MODULE #12: Phylum Arthropoda

Class Crustacea: The Crayfish

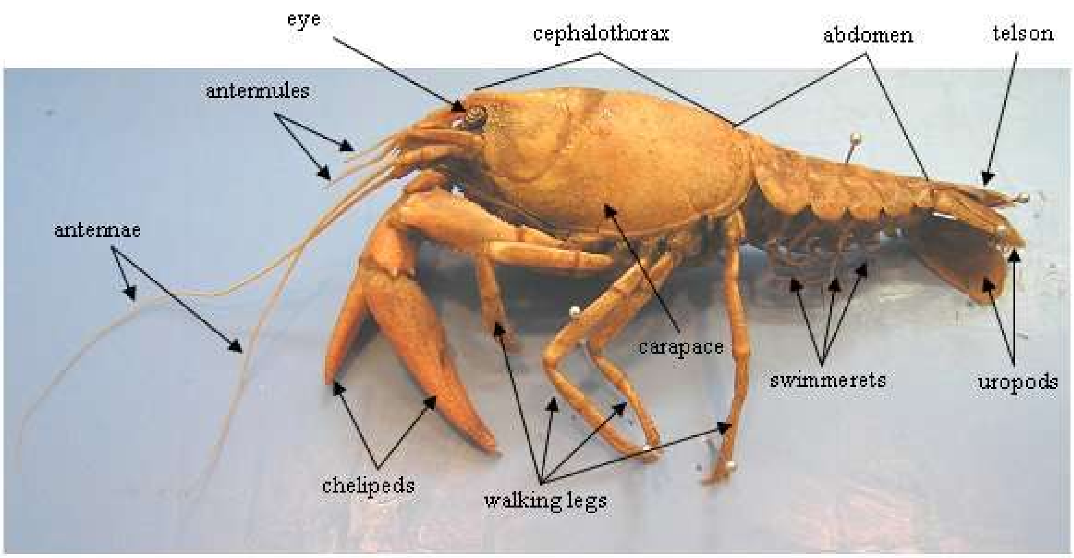
The first arthropods that we will study come from class Crustacea. Most crustaceans live in either fresh water or marine environments (like the crayfish or the lobster), although some species (like the pill bug, which is often called the “roly-poly”) are land dwellers. Since the crayfish is the “standard” crustacean to study, we will start there.

The crayfish, often called the “crawdad,” lives in fresh water. It looks much like a lobster, which is the marine “equivalent” of the crayfish. Lobsters, however, grow to be much larger than crayfish. If you go to virtually any river in the United States and look at the shoreline, you will probably see crayfish busily moving up and down the shallow waters of the shore, looking for food. Many fishermen will tell you that crawdad meat is one of the best baits that you can use to catch fish. In the southern United States (and many other places), crayfish are used in a variety of popular dishes. Of course, you have to exercise a bit of caution when you try to catch them, because their claws (chelipeds) can give you a pretty good pinch!

The crayfish has a detailed external anatomy that deserves some attention. A photo of the crayfish, showing most of its major exterior features, is given below.

Photo by Kathleen J. Wile

FIGURE 12.2
The Crayfish



The first thing that you should notice is that the crayfish is one of those arthropods with a cephalothorax. The cephalothorax is covered in a single plate called the carapace (kehr' uh pace). The abdomen is separated into six segments, each with its own protective plate of exoskeleton.

The six sets of appendages shown in the crayfish above all perform different functions:

ØWalking legs - These appendages are used for locomotion when the crayfish is on land or moving on the bottom of the lake or river in which it lives.

ØSwimmerets - These aid in swimming as well as reproduction. In male crayfish, the first and second swimmerets transfer sperm to the female during mating. In females, the swimmerets carry both the eggs and the developing offspring.
ØUropods and telson - These appendages form the flipper-shaped tail that the crayfish uses for swimming.
ØChelipeds (kee' luh pedz) - The chelipeds (usually called “claws”) are used for defense as well as to grab onto prey.
ØAntennules - These small antennae aid the creature in balance and provide taste and touch sensations.
ØAntennae - These longer appendages are much more sensitive than the antennules, providing the crayfish with strong senses of taste and touch.

These appendages are all controlled by the nervous system, giving you some idea of how complex it is.

The Crayfish's Respiratory System

The crayfish gets its oxygen from the water through two sets of gills that are located in the cephalothorax. Gills are amazing organs that are present in most of the animals that live underwater. As you know, all aerobic organisms need oxygen to survive. For land-dwelling creatures, the oxygen is readily available from the surrounding air. But how do organisms that live underwater get their oxygen?

Well, oxygen gas is dissolved in the water. The problem is how to get the oxygen out of the water and into the creature. In the case of hydra, jellyfish, and other invertebrates that we studied in the previous module, the organism is designed to allow oxygen to diffuse into the body, while waste gases diffuse out. Although this system works well for these creatures, it will not work for many water-dwelling animals. Crayfish, for example, are protected and supported by an exoskeleton. No oxygen is going to diffuse through that! Even though other water dwellers do not have exoskeletons (the vertebrate fish, for example), they often have scales or some other covering that would prevent such an exchange of gases with the environment.

How then, do these creatures get the oxygen that they need? They use gills, which take oxygen that has been dissolved in the water and transfer it to the bloodstream. At the same time, carbon dioxide in the blood is released into the gills, which transfer it to the water. The gills, therefore, act as a transfer station, transferring dissolved oxygen from the water and into the blood while at the same time transferring carbon dioxide from the blood and into the water.

The two sets of gills in a crayfish reside in two gill chambers that are slightly posterior to the head on each side of the crayfish. One of these sets of gills is shown in the figure below.

FIGURE 12.3
The Gills on a Crayfish

Photo by John Skipper

The crayfish has small openings on the ventral side of the gill chambers that allow water from the surroundings to flow inside to the gills. Blood traveling through the gills can then release carbon dioxide into the water and absorb oxygen. Do you see what's happening in the gills? Since the exoskeleton cannot allow gases to be exchanged with the surroundings, God has designed gills that can do what the entire body of a hydra or jellyfish does. Of course, to make this system work, there has to be continuous circulation of water through the gill chambers. This is accomplished by the motion of the crayfish's swimmerets as well as tiny appendages near the mouth called maxillae (mak sil' ay – singular is maxilla). Although the maxillae are involved in keeping water flowing through the gills, they also help the crayfish handle food.

Interestingly enough, many water-dwelling crustaceans (including the crayfish) can actually store up a lot of water in their gill chambers so that they can make brief excursions out of the water. The gills continue to exchange oxygen and carbon dioxide with the stored water until all of the oxygen is used up. After that, the crayfish must return to the water or it will suffocate. This situation is very similar to a land-dwelling animal that holds its breath while underwater. The lungs can continue to absorb oxygen from the stored air, but eventually, the animal must return to the surface of the water and breathe again. Crustaceans that have this ability typically use it to seek out new food sources near the shore of the lake, river, stream, or ocean in which they live. Some use it to move from one body of water to another.

Before we leave this section, it is important to dispel a myth that seems to be very popular in schools today. As you might already know, water is composed of two hydrogen atoms connected to an oxygen atom (H2O). Thus, in a way, there is oxygen in every water molecule. For some reason, this makes some students (and a few teachers, unfortunately) think that gills somehow decompose water, separating the hydrogen and oxygen atoms. Then, the creature uses the oxygen atoms to perform respiration. This is completely untrue. The only way that gills can get oxygen is to extract the oxygen gas that is dissolved in the water. If a crayfish (or even a fish) were put in oxygen-poor water, it would suffocate immediately. In other words, if the water does not have adequate oxygen dissolved in it, a crayfish (or fish) can actually drown! The only way these creatures can get oxygen is if that oxygen has been dissolved in water. The oxygen atoms that are in a water molecule are not available for respiration!

Think about the last time you saw an aquarium with lots of fishes and other water-dwelling animals in it. If you paid careful attention, you probably saw bubbles coming up from the bottom of the tank. Those bubbles were the result of air being pumped into the aquarium so that oxygen from the air can dissolve in the water, replenishing the oxygen used by the creatures in the aquarium. This keeps the aquarium's inhabitants from drowning. If an aquarium (or fish bowl) does not have air being pumped into it, it either has lots of plants and phytoplankton performing photosynthesis to replenish the oxygen being used up by the animals, or it has only a few animals in it. If there are only a few animals in the tank, the oxygen that dissolves into the water from the air above the surface is enough to replenish the oxygen used by the few animals in the tank.

The Crayfish's Circulatory System

Circulation is closely tied to respiration. After all, if the gills get oxygen from the water but the animal cannot send it anywhere, the oxygen wouldn't do much good, would it? Transporting oxygen to the places where it is needed is the job of the circulatory system. As we mentioned in the previous section, arthropods have open circulatory systems. These circulatory systems are very interesting, because they allow for direct contact between the tissues and the blood. This is quite different from the circulatory system that you find in vertebrates. In the vertebrate circulatory system, the blood never leaves the blood vessels. Instead, the exchange of substances between the blood and the tissues occurs through thin-walled vessels called “capillaries.” In arthropod circulatory systems, however, the blood stays in blood vessels for only part of its trip through the animal. It is then dumped into the tissues, bathing them with the substances they need. The figure below illustrates many different systems in the crayfish. For right now, we will focus on the circulatory system.

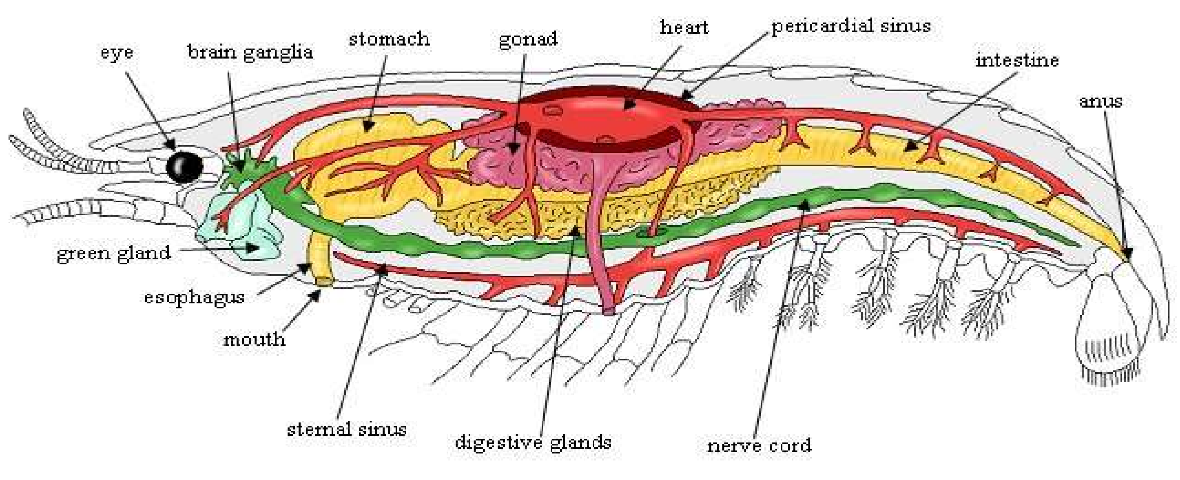


FIGURE 12.4
The Major Systems of a Crayfish

Illustration by Megan Whitaker

A crayfish has a heart in the dorsal part of its body. It rests in a cavity called the pericardial (pehr uh kar' dee uhl) sinus (sye' nus). Blood collects in this cavity, and it enters the heart through one of three openings in the heart's surface. Each opening has a valve that closes when the heart is ready to pump. Once it absorbs the blood and closes these valves, the heart pumps blood through a series of blood vessels that are open at the other end. These vessels dump the blood directly into various body cavities. This allows blood to bathe every cell in the area, giving up the oxygen it is carrying and absorbing the carbon dioxide that the cells need to give up.

Gravity causes the blood to fall into the sternal (stir' nuhl) sinus, where it is collected by blood vessels that are open at one end. Unlike the blood vessels that dump the blood into the body cavities, these vessels carry the blood back towards the pericardial sinus. On its way there, the blood is passed through the gills, where it can release the carbon dioxide it has collected from the tissues and pick up a fresh supply of oxygen. The blood also passes through a green gland, which cleans it of impurities and dumps those impurities back into the surroundings. Once the blood has passed through the gills and the green gland, it makes its way back to the pericardial sinus to begin the trip all over again.

Why do arthropods have this unusual form of circulatory system? Well, it turns out to be a very efficient means by which gases and other vital substances can be sent to the cells. After all, the blood is in direct contact with the cells that it needs to supply. This obviously makes exchanging gases and other substances quite easy. If the open circulatory system is so efficient, why don't other organisms have it? Well, some do. Mollusks, for example, have an open circulatory system. Such systems come at a cost, however. Animals with open circulatory systems rely on gravity to make their blood flow properly. After all, once the blood is released from the blood vessels, gravity must pull it down through the tissues and into the sternal sinus. If the animal happens to be on its back, blood doesn't flow properly, and if the animal stays on its back for an extended amount of time, tissues can die. Thus, although an open circulatory system provides for an efficient exchange between the blood and the tissues, it does restrict the ways in which the animal can position itself. Animals with closed circulatory systems can stay on their backs for as long as they want, because they do not rely on gravity for proper blood flow.

Now before we go any further, we want you to stop a moment and think about what you have been reading. The crayfish has a means by which it can extract dissolved oxygen from the water and transport it throughout its body. The system that does the transporting allows direct contact between the blood and the cells. In addition, the chemical nature of the blood allows it to pick up oxygen where it is supposed to (in the gills) and release it where it is supposed to (in the cells). At the same time, the blood can pick up carbon dioxide where it is supposed to (in the cells) and release it where it is supposed to (in the gills). Isn't that amazing?

As amazing as all of this is, we are not done exploring the wonders of the crayfish's circulatory system. Remember, the exoskeleton protects and supports the crayfish, but this exoskeleton can be damaged. Crayfish (and many other crustaceans) can lead pretty violent lives. When attacked by a predator, a crustacean can usually defend itself fiercely. As we already mentioned, the claws of a crustacean can be used to battle off enemies. Well, in the midst of such battles, it is not uncommon for a crustacean to lose one of its appendages. Its antennae could be broken off, it could lose a leg, or it could even lose a claw! You would think that such a disaster would cause all of the crayfish's blood (which is bathing the tissues) to flow out into the surroundings, killing the creature.

That's what you would think, but it's not what happens! You see, the crayfish and most other crustaceans have a double membrane in each appendage. When the crayfish loses an appendage, the membrane seals the resulting hole, keeping the blood in the body! If this isn't incredible enough, once the membrane seals the hole, the crayfish can actually regenerate the missing appendage. This isn't a means of asexual reproduction, as is the case with the planarian. It is a repair mechanism built into most crustaceans! Crustaceans seem to know all about this marvelous mechanism, because if a crayfish is caught by one of its appendages, it will willingly break it off in order to escape!

Clearly there is a lot of detailed engineering going on here. Not only is there an enormous amount of design evident in just the circulatory system of crustaceans, but there are fail-safe mechanisms as well! In the case of disaster, built-in systems react to minimize the damage and then rebuild whatever appendage was lost. That engineering is just one more example of the fact that God's creation is a continuing testament to His majesty!

The Crayfish's Digestive System

Crayfish are scavengers, eating virtually anything that can be digested. In order to eat something, the crayfish first uses its mandibles to break the food into small chunks. The food then enters a short esophagus and goes into a stomach that essentially has two regions. The first region, which is on the anterior side of the stomach, grinds the food into fine particles. These fine particles are then sent to the other region of the stomach, which is on the posterior side. This region sorts the particles. If they are small enough, they are sent directly to digestive glands which secrete enzymes, completing the digestion process. If the particles are too large to be digested immediately, they are sent to the intestine. As they travel through the intestine, they are exposed to digestive enzymes, which digest what they can. Anything that remains at the other end of the intestine is considered indigestible and is expelled out the anus.

The Crayfish's Nervous System

A crayfish's brain is comprised of two ganglia, each of which has a nerve cord. These nerve cords join together posterior to the stomach and run along the ventral side of the crayfish. At regular intervals, there are ganglia that continually process the signals running down the nerve cord. This system is fed information from various appendages throughout the body. The crayfish has compound eyes that send sight information to the brain. The antennules and antennae send taste and touch information to the nervous system. Also, tiny bristles are found all over the crayfish's body, providing a sense of touch. These bristles are necessary because the exoskeleton is so hard that it is not very sensitive to touch. The bristles make up for that, providing touch sensations to parts of the body that otherwise would not have them.

One rather interesting feature of the crayfish's nervous system can be found at the base of the antennules. As we mentioned before, antennules help the crayfish keep its balance. Here's how: at the base of each antennule is a statocyst (stat' uh sist).

Statocyst – The organ of balance in a crustacean

These statocysts are little containers that are lined with tiny hairs, each providing a sense of touch. Inside each hair-lined container, you will find a grain of sand, called a statolith (stat' oh lith). This statolith shifts when the crayfish is knocked off balance. The hairs detect that shift and send a message to the brain. The brain then sends signals to the muscles, which work the abdomen, swimmerets, telson, and uropods until the crayfish has righted itself.

The Crayfish's Reproductive System

Reproduction in the crayfish begins in the gonad, which produces gametes.

Gonad – A general term for the organ that produces gametes

In males the gonad is called the testis (plural is testes), and in females the gonad is called the ovary (plural is ovaries). In male crayfish, sperm are formed in the gonad and transferred to the first and second pairs of swimmerets. Crayfish usually mate in the fall. Male crayfish deposit their sperm into special containers that the female has. The female then stores the sperm until spring.

In the spring, the female produces eggs. When the eggs travel through the oviduct, they are fertilized by the sperm and go to the swimmerets. The fertilized eggs attach themselves to the swimmerets and develop for approximately six weeks, at which point the eggs hatch. The newborns look like miniature versions of the parents, and they tend to cling to the mother for many weeks after they hatch. During the first year of life, the average crayfish molts seven times. This is because the body experiences rapid growth, and the exoskeleton gets too restrictive. After a year is passed, crayfish tend to molt only twice per year. The average crayfish lives four to eight years.

Other Crustaceans

We have concentrated on the crayfish in this module because it is a good representative of the organisms from class Crustacea. Of course, there are many, many different kinds of crustaceans, a few of which are presented in the figure below.

Lobsters, shrimps, and crabs live in virtually every marine environment and are popular dishes for many seafood lovers. Another marine crustacean that you see in nearly every marine environment is the barnacle (bar' nuh kuhl). Many students mistake barnacles for mollusks, because they appear to have a shell. Well, that's not really a shell. It's an exoskeleton formed out of calcium rather than chitin. Constantly moving appendages bring water into the exoskeleton, allowing the barnacle to breathe and take in food. Barnacles will stick to virtually anything. Although they usually attach themselves to rocks, barnacles have been found on boats, lobsters, large clams, and even whale teeth!

An Important Note

As we did with the earthworm, we have thrown a lot of material about the crayfish at you. Since this creature is such a good example of an arthropod, we want you to remember all of it. In other words, like the earthworm, you need to be able to point out all of the major organs and systems in a crayfish and know how they work. Thus, you will need to commit Figures 12.2 and 12.4 to memory. In addition, you will need to have a solid working knowledge of all the systems discussed in this section. This may seem like a lot, but it is really necessary. The good news is that although we will study several more examples of arthropods, you will not need to have such a detailed knowledge of them. Instead, you will just need to know the basics.