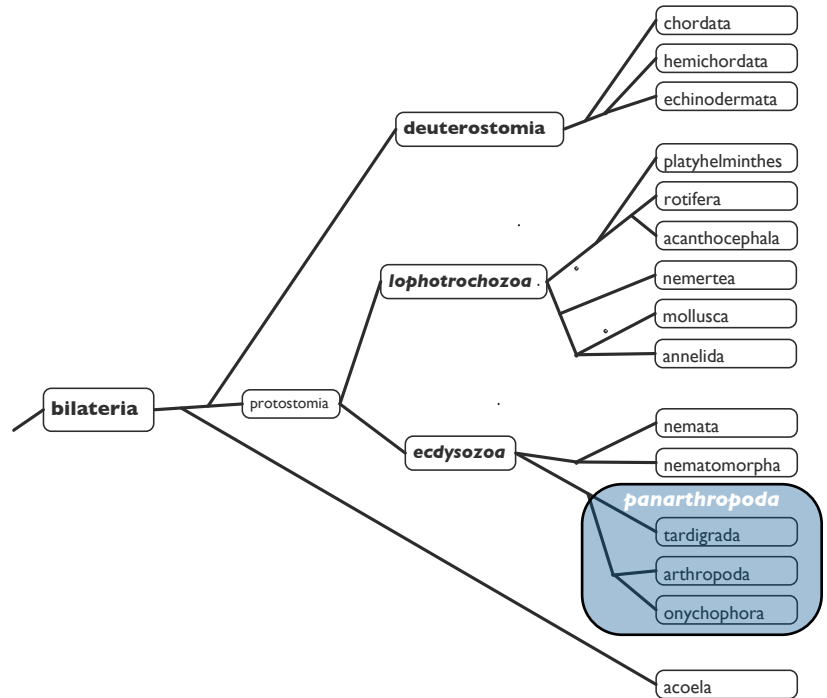


phylum onychophora

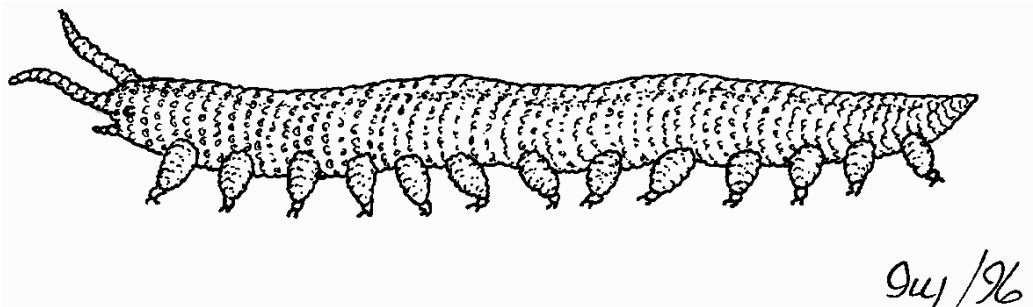
Velvet worms

Once considered to represent a transitional form between annelids and arthropods, the Onychophora (velvet worms) are now generally considered to be sister to the Arthropoda, and are included in the clade Panarthropoda. They are no longer considered to be closely related to the Annelida. Molecular evidence strongly supports the clade Panarthropoda, indicating that those characteristics which the velvet worms share with segmented worms (e.g. unjointed limbs and metanephridia) must be plesiomorphies.

Onychophorans share many synapomorphies with arthropods. Like arthropods, velvet worms possess a chitinous exoskeleton that necessitates molting. They also possess a tracheal system similar to that of insects and myriapods. Onychophorans have an open circulatory system with hemocoels and a ventral heart. As in arthropods, the fluid-filled hemocoel is the main body cavity. However, unlike the arthropods, the hemocoel of onychophorans is used as a hydrostatic skeleton.



Onychophorans feed mostly on small invertebrates such as insects. These prey items are captured using a special "slime" which is secreted from large slime glands inside the body and expelled through two oral papillae on either side of the mouth. This slime is protein based, sticking to the cuticle of insects, but not to the cuticle of the velvet worm itself. Secreted as a liquid, the slime quickly becomes solid when exposed to air. Once a prey item is captured, an onychophoran feeds much like a spider. The salivary glands pump digestive enzymes into the prey item, liquifying the interior of its body. The velvet worm then sucks up the liquid, leaving only an empty exoskeleton.



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* Examine the plastimount velvet worm specimen.

phylum tardigrada

The phylum Tardigrada is included within the clade Panarthropoda, although the node which joins them with the Arthropoda and the Onychophora remains unresolved. Tardigrades share some characteristics with arthropods, including metamerism, limbs (although unjointed in tardigrades), a chitinous cuticle with muscular attachment, and perhaps malpighian tubules.

Tardigrades, often referred to as “water bears” are among the most amazingly durable animals on the planet. (The term “bear” refers to the characteristic way in which tardigrades walk, resembling a bear.) These tiny, segmented animals demonstrated the ability to withstand extreme cold (down to -273°C), extreme heat, and radiation (up to 151°C); surviving for many hours even in the vacuum of space. They have even shown an ability to withstand prolonged exposure to preservatives such as diethyl ether and ethanol (100%).

Tardigrades can also exist for at up to 8 years without water, a phenomenon known as **anhydrobiosis**. They are generally aquatic, and are often found in casual bodies of water, including the water films associated with terrestrial mosses. In habitats such as these, desiccation is a constant threat. When drying occurs, the tardigrade enters into an encysted state referred to as a “tun.” While in the tun state, the tardigrade is relatively impervious to external conditions, and may exist unharmed for many years, despite exposure to cold, heat, radiation, chemicals, etc.

* Examine the tardigrade specimens. Note the characteristic bear-like gait.



phylum arthropoda

The phylum Arthropoda is the largest and most diverse animal phylum. Arthropods have exploited almost every habitat on earth. The arthropods are ecdysozoans, and possess a chitinous exoskeleton that must be shed in order for growth to occur. Included in the clade Panarthropoda, the arthropods are sister to the Onychophora and the Tardigrada.

The success of arthropods has been attributed to several key characteristics. The arthropods possess a unique, versatile, chitinous exoskeleton, which protects them from water loss, foreign pathogens, and damage from external forces. The jointed appendages for which the arthropods are named (Arthropoda = Gr. [*arthro*, jointed] + [*poda*, foot]) have been molded by selection into a variety of helpful structures. The book lungs of spiders, the complex mouthparts of crayfish, and the wings of insects are all examples of modified arthropod appendages. Another reason for the success of arthropods is metameric segmentation. Selection has resulted in a high degree of **tagmatization** (specialization of groups of segments for certain purposes) in arthropods, resulting great diversity of form. Many arthropods possess highly efficient tracheal systems for exchanging gasses. This respiratory system allows arthropods to get oxygen to tissues quickly enough to achieve metabolic rates high enough for flight and endothermy.

Classification (examples)

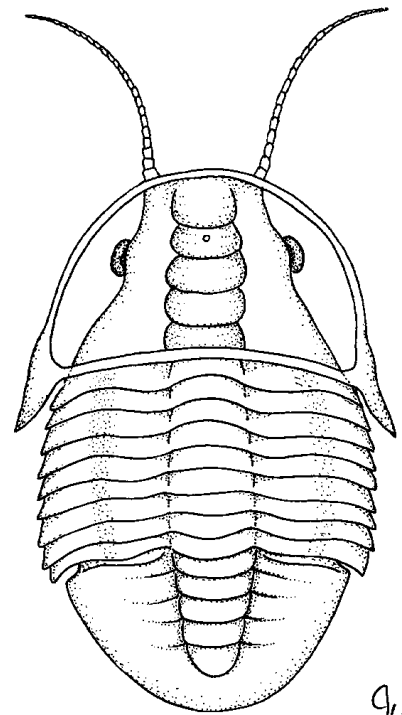
Discussion of groups of organisms

Subphylum Trilobita - Trilobites. Members of this group possess three tagmata, each with three lobes, and biramous appendages. The trilobites are all extinct.

Subphylum Chelicerata - Horseshoe crabs, sea spiders, arachnids. Members of this group possess two tagmata, chelicerae, and no mandibles.

Subphylum Myriapoda - Millipedes, centipedes, pauropoda, and symphyla. Myriapods have elongated bodies, and are named for the many legs they possess. Usually two uniramous legs per somite.

Subphylum Crustacea (*Pancrustacea*) - Includes the traditional crustaceans and the insects. The pancrustacea are an extremely diverse group with ancestrally biramous appendages.



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Subphylum Trilobita

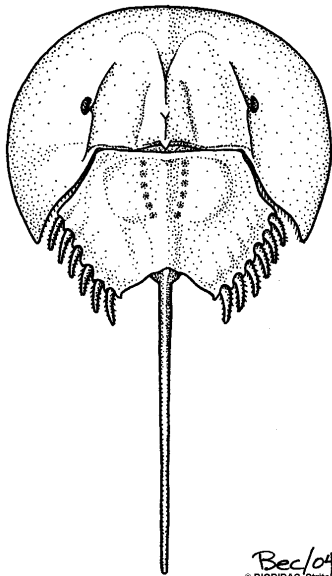
The trilobites are an ancient group of marine benthic arthropods, that are commonly found as fossils. The trilobites were probably similar in lifestyle to horseshoe crabs.

Anatomy

The body of a trilobite had three tagmata: cephalon, thorax, and pygidium. However, the name "tri-lobite" refers to the three lobes of each somite (one medial and two lateral). Trilobites possessed a pair of biramous appendages associated with each somite.

The benthic lifestyle of trilobites is reflected in the anatomy of the body, which is flattened dorsoventrally. Compound eyes were located on the dorsal aspect of the body. Trilobites had no mouthparts, but possessed a ventrally directed hypostome that was probably used for feeding on marine detritus. A pair of antennae were attached to the cephalon.

*Observe the trilobite fossils. Note the structures discussed above.



Bec/04
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horseshoe crab, dorsal view

Subphylum Chelicerata

The Chelicerata comprise three classes: Merostomata, Pycnogonida, and Arachnida. Chelicerates generally have two tagmata, a prosoma and an opisthosoma. The appendages of chelicerates are primitively biramous, but uniramous in modern groups. The first set of appendages is adapted for use in feeding, and is referred to as the **chelicerae**. The second set of appendages are the **pedipalps**, which are usually involved in sensation or manipulation of food items. Most chelicerates possess 4 pairs of walking legs.

Merostomata

Despite their name, horseshoe crabs are not crustaceans, but chelicerates. Horseshoe crabs are benthic chelicerates that are probably similar in lifestyle to the extinct trilobites. The similarity is also evident in the larvae of horseshoe crabs, which are similar in appearance to trilobites.

*Examine and draw the preserved whole mount slide of *Limulus* larvae with a

compound microscope.

The **prosoma** of horseshoe crabs is covered by a hard, heavily calcified **carapace**. Two large **compound eyes** are easily visible on either side of the head. Much smaller **simple eyes** can also be found at the anterior end of the **median ridge** that runs down the dorsal aspect of the carapace. Ten **chelate** walking legs are attached to the ventral surface of the prosoma. The pedipalps are undifferentiated, and comprise the first two walking legs.

The **opisthosoma** is smaller than the prosoma, and joined by a broad **hinge** that allows the body to flex. On the outer margin of the opisthosoma is a set of **moveable spines**, reflecting the ancestral segmentation of the abdomen. The abdominal appendages are modified into leaf-like stacks of respiratory structures called **book gills**. The **telson** (or tail spine) extends from the posterior end of the opisthosoma.

* Examine the preserved *Limulus* sp. specimen.

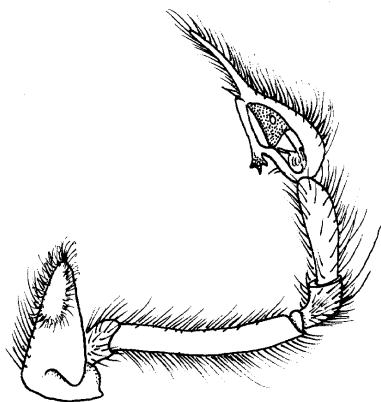
Arachnida

Arachnids are undoubtedly the most diverse and well-known of the chelicerates. The most familiar arachnids are the spiders. However, the most speciose group of arachnids are in the order Acari, which include ticks and mites.

Ticks have a broadly joined prosoma and opisthosoma. Together, this largest portion of the body is referred to as the **idiosoma**. The mouthparts are located on a small tagmata called the **gnathosoma**. The pedipalps attach to the gnathosoma, and are used by the tick to attach to the skin of its host. The chelicerae are blade-like, and covered by a **cheliceral sheath**. When attaching to a host, the tick uses its chelicerae to cut through the skin. The **hypostome** is used like a straw, to suck fluids from the host.

* Examine the preserved whole mount slide of a tick. Note the prosoma, opisthosoma, hypostome, cheliceral sheath, pedipalps. (if the cheliceral sheath is closed, the hypostome will not be visible.)

The prosoma and opisthosoma of spiders are joined by a narrow, waist-like pedicel. All of the appendages are attached to the prosoma. The chelicerae are located at the anterior end of the cephalothorax. At the distal end of each chelicera is a **cheliceral tooth** (sometimes referred to as a "fang"). The venom glands are located inside the cephalothorax and deliver venom through the chelicerae. The cheliceral teeth are hollow, and act like syringes to deliver venom into prey items. When a prey item is captured by the spider, digestive enzymes are pumped by a special pumping stomach (inside the cephalothorax) into the wound created by the cheliceral teeth. Venom and digestive enzymes begin digesting the prey item outside the spider's body. The liquified interior of the prey item is then sucked up through the pharynx of the spider.

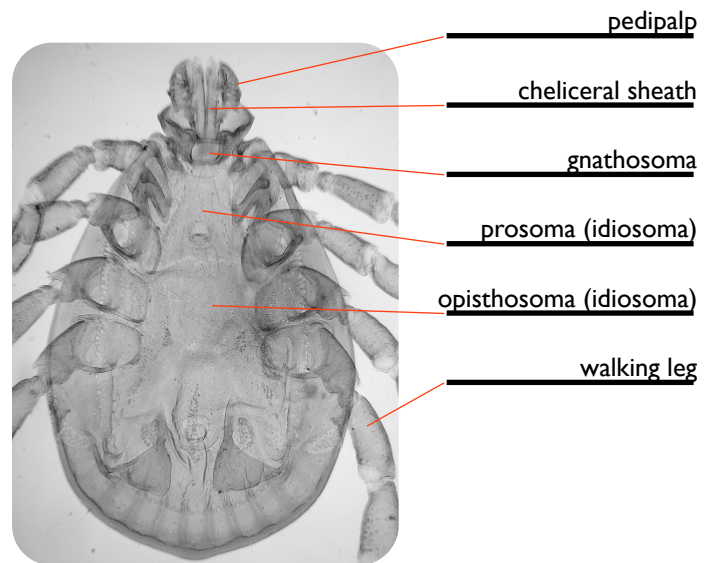


spider pedipalp

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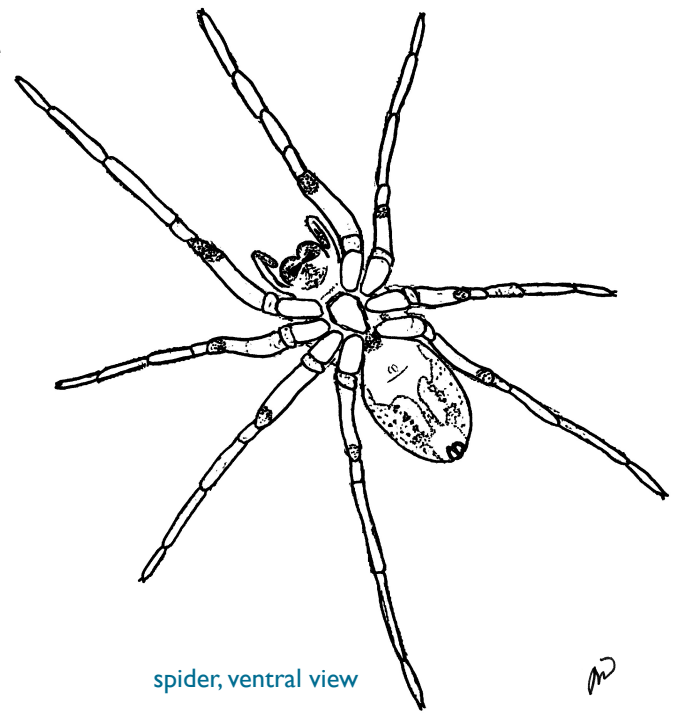
The **pedipalps** are located on either side of the chelicerae, and are used in food manipulation. Male spiders use the pedipalps to deliver sperm to the female. As a result, the pedipalps of males will appear different (more bulbous) from the pedipalps of females. There is also usually size dimorphism between the sexes. Females are generally larger than males, sometimes drastically so (especially among web-building spiders.)

The walking legs attach to the ventral surface of the cephalothorax. Between the legs is a roughly pentagon-shaped plate called the **sternum**. The proximal segment of each leg is the **coxa**. Continuing in a distal direction, the next leg



tick, WM

segments are: **trochanter, femur, patella, tibia, metatarsus,** and **tarsus**. The names of these segments roughly mirror the names of the bones in the human leg. The trochanter is a very sort segment that connects the coxa to the rest of the leg. The femur is the longest portion of the leg. Between the femur and the tibia is a short segment called the patella. At the end of each tarsus is a tiny tarsal claw. These are visible under a dissecting scope.



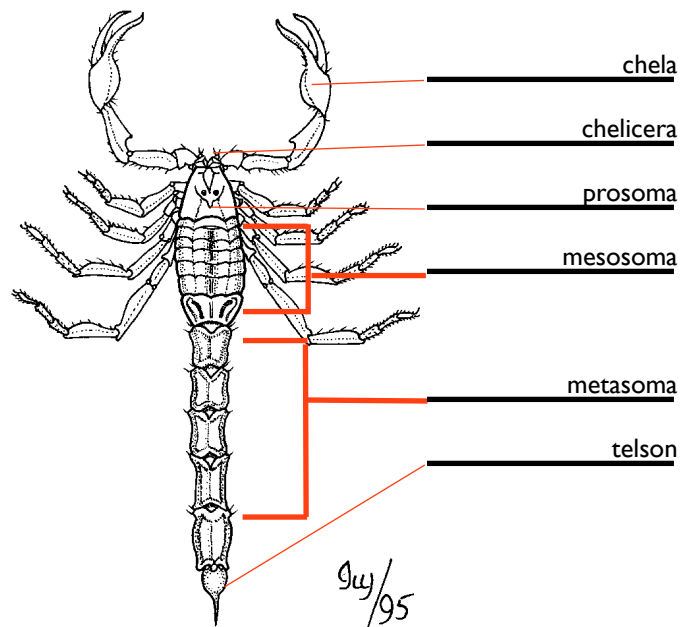
spider, ventral view

The opisthosoma is usually the largest portion of the body, and contains the heart, intestine, silk glands, and reproductive organs. On the ventral surface of the opisthosoma, about half the distance between the midpoint of the opisthosoma and the anterior end of the opisthosoma is an opening called the **epigastric furrow**. Inside the epigastric furrow are the **book lungs** which the spider uses to exchange gasses. These are most likely homologous to book gills of horseshoe crabs.

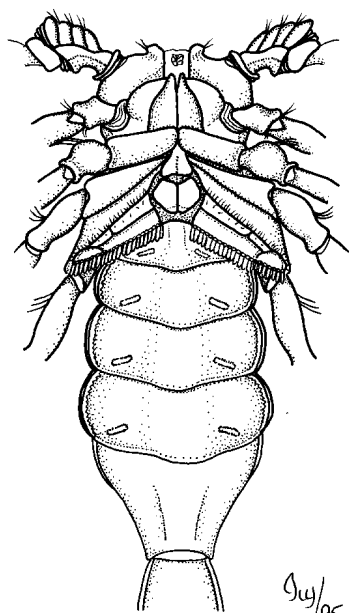
At the posterior end of the opisthosoma is a set of 4 or 6 **spinnerets**. These are used to produce silk secreted from the silk glands in the abdomen.

- * Examine and draw the preserved wolf spider (*Hogna carolinensis*). Label the prosoma, opisthosoma, coxa, trochanter, femur, patella, tibia, metatarsus, tarsus, pedicel, chelicerae, pedipalps, spinnerets. Determine if your specimen is male or female.

Scorpions possess small chelate chelicerae. Instead of using the chelicerae to deliver venom, scorpions deliver venom using a modified telson at the posterior end of the body. The pedipalps of scorpions are large chelate pincers used to grasp prey items. These are sometimes referred to as **chela**. Like most chelicerates, scorpions are fluid feeders. Tiny bits of food items are removed using the chelicerae, and digestion begins in a compartment surrounding the mouth. Liquified food is then ingested.



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scorpion, ventral view

The body of the scorpion consists of two main tagmata, the cephalothorax and opisthosoma. The opisthosoma is divided into a pre-abdomen (**mesosoma**) and post-abdomen (**metasoma**). The main part of the abdomen is the mesosoma. The scorpion's "tail" is the metasoma. The posterior-most segment of the metasoma is the sharp, sclerotized telson, which is used as a **stinger**. Inside the stinger are two poison glands which produce the venom delivered by the sting.

On the ventral surface of the body, four pairs of walking legs are attached to the prosoma. At the anterior end of the mesosoma are two comb-shaped structures called **pectines**. The teeth of the pectines contain many microscopic **peg sensilla**, which contain chemo- and mechanosensory neurons. The

pectines are also used by the female to pick up the spermatophore deposited by the male. The larger abdominal segments possess a pair of slit-like spiracles. These spiracles open into book lungs which are used to exchange gasses.

- * Examine the preserved scorpion. Note the prosoma, mesosoma, metasoma, telson, chelae, pedipalps, pectines, spiracles. The sex is difficult to determine, and sex differences depend on species.
- * Examine the various preserved and live arachnid specimens.

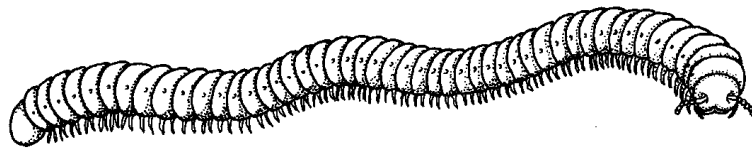
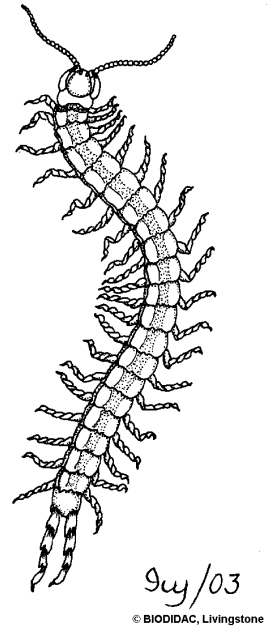
Subphylum Myriapoda

The myriapods get their names from the large number of walking legs they possess. The two biggest groups of myriapods are the centipedes and the millipedes (orders Chilopoda and Diplopoda, respectively.) Each of these groups has many segments and many legs. The body consists of the head and the segmented trunk. The head possess two antennae, and two lateral eyes.

Chilopoda

The chilopods are commonly referred to as centipedes. Although the term "centipede" means one hundred legs, the chilopods actually have up to 177 segments, with two legs per segment. Centipedes are predators, capturing small animals with their first set of legs (maxillipeds), which are modified for venom delivery. These appendages are referred to as **forcipules**. Each of the walking legs possesses a tarsal claw, which in many cases can deliver small amounts of venom. The most posterior set of legs is referred to as the **anal legs**.

- * Examine the preserved centipede specimens.



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Diplopoda

The diplopods are also known as millipedes, meaning "one thousand legs". As with centipedes, this is a misnomer. Millipedes usually have between twenty-five and one hundred segments, each with two pairs of legs. The term "diplopoda" means "double foot," referring to the tagmatization of pairs of segments, resulting in two

pairs of legs per **diplosegment**.

The exoskeleton of millipedes is highly calcified and is very hard, unlike the softer, more flexible cuticle of centipedes. When irritated, the millipede secretes toxic substances from **repugnatorial glands**. The openings to these can be visualized in lateral lines on either side of the body. One may wish to wear protective gloves when handling millipedes to prevent exposure to these toxins.

Millipedes are not venomous like centipedes. They are mostly detritivores and scavengers, feeding mainly on decaying plant material. Millipedes are generally less active than centipedes, with their legs moving in sinusoidal waves which alternate down the length of the body.

Males and females can be distinguished by the appendages on the 3rd segment (7th ring), which are different in males. Males possess gonopods, special appendages used for mating. Because one pair of gonopods is hidden, it will look like there is a gap in the legs, or like legs are missing. For females, the legs on the 3rd segment will look the same as the rest of the legs.

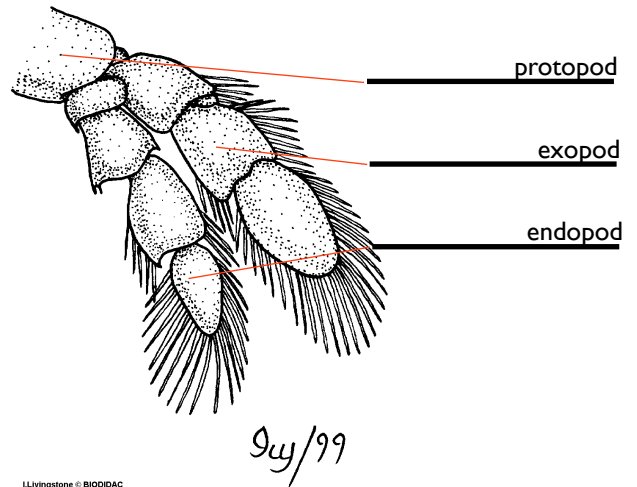
- * Examine the live and preserved millipede specimens. You are welcome to gently handle the live millipedes. They will not bite. Can you tell the sexes?

Clade Pancrustacea: Crustacea

The crustaceans and insects are included in a group together known as the Pancrustacea. The term Crustacea refers to a paraphyletic group that excluded the hexapods. Crustacea include marine, freshwater, and terrestrial forms. This diverse group includes shellfish such as crabs, lobsters, shrimp, and crayfish. It also includes barnacles and numerous small planktonic species.

Anatomy

Crustaceans are often referred to generically as “shellfish,” recapitulating the fact that they possess a hard, calcified exoskeleton. The crustaceans possess several characteristics which distinguish them from the rest of the arthropods. The mouthparts of crustaceans are complex, comprising mandibles, maxillae, and maxillipeds. Also, unlike other arthropods, crustaceans possess two pairs of antennae: **antennae** and smaller **antennules**. Primitively, crustaceans possess a pair of **biramous** appendages on each body segment. The term “biramous” means that they possess two branches. While this characteristic was once considered important for defining groups of arthropods, it is now considered to be a plesiomorphic state for most if not all arthropods. In some groups, certain appendages have been lost or adapted for specific uses. In the larger crustaceans, some appendages have a special extension that acts as a gill.



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generalized biramous appendage

Biramous appendages consist of a basal (proximal) portion called the **protopod**, and two branches: a lateral **exopod** and a medial **endopod**. The protopod often has two segments, the proximal **coxa**, and distal **basis**. In some cases, there may be lateral (**endites**) or medial processes (**exites**) on the protopod. The walking legs of larger crustaceans are the endopod of the appendage to which they are attached. The protopod of the walking leg also possesses an exite called the **epipod** which is used as a gill. The exopod associated with the walking legs has been lost.

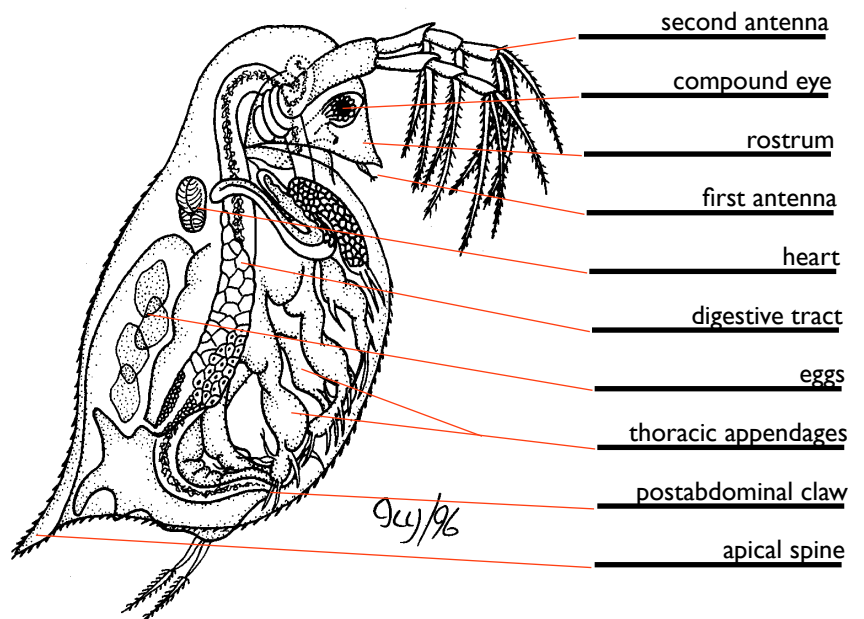
* Examine the biramous appendages of the preserved crayfish.

Class Ostracoda

Ostracods are small, usually planktonic crustaceans. The ostracods possess a bivalve carapace that encloses the entire body. They feed by extending setae-covered limbs. Outwardly, ostracods are somewhat similar to *Daphnia* described below.

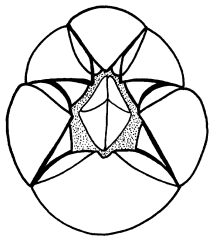
Class Branchiopoda

Branchiopoda (Gr. [*branchion*, fin or gill] + [*poda*, foot]) comprises small, often planktonic, crustaceans such as fairy shrimp, brine shrimp, and water fleas (*Daphnia*). Most of the branchiopods are found in freshwater. One of the derived characters found in the branchiopods is the presence of flattened, leaf-like thoracic appendages called **phyllopodia**. Phyllopodia are used for gas exchange and to generate currents for filter feeding.



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* Prepare a wet mount slide of the live *Daphnia*. Examine and draw. Label the following structures: antennae,



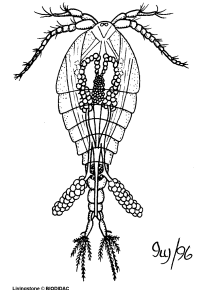
compound eye, eggs (if present), phyllopodia, rostrum, apical spine, postabdominal claw, digestive tract, heart.

- *Examine prepared slides of *Daphnia* and *Eubranchipus*.

Class Maxillopoda

Maxillopods include several subclasses that were previously considered to be classes, including organisms such as barnacles and copepods. These are diverse organisms that include sessile forms, zooplankton, and parasites.

Barnacles are generally sessile crustaceans in the subclass Cirripedia that are commonly found on marine substrates. Unlike the rest of the sessile barnacles are hermaphroditic. Ships, whales, turtles, and rocky beaches are often covered with barnacles. Indeed, almost any structure left in the ocean for even a relatively short period of time may become encrusted with barnacles. Rather than a hardened exoskeleton, barnacles possess a set of calcareous plates which protect, and sometimes totally encase the body. Barnacles feed using cirri, setae-covered thoracic appendages which are extended out from between the plates.



- * Observe the preserved barnacle specimens.

The planktonic copepods possess one of the highest biomasses of any animal in the ocean. Copepods such as *Cyclops sp.* are very common in freshwater as well. As adults, copepods and other maxillopods possess a single primitive median eye found in the nauplius larva. The nauplius is an autapomorphic larval form found only in the crustaceans. This larval form is planktonic, and has three sets of appendages: antennules, antennae, and mandibles.

- * Prepare a wet mount slide of the live copepods, *Cyclops sp.*

Class Malacostraca

The largest and most well known crustaceans are in the class Malacostraca. This class includes shrimp, krill, crabs, lobsters, crayfish, and isopods. The order Amphipoda includes tiny shrimp-like organisms often associated with intertidal zones. The order Isopoda includes sow bugs and pill bugs (roly-polies.) These organisms are truly terrestrial, although they require a great deal of moisture in their habitat (or microhabitat) due to relatively high water loss. Isopods respire using autapomorphic structures called pseudotracheae, derived from the epipod of the pleopods. Order Decapoda comprises most of the rest of the Malacostraca. Shrimp, krill, crabs, lobsters, and crayfish are all in the Decapoda.

- * Examine the preserved specimens of various members of class Malacostraca.
- * Examine the live specimens of crayfish, amphipods, and any other malacostracans available.

Crayfish Dissection

- * Examine the external features of the preserved crayfish specimen. Draw each of the appendages listed below from your specimen. You will need to know these.

Like most crustaceans, crayfish possess two sets of "antennae". The first set are the shorter biramous **antennules**. The second set are the longer **antennae**. The antennae possess a very long endopod and a very short exopod.

The mouthparts are quite complex in decapods, consisting of several sets of appendages. The first set (most anterior) are the **mandibles**. These have a long, serrated edge used for crushing or cutting food items. It will be noticeably hard when touched with a sharp probe. The next set of appendages are the **first maxilla**. These are used in food handling and will be short, thin, and flat. The **second maxilla** are used to ventilate the branchial chamber. It has a distinctive "tomahawk" shape. The exopod and the epipod of the second maxilla form a paddle-like structure called the **bailer**. The maxillipeds are mainly involved in food handling and possess a long, thread-like exopod which distinguishes them from the maxilla. The **first maxilliped** is the most anterior maxilliped pair, and has a long exopod and a very short endopod, unlike the second and third maxilliped. The **second maxilliped** has a short, thick endopod, a longer exopod, and a gill. The **third maxilliped** has a longer endopod,

a shorter exopod, and a gill.

In all decapods, each of the five pairs of walking legs has lost its exopod (i.e. it is secondarily uniramous). Each of the walking legs consists of a long endopod (the leg) and a gill (except the fifth walking leg, which lacks a gill). The endopod of the **first walking leg** is chelate and used for defense.

These legs are called **chelipeds**. The **third walking leg** in females bears a genital pore on the medial aspect of the coxa. In males, the genital pore is in the same position, but on the **fifth walking leg**.

On the abdomen are tiny biramous appendages called swimmerets. The **first set of swimmerets** in males features a fused endopod and exopod, creating a tube for sperm transfer. In females the first swimmerets are either very small, or missing completely. The **second set of swimmerets** is also involved in sperm transfer, and is modified in males. In females, the second swimmerets possess filamentous endopods and exopods of roughly the same length. The **third, fourth and fifth swimmerets** are smaller and look similar in males and females. The posterior-most portion of the body is the telson (attached to the abdomen). Just ventral to the telson is the posterior-most set of appendages, the **uropods**. These are flattened appendages that make up the "tail fan" and are used in swimming.

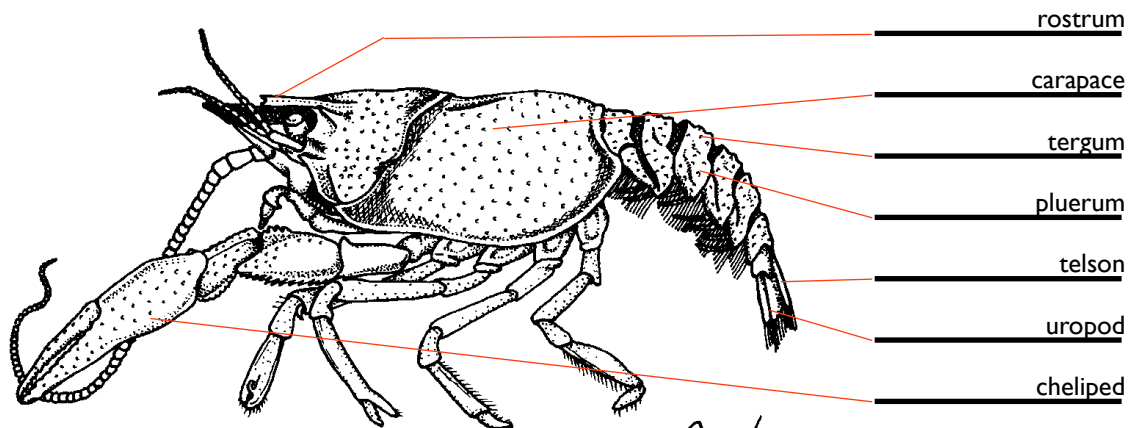
The anterior tagmata of the crayfish are covered dorsally by the **carapace**. The carapace extends outward, and also forms the **branchiostegite** which covers the gill chamber. On the rest of the body, which is not covered by the carapace, the exoskeleton is composed of three hardened plates on each abdominal segment. The **tergum** covers the dorsal surface and the **sternum** covers the ventral surface. On each abdominal segment, the tergum is fused to two lateral **pleura**, (one on each side) which extend downward covering the sides of the segment and extending past the point where they meet with the sternum.

✳ Examine the internal structures of the preserved crayfish specimen.

Begin by removing the left portion of the carapace that covers the gills (the branchiostegite). This can be done easily enough by using scissors to make a cut from the posterior end of the carapace forward, just to the left of the dorsal longitudinal groove. The tip of the scissors can be inserted beneath the carapace to begin the cut. (No stabbing is necessary.) Care should be taken not to damage the gills beneath the carapace. Once the branchiostegite is removed, the gills should be easy to distinguish. Note that the gills are not actually inside the body. They are merely covered by this overlapping bit of carapace.

Open the body of the crayfish by making a lateral incision beginning about halfway up the left side of the cephalothorax at the posterior end. With scissors, cut toward the anterior. Make a similar incision on the right side of the body. At the rostrum, make an arching cut to connect the two lateral incisions. Now the top of the carapace can be gently removed, using a small scalpel to carefully separate the tissue connecting the exoskeleton to the viscera.

The **pericardial sinus** should be readily visible surrounding the **heart**. It will look like a large empty space (unless the specimen is injected, in which case it will be filled with latex.) The heart itself will look roughly hexagonal, and be the dorsal-most organ.



9/4/03
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Around the heart and pericardial sinus is the large, granular **digestive gland**. Anterior to the stomach and the digestive gland is the **cardiac stomach** and the **gastric mill** (the posterior portion). If you remove the cardiac stomach, or at least move it out of the way, the **antennal glands** will be visible below it. The antennal gland is an excretory structure that empties through a tiny pore on the protopod of the antenna. This gland is also called the green gland.

Clade Pancrustacea: Hexapoda

Recently, molecular studies have challenged previous notions regarding the evolutionary context of the insects. Traditionally, the insects were placed in a group called Uniramia, defined by the presence of uniramous appendages. This group was considered sister to the Myriapoda and, more distantly, to the Crustacea. Recent molecular evidence has pretty well established the position of the Hexapoda within the Pancrustacea. What has not been well established is which group of crustaceans is sister to the Hexapoda.

In terms of diversity and number of species, insects are the most successful class of animals. They possess all of the characteristics that have contributed to the success of the rest of the arthropods, as well as some characteristics distinct to insects. Insects usually possess wings, which provide extraordinary dispersal ability. Also, the insects possess a unique, very efficient tracheal system, allowing insects to achieve extremely high metabolic rates relative to size.

Metamorphosis

There are three main schemes of metamorphosis in the insects. Some insects undergo no metamorphosis. **Ametabolous** insects emerge from the egg looking like a smaller version of the adult, and get larger with each molt. The order Thysanura, which are sister to the rest of the insects are ametabolous and also possess many other characteristics considered to be plesiomorphic for the insects. Orders such as Hemiptera (true bugs) and Orthoptera (grasshoppers, crickets) undergo **paurometabolous** metamorphosis. Paurometabolous insects develop from a nymph, which is different from the adult, but gains more adult characteristics with each molt. This type of metamorphosis is sometimes called "gradual metamorphosis". Some insects undergo what is referred to as "incomplete metamorphosis." Insects like dragonflies (order Odonata) begin as a naiad, which is aquatic, and develop into an winged, flying adult. The development of adult characteristics occurs mainly during the final molt, but this type of metamorphosis (**hemimetabolous**) lacks the pupa phase. Most insects are **holometabolous**, undergoing "complete metamorphosis". A **larvae** hatches from the egg, growing as it molts. Each molting stage is referred to as an **instar**. After several instars, the larvae develops into an immobile, dormant **pupa**. The pupa is covered by a tough chitinous covering called a **chrysalis**. During this phase, many anatomical changes occur. Eventually, the chrysalis is shed, and the adult form emerges.

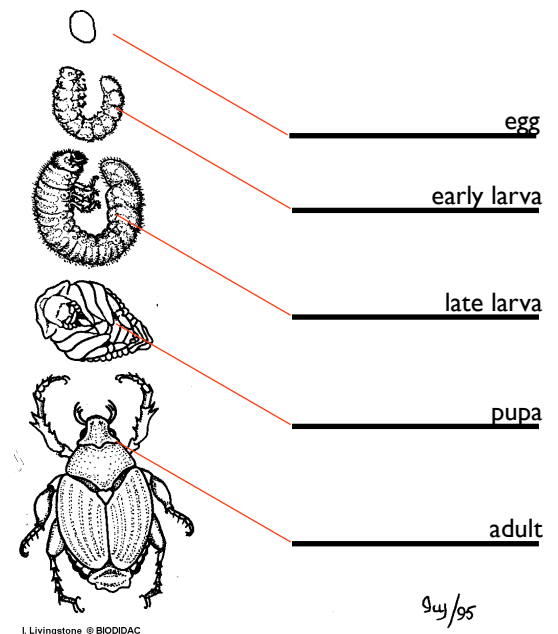
Anatomy

Insects possess three tagmata: head, abdomen, and thorax. Most insects possess four wings and six legs, all of which are connected to the thorax. In the flies (order Diptera), the hind wings are modified into what looks like a tiny ball on the end of a stick. These **halteres** beat up and down to act like gyroscopes, stabilizing the animal during flight. Beetles (order Coleoptera) only use their hind wings in flight. The forewings exist as hardened wing-covers called elytra, that obscure and protect the hind wings.

- * Examine the preserved insect specimens and the metamorphosis examples.

Grasshopper dissection

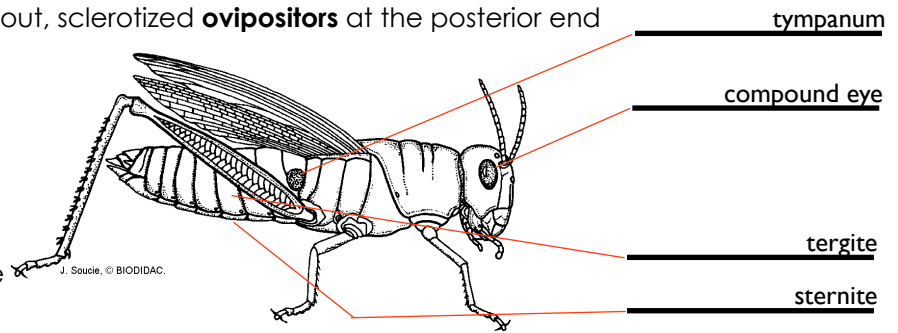
- * Examine the external features of the preserved grasshopper specimen.



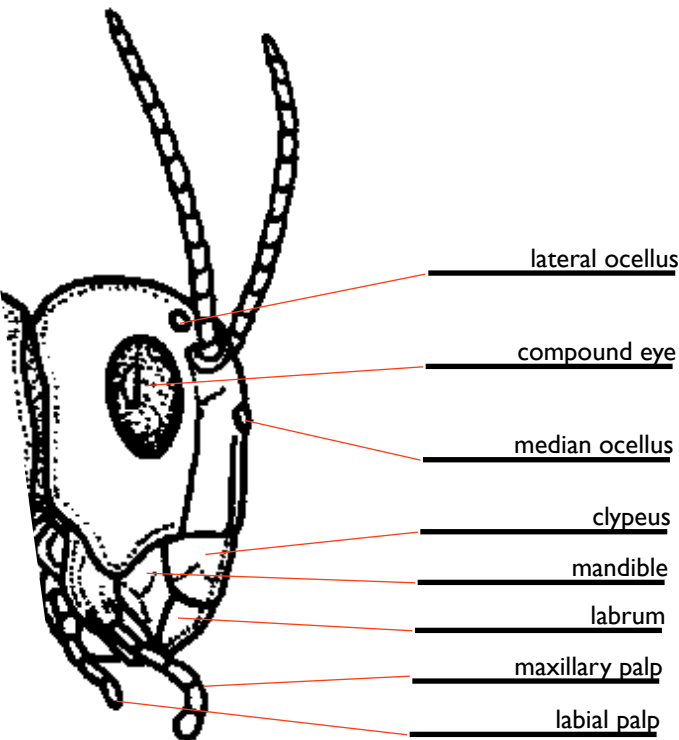
Note the three tagmata of the body of the grasshopper (order Orthoptera). The hind legs are much longer in the grasshopper, allowing them to jump great distances. The four wings allow the grasshopper to fly as well. When jumping, both the legs and wings are used.

On female specimens, there will be a pair of stout, sclerotized **ovipositors** at the posterior end of the abdomen. These should be quite noticeable. The ovipositors of the female are used to deposit eggs into a substrate. On males, there will be four tiny **cerci** oriented around the **epiproct**.

Each abdominal segment possesses a dorsal tergite, which wraps around the dorsal surface and a smaller sternite, which covers the ventral surface. Near the point where the tergite and sternite meet, on the anterior corner of the tergite, on each abdominal segment (on each side of the animal) is a tiny spiracle. The spiracles open into trachea that branch into tracheoles which deliver oxygen directly to the tissues that are using them.



Grasshoppers have an auditory sensory structure called a **tympanum** (eardrum). The orthopteran tympanum is, of course, not homologous with the tympanum of tetrapods. This structure should be visible on the first abdominal segment, when the wing and leg are moved aside.



Orthopterans have two large **compound eyes** made up of hundreds of tiny **ommatidia**. In addition to the compound eyes, grasshoppers also have three simple eyes or **ocelli**. The three simple eyes comprise two **lateral eyes**, located between the compound eye and the antenna, and one **median eye** located directly between the two compound eyes.

The mouthparts of the grasshopper are quite complex. The upper "lip" or **labrum** is connected to the head by a sclerotized plate called the **clypeus**. On either side, and behind the labrum are the **mandibles**. Just posterior to the mandibles are a pair of **maxilla**. Attached to the maxilla are two sensory **maxillary palps**. Posterior to the maxilla, on the ventral surface of the head is the **labium**. This single structure possesses two **labial palps** on either side.

* Examine the internal structures of the preserved grasshopper specimen.

Begin by making a dorsal incision with scissors beginning at the anterior margin of the prothorax. Extend the cut posteriorly, continuing all the way down the length of the abdomen to the posterior end of the body. Use dissection pins to retract the cuticle on either side, carefully removing connective tissue from the inner layer of the exoskeleton. Note the string-like tissue extending inward from the spiracles in the abdomen. These are trachea.

The digestive tract should be visible running down the middle of the interior of the body. The anterior section of the digestive tract is the **crop**. Just posterior to the crop is the **gizzard**, which is used to grind food particles. One of the most obvious characteristics of the digestive tract of the grasshopper is a ring of fingerlike projections posterior to the gizzard, projecting both anteriorly and posteriorly. These **gastric caeca** are used to allow certain particles to digest over a longer period of time. Farther down the body, attached to the intestine

is a similar, but much smaller ring of hairlike projections that are the **malpighian tubules**. The malpighian tubules draw nitrogenous wastes and water from the hemolymph, depositing the filtrate into the lumen of the intestine to be removed with the feces.

If the specimen is a female, the **gonads** will be noticeable in the dorsal portion of the abdominal cavity. Posterior to the gonads, near the tip of the abdomen is a spiral, tube-like structure, the **spermatheca**. The spermatheca are used by the female to store sperm after copulation.



questions

Arthropods

1. Onychophorans were once thought to be a transitional form between annelids and arthropods. Based on what is now known about the relationships among the annelids and the panarthropoda, why does this not make sense?

Chelicerates

1. In what ways are chelicerates different from other arthropods?
2. What are the comb-like structures on the ventral surface of scorpions? What are they used for?
3. Was your spider male or female? How can you tell?

Crustaceans

1. What does biramous mean?
2. How can you tell the sex of a crayfish?

3. How do branchiopods like *Daphnia* feed?

Insects

1. In what way are insects related to crustaceans? How is this a problem for the traditional phylogeny of arthropods?
2. How many eyes do grasshoppers have?
3. Which tagmata are the third set of legs attached to on a grasshopper?

Drawings

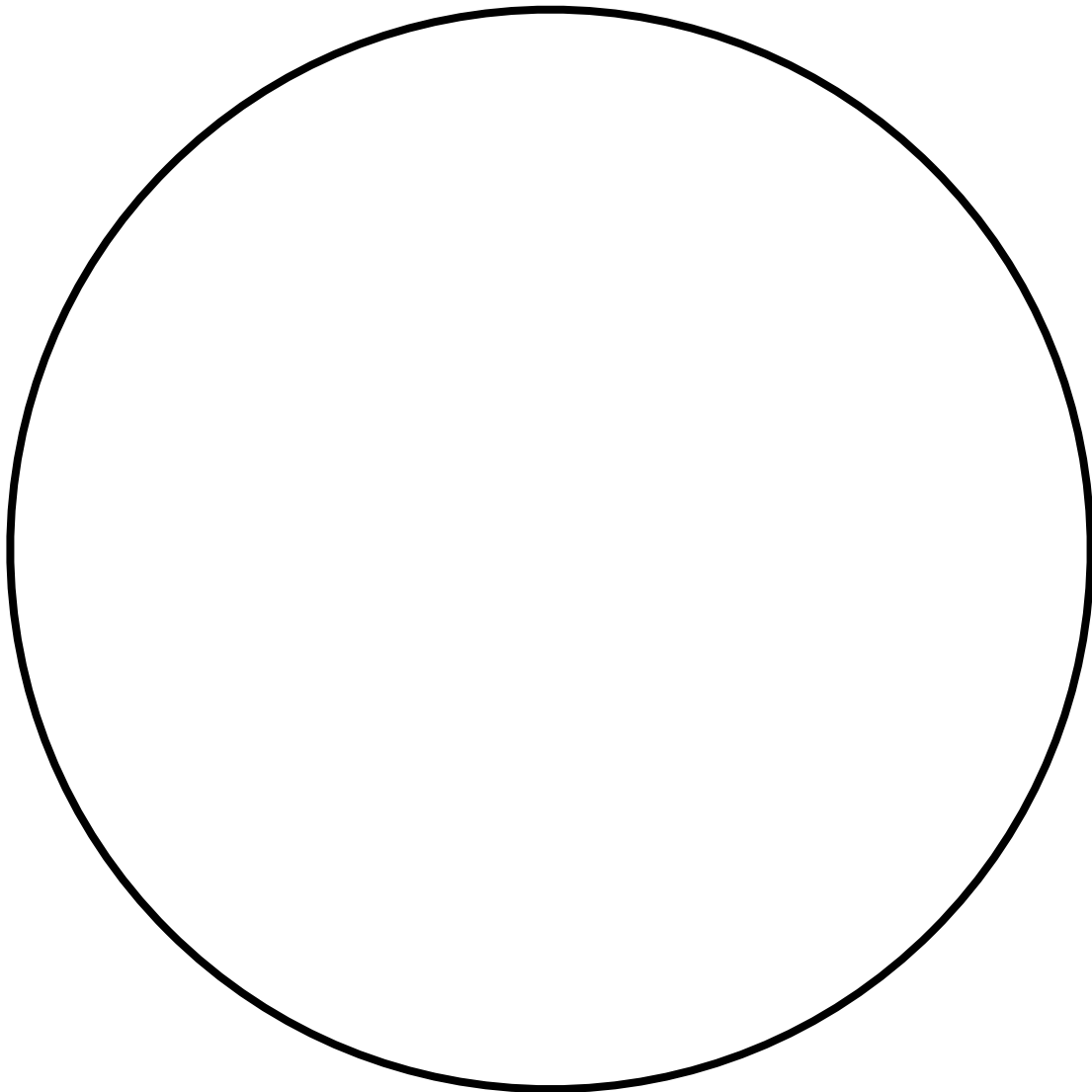
Limulus sp. larvae, WM

Kingdom: _____

Phylum: _____

Class: _____

Order: _____



Drawings

Hogna carolinensis, preserved

Kingdom: _____

Phylum: _____

Class: _____

Order: _____

Drawings

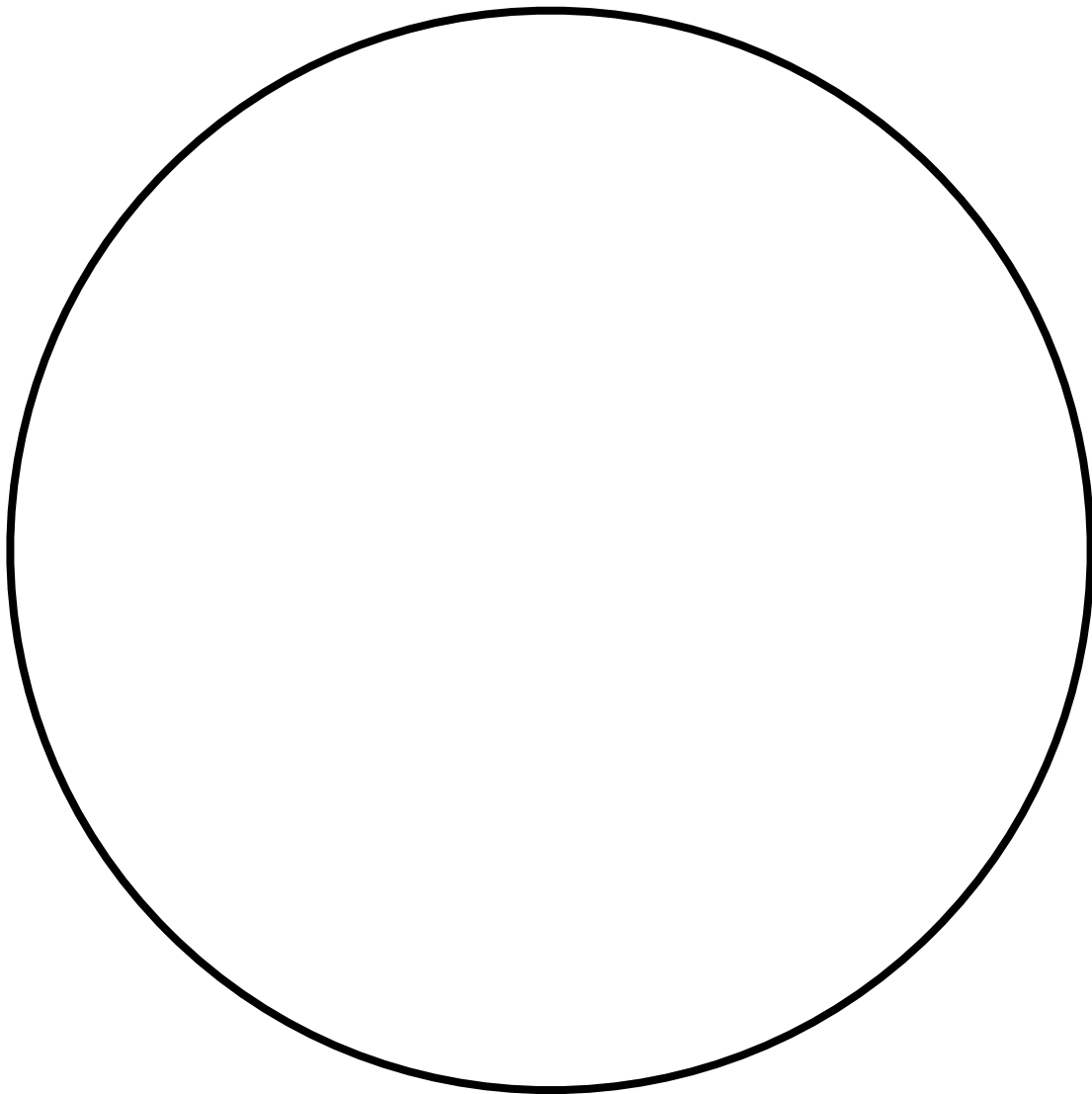
Daphnia sp. live, WM

Kingdom: _____

Phylum: _____

Class: _____

Order: _____



Drawings

Crayfish appendages

Kingdom: _____

Phylum: _____

Class: _____

Order: _____