

Kingdom Animalia: The Invertebrates

Members of the Kingdom Animalia are eukaryotic, multicellular organisms that are also heterotrophic— i.e., they obtain food from external sources. Invertebrates are animals that lack a backbone and have some other means of supporting their internal tissues. Sponges have the simplest support system with many members having protein fibers, called spicules, made of spongin to provide rigidity. Anemones, jellyfish, and related animals maintain body shape with internal water pressure. Higher invertebrates often have external or internal skeletons to support their internal organs.

Invertebrate classification is based on a collection of morphological and life cycle characters that show degrees of relatedness between taxa. One of the more important morphological features of animals is the presence (or absence) of primary body layers. The most primitive invertebrates have only two body layers: an outer layer, the ectoderm, and an inner layer, the endoderm. Ectoderm forms the outer skin and, in many cases, the nervous system. Endoderm forms the gut lining and sometimes the lining of major digestion-related organs, such as the liver. More advanced animals have a third, mesoderm, layer that forms muscle and the remaining organ tissues.

Another morphological feature used in classification is the basic body symmetry of animals. The simplest body plan is asymmetrical; that is, their body has no planes of symmetry. A few sponges are asymmetrical, but most of them are radially symmetrical, where there are multiple planes of symmetry. Jellyfish, *Hydra*, and anemones are animals that are radially symmetrical. By far the most common body plan among animals is bilateral symmetry. Bilateral animals can be divided along an axis to form halves that are mirror images of one another. These animals have a top and bottom, head- and tail-ends, and right and left sides. Humans are bilateral animals.

Body cavity type is yet another feature used to evaluate the degree of evolutionary relatedness. The most primitive animals lack a cavity between their gut and outer body wall and are thus called acoelomates. Jellyfish and flatworms are examples of acoelomate animals. More advanced animal groups do possess a cavity between their gut lining (endoderm) and outer body wall (ectoderm). In these cases, the major dividing criterion for relatedness is whether or not the cavity is lined on both sides with mesoderm. Those in which their cavity is not lined on both sides with mesoderm are pseudocoelomates; whereas those cavities completely lined with mesoderm are eucoeloms. Roundworms and rotifers are pseudocoelomates; whereas earthworms, snails, starfish, and humans are all eucoelomates.

Animals can also be classified on the basis of their developmental origin of their mouth, as well as the development of other features. In protostomes, the early developmental opening called the blastopore eventually becomes the mouth. Zygote cells of developing protostomes have spiral cleavage in which the planes of cell division are diagonal to the embryo's vertical axis. Also, even early in embryonic development, cells are pre-cast into certain roles. If something should happen to one of them, other cells could not take over the duty and eventual fate, thus protostomes also have determinate cleavage. A third feature of protostome development is the way in which the coelom is formed; their cavity begins as a solid mass of mesoderm cells that splits to form the coelom.

Deuterostomes have both radial and indeterminate cleavage. Their embryonic cells divide in planes perpendicular or parallel to the zygote's vertical axis, and cells from early divisions are not pre-cast into defined roles. In addition, the embryonic blastopore becomes the organism's anus.

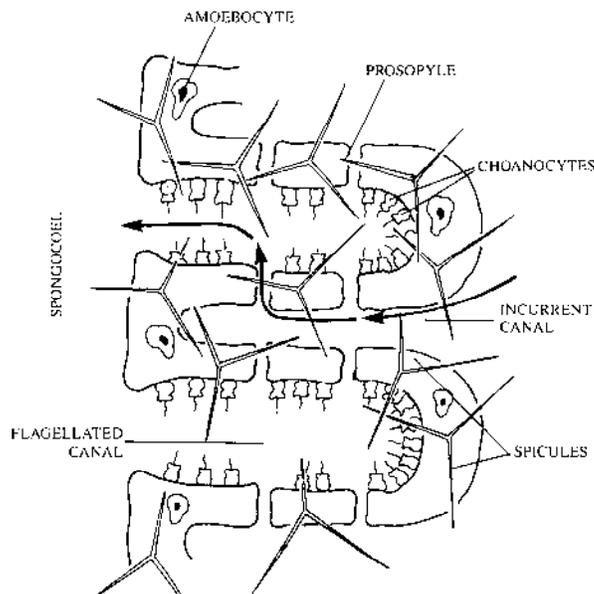
TABLE 57. Summary of characteristics for some phyla, after Campbell (1990).

Phylum	Symmetry	Cleavage	Body Cavity	Digestive Tract	Circulatory System
Porifera	none & radial	none	none	none; have pores	none
Cnidaria	radial	determinate	none	gastrovascular cavity	none
Platyhelminthes	bilateral	determinate	none	gastrovascular cavity	none
Rotifera	bilateral	determinate	pseudocoelom	complete	none
Nematoda	bilateral	determinate	pseudocoelom	complete	none
Tardigrada	bilateral	determinate	pseudocoelom (?)	complete	none
Annelida	bilateral	determinate	eucoelom	complete	open or closed
Arthropoda	bilateral	determinate	eucoelom	complete	open
Mollusca	bilateral	determinate	reduced eucoelom	complete	open or closed
Echinodermata	secondarily radial	indeterminate	eucoelom	complete	open or none

Phylum Porifera – Sponges

Sponges are sessile, mostly marine, multicellular animals that lack almost all the complex features of higher animals. Rather they are a loose organization of cells that work together to siphon planktonic food, filter it, and distribute energy. Sponges often incorporate algal cells in their epidermal tissue. The basic body plan of sponges involves two cell layers, an outer **epidermis** and inner layer made up of flagellated **collar cells**, separated by a gelatinous matrix, the **mesohyl**. Body support is provided by a skeletal matrix of spicules. The entire sponge body is covered with small, incurrent pores that bring in water under currents set up by the collar cells' beating flagellae. Food particles captured by the collar cells are transferred throughout the body via wandering amoeboid cells called **amoebocytes**.

FIGURE 48. Diagram of *Grantia* anatomy.



There are a few species of freshwater sponges found in Michigan. They may be common in streams, at lake outflows, and along wave-swept shorelines. Freshwater sponges tend to have very simple body plans, whereas marine sponges can be more complex.

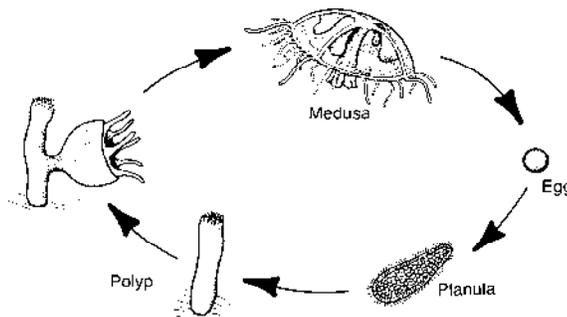
Phylum Cnidaria – Hydra, Sea Anenomes, Coral, and Jellyfish

Cnidarians also have a simple body plan. It includes an outer epidermis, a simple gastrovascular cavity lined with gastrodermis (an endoderm), and a jelly-like mesohyl separating the two layers. The digestive system has only one opening, serving as both mouth and anus. The gastrovascular opening is often surrounded by tentacles that are armed with cells bearing stinging capsules called **nematocysts**. Contact with either prey or enemies cause nematocysts to fire small, toxin-filled darts into them resulting in paralysis of their prey.

Some species undergo metagenesis, which is the life cycle involves alternation of two body forms: 1) a *Hydra*-like **polyp stage** and 2) a jellyfish-like **medusa stage**. In some groups of cnidarians, the polyp stage is dominant, while in others the medusa prevails. For species that exhibit metagenesis, asexual reproduction is accomplished by budding in the polyp stage and sexual reproduction usually occurs in the medusa.

Gonionemus is a small, marine cnidarian that has both polyp and medusa stages. From its egg, a ciliate-like, planula larva develops that can remain free-swimming for several hours until it becomes attached to an object, after which it grows to produce a thin polyp with short tentacles. The polyp stage is reduced, fairly inconspicuous, and produces medusae as lateral buds. Its medusa resembles a small bell with tentacles, heavily armed with nematocysts, lining the rim. Projecting inwards from the margin is a thin shelf called the **velum**. The mouth is an opening at the end of the **manubrium**, a central structure dangling from the bell's inner surface. The gastrovascular cavity consists of a central **stomach** leading to a complex set of canals. **Radial canals** radiate from the top of the manubrium towards the bell's rim where they join the **ring canal** running along its margin. Medusae can swim vertically by rhythmic muscular contractions producing a series of pulsations driving the animal upwards. Small sensory **statocysts**, located between the tentacles around the bell's margin, can detect any shift from a horizontal position as the animal moves laterally in water currents. Medusae respond to shifts in horizontal position by altering the animal's pulsations in order to maintain its gravitational equilibrium. Sexual reproduction in *Gonionemus* is confined to the medusa stage. Eggs and sperm are produced in **gonads**, which extend from the radial canals.

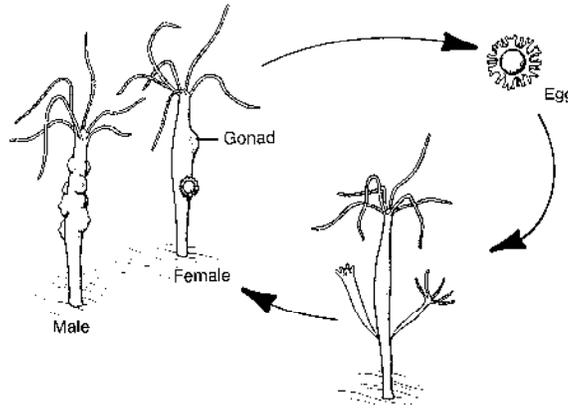
FIGURE 49. Life cycle of *Gonionemus*.



Hydra is the most well-studied freshwater cnidarian, but it lacks both the planula and medusa stages. It is unusual in having sexual structures on the polyp. Most reproduction in *Hydra* is asexual and is accomplished budding small polyps off its main trunk. Towards the end of *Hydra*'s growing season, male individuals produce **spermaries** and females produce

ovaries. Eggs and sperm are liberated into the water column and fertilization results in a zygote, from which a new polyp develops.

FIGURE 50. Life cycle of *Hydra*.



Acoelomates

Phylum Platyhelminthes – The Flatworms

Flatworms are bilaterally symmetrical, acoelomate animals with a fully developed mesoderm and whose digestive system, if present, consists of a primitive gastrovascular cavity. Two flatworm classes, Trematoda and Cestoda, are entirely parasitic, many of which have complex lifecycles involving more than one host.

Class Turbellaria – Free-living flatworms

The vast majority of free-living flatworms are marine, but there are several extremely common freshwater forms. *Planaria* (= *Dugesia*), the most well-known freshwater turbellarian, has been used widely to study regeneration and primitive learning.

The planarian gastrovascular cavity can be seen in detail in individuals fed carmine-dyed liver. The mouth is at the end of an extendable pharynx, located midway on its ventral side. The pharynx opens into a **3-branched intestine**, two branches extend posteriorly and the remaining branch feeds the body's head end. Planarians have no circulatory system; they rely on diffusion and a thin body to obtain oxygen, distribute food, and possibly excrete nitrogenous waste. Maintaining the appropriate salt balance (and possibly nitrogen excretion) is accomplished by simple **pronephridia** consisting of branched tubules connecting a number of blind pouches with flagelled **flame cells**. Flame cells collect fluids from the body and, with flagellar movements, create currents to expell them from the body through nepridiopores.

Planarians have two caudal, **dorsal ganglia** that serve as the brain with several nerve endings extending to the head end and **two ventral nerve cords** extending towards the tail end. These cords are interconnected by **cross commissures** at regular intervals along their length. Two **eyespots** lie above the dorsal ganglia that are capable of light detection, but do not produce complex visual images. Just lateral to the eyespots the body widens to form two **auricles**; these contain a high concentration of sensory nerves for chemoreception.

Asexual reproduction in Planaria is accomplished by **transverse fission**. As the planarian grows, a second set of ganglia often develops towards the tail end. Soon after the appearance of this 'second brain', new eyespots, auricles, and digestive system follow until a complete, but smaller body is formed at the tail end. A few days later, this new, independent individual is pinched off the original organism.

Planarians have extraordinary powers of regeneration. They can be cut into several pieces and each piece will often develop into a new individual. Steps in regeneration can be classified as **wound healing**, tissue **dedifferentiation**, then **redifferentiation** of missing tissues.

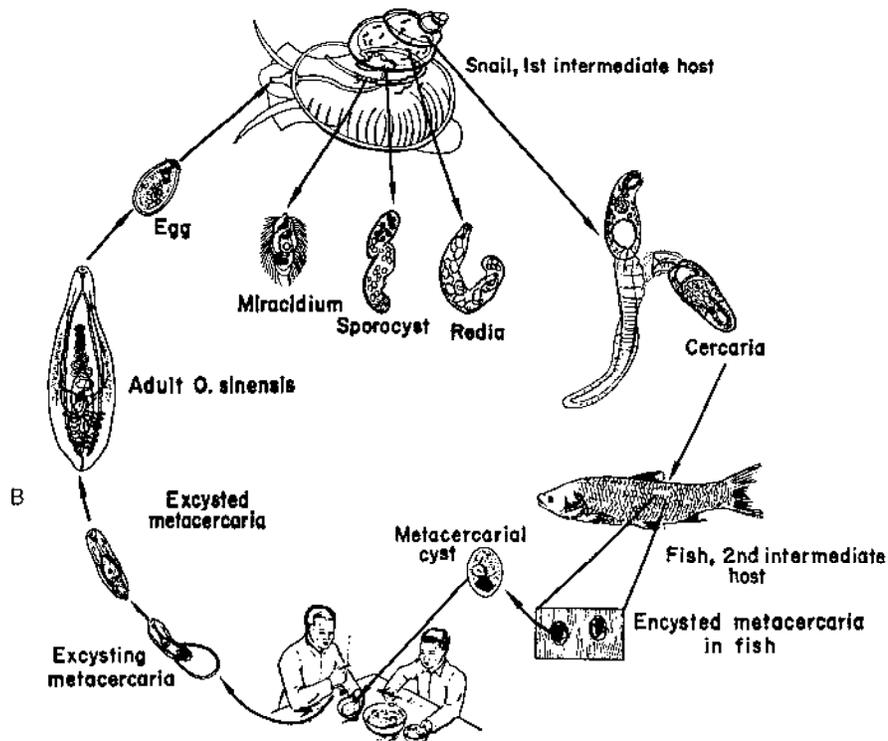
Mature planarians are **hermaphroditic**: they have both male and female reproductive systems in the same individual. The female portion has a **paired oviduct**, each beginning with an **ovary** located just caudal and lateral to the eyespots. The two ovaries meet just posterior to the pharynx and have highly branched yolk glands along their entire length. The male system is also paired. It consists of two long **sperm ducts** running along each side of the body and grape-like clusters of **testes** at regular intervals. Both systems empty through a common **gonopore**.

Class Trematoda – Flukes

While many flukes resemble free-living flatworms, they are entirely parasitic. Many exhibit highly complex lifecycles involving one or more intermediate hosts. Flukes infecting human blood and liver are among the most well known examples of this class, but it should be understood that almost all vertebrates living in or around freshwater habitat are infected with at least one species of trematode.

In a typical trematode lifecycle, adult worms reproduce sexually in specific tissues of the **definitive host**. Eggs enter the blood stream, or by some other method, make their way to the gut and leave the host in its feces. Eggs exposed to water hatch into a ciliated **miracidium**, which darts about seeking and **intermediate host**. The intermediate host is usually a mollusk, often an aquatic snail, where it transforms into a **sporocyst**. Sporocysts and the next stage, **redia**, are germinal sacs that function to build large populations within the infected host. Redia produce large numbers of **cercariae** that leave the primary intermediate host. Cercariae have a primitive gut, sometimes one or more ventral suckers, and most often a tail for swimming. Depending on the species, cercariae either seek a secondary intermediate host, in whom they form an encysted **metacercaria**, or develop directly into metacercaria on vegetation surrounding the aquatic habitat. Definitive hosts are infected by ingesting prey with metacercariae or by eating vegetation with encysted metacercariae.

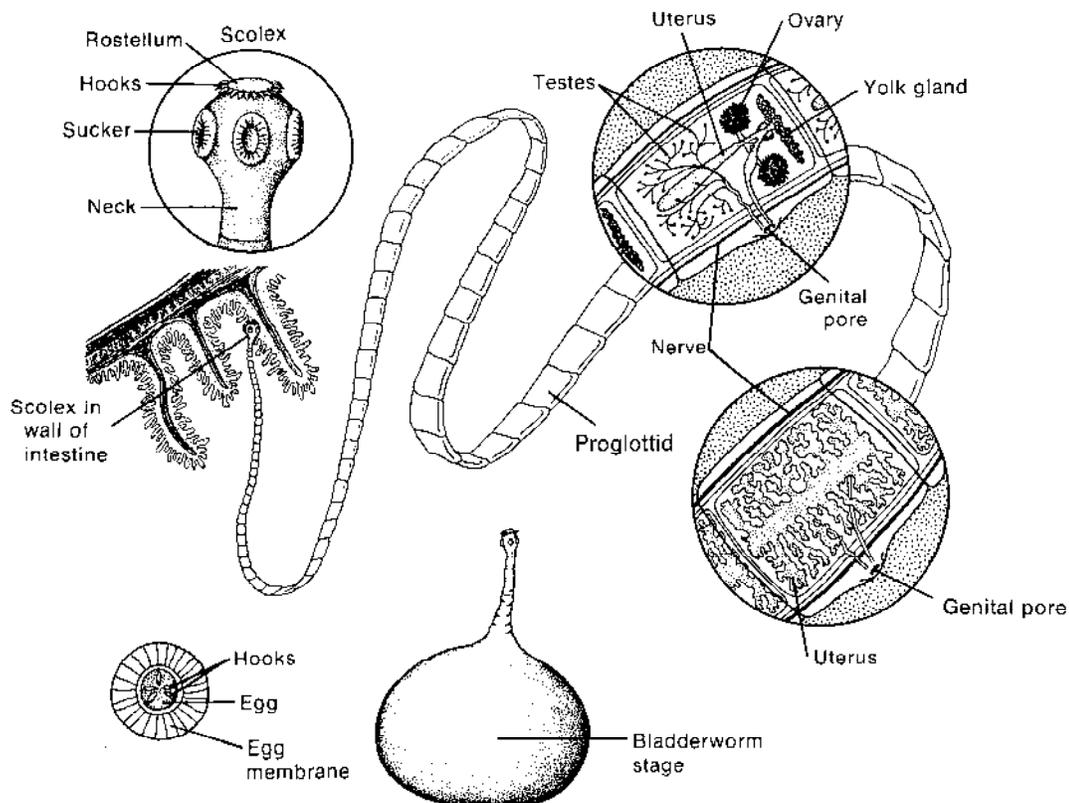
Opisthorchis (= *Clonorchis*) *sinensis* the Chinese Liver Fluke, is found throughout Asia. Up to 70% of some local human populations are infected with this parasite and often nearly 100% reservoir hosts (such as dogs, cats, and mink) are infected where the disease is endemic. In this case, freshwater snails ingest *O. sinensis* directly from sediments in fecal contaminated waters. Miracidia, sporocysts, and redia develop within the primary intermediate host and cercariae are shed back into the water. Cercariae seek out the secondary intermediate host, usually fish belonging to the Minnow Family, where they encyst as metacercariae. Humans are infected by eating raw fish. Worms make their way to the liver via the bile duct and mature in about three weeks.

FIGURE 51. *Opisthorchis sinensis*, the Chinese Liver Fluke, life cycle.

Class Cestoda – Tapeworms

Tapeworms are the most specialized of the Platyhelminthes; they lack any form of a digestive tract. The anterior-most portion of an adult tapeworm is the **scolex**. Adapted for adhering to the host, the scolex has suckers and often a rosette of anterior hooks called a **rostellum**. Behind the scolex is a narrow neck followed by a long **strobilus**. The strobilus is composed of three to several hundred segments called **proglottids**, and each mature proglottid contains a complete set of male and female reproductive parts. However, the male portion in each proglottid usually develops much earlier than the female counterpart to prevent self-fertilization.

Cestodes, like many trematodes, generally have complex lifecycles involving more than one host. One of the best known cestodes of man is the pork tapeworm, *Taenia solium*. Egg-filled proglottids of *T. solium* are passed in human feces. Each egg contains a developing embryo, the **embryophore**, with three pairs of hooks and a thick outer coating. Pigs consume food contaminated with human feces and thereby also ingest embryophores. Inside the pig's intestines, the embryophore's outer coating dissolves thus liberating small **oncospheres** that borrow through the intestinal wall and into the surrounding blood vessels. Oncospheres are carried by the blood to all parts of the body where they enter tissues and develop into bladder worms, or the **cysticercus**. Humans are infected with tapeworms by eating poorly cooked pork that is riddled with bladderworms.

FIGURE 52. *Taenia solium*.

We will examine two dog tapeworms: 1) *Taenia pisiformis*, which is very similar to *T. solium* except the intermediate hosts are rodents, and 2) *Dipylidium caninum* whose intermediate host is the flea.

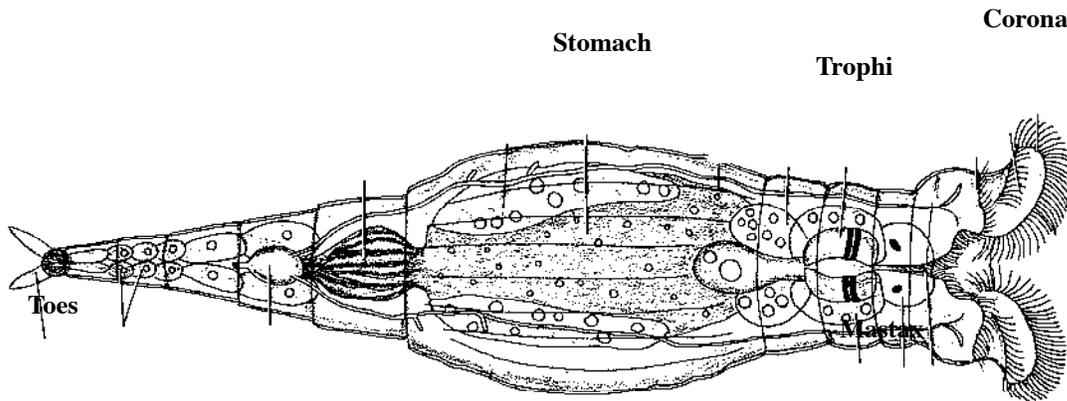
Pseudocoelomates

Phylum Rotifera

Rotifers are microscopic, pseudocoelomate animals found in almost all freshwater habitats. Like other pseudocoelomates, rotifers have a **complete digestive tract** with both mouth and anus. They are characteristic in having an anterior, ciliated **corona** that functions both in locomotion and in creating currents to bring in food, and they possess a muscular pharynx, the **mastax**, bearing teeth-like **trophi** to grind up food. Rotifers are mostly female and reproduce almost entirely by parthenogenesis. Males and sexual reproduction are frequent only during periods when resting eggs are required to survive harsh conditions. In most species of rotifers, males have never been observed.

Rotifers can be divided into three informal groups: 1) solitary rotifers bearing a shell, or lorica, 2) non-loricated solitary rotifers, and 3) colonial rotifers.

FIGURE 53. Anatomy of *Philodina* sp., a typical nonloricate rotifer.



Phylum Nematoda – The Roundworms

Nematodes are probably the most numerous and diverse group of animals on earth. Free-living nematodes are found in almost all natural habitats including soils, hot springs, glaciers, deep seas, and high mountain peaks; and a large number of roundworms are parasitic on plants, vertebrates, and other invertebrates.

Nematodes have a long, cylindrical body that is tapered on both ends. The body wall exterior is covered with a thick cuticle and the muscle portion is composed entirely of longitudinal muscle fibers, which results in nematodes' characteristic whip-like locomotion. The pseudocoelom is filled with fluid, the digestive tract, male or female reproductive structures, and sometimes, excretory glands. Their nervous system consists of an anterior, nerve ring (the brain) and dorsal, lateral, and ventral nerve cords.

Most roundworms are dioecious—that is, the sexes are separate. During copulation, the male usually wraps its tail end around the female so that it come into contact with her genital opening. Copulatory spicules of the male are extended through his cloaca and anus and inserted into the female's gonopore to hold it open for sperm transfer.

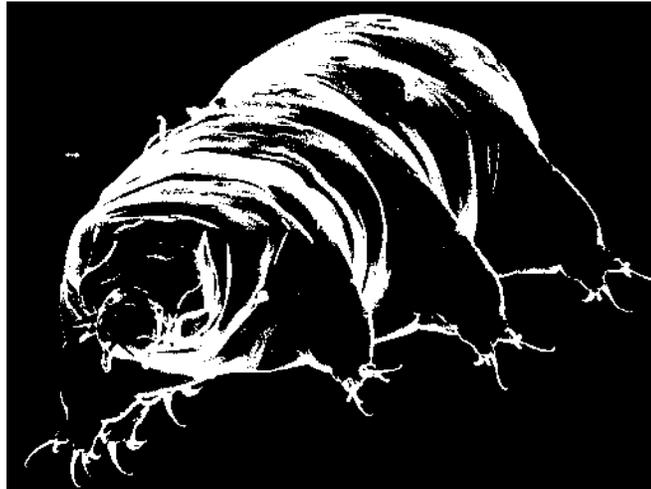
Ascaris lumbricoides is a common human intestinal roundworm found worldwide but most common in the Orient. They are among the largest roundworms to infect humans; females may be up to 20" long. Fertilized eggs are released by the female and expelled through human feces. Eggs do not hatch in soil, but larvae do develop within the egg membrane. Soils contaminated with human feces are frequently encountered in agricultural fields of the third world. *Ascaris* eggs work their way into crevices in the hands and fingernails of people working in these fields and get ingested along with food. The eggs hatch inside the intestine and larvae burrow into the gut lining, are picked up by the blood stream, and tour through the entire body. They travel to the heart and lungs, where they migrate to the air passages, up the trachea to the back of the throat, and are swallowed. Once in the small intestine, they grow and mature to adults.

Phylum Tardigrada – The Water Bears

Water bears are among the most unusual and fascinating animals on earth. There is very little agreement among workers as to the phylogenetic relationships of tardigrades to other animal phyla, but I have placed them with the pseudocoelomates because they possess a number of traits in common.

Tardigrades are small cylindrical animals with two eyespots, four pair of short legs ending with sharp claws, a circular mouth, and a muscular pharynx bearing sharp stylets for piercing food. They have a complete digestive tract, no circulatory or respiratory system, and their sexes are usually separate. Most individuals encountered are female, males have been found in relatively few species, and reproduction is usually parthenogenic.

FIGURE 54. Scanning electron micrograph of *Milnesium tardigradum*.



Tardigrades are found in many of the same habitats as rotifers and nematodes. They are most likely to be found in between sand grains along wet shorelines of oceans, lakes, and streams; and they are common in certain mosses and leafy liverworts in terrestrial habitats. We will attempt to extract them from mosses and liverworts. Like some rotifers and nematodes, many tardigrade have the ability change their morphology and physiology to withstand long periods of drought in a cryptobiotic, or suspended animation, state. Cryptobiotic tardigrades have been exposed to liquid nitrogen, several hundred roentgens of X-rays, and being dried for more than 50 yr., only to spring back to life in a drop of water.

Eucoelomate Protostomes

Phylum Mollusca

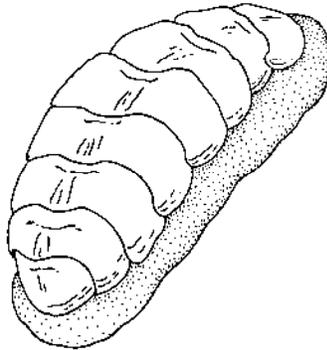
All mollusks have a mantle, and in many, it is used to secrete a shell and it also encloses a mantle cavity that harbors gills for gas exchange. In addition, they have: 1) a complete digestive tract, 2) an open circulatory system (it is largely closed in the cephalopods) with a heart, 3) a pair of of kidneys involved in nitrogenous waste excretion and osmoregulation, 4) a ventral, muscular foot for locomotion, 5) a reduced coelom , and 6) spiral and determinate cleavage.

Molluscan shells not only provide protection for the animal living within, but they also survive long after the animal inside has died. Because of this, mollusks are well represented in the fossil record. Their diversity is enormous; even after being collected by amateur and professional malacologists for centuries, new species are continually being described. Over 65,000 living species have been described, as well as approximately 35,000 fossil species. In this lab, we will examine 4 of the 8 classes in this phylum: the Polyplacophora, Bivalvia, Gastropoda, and Cephalopoda.

Class Polyplacomorpha – Chitons

Chitons are well designed for living in intertidal zones and along wave-swept rocky marine shorelines. They have a bilaterally symmetrical, ovoid body that is dorsoventrally flattened and a broad foot by which they are firmly attached to the substrate. Perhaps the most distinctive chiton feature is their shell, which is divided into eight overlapping plates. Their body shape and protective armor allow them to withstand the constant pounding of waves.

FIGURE 55. Sketch of a chiton.



Chitons obtain food by scraping algae and other microorganisms from hard marine substrates with their tongue-like **radula**. They remain idle during most daylight and low tide hours and usually become active only after dark or when the tide is ideal.

Class Gastropoda – Snails, Slugs, and Limpets

Gastropods represent the largest class of mollusks. They have a ventral foot for locomotion and a single shell, when present. Many gastropods show two separate evolutionary adaptations: body **torsion** and shell **coiling**. Most specimens show torsion—that is, their internal organs and mantle have undergone a 180° counterclockwise rotation so that the mantle cavity, gills, anus, and excretory openings are in the body's anterior portion, just behind the head. This means the digestive tract is twisted to form a U-shape and organs originally on the animal's left side are now on its right. Most, but not all, gastropods have coiled shells—limpets are an example of gastropods without coiled shells, although they do show torsion.

A majority of gastropods have gills enclosed within their mantle cavity, but in the land snails and many freshwater species the mantle cavity has been converted to a lung. In this case, the edges of the mantle cavity are sealed to the animal's back except for a small opening, the **pneumostome**, which is used for ventilation. Garden slugs are excellent for observing the mantle and pneumostome.

Gastropods exhibit almost all types of feeding including: herbivory, carnivory, scavenging, detritus feeding, suspension feeding, and some are even parasitic. Nearly all feeding involves a toothed radula that is used to rasp away food and convey it to the oral cavity.

Class Bivalva – Clams, Oysters, and Mussels

Bivalves have a laterally compressed body and a shell with two **valves**, which are hinged dorsally and open ventrally to expose the **hatchet-shaped foot**. Two halves of the mantle join at the ventral end to form incurrent and excurrent siphons. Clams burrow anterior-end-first into the sediment thereby leaving their posterior end exposed to the water column. Water is pumped in through the incurrent siphon by water currents set up resulting from ciliar movements in the gills. Water enters the mantle cavity, bathes gills with oxygen, and exits through the excurrent siphon. Gill cilia filter out suspended

particles and move them to the mouth. However, some particles are rejected, packaged in mucus, and expelled from the shell as pseudofeces. Food is directed to the mouth by labial palps and passes through the esophagus into the stomach, where digestive glands add enzymes to breakdown the food. Bivalves have long intestines that extend dorsally into the pericardial cavity and, in most cases, pass directly through the heart before ending in an anus close to the excurrent siphon.

Most bivalves are dioecious. Females often brood eggs in the mantle cavity or inside the gills. Males dump large amounts of sperm into the water column and some make their way into the female's incurrent siphon to fertilize the eggs. Eggs of most marine bivalves have a free-swimming larval stages before developing typical bivalve morphology, but in many freshwater clams, larvae, called **glochidia**, are modified for attachment to fish gills and fins. Their brief period of parasitic existence lasts for 10–30 days and is primarily used for dispersal.

Class Cephalopoda – Squid, Octopuses, and Nautilus

The term 'cephalopod' means 'head foot', referring to the foot, now modified as tentacles, being attached near the head. Cephalopods are all predacious, feeding primarily on small fish, crustaceans, and worms. They are visual predators that have well developed eyes comparable to those of vertebrates. All cephalopods, except the *Nautilus* and its fossil relatives, lack a shell; and in most, the mantle is lengthened, streamlined, and otherwise modified in an evolutionary trend towards swimming.

Most cephalopods are propelled through the water by rapidly expelling water from their mantle cavity. Water passing through the mantle cavity also provides oxygen for the gills.

Phylum Annelida

The most distinctive feature of annelids is their body is divided by septa into repeated segments in which each segment has parts of the circulatory, excretory, digestive, and nervous systems. Other features of the annelids are: 1) their circulatory system is closed, 2) excretion is by nephridia, 3) they have a complete digestive tract, 4) the nervous system is composed of a pair of anterior dorsal ganglia (the brain) that are connected to two subpharyngeal ganglia by circumpharyngeal connectives and they have a double, ventral nerve cord, 5) each segment has circular and longitudinal muscle layers, 6) their coelom is relatively large, and 7) their cleavage is spiral and determinate.

Class Oligochaeta – Earthworms

Oligochaete means 'few setae', which refers to the observation that members of this class possess fewer and more reduced setae than the polychaetes. Oligochaetes are most diverse in soils and freshwater habitats. We have already examined a member of this group with the earthworm dissection.

Class Polychaeta

Polychaetes are mostly marine. *Nereis* is one example of this group. It has fleshy projections on each segment called **parapodia** that help the worm move through sandy sediments and increase surface area for gas exchange. Protruding from each parapodium are numerous setae.

Class Hirudinea – Leeches

This group is known collectively as the leeches. Some of the members of this class are blood-sucking ectoparasites on vertebrates, but some are predators and many are detritus feeders. They are typically dorso-ventrally flattened and have 32 internal segments (although they often appear to have more externally). Leeches often have both anterior and posterior suckers with the mouth located within the anterior sucker. Some forms evert their pharynx in order to feed and many of them have sharp teeth used to puncture their host's skin. Leeches lack setae.

Phylum Arthropoda

The arthropods are the most numerous and perhaps most diverse group of organisms on earth. A full three quarters of all known species are arthropods. With such high diversity, arthropod taxonomy is constantly changing with new species being described and known ones being rearranged. This phylum contains the spiders, ticks, mites, centipedes, millipedes, insects, crustaceans, and scorpions. In addition to the above list many fossil forms are known. The phylum consists of five groups of extant species: the class Arachnida (spiders), the subphylum Crustacea and the uniramious classes the Chilopoda, Diplopoda, and Insecta. All arthropods have an external, segmented skeleton (exoskeleton) composed mainly of chitin. Some members have additional proteins or calcium carbonate added to the chitin for stiffness. Growth requires that the exoskeleton be shed periodically to allow the body to expand. Another feature of arthropods is their jointed appendages. The insects are unique among arthropods in that they have evolved true wings for flight.

Subphylum Trilobitomorpha

Trilobites are all fossils. This group of Arthropods have been extinct for 200 million years. The 4000 or more known fossil species were most common between 400–600 million years ago. The trilobites were exclusively marine, but exploited a variety of niches.

Subphylum Chelicerata

Subphylum Chelicerata includes horseshoe crabs, sea spiders, spiders, mites, ticks, scorpions, and harvestmen. The first pair of appendages on specimens of this group are modified to form chelicerae with claws. (Note this is the first pair of appendages and are therefore head appendages. They are analogous, not homologous to the clawed first thoracic appendages of crabs and lobsters). In addition to the head chelicerae, they also possess a pair of pedipalps which are jointed appendages with sensory and reproductive functions.

Class Arachnida – Scorpions, Spiders, and Ticks

Examine the preserved spider specimen. Note that the body consists of two distinct regions, the anterior cephalothorax and the posterior abdomen. The cephalothorax consists of the fused head and thoracic segments. The large fang-like chelicerae can be seen at the front vertex of the head. The chelicerae are hollow and serve as a means of conducting venom and digestive enzymes into the body of the prey. Most spiders have eight pairs of eyes positioned strategically around the front, sides, and rear aspects of the head region. Some species of spiders like the salticids have eyes which function like high resolution telescopes for long range detection of prey. The cephalothorax also has four pairs of long jointed legs. The abdomen is a large sac like structure which houses the gonads and has a pair of spinnerets located along the ventral or underside of the abdomen.

Subphylum Uniramia

Subphylum Uniramia contains the millipedes, centipedes and insects. The insects are the most species-rich taxon in the animal kingdom. This class is believed to contain well over a million species. All have mandibulate mouthparts with flattened maxillae and compound eyes, but differ from the Crustacea in that they all feature uniramous or nonclawed jointed appendages. The Uniramia also bear a single pair of preoral antennae on the head as their first appendage. The uniramian body plan has been extensively modified so that a variety of locomotory modes may be utilized. In addition, the subphylum fills a bewildering variety of ecological niches, from parasitic, herbivorous, and parasitic conditions. The diversity of structure, and the high number of species, makes coverage of the diversity in this group makes detailed coverage impractical in an introductory class.

Class Insecta

The insects are characterized by the presence of three distinct body regions: The head, thorax and abdomen. Most insects have 3 pairs of functional walking legs, although, in some species they may be vestigial. Most insects also have a two pair of functional wings arising from the thorax; but in some groups wings are absent. There are more species of insects than any other group of plant or animal. Estimates of the number of species of insects ranges from 5–30 million, less than a million of these are described. They play a critical role in conversion of vegetable matter into animal protein, and therefore are essential components in many ecosystems. Insects are common in all terrestrial and freshwater aquatic environments, but they are uncommon in marine habitats. Insects have evolved a number of life-history strategies. Some insects are phytophagous (plant feeding), while others are predators; parasites and detritivores. Many of the biting flies and insects are important vectors of diseases effecting humans and livestock (e.g., malaria). Some insects are significant pests of cultivated crops, but the total number of harmful species is extremely small. Most species are not pests and are not harmful, but beneficial components of the natural environment.

Class Chilopoda – Centipedes

Class Diplopoda – Millipedes

Subphylum Crustacea

Subphylum Crustacea have the water fleas or cladocera, wood lice, scuds, shrimp, lobsters, crabs, and shrimp crustaceans all bear mandibulate mouthparts with paired flattened maxillae as found in the Uniramia. Unlike the Uniramia, the Crustacea all possess two pairs of preoral antennae and biramous or clawed appendages. Most members of this subphylum can be found in marine and freshwater habitats with some species such as the wood lice found in moist terrestrial habitats.

Daphnia sp. Anatomy

The cladocera are microscopic organisms which make up a large proportion of the zooplankton of freshwater lakes and ponds. They feed mainly upon phytoplankton, animal like protists, and bacteria that live in suspension with them. Cladocerans are important food items for fish fry and adult fish like the bluegill sunfish, *Lepomis macrochirus*. Obtain a microscope slide of *Daphnia* from the demonstration table and observe the specimen under low power of a compound microscope. Note the large **antennae** projecting anteriorly from the head. The antennae provide its major source of locomotion as well as chemoreception. Near the base of the antennae are the large dark **compound eyes**, which are composed of smaller circular **ommatidia**. Next look at the trunk of *Daphnia* and note that it is covered by a bivalve shell, the **carapace**. Between the dorsal surface of the trunk and the carapace is a space which serves as a **brood chamber**. Within the brood chamber look for eggs or developing larvae. The trunk has five pairs of **foliaceous legs** which serve as both respiratory organs and filter feeding appendages. At the posterior end of the trunk is the clawed **furca**. The furca functions to keep the carapace clear of debris so unhampered filter-feeding and gas exchange can occur.

Eucoelomate Deuterostomes

Phylum Echinodermata – Sea Stars, Brittle Stars, and Sand Dollars

The echinoderms are all marine organisms and include brittle stars, sea stars, sea urchins, sand dollars, sea cucumbers, sea lilies, and many extinct forms (e.g., crinoids). They are placed among the Deuterostomes which among other things means that they have radial cleavage in the early embryo, that is complete and indeterminate developmental characteristics shared with the chordates. The echinoderms are generally characterized by having secondary radial symmetry, an endoskeleton of calcareous ossicles, an extensive coelom, complete digestive tract and a poorly developed nervous system. Two unique characters set them apart from all other phyla, namely the water vascular system and the generally five parted body plan (pentamerism). Echinoderm larvae closely resemble those of the prochordate *Saccoglossus*, a character that suggests a close relationship between the echinoderms and the chordates.

External Anatomy of the Sea Star.

Study a preserved specimen of a sea star. Note the five arms or rays, projecting from a poorly defined central disc. Observe the two surfaces of the animal. The oral surface is usually concave and can be identified by the rows of tube feet along each arm. The other surface is the aboral surface. First study the aboral surface. Note that it is covered with spines. In the center of the central disc located slightly off-center. This is the **madreporite**, through which sea water enters the water vascular system. The two arms closest to the madreporite are called the **bivium**, the remaining three the **trivium**. The surface of the animal is rough; this is because of the extensions of the endoskeleton called **spines**. Between the spines are small soft projection called **dermal branchiae**. **Pedicellariae** are tiny pinchers scattered between the spines. These serve to clean the animal's external surface.

On the oral surface, note the central **mouth**. Along each arm there is an **ambulacral groove**. Each groove is filled with several rows of **tube feet** which are connected to the water vascular system and provide the means of locomotion of the starfish. Each one of these tube feet is slender and has an expanded tip for clinging to surfaces. At the end of each are eye spots. These are small and pigmented, but are difficult to see on preserved specimens.

Exercises

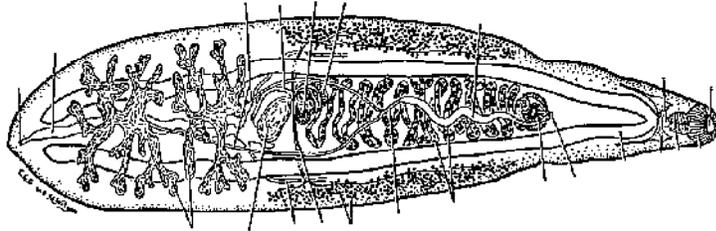
1. Examine the sponge on display. Examine the prepared slide of *Grantia* cross-section sketch and label the spongocoel, collar cells, and incurrent pores. Also view the microscope slide of sponge spicules on demonstration. Sketch a few spicules and indicate their size.

2. Observe the *Gonionemus* medusa on display. Sketch the animal and label its bell, manubrium, velum, radial and ring canals, statocysts, tentacles, and gonads.

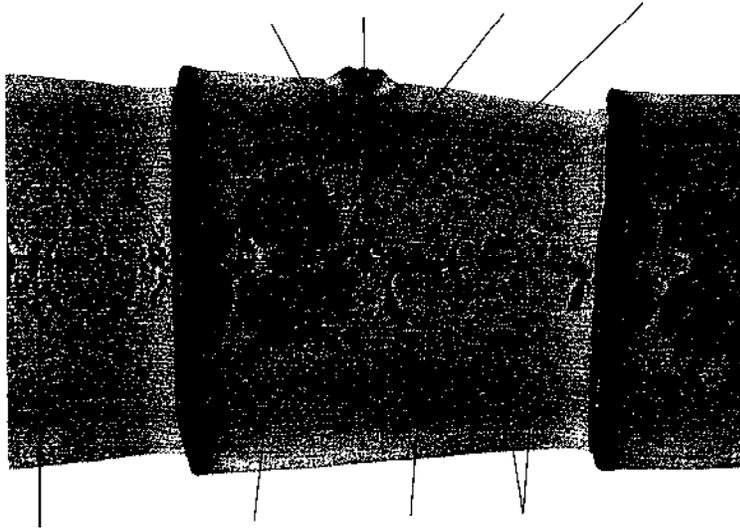
3. Observe the living *Hydra* on display. Pipette an individual *Hydra* into a small petri dish and observe under a dissecting scope. Next pipette a few cladocerans or copepods from the pond water sample into the same petri dish and observe *Hydra* capture and consume one of these prey items. Briefly describe your observations. Also examine prepared slides of *Hydra* sexual structures and be able to identify spermaries and ovaries.

4. Observe the living *Planaria* on display. You may pipette and individual into a petri dish and examine it under the dissecting microscope. Note its movement and locate the eyespots, pharynx, and branched intestine. Also obtain a prepared slide of *Planaria*. Be sure you can identify structures digestive system, the eye spots, and auricles.

5. Observe the prepared slide of *Opisthorchis sinensis*. Label the following on the diagram below: mouth, cecum, ventral sucker, ovary, uterus, vitelline glands, testes, and seminal vesicle. Also view the other examples of trematodes on display.

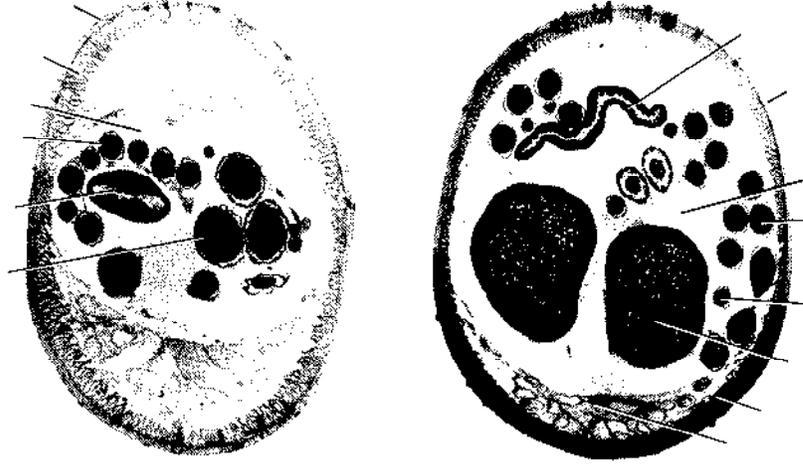


6. View a prepared slide of *Taenia pisiformis*. Sketch and label parts of the scolex and gravid proglottid, then label parts of the mature proglottid in the diagram below. Also observe the *Dipylidium caninum* on display and know its lifecycle.



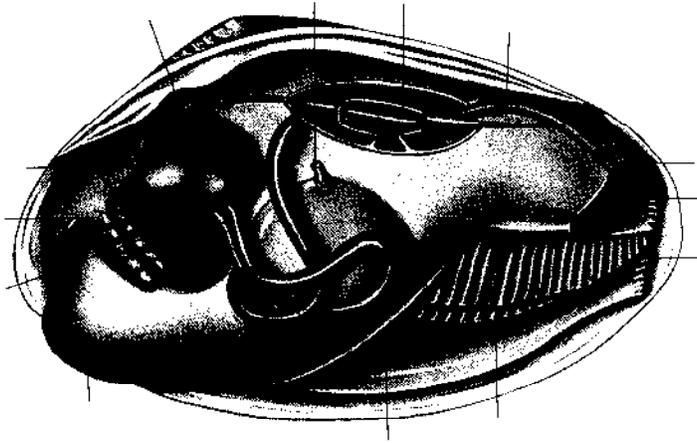
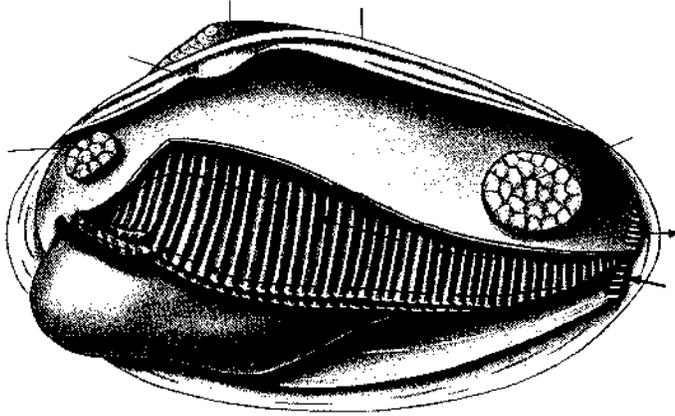
7. Place a drop of water containing living rotifers from the Mixed Rotifer cultures on a microscope slide. You will not need a coverslip if you observe them at 40X and 100X with a compound scope. Sketch a few of these and label the lorica, foot, corona, and mastax.

8. Observe the dissected male and female *Ascaris* worms on display and locate the following structures: cuticle, intestine, oviducts, uterus, testes, and vas deferens. Also observe prepared slides of cross-sections of male and female *Ascaris* worms. Note the cuticle, epidermis, longitudinal muscle layer, pseudocoelom, intestine, oviducts, uterus, testes, and vas deferens in these cross sections.

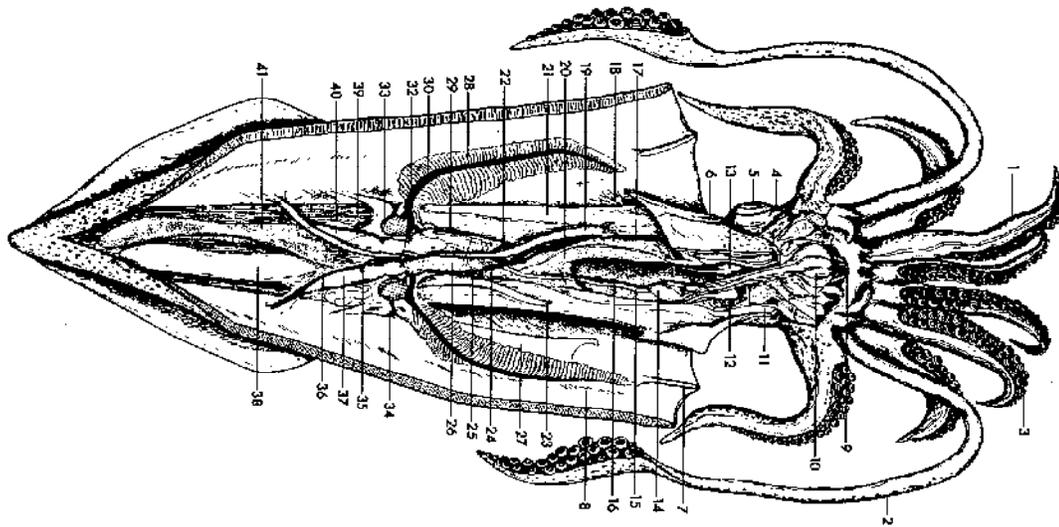


9. Moss containing cryptobiotic tardigrades, rotifers, and nematodes have been soaking for several hours in water so that most of these animals will be revived from their 'suspended animation' state. Squeeze the soaked moss into into its beaker and wait a few minutes for all the animals to settle to the bottom. Next, pipette some of the beaker's bottom material to a small petri dish for observation under the dissecting scope at 20–30X. You may wish to transfer animals to a microscope slide for closer examination using a compound scope. Sketch and label your observations below:
10. Observe living snails on display. Note how they move, feed, and use their tentacles to explore the environment. Are the tentacles used for chemoreception, tactile stimuli, light reception, or some combination of the above? Can you find the pneumastome? Also take a look at the sea tank in Room C-4; it has several living chiton and gastropods.

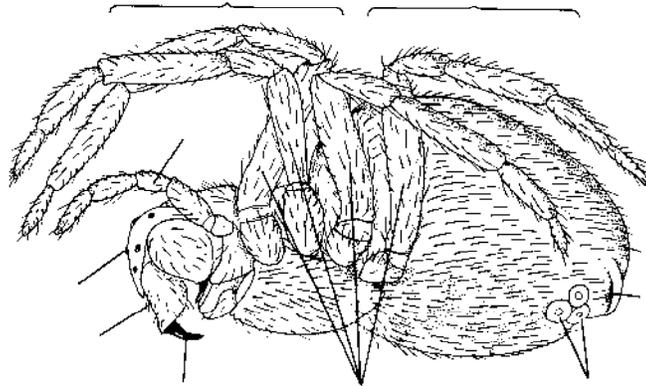
11. Read over the clam dissection guide included in the manual appendix, observe the clam dissections on display, then label the structures on the diagrams below. Also look at prepared slides of mussel glochidia, sketch and label your observations below. The sea tank in C-4 also has many marine bivalves. Note the wide diversity expressed there.



12. Observe the dissected squid on demonstration and label the following parts on the diagram below: the mantle, tentacle, arms, eye, stomach, caecum, digestive gland, gill, mantle cavity, radula, jaws, and funnel.

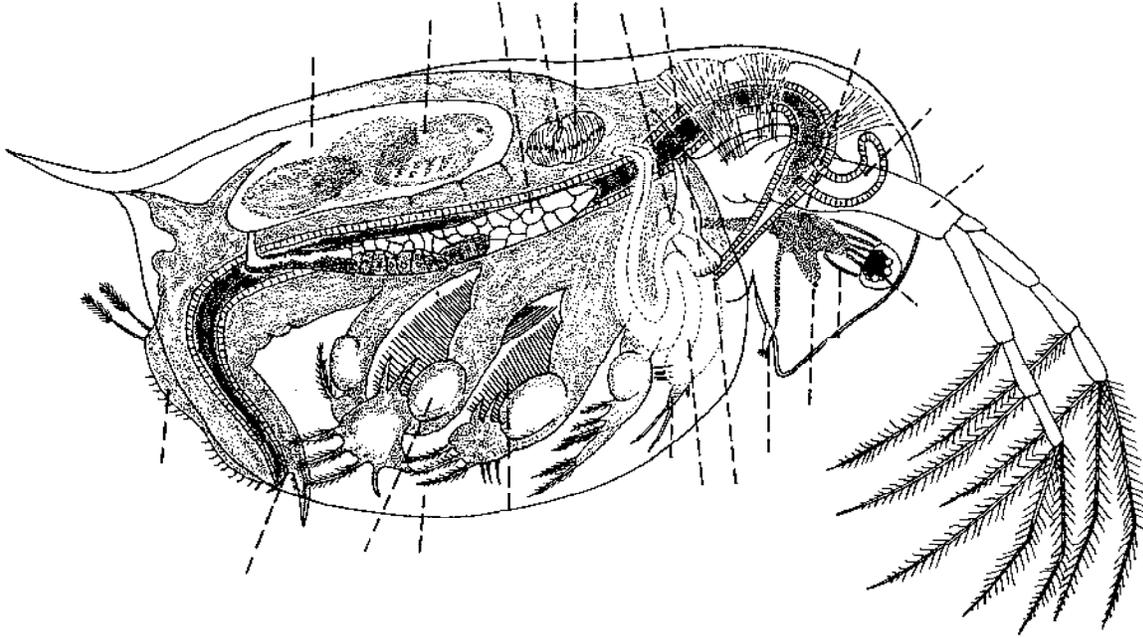


13. Observe the clam worm, Neries, and leeches on display .
 14. Observe the spider on display and label parts on the diagram below.

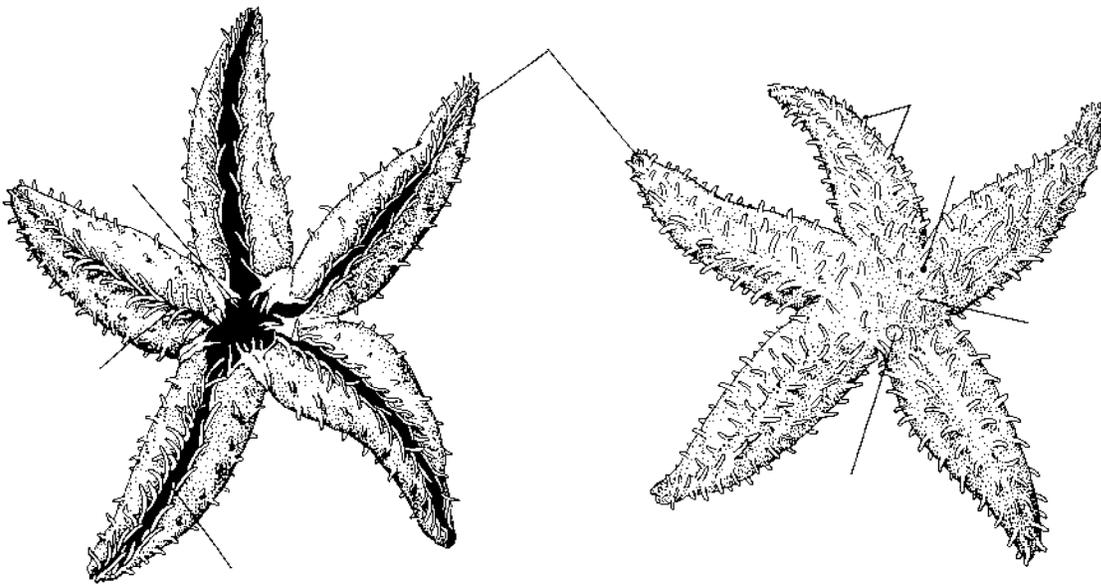


15. Examine the various insects, millipedes, and centipedes on display. Be able to identify them to the class level.

16. Read over the *Daphnia* anatomy section in this document, examine a prepared slide of *Daphnia* (or some other cladoceran), then on the diagram below, label those structures that are in bold in the text.



17. Examine the pond water sample under dissecting and compound microscopes. Identify several of the invertebrates you find to phylum, subphylum, and/or class level.
18. Read over the guide to sea star external anatomy in this document, view the sea star on display, then on the diagram below, label those parts that are in bold in the text. View the examples of echinoderms on display in the lab and in C-4..



19. Ask the TA for an exit quiz.