of course, that any pathogens which the mosquito carries get mixed into your bloodstream along with the chemical that keeps the blood from clotting!

Order Orthoptera: Grasshoppers and Crickets

The last order that we want to discuss is order Orthoptera (or thahp' tur uh). We will not spend much time on it, though, because we have already made an in-depth study of the grasshopper, one of its members. Members of this order have one pair of leather-like wings that cover and protect their membranous wings. They typically have a pair of legs that are quite a bit larger than the other two pairs of legs, and they use them for jumping.

Grasshoppers and crickets are well known for their chirping, which is technically called “stridulation” (strid yoo lay' shun). In order to stridulate, a grasshopper has a row of small pegs on the largest joint of each of its hind legs. These pegs are rubbed over the veins of the wings, causing the sound that we call “chirping.” Usually, only the male stridulates. Each species has its own unique song, so stridulation serves to attract females to males for the purpose of mating.