

## Lab 6 – Phylum *Arthropoda*

### Objectives:

- Understand the taxonomic relationships and major features of arthropods
- Learn the external and internal anatomy of the crayfish and an insect
- Use the live and preserved invertebrate specimens to understand the major advantages and limitations of exoskeletons in relation to the hydrostatic skeletons of worms and the endoskeletons of vertebrates, which you will examine next week

**Textbook Reading:** pp. 705-714, 1016, 1078 (Fig. 50.8), 978 (Fig. 45.16), 1028-1029 (Figs. 48.3 & 48.4), 1046 (Fig. 49.1), 1098 (Fig. 51.6)

### Introduction

Arthropods are the largest group of animals, comprising over 1,000,000 terrestrial and aquatic species. By comparison, chordates (including vertebrates) number roughly 40,000 species. Arthropods were not only the first really successful group of animals to invade land, they are the most successful group of terrestrial animals. The invasion of land by arthropods 430 million years ago opened up many new niches and led to an adaptive radiation unparalleled by any group of organisms. Arthropods are found flying thousands of feet above the surface of the earth and thousands of feet below the ocean surface, and just about everywhere in between.

Given their numbers and diversity, arthropods have had profound effects on the plants and animals around them, including humans. Many, especially crustaceans, are important food sources. Some insect species (butterflies, moths, bees, and flies) are necessary for the propagation of fruit and vegetable plants, and thus it is not surprising that pollinating insects evolved simultaneously with flowering plants. Others are important for pharmaceutical research: the venom of certain spiders, for example, may be useful in the treatment of Alzheimer's disease. Other arthropods, such as ladybugs and preying mantids, control crop pests.

On the negative side, many arthropods, especially insects, are harmful to plants and destroy crops and forests. Still others are pests of animals by serving as vectors of disease: malaria, yellow fever, bubonic plague, and elephantiasis are all transmitted to humans by biting insect vectors such as mosquitoes, fleas, and flies.

### Arthropod Characteristics

1) All arthropods possess a **jointed exoskeleton** composed of a polysaccharide, **chitin**, secreted by the epidermis. It is thought that arthropods evolved from a segmented, worm-like ancestor with simple unjointed appendages - probably a primitive onychophoran (velvet worm) or an ancestor of one - that initially developed a polysaccharide exoskeleton for protection against predators and desiccation. The exoskeleton subsequently acquired support and locomotor functions. The exoskeleton serves as a base for muscle attachment, and the muscle systems of arthropods (as well as their modes of locomotion) are the most complex and diverse of the invertebrates. Finally, the exoskeleton may possess pigments that serve as camouflage to hide the animal from predators, or that alternatively act as **warning** or **aposematic coloration** (such as the black and yellow stripes of wasps and bees) to advertise to potential predators that the animal is protected by stings or toxins.

The evolution of an exoskeleton created a number of problems. How does an animal encased in an inflexible "suit of armor" move about? How does it get blood to its body organs? How does it exchange oxygen and carbon dioxide through its "armor"? To deal with these problems involving locomotion, circulation, and respiration, new structures evolved, or existing structures were lost or modified:

2) The name of the phylum reflects another diagnostic character: **jointed feet** (*arthro*, joint; *poda*, foot). The variety of functions performed by arthropod appendages is noteworthy, and includes walking, swimming, prey capture and handling, copulation, and sensory perception. No other invertebrate group has made such broad use of an appendage originally designed for locomotion.

3) The acquisition of legs reduced the emphasis on body segments for locomotion (as in annelids). Hence, many arthropods exhibit **a loss or fusion** of body segments into distinct body regions (e.g., head, thorax, and abdomen).

4) Similarly, the coelom lost its primary function as a hydrostatic skeleton for locomotion (as in annelids and nematodes). The coelom of arthropods became greatly reduced until the major body cavity was a **hemocoel**, a large, central space with a few sinuses extending out from it, filled with blood that directly bathes the animal's organs. Arthropods have an **open circulatory system** whereby blood is pumped out of the animal's heart through a few arteries and then into the open sinuses (hemocoel) where it bathes the tissues directly. Eventually, blood returns to the posterior portion of the heart, probably by means of the animal's body motions and muscle contractions.

5) Another consequence of the exoskeleton is that it limits gas exchange across the body surface of the animal. Arthropods evolved new organs for respiration, such as the **gills** of crustacea and the **tracheae** of insects. Open circulatory systems (and their slower rate of blood flow) are usually associated with animals that have relatively low metabolic needs. Given the high level of activity in many arthropods (such as honeybees), consider how the presence of the tracheal system enables these animals to fulfill their high metabolic demand.

6) Although the exoskeleton has many advantages, it also has a few disadvantages. The rigid, non-living exoskeleton prevents the animal from gradually increasing in size. Arthropods deal with this problem by **molt**ing: a new, soft exoskeleton is formed beneath the existing one and the old exoskeleton is split apart and shed. Immediately following the molt, the arthropod exhibits a growth spurt. During the period of growth, the animal inflates and stretches its body by water or air pressure, and is particularly vulnerable to predators. Stages between molts are termed **instars**. Many arthropods possess complex life cycles. In some, (e.g., centipedes and wingless insects), young hatch as mini-adults and then go through one instar after another until sexual maturity. In others, young hatch as larvae and then undergo partial metamorphosis into adults (e.g., crickets) or complete metamorphosis into a pupa with a cocoon and then into an adult (e.g., butterflies).

7) Arthropods possess a complex nervous system consisting of a dorsal brain and a ventral nerve cord, and **compound eyes**.

The different phyla and classes of arthropods are distinguished from each other on the basis of how the ancestral appendages have been modified into feeding and/or sensory structures:

**Phylum Chelicerata:** in members of this subphylum, the first pair of appendages has been modified into fang-like or pincer-like mouthparts called **chelicerae**. The second pair of appendages, the **pedipalps**, may be modified as grasping, walking, or sensory structures; male spiders often use them for copulation. Chelicerates lack antennae. We will examine two classes of chelicerates: **Class Merostomata**, the horseshoe crabs, and **Class Arachnida**, spiders, scorpions, ticks, and mites.

**Phylum Crustacea:** members of this subphylum differ from chelicerates in having **mandibles** rather than chelicerae as their first pair of mouthparts. Mandibles are modified from the basal segment of the ancestral legs, and function in biting and chewing (although in some species they may be secondarily modified for piercing and sucking). Mandibles are never pincer-like or fang-like, however. Crustaceans also are distinguished from other arthropods by their possession of **two pairs of antennae**. To understand crustacean anatomy and physiology, you will do a detailed dissection of a crayfish and examine several species of living crustaceans (living crayfish, various crabs and water fleas).

**Phylum Uniramia:** like crustaceans, members of this subphylum have mandibles, rather than chelicerae, as mouthparts. They differ from crustacea, however, by the possession of only **one pair of antennae**. In addition, members of this phylum are primarily terrestrial. We will examine two subphyla of unirames: **Phylum Myriapoda**, the centipedes and millipedes, and **Phylum Hexapoda**, the insects (e.g., beetles, bees, ants, butterflies, crickets, roaches, and more).

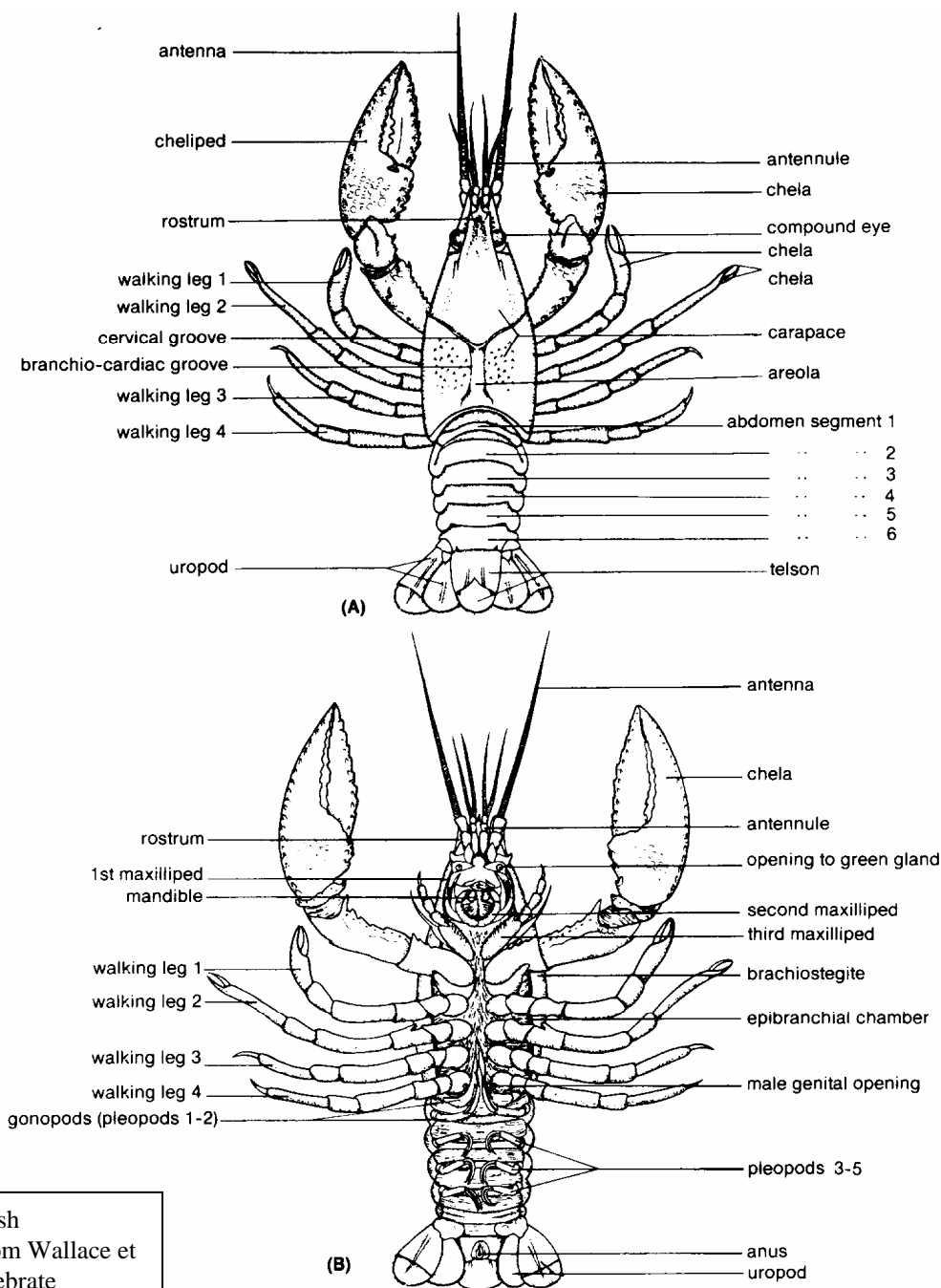
# Specimens of Arthropods

## A) Crustaceans

Crustaceans for the most part are marine organisms and have undergone a remarkable radiation in terms of their diversity. Some crustaceans, such as lobsters, shrimp, and crabs, may be familiar to you, but less familiar crustaceans include barnacles, fairy shrimp, and brine shrimp. A few crustaceans, such as the water flea (*Daphnia*), inhabit freshwater (including the pondwater of the Amherst College campus), and some, such as the sowbug, have colonized land (turn over a log the next time you are on a hike, and you will probably see some).

### 1. Preserved specimen for dissection.

We will examine and dissect preserved specimens of the freshwater crayfish (probably *Procambrus* spp., Figure 1). Crayfish, (also called crawfish or crawdads, depending upon where you're from) provide a good introduction to the basic morphology of crustaceans (and arthropods) given their large size. Moreover, they are quite tasty, whether fried, boiled in cayenne pepper, or served as crawfish etouffé (but don't eat your preserved specimen!).



**Figure 1:** Crayfish appendages (from Wallace et al. 1989, Invertebrate

Obtain a specimen from your lab TA and place it in a dissecting pan. **Examine the external morphology of your animal first.** The body of crustaceans is divided into three regions, the head, thorax, and abdomen. In crayfish, a protective **carapace** covers the head and thorax, which are collectively referred to as the **cephalothorax**. The **abdomen** is segmented and flexible. Given that arthropods are characterized by a fusion and reduction in segments, why do you think the crayfish retains a segmented, flexible abdomen? Finally, note the **jointed appendages** on the ventral surface of your animal (Figure 1).

The carapace extends anteriorly as a pointed rostrum, or snout. Stalked, **compound eyes** and **antennae** are located on either side of the rostrum. Note that there are two pairs of antennae (a distinguishing characteristic of the phylum), a small, anterior pair (first antennae) followed by a larger, posterior pair (second antennae). At the base of each second antenna are small **excretory pores** that are connected to internal **green glands**. A careful Locate the remaining smaller, ventral appendages on the animal's head that manipulate and grind small bits of food. The jaw-like **mandibles** cover the mouth and are located posterior to the excretory pores. The mandibles bear mandibular palps to sort food. Behind the mandibles are two additional pairs of mouthparts, the maxillae.

Examine the second body region of the animal, the **thorax**. Note the ten, large, thoracic appendages (which are the basis for the descriptive name of the order to which crayfish and their immediate relatives, shrimp and lobsters, belong: *Decapoda*). The anteriormost and largest pair of appendages are the **chelipeds** or claws, used for defense and feeding. The remaining four pairs of legs are walking appendages.

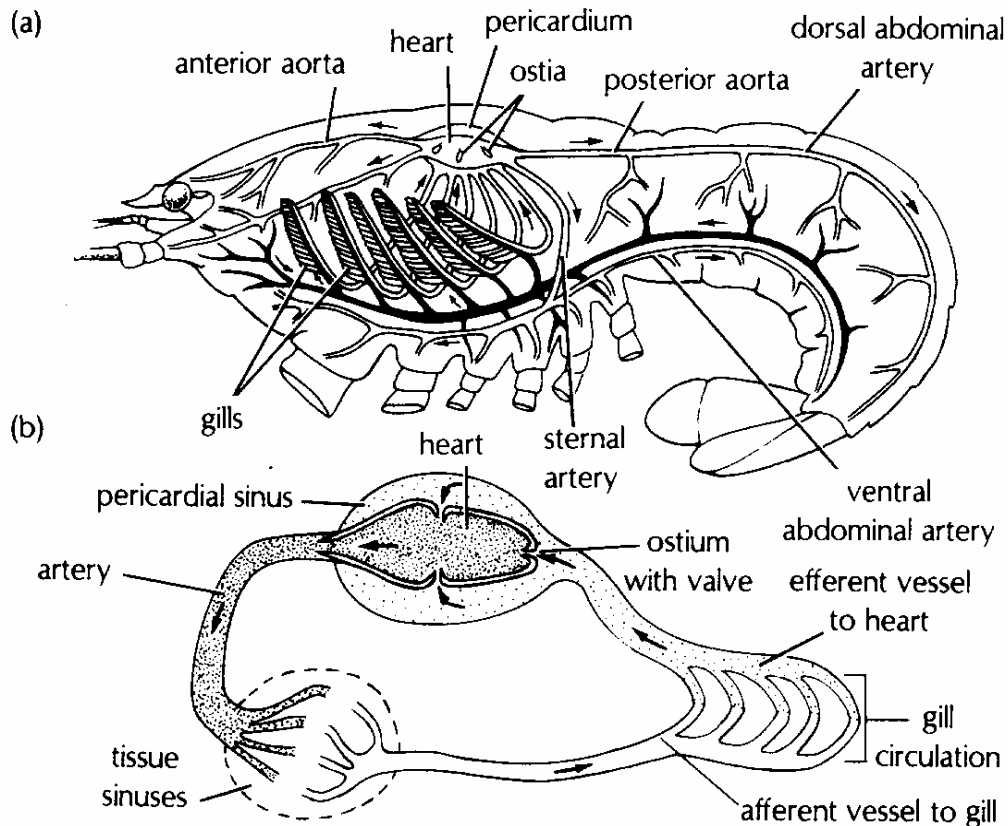
The abdominal appendages consist of five pairs of small, leg-like **swimmerettes** followed by a pair of larger, wider **uropods**. Together with a median, posterior **telson**, the uropods function primarily for swimming. The swimmerettes function in gas exchange by creating water currents. In mature males, the first two pairs of swimmerettes are thickened and elongated as copulatory organs for sperm transfer to females. In mature females, the five pairs of swimmerettes are similar in size and appearance, and also function to form a brood chamber for holding eggs and larvae.

You can also determine the sex of your crayfish by finding the **gonopores**, although these often may be hard to find. In males, the gonopores are located at the base of the last pair of walking legs on the thorax. In females, the gonopores are located on the base of the second pair of walking legs. What sex is your crayfish?

As you may have guessed by now, fertilization is internal in most, but not all, crustacea (which crustacea do you expect would lack internal fertilization, and why?). In species with internal fertilization, the eggs often are attached to the outside of the female's body in brood chambers following copulation (look for these in *Daphnia*!), before hatching into free-swimming larvae. What advantages might a brood chamber offer for the development of offspring?

**Now examine the internal morphology of your crayfish.** Carefully remove one side of the dorsal carapace by lifting it up off of the thorax, thereby exposing the animal's **gills** (Figure 2). The carapace covering the gills forms a gill chamber: water enters the gills posteriorly, flows over the gills, and exits anteriorly.

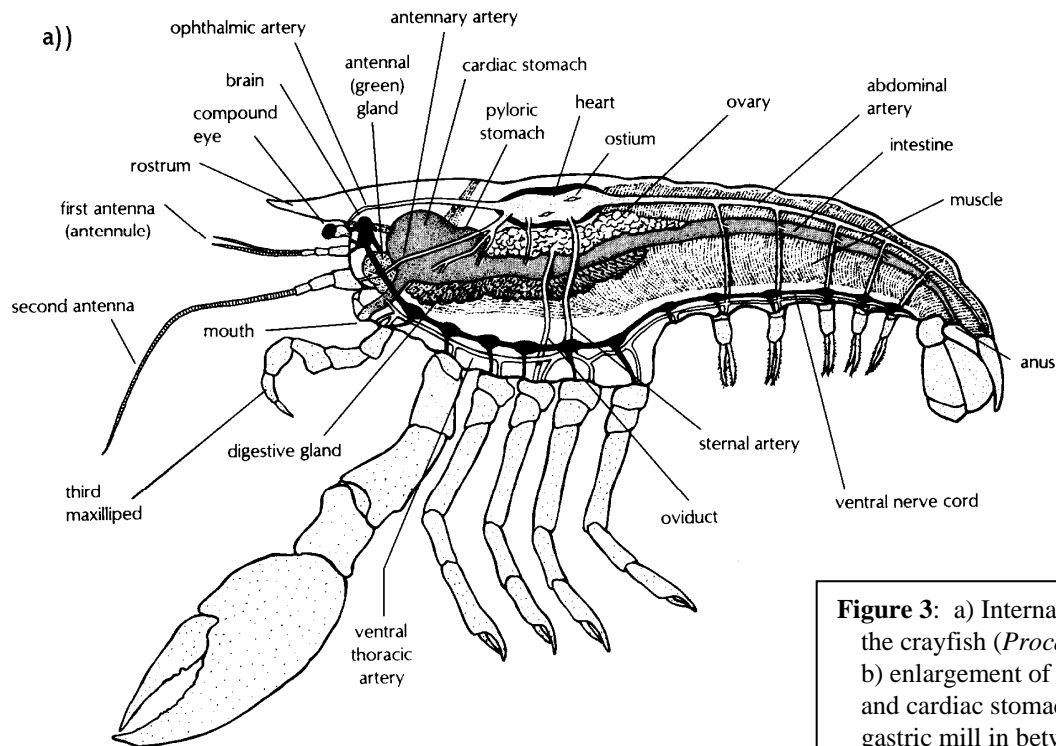
Remove the dorsal portion of the cephalothorax by cutting along the midline of the carapace and peeling it away. In so doing, you will have exposed the **hemocoel**, the main, blood-filled body cavity of arthropods. Located dorsally and anteriorly is a small, block-shaped organ, the **heart** (Figure 2). Several small holes (**ostia**) are located on the sides of the heart, giving it the appearance of Swiss cheese. Use the dissecting microscope to better see the ostia. Blood flows out of the heart via arteries (which do not preserve well and hence cannot be seen in your specimen) and then to the hemocoel where it bathes various tissues before flowing to the gills for gas exchange. The oxygenated blood then re-enters the heart via the ostia.



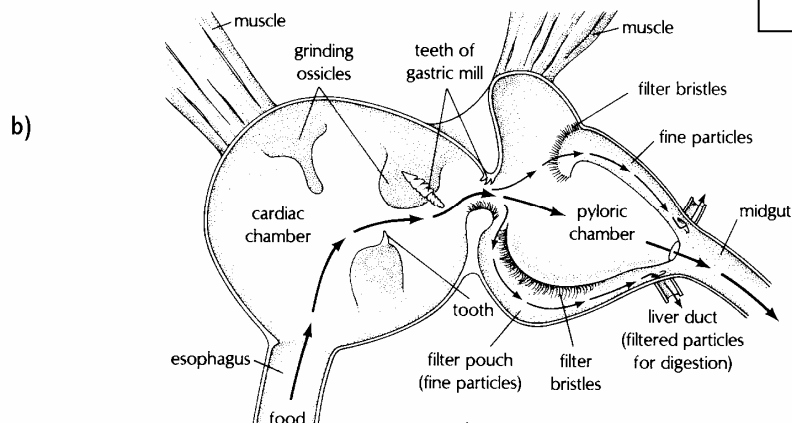
**Figure 2:** Circulatory and respiratory systems of the crayfish (From Pechenik, 1991)

On either side of the heart are large, yellow lobes that are extensions of **digestive glands** (Figure 3a). The digestive glands secrete enzymes and absorb and store nutrients. Ventral and posterior to the heart and buried between the digestive glands, are the gonads, which may not be visible in immature animals.

Remove the heart and digestive glands to expose the **stomach** and **intestine** (you can also obtain a better view of the latter organ by removing the carapace covering the abdomen). The intestine passes dorsally through the abdominal muscles of the crustacean and terminates in an anus located under the telson. The abdominal muscles are the major edible portion of crayfish, shrimp, and lobsters. The "deveining" of shrimp called for in many cookbooks is a misnomer; in actuality, it is the intestine that one removes when deveining shrimp.



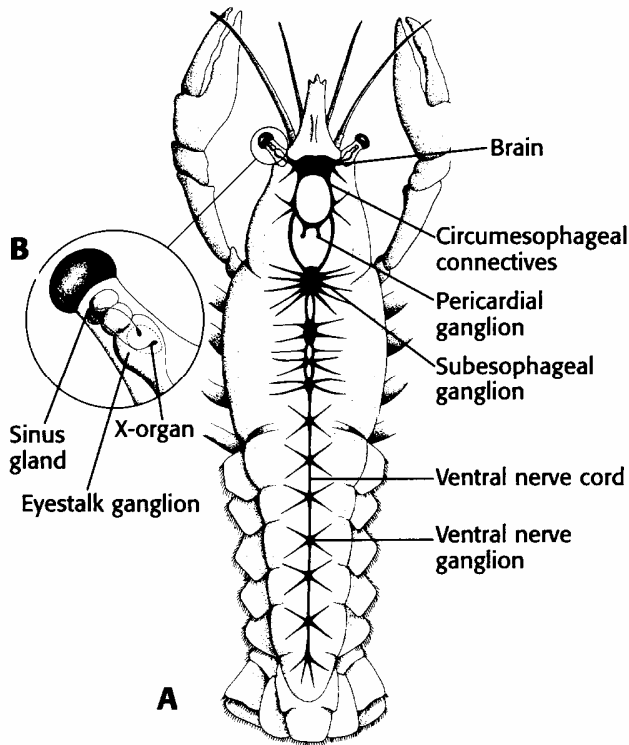
**Figure 3:** a) Internal anatomy of the crayfish (*Procambrus* spp), b) enlargement of the pyloric and cardiac stomachs with the gastric mill in between (figure from Pechenik, 1991, Biology of the Invertebrates)



The large stomach displays a hard, prominent ridge on the dorsal surface. This ridge, the **gastric mill**, serves as a set of "internal" teeth for grinding food, and separates the stomach into an anterior **cardiac stomach** and a posterior **pyloric stomach** (Figure 3b). The cardiac stomach grinds up food particles, whereas the pyloric stomach digests and absorbs nutrients. If you remove the stomach, cut it open, and flush it out with water, you will find that the walls of the cardiac stomach are greatly thickened and lined with "teeth", whereas the pyloric stomach is folded and has an entrance lined with hair-like setae. Why do you think the stomach of the crayfish is divided into different parts with different structures, and how do you think these structures function to process and digest food?

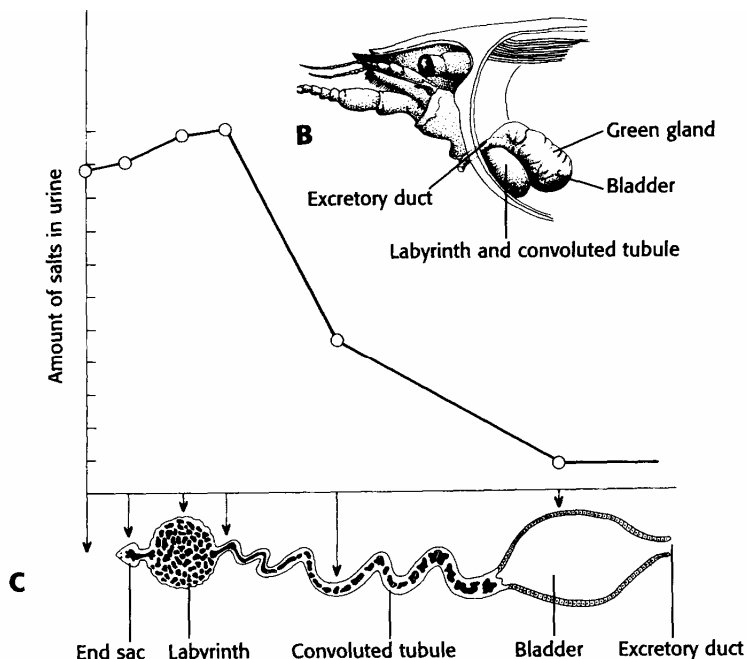
With a careful, deep ventral dissection of the head and a little searching, you may be able to see parts of the nervous and excretory systems of your crayfish. A ganglionated **brain** is located

anteriorly to the stomach, above the mouth. Two nerve cords run posteriorly from the brain to a subesophageal ganglion. A ventral, ganglionated nerve cord then travels posteriorly from here to the tail along the main body of the animal (Figure 4).



**Figure 4:** A. Nervous system of a crayfish. B. Enlarged view of the compound eye of the crayfish, to indicate the communication between the brain and the eye (from Hopkins & Smith, 1997, Introduction to Zoology).

In the anterior most part of the head, on either side, are paired, circular organs known as **green glands** (Figure 5). Green glands (the "tomale" of lobsters) function primarily in **osmoregulation**, that is, salt and water balance. Why might osmoregulation be important for an animal that inhabits freshwater? For an animal that inhabits saltwater?

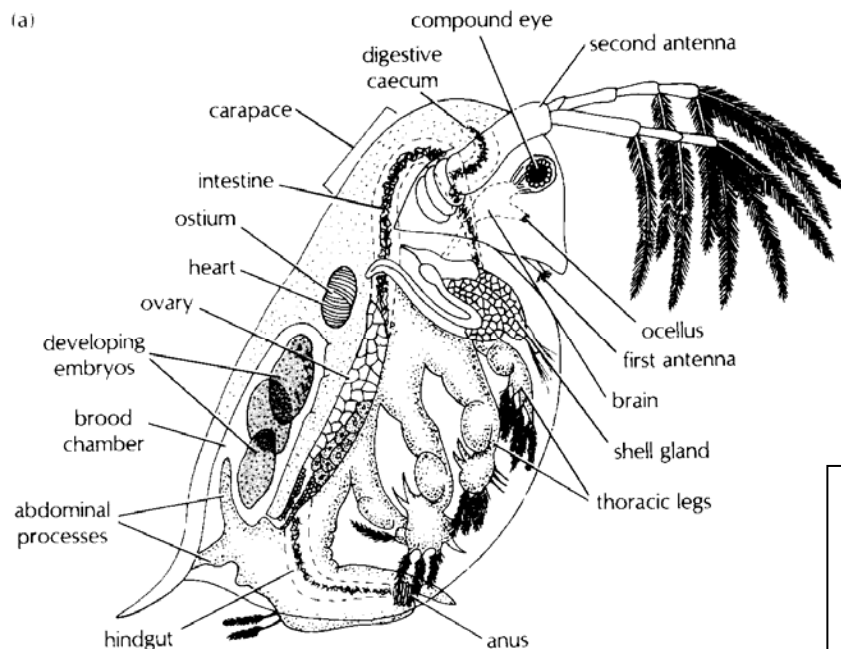


**Figure 5:** B. Green glands of the crayfish, organs responsible for controlling salt and water balance. C: Schematic graph of the internal morphology of the green gland, with a graph of the absorption of salts at each region (from Hopkins & Smith, 1997, Introduction to Zoology). **You won't be able to see the details of the internal structures of the green gland (they're too small) but you should have a sense of how they are similar and different than the vertebrate systems you will see.**



## 2. Live specimens for you to examine:

- a) Crayfish (*Procambrus* spp.) – observe the mouthparts and appendages in action in the living crayfish. Note the rapid movements of the swimmerettes, which keep fresh water flowing over the surface of the gills.
- b) Fiddler crabs (*Uca* spp.) – Do all of the fiddler crabs have symmetric chelipeds? Why might they have claws that differ so much in size? Is it natural selection that led to the difference in claw size or sexual selection?
- c) Hermit crabs (*Paguristes* spp.) -- Hermit crabs differ from other types of crabs in that they do not have an abdomen that is covered in a hard carapace. They borrow shells from marine snails to protect themselves, and when they grow they just find a new shell. Watch the interactions between the hermit crabs as they tussle over shells, and see if you can catch one in the act of switching shells – they are quick at it!
- d) Water fleas (*Daphnia pulex*) – These arthropods have extended parental care in which the mother broods the developing embryos under her carapace (Figure 6). Put a small drop from the culture jar on a depression slide and **use your dissecting or compound microscope to locate a brooding female**. What advantages and disadvantages might be associated with extended parental care of this sort? What is a primary function of the legs in adult *Daphnia*?



**Figure 6:** Internal and external features of a water flea, *Daphnia pulex* (from Pechenik 1991, *Biology of the Invertebrates*).

## B) Phylum Hexapoda (Insects) - Madagascar hissing cockroach, grasshopper and crickets - live and dissections

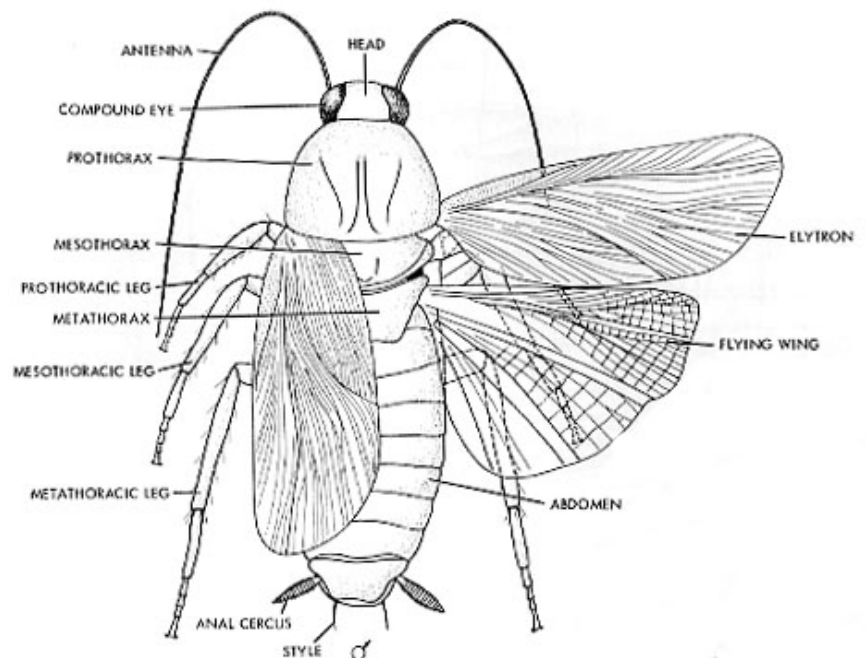
The insects are the most successful of all animals. Depending upon the source, the number of species of insects on our planet ranges from 800,000 to 1.5 million. These numbers almost certainly are underestimates, and the actual number of insect species on earth may be closer to 2 or 3 million. One reason for the insects' extraordinary success is that they were one of the first groups of animals to colonize the land and the air. In fact, insects are the predominant arthropod on land, in the air, and in freshwater (but not in marine environments, which may explain the diversity of crustaceans living in oceans and estuaries). In addition, the radiation of some insect groups occurred simultaneously with the appearance and radiation of the angiosperms, or flowering plants. Although the crayfish provides an overview of some arthropod characteristics, it is an animal adapted for life in the water. Life on land requires new methods of gas exchange and water regulation. Accordingly, our examination of insects focuses on adaptations for respiration and excretion.

### I. Madagascar Hissing Cockroach and Pre-Dissected Grasshopper

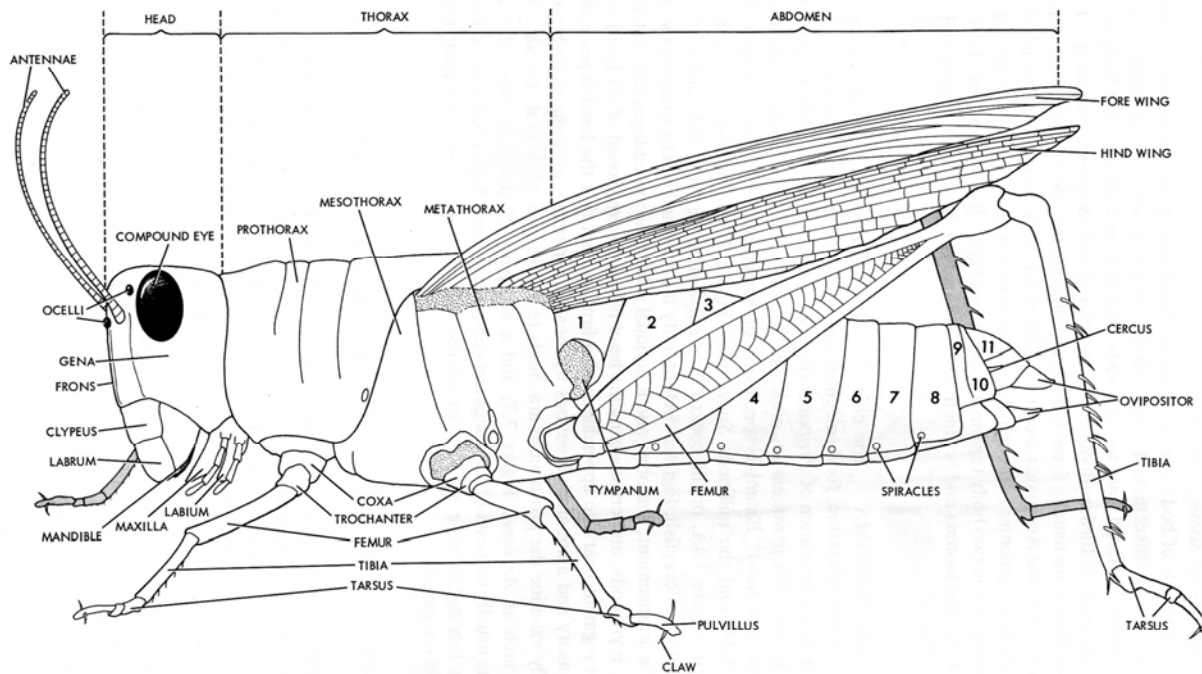
Examine the external morphology of the living roaches in the front of lab. (Yes, you can pick them up, if you would like!) Similar to crustaceans, the body of insects is divided into three regions, the **head**, **thorax**, and **abdomen** (Figure 7). In modern insects, the thorax alone bears legs, one pair to a segment. Not only do the legs of roaches (and other insects) function for locomotion, but also many have fine hairs that react to tactile and chemical sensory input.

Unlike crustaceans, the head of the cockroach bears one pair of long, slender antennae. What kind of sensory stimulation would you expect antennae to respond to? The head also bears a pair of large, **compound eyes**. (Revisit the structure of an insect compound eye by examining Figure 6 in the Mollusk lab.) Mouthparts consist of mandibles and maxillae. On the very posterior segment of the cockroach's abdomen are two projections that resemble paired tails. These "tails" are the **cerci**, which function as sense organs. Touch the cerci of a live cockroach with the point of a needle. What happens?

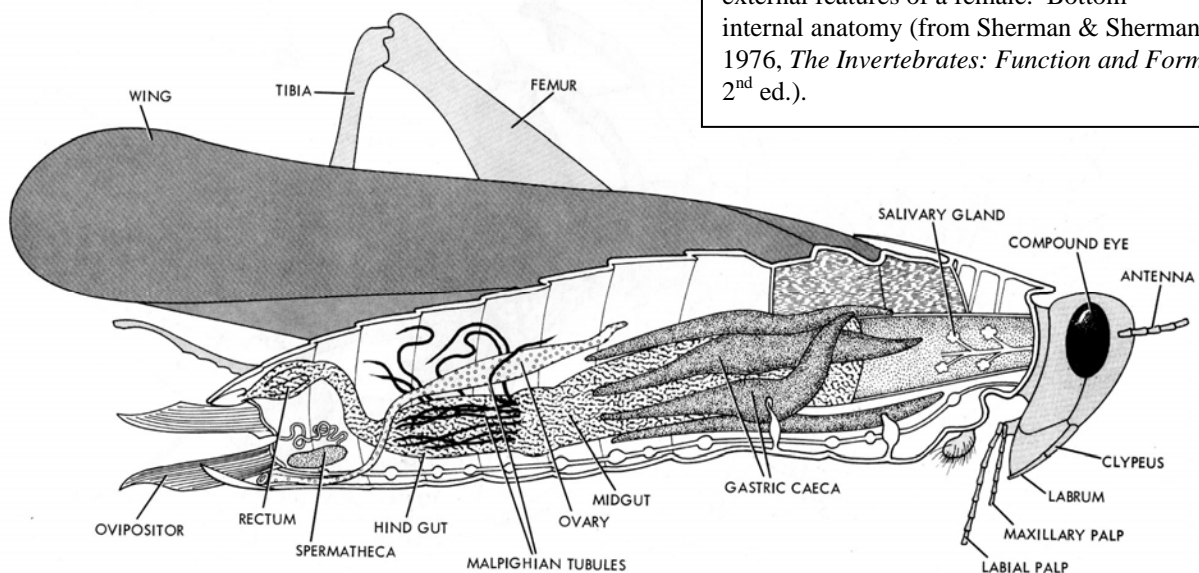
**Figure 7:** External anatomy of the cockroach (from Sherman & Sherman, 1976, *The Invertebrates: Function and Form*, 2<sup>nd</sup> ed.)



Examine the internal anatomy of the dissected grasshopper in the front of the lab (Figure 8). For this demonstration, the dorsal plates covering the abdomen were removed by making an incision along the outer edge of each plate. The grasshopper was then covered with water, which causes the internal organs to float and makes them easier to see, and prevents them from drying out. The internal organs are visible to the naked eye, but you may want to examine the grasshopper under the dissecting scope for a closer look.



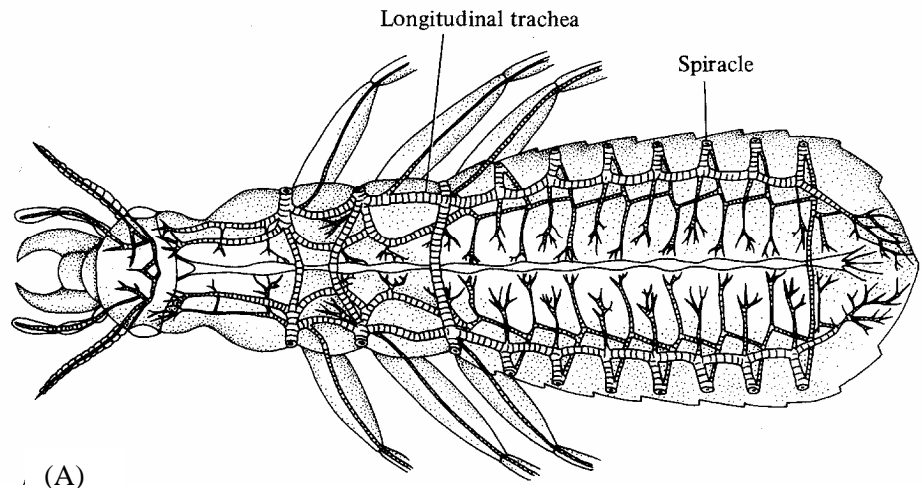
**Figure 8.** The grasshopper *Romalea*. Top - external features of a female. Bottom - internal anatomy (from Sherman & Sherman, 1976, *The Invertebrates: Function and Form*, 2<sup>nd</sup> ed.).



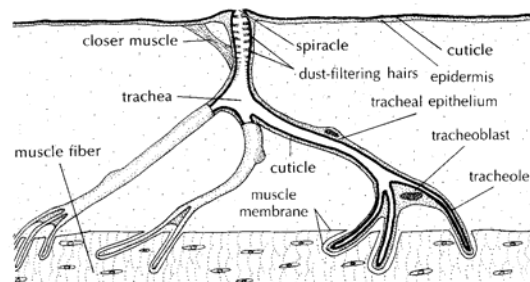
The most obvious structure, once the dorsal abdominal plates have been removed, is a mass of white tissue. These are the **fat bodies**, which store fat, and convert protein and carbohydrate to fat. (If the grasshopper is a female, the large egg-filled ovaries have also been pushed to the side.)

The exchange of gases in insects occurs through the **tracheal system**, which is an extensive, branching system of tubules that permeates throughout the entire body (Figure 9). Branches extend to every organ in the body, and the terminal divisions are such that each cell in the insect body is only a short distance from a tubule of the tracheal system. Because cells can directly exchange gases with the environment, insects can maintain a high level of metabolic activity even though they have an open circulatory system (as long as the body is small in size so as to circumvent limitations on bulk flow rates of gases through the tracheal tubules). The shiny white tubes running through the animal are the tracheal tubes, which connect to external openings in the exoskeleton called **spiracles**. You may be able to see the spiracles along the lateral margins of the abdomen. Additional spiracles are located on the dorsal part of the thorax. Insects pass air through the tracheae by a variety of body movements. In the grasshopper, contraction of the abdominal muscles forces air out through the thoracic spiracles, and relaxation of the dorsal muscles draws air in through the abdominal spiracles.

**Figure 9:** A. The tracheal system of a generalized insect. Spiracles are openings in the outer carapace of the insect that lead to the tracheal system. In the dissection of the grasshopper, the tracheae will appear as air filled tubes, which look like glass noodles (from Pechenik 1991, *Biology of the Invertebrates*). B. Diagram of the insertion of the tracheal system directly on muscles and other body tissues in terrestrial insects. The finest tubes, the tracheoles, develop from the tracheoblast cell (from Withers, 1992, *Comparative Animal Physiology*).



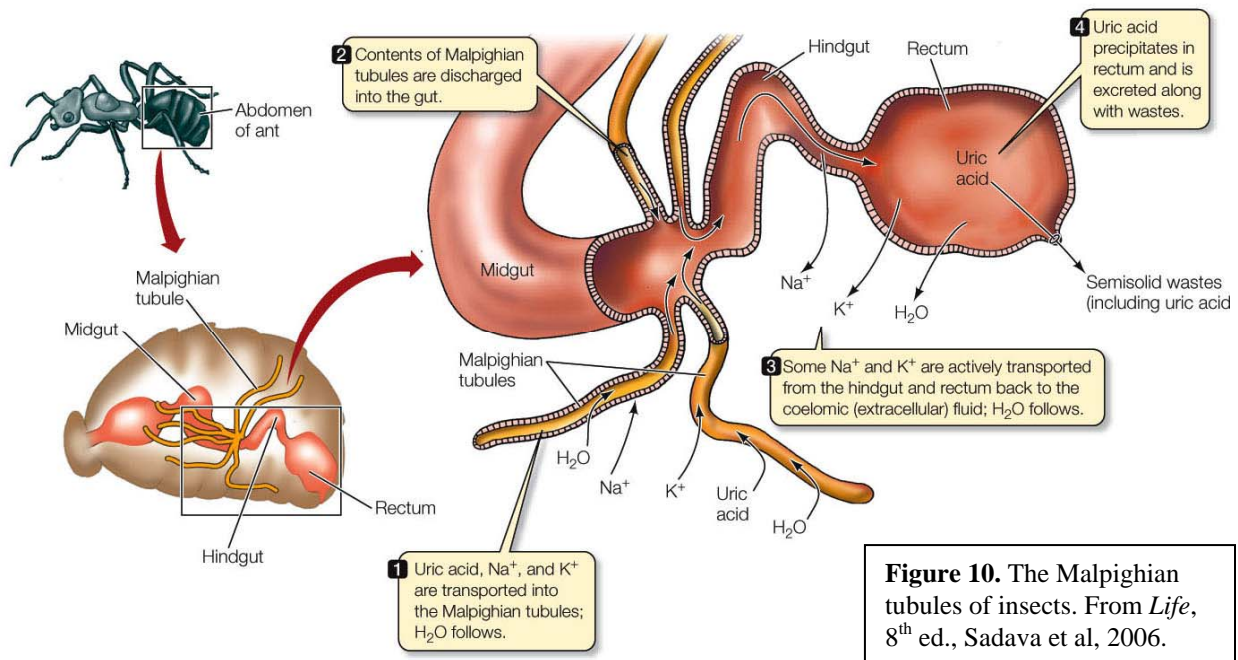
(A)



(B)

If necessary, use a probe or needle to tease away some of the fat bodies to view the digestive tract. Anteriorly, the esophagus expands into a large, thin-walled **crop**, an organ for storing food. The crop eventually narrows into a muscular sac, the proventriculus or **gizzard**. The mouth of the grasshopper has no means for grinding up food; the gizzard performs this function. The gizzard leads into the next part of the digestive tract, the **mid-gut**. Coming off the anterior end of the midgut are the **gastric caeca**, finger-like projections formed by outpocketings of the midgut. *What do you suppose the functions of the gastric caeca are?*

The termination of the midgut and beginning of the **hindgut** is marked by an outgrowth of a few dozen slender, yellow **Malpighian tubules**. The Malpighian tubules float in the hemocoel of insects and absorb various waste products, especially uric acid, from the blood (Figure 10). These wastes then drain into the hindgut for excretion. Some reabsorption of water may also take place in the Malpighian tubules. The hindgut terminates in the **rectum**, a muscular sac for storage of wastes, which empties into an anus.



## II. Instructions for working with living crickets:

### A. Insect External Anatomy

1. Use Figure 8 above to familiarize yourself with the external and internal anatomy of an adult grasshopper (*Romalea* sp.), which is a close relative of the common cricket (*Acheta domestica*). Note the prominent segmentation, three body regions, and jointed appendages.

2. Identify the following structures on a living cricket: head, thorax, abdomen, antennae, ocelli, compound eye, multiple leg segments, tympanum, ovipositor (if female).

## B. Osmoregulation and Removal of Metabolic Wastes in Insects

As you learned above, the principal excretory organs of insects are **Malpighian tubules**, which are ectodermal evaginations of the gut. Study the structure and function of Malpighian tubules by performing the exercise below.

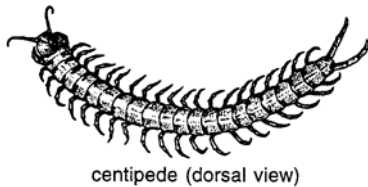
1. Ask your instructor to anesthetize a live cricket with carbon dioxide (approx. 3 minutes in a CO<sub>2</sub> chamber). Then, inject 0.05 ml of indigo carmine between the last two abdominal segments into the hemocoel.
2. Wait 30 minutes, then euthanize the animal by placing it in the killing jar in the hood for five minutes. **\*Note:** while the cricket is unconscious, note the opening and closing of the **spiracles** along both sides of the abdominal wall, which is how insects “breathe.”
3. Using a fine pair of scissors, carefully remove the dorsal body wall. Try to do so without penetrating the soft tissues. Cut up the right edges of the terga and across the first tergum of the thorax and back to the seventh abdominal segment. Dissect the terga away from the body and turn aside the flap so formed. Mount the specimen in a wax lined tray (by means of fine insect pins). Find the midgut/hindgut junction and look for the Malpighian tubules, which should have blue dye particles in their lumens (inner space). **What does this result illustrate?**

## C. Gas Exchange\*

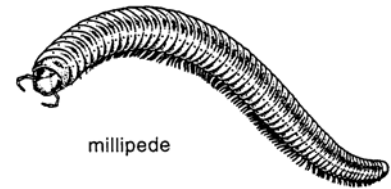
1. In your dissected cricket, observe the fine, filamentous tubules of the tracheal system (these will NOT have dye in them – why not?) that extend throughout the entire body of the cricket. Is the distribution of tubules random or if there is some organized pattern present? Remove some of the tissues containing tracheae and mount on a microscope slide for viewing with a compound microscope (add a drop of saline and a cover slip).
2. A supplemental technique to consider is to try staining a small piece of fat body containing tracheal tubes removed from the cricket. Do so with a drop of methylene blue (which penetrates cells and stains the nuclei), add a coverslip and observe under high power (40X) of the compound microscope. Which tissues are stained? Unstained (e.g., are acellular and have no stained nuclei)? Consider how the structures relate to function.
3. Compare the relationship of the cricket tracheal tubes and spiracles to those of a tomato worm larva, which are on a whole-mount slide on a demonstration microscope.

### C) Phylum Myriapoda, preserved specimens, demonstrations

Myriapods represent the other subphylum of the phylum Uniramia. Like insects, myriapods possess a single pair of antennae; they also have mandibles, a tracheal system, Malpighian tubules, and similar nervous and circulatory systems. They differ from insects, however, in having a body divided into two, not three, regions: a **head** and a **multi-segmented trunk** bearing many legs.



Two myriapods are on display for you to examine. Centipedes (**Class Chilopoda**) possess a single pair of appendages per trunk segment. The appendages of the first trunk segment are modified into **poison claws**. The venom is paralytic to small, and even not so small, prey; some *Scolopendra* centipedes measuring 5 inches in length are quite capable of dispatching a mouse. The venom is usually non-lethal to humans, although a bite from a 5-inch centipede can be quite painful. As you may have guessed, centipedes are active predators. Many species have scent glands that emit repellant secretions. Armed with poison claws and scent glands, centipedes have few natural enemies. With their bright colors, and long legs and antennae, centipedes can be quite conspicuous...why do you think this is the case?



Millipedes (**Class Diplopoda**) differ from centipedes in having two pairs of appendages per body segment. In actuality, the trunk segments are fused into groups of two. Millipedes lack poison glands, but some possess scent glands. Unlike centipedes, most millipedes are herbivorous. Can you identify features of centipedes and millipedes that give some clue as to their lifestyle?

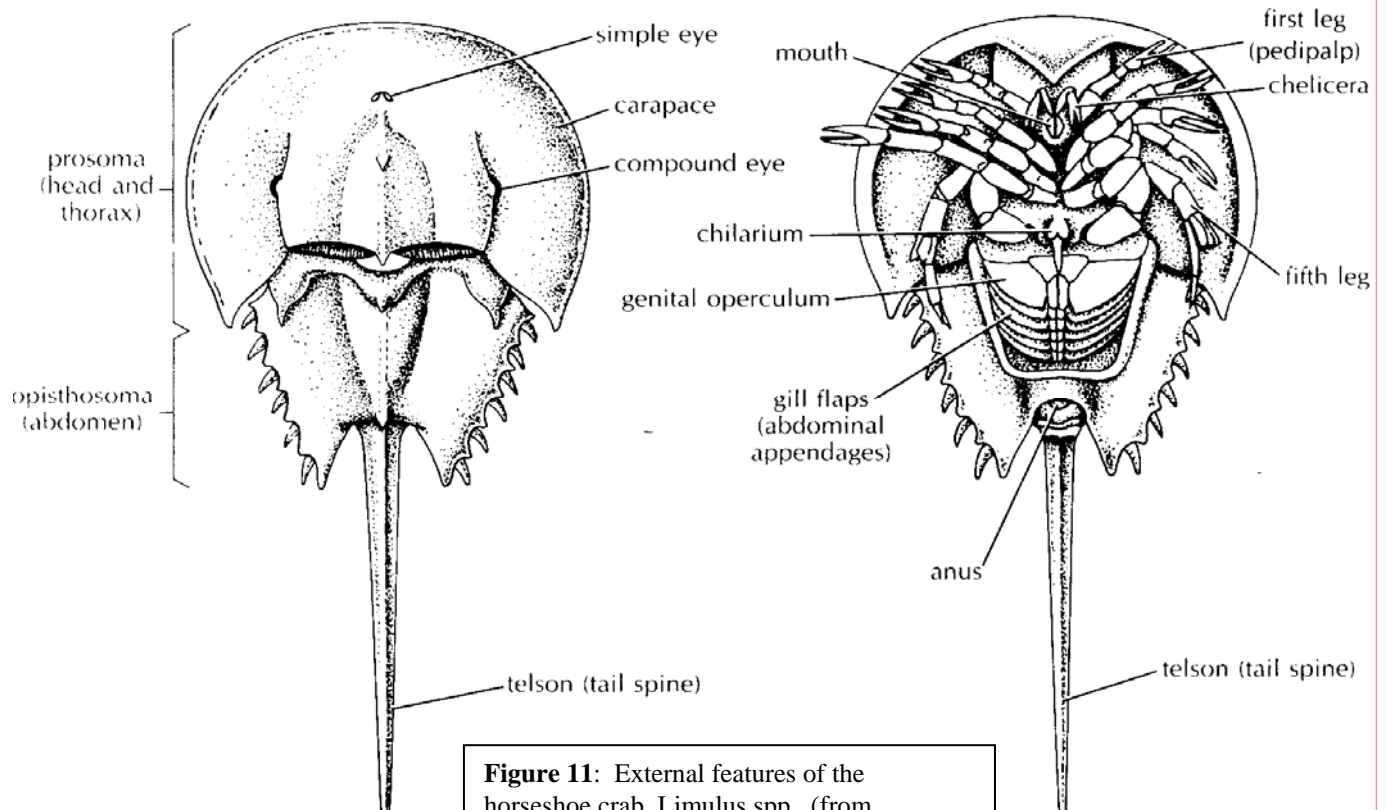
### D) Phylum Chelicerata

#### (1) Class Merostomata, preserved specimen, demonstration (Figure 11)

The merostomates are one of three classes of the phylum Chelicerata, the others being the arachnids and the pycnogonids (sea spiders). The class is comprised of marine species that are evolutionary relicts: their fossil record stretches back nearly 500 million years. Today, the class is represented by only a few living specimens. The specimen on display is the **horseshoe crab**, *Limulus polyphemus*, the only species found in the United States (along the Atlantic coast and Gulf of Mexico; thousands come together each year in Chesapeake Bay for a giant mating "orgy"). Although they bear pincer-like mouthparts, or chelicerae, horseshoe crabs are harmless scavengers.

Like all chelicerates, the body of the horseshoe crab is divided into two regions, a **cephalothorax** and an **abdomen** (Figure 11). The cephalothorax is enlarged into a helmet-like **carapace** that protects the soft body parts lying underneath and enables the animal to plow through the sand. A smaller, spiny abdomen articulates with the carapace. Extending posteriorly from the abdomen is a long **telson**, which the animal uses for righting itself (should it flip over on its back) and pushing the animal along. On the dorsal surface, locate two compound eyes. Each facet of the eye corresponds to a separate lens and set of photoreceptor cells. Because these cells are large relative to other organisms, the vision system of the horseshoe crab is a favorite of neurobiologists studying how organisms see. A pair of simple eyes is also present on the dorsal surface.





**Figure 11:** External features of the horseshoe crab, *Limulus* spp. (from Pechenik 1991, *Biology of the Invertebrates*).

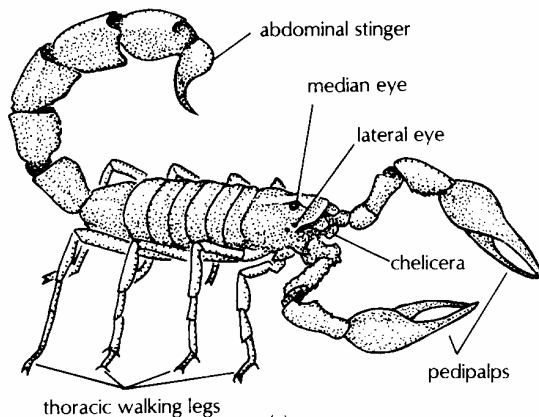
Flip the animal over on its "back" to examine its ventral surface. Note the pincer-like **chelicerae** anterior to the mouth. Five pairs of walking legs are located behind the chelicerae. The **pedipalps** form the first pair of walking legs, and in males also acts as a clasping organ for mating. The basal segments of the first four pairs of legs bear numerous spines on their median side (**gnathobases**). Food is picked up by the chelicerae, then moved back to the gnathobases where it is macerated, and finally passed *forward* to the mouth. The abdomen lacks appendages, but bears six plates. The first plate contains the genital openings; the remaining five plates are **book gills** for respiration. Why are the gills so thin?

## (2) Class Arachnida, preserved specimens and microscope slides, demonstrations

The arachnids are the largest class of chelicerates, many of which are familiar to you: spiders, daddy longlegs, ticks, mites, scorpions, and tarantulas. Examine the various arachnids on display, and note that although they may differ in length and in shape, they share the same, **two-part** body plan consisting of a **cephalothorax** and an **abdomen**. There may be **simple eyes** on the cephalothorax, but arachnids lack compound eyes and antennae. The cephalothorax bears six pairs of appendages: the **chelicerae**, the **pedipalps**, and **four pairs of walking legs**. Arachnids are terrestrial, and in some species, such as spiders, the bases of one or two pairs of abdominal appendages are modified as **book lungs**. Other species lack book lungs, and respire by means of **tracheae**.



i) **Scorpions** are the oldest known terrestrial arthropods, and may have been the first arthropods to have invaded land. Fossilized scorpions date back to the Silurian period, 430 million years ago. These species were aquatic and had gills. Terrestrial scorpions appeared in the Devonian, about 50 million years later. Scorpions are easily identified by their **abdominal stinger** and **claw-like pedipalps** (Figure 12). Scorpions capture and grasp their prey with the pedipalps, and then paralyze the prey by injecting it with venom from the sting. The venom of most scorpions, a neurotoxin, is sufficiently toxic to kill invertebrate prey, but is usually not very harmful to humans. Certain species occurring in North Africa, Mexico, Arizona, and New Mexico (e.g., *Centruroides sculpturatus*), however, have highly toxic venom that can be fatal to humans. The venom of these species reputedly is equivalent in toxicity to cobra venom; it can kill a dog in minutes and a human in a few hours.



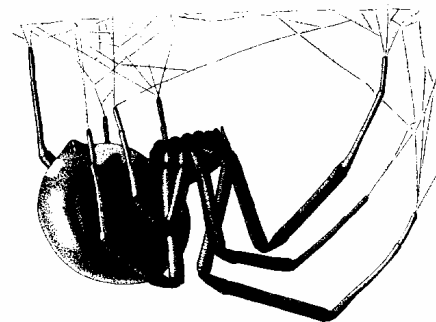
**Figure 12:** External features of the scorpion (from Pechenik 1991, *Biology of the Invertebrates*).

In addition to their venomous stinger and clawed pedipalps, scorpions have a few other noteworthy features. The abdomen is composed of a **seven-segmented preabdomen** and a **five-segmented postabdomen**, and is believed to be a primitive character reflecting arthropod evolution from a segmented, worm-like ancestor. In addition, development in scorpions differs from that of most arthropods in being either **ovoviviparous** (eggs are retained and hatch within the female's body, but are not laid), or **viviparous** (young are born alive).

Development takes from several months to a year or more. At birth, the young are mini-replicas of their parents, and immediately crawl onto their mother's back. The young remain there through the first molt, and then gradually leave their mother and become independent.

ii) The **black-widow spider** is an example of an orb-weaving, or web-building, spider (Figure 13). Note the two-part body plan, and the narrow waist (or **pedicel**) connecting the abdomen to the cephalothorax. The posterior end of the abdomen bears short **spinnerettes** that eject **silk**. The silk of spiders is a protein similar to the silk of caterpillars, and is secreted from silk glands. Depending on the species, the silk may be used for draglines, nests, cocoons, or webs. Spider silk is very strong for its diameter, and thus there is interest among the research community in creating artificial "spider silk".

Like other orb-weavers, the black widow has long, slender legs, which it uses to construct a web for prey capture. Eyesight is poorly developed in orb-weavers, but these spiders are highly sensitive to vibrations (try holding a violinist's tuning fork next to a spider web sometime, and see what happens). A web-builder can determine from thread vibrations both the size and location of prey, and whether or not the prey is potentially harmful. Being



**Figure 13:** Black widow spider (from Barnes 1980, *Invertebrate Zoology*).

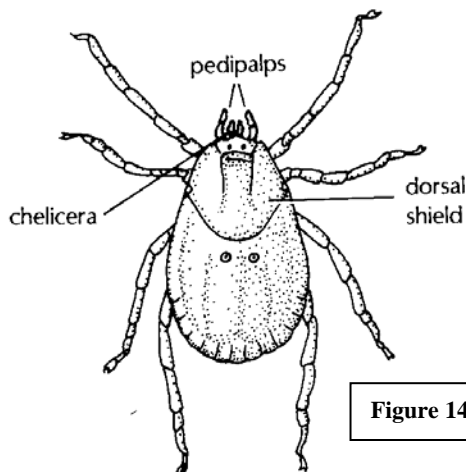
protein, webs are not inexpensive to make, and many spider species "recycle" their webs by eating the old silk and spinning a new web. Some spider species are kleptoparasites, and beat up other species and steal their webs. The exact shape and structure of webs differs among spider species, and different genera can be identified in the field simply from knowledge of their webs.

Once captured in the web, the orb-weaver may wrap the prey with silk before or after biting it with its chelicerae and injecting it with venom. The venom of most spiders is not harmful to humans, but a few species, such as the black widow and brown recluse, have dangerous bites. The venom of the black widow is a neurotoxin, and produces muscle spasms, nausea, and respiratory paralysis. The venom of the brown recluse is hemolytic; it destroys tissue in the area of the bite.

Although they are of interest because of their harmful venom, black widows have recently caught the attention of biologists because females of the species routinely eat males during copulation. Why males should essentially commit suicide during copulation has puzzled evolutionary biologists, because it would seem to reduce a male's fitness, measured in terms of survival and reproduction. Recent research suggests that males benefit from such a sacrifice: eating a male prolongs copulation, and the number of eggs a male fertilizes increases with the duration of copulation.

iii) **Tarantulas** are relatively harmless to humans, although they possess chelicerae that hold the prey and inject venom. Although some are web-builders, most species of tarantulas stalk their prey: note the animal's long legs and well-developed eyes. The hairs covering the animal function in anti-predator defense: when disturbed, the tarantula can shed these hairs, which penetrate the skin and cause an irritating itch.

iv) **Ticks** and **mites** have had major impact on humans as pests and vectors of disease. Many are ectoparasites (e.g., scabies-causing mites, chiggers, and ticks, which can transmit Lyme disease and Rocky Mountain spotted fever). A few species are free-living, however. Over 25,000 species have been described to date, compared with about 32,000 species of spiders, but most biologists think this number is a gross underestimate. Mites, in particular, are ubiquitous: males of one species actually use the nostrils of hummingbirds to move from flower to flower in search of females. When the hummingbird visits a flower, the mite sprints down the bill of the bird and into its nostrils at a speed that for its size (< 1 mm in length) is equivalent to the speed of a cheetah! (This particular mite feeds on nectar, and thus adds insult to injury by competing with the hummingbird for food).



Examine the microscope slide of the deer tick, *Ixodes dammini*, on demonstration (Figure 14). The deer tick is the vector of the spirochaete bacteria responsible for Lyme disease. Note the apparent lack of a cephalothorax and abdomen; these two regions are fused, and in most cases are covered with a single shield or **carapace**. Also examine the **chelicerae**: would you expect them to be fang-like or pincer-like, given the tick's blood-sucking lifestyle?

**Figure 14:** External features of the deer tick (from Pechenik 1991, *Biology of the Invertebrates*).

## **Animal Diversity and Organ Systems Quiz II: Mollusks and Arthropods**

The questions that follow will more specifically guide your review. The list of questions is not exhaustive, but should direct your attention to specific key aspects of the animals that you will be quizzed on. Some questions will require that you synthesize information from lectures, your book **and** the lab.

### **Questions on Phylogeny:**

1. What are the major features of mollusks?
2. What are the major taxonomic divisions (e.g., classes) in the phylum *Mollusca*?  
How do the three classes studied in lab differ from one another?
3. What are the major features of arthropods?
4. What are the major taxonomic groups (e.g., phyla) in the superphylum *Arthropoda*?
5. If comparing two organisms, what characteristics do they share because of homology (history)? What do they share because of convergent evolution?
6. What features of millipedes give some clues as to their lifestyle?

### **Questions on Organ Systems Anatomy and Physiology:**

#### **Circulatory System:**

1. What are the three major components of circulatory systems?
2. How does blood (hemolymph) transport differ between organisms with closed and open circulatory systems?
3. What type of circulatory (open or closed) does each type of organism have?
4. What about the lifestyle of an animal correlates with having an open or closed circulatory system, respectively?

#### **Respiratory System:**

1. By what process does the exchange of gases across a respiratory surface occur?
2. What are the three factors that evolution has acted upon to increase the efficiency of gas exchange across respiratory surfaces?
3. What particular type of respiratory surface is used in each type of animal?
4. How does each animal prevent the external respiratory medium (e.g., air or water) from becoming depleted of oxygen and saturated with carbon dioxide?

#### **Digestive System:**

1. What are the three major processes that occur in the digestive system?
2. How does each animal obtain and process its food? What structure(s) manually break down food particles (if applicable)?
3. What is the function of the intestine in all animals? What are the implications of increasing the length, evaginations and/or folding of the inner layer of the intestine?
4. What is a radula? How does it function in herbivorous and carnivorous mollusks?
5. Given the morphological and anatomical features of the squid (beak-like radula, tentacles around mouth), what sort of food do you think it eats? Would you expect to find squid in the same habitats as snails or clams, and if not, where would you expect to find them?
6. What is the pathway of the digestive tract in squid?

**Nervous System:**

1. What structures act as the “brain” (e.g., anterior accumulation of nerve cell bodies) in crayfish and squid?
2. What about the major nerve cords in crayfish and squid - are they dorsally or ventrally located?
3. Clams clearly detect and respond to sensory stimuli. Do they have a brain?
4. The eyes of a squid and a mammal have very similar structures. Is this an example of homology or convergent evolution?
5. What kind of eye do insects (e.g., cockroach and crickets) have?

**Excretory System:**

1. Marine clams such as *Mercenaria* are *osmoconformers*. What does that mean?
2. Which organs does the freshwater crayfish use for salt and water balance (e.g., osmoregulation)?
3. Which structures do insects (e.g., cricket and cockroaches) use for osmoregulation and excretion of metabolic wastes?

**Musculoskeletal Systems and Movement:**

1. The evolution of an exoskeleton created a number of other problems. How does an animal encased in an inflexible "suit of armor" move about? How does it get blood to its body organs? How does it exchange oxygen and carbon dioxide through its "armor"?
2. What structure secretes the shell of mollusks?
3. How does a cherrystone clam close or open its shell?
4. Where/what is the shell-equivalent in cephalopods?
5. Compare and contrast the way (and the structures involved) that a clam burrows into the sand versus how a squid swims.
6. What type of skeleton do arthropods have? What are the implications of this type of skeleton with respect to growth?
7. With their bright colors, and long legs and antennae, centipedes can be quite conspicuous. Why?
8. What types of appendages are used for locomotion in the different kinds of arthropods?
9. What other functions (besides locomotion) have appendages in this group evolved to serve?

**Reproductive System:**

1. How can you tell the sex of a crayfish by its external anatomy?
2. Can you identify the gonads in the different animals?
3. Where does fertilization occur for clams? for squid? for crayfish? for crickets?
4. As you may have surmised, fertilization is internal in most, but not all, crustaceans. In species with internal fertilization, the eggs often are attached to the outside of the female's body in brood chambers following copulation, before hatching into free-swimming offspring. What advantages and disadvantages might a brood chamber offer for the development of offspring?
5. Why might fiddler crabs have chelipeds that differ so much in size?