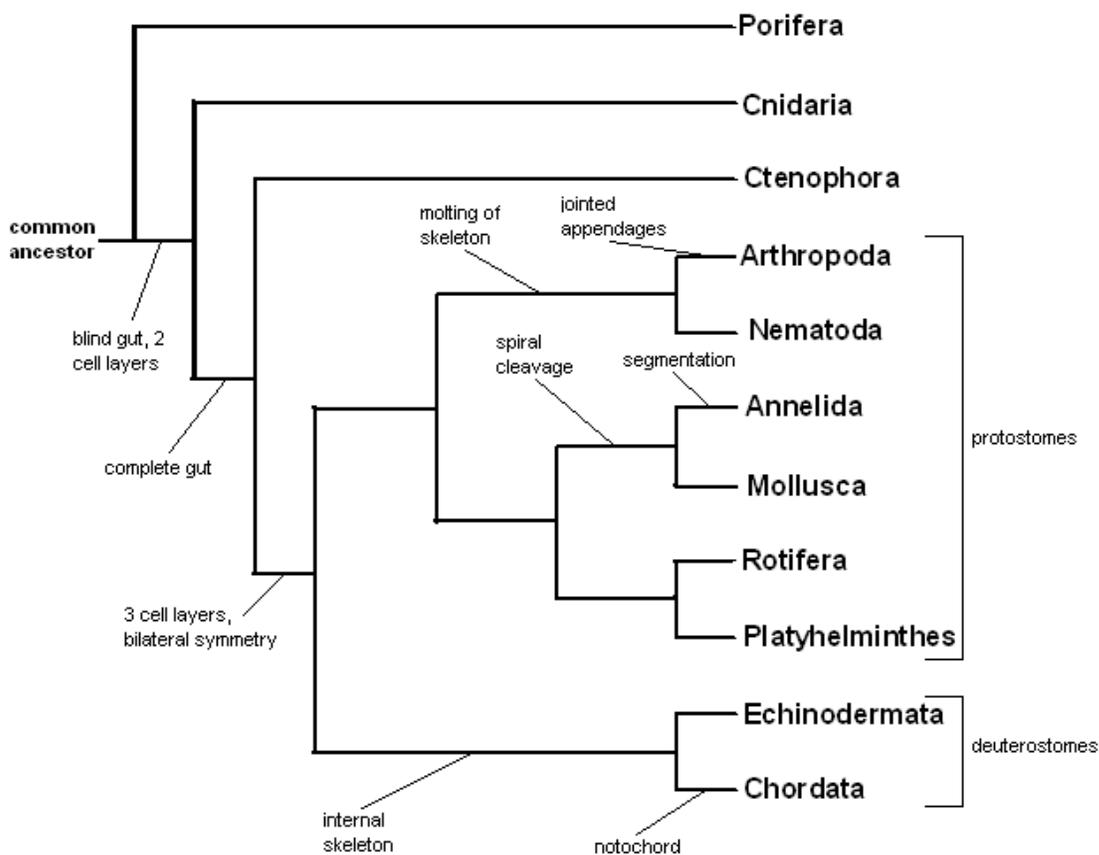


Invertebrates

More than a million species of animals have been described. They occur in virtually every habitat, from the deepest recesses of the oceans to the driest deserts of the world. While these animals vary greatly in form and function, they all can be characterized as multicellular organisms that obtain their food by ingesting other organisms or their by-products (i.e., they are heterotrophic organisms). The fossil record indicates that the first animals arose in the Precambrian seas (> 600 mya), most likely from colonial protists that underwent a specialization of cells and a division of labor. Once established, this new way of life led to an explosive diversification of body forms. During the first 10-20 million years of the Cambrian period, representative of nearly every phylum of Kingdom Animalia emerged.

The evolutionary history of animals has not been completely resolved, but a fairly comprehensive picture has emerged in recent years. Traditionally, biologists have generated hypotheses about evolutionary relationships by noting the phenotypic similarities and differences among species. More recently, comparisons of the DNA of both living and extinct species have been used to further clarify the relationships among animals. Currently, the animal kingdom is divided into several major groups, based on their evolutionary history (Fig. 1). Today, we will focus on the **Invertebrata**, a group that includes all animals that lack a vertebra (or back-bone). In Fig. 1, you can see that invertebrates belong to a paraphyletic group, which encompasses all animals except those with the Phylum Chordata. Invertebrates, both living and extinct, vastly outweigh chordates in terms of diversity and biomass; for example, The Invertebrata includes about 95% of the known species of animals. The phylogenetic tree depicts some of the evolutionary changes that define each group of animals.



The sponges (**Phylum Porifera**) belong to a lineage that most closely resembles the first animals. These marine animals possess simple, asymmetrical bodies comprised of loosely aggregated cells. These animals lack true tissues and organs.

A second evolutionary lineage includes the cnidarians (**Phylum Cnidaria**). Cnidarians are characterized by **radial symmetry** and the presence of true tissues that are organized into two layers (the **diploblastic** condition). Cnidarians also possess stinging cells called **cnidocytes**.

The third major animal line contains most of the known phyla of animals. Members of this lineage possess three layers of tissue (i.e, they are **triploblastic**) and **bilateral symmetry**. Despite these two synapomorphies, this lineage contains a great diversity of body plans. Biologists further divide this lineage based on the presence of a body cavity (coelom) and the development of the digestive tract. Some of these animals have bodies with just one outer opening that serves as both a mouth and an anus. Others have two openings and the digestive tract forms a tube. Those animals with a mouth and an anus referred to as protostomes or deuterostomes, depending how the mouth and anus develop. In **protostomes**, the first embryonic opening, or **blastopore** develops into a mouth. In **deuterostomes**, the blastopore develops into the anus.

In this and the following laboratory exercise, you will investigate body form and function in representatives of five major phyla: Porifera, Cnidaria, Platyhelminthes, Annelida, and Arthropoda. The specific animals that you will study are the sponge, hydra, flatworm, earthworm, and crayfish. You will examine or dissect these organisms and relate their structures to their functions, lifestyles, and evolutionary history. Some structures will appear repeatedly among these organisms, while other structures will occur in only one or a few species. Thus, as you study each animal, keep in mind the relationship between form and function, the relationship between environment and lifestyle, and the evolutionary history of the organism.

OBJECTIVES:

- Compare and contrast the anatomy of representative animals, describing similarities and differences in organs and body form that allow the animal to carry out particular functions.
- Relate the morphology of the animals to function in their environment.
- Discuss how similarities and differences in morphology may indicate phylogenetic relationships.
- Identify characteristics that are indicative of major phylogenetic branching points.
- Know the **bold** structures listed for each organism as well as the Kingdom and Phylum. Use your *Photographic Atlas for the Biology Lab* (phot atlas) to identify structures.

WHAT YOU WILL DO IN LAB:

To guide your investigation of form, function, and relationships among five phyla. You will **record your findings for each organism in the appropriate columns of Summary Table 1** near the back of this handout. This information will be used to **answer questions in the Applying Your Knowledge** section. Any information from these sections is **fair game for next week's quiz and the lab practical**. If you want to read more material about each phylum, look at chapters 31 and 32 of your text, *Life*.

12 CHARACTERISTICS YOU WILL EXAMINE IN EACH PHYLUM

- 1. Symmetry.** Determine whether the organism is:
 - asymmetrical (no apparent symmetry),
 - radially symmetrical (the arrangement of parts around a central axis), or
 - bilaterally symmetrical (right and left halves are mirror images).
- 2. Tissue organization.** Investigate whether the cells of the organism are organized into well-defined tissue layers and determine the number of distinct layers present.
- 3. Openings into the digestive tract.** Determine where food enters the body and digestive waste exits. Some animals have only one opening to the digestive tract that functions as both a mouth and anus. Others have a tubular digestive tract (a “tube within a tube”) with two openings - an anterior mouth and a posterior anus.
- 4. Circulatory system.** Determine whether the animal has no respiratory system, an open, or a closed circulatory system. In an open circulatory system, the blood flows through coelomic spaces in the tissue as well as in blood vessels. In animals with closed circulation, the blood flows entirely through vessels.
- 5. Habitat.** Determine whether the organism is a terrestrial, marine, freshwater, or parasitic. Keep this in mind as you address characteristics 7-10.
- 6. Type of locomotion.** Determine how the organism moves. Does it swim, crawl, walk on legs, burrow in the substrate, or fly? Are specific cellular structures such as cilia used for locomotion?
- 7. Organs for respiration (gas exchange).** Determine how oxygen enters the body and carbon dioxide exits the body. Some animals use their skin as the site of gas exchange. Others have specialized organs, including the gills of aquatic organisms and the lungs of terrestrial organisms. Insects have a unique respiratory system with structures called spiracles and tracheae.
- 8. Organs for excretion.** Determine how the animal eliminates nitrogenous waste from the body. In many animals, these wastes diffuse out of the body through the skin. In others, there are specialized structures such as malpighian tubules, lateral excretory canals, metanephridia, and kidneys.
- 9. Support systems.** Determine what type of support system the animal possesses. An endoskeleton lies inside the epidermis or skin of the animal and an exoskeleton lies outside the body wall. Some animals lack true skeletons, but may be supported by fluid. Fluid within and between cells and within body chambers such as a gastrovascular cavity, serve as a “hydrostatic skeleton.”
- 10. Segmentation.** Determine whether the animal has linear repetition of similar body parts. The repetition of similar units or segments is called segmentation. Segments can be similar in appearance and function or they can be specialized in structure and function. Other animals have no segmentation.
- 11. Appendages.** Determine whether appendages (organs or parts attached to a trunk or outer body

wall) are present. Note whether they are present all along the length of the body or are restricted to one area. Are they all identical or are they specialized for different functions?

12. **Type of nervous system.** Determine the type of nervous system that the animal possesses. Is there a distinct brain or nerve cord or is there a diffuse nervous system? Is there a nerve cord? If so, where is this nerve cord located? On the dorsal side or the ventral side of the body? Are sensory organs present? If so, which ones?

Phylum Porifera—Sponges:

Sponges are among the simplest of living animals. The body of a sponge is a loose aggregation of cells that surrounds a water canal system. You will observe the unique body structure of a sponge by first observing a preserved specimen and then a prepared slide of a longitudinal section of the marine sponge.

1. Observe the sponges on display at the back of the room and examine their external characteristics with a dissecting microscope. Compare your observations with Fig. 7.5 in your photo atlas.

Note the vase-like shape of some sponges and the large opening at one end of the body. This opening is called the **osculum**. In contrast to what you might think, the osculum is not a mouth. Rather, it serves as an outlet for the water that passes through the sponge's body. Water enters the central cavity, called the **spongocoel**, from channels and pores in the body wall. The spongocoel is neither a digestive tube nor a chamber, because particles of food are absorbed by cells that line the body wall. Note that the body wall consists of numerous folds and channels.

2. Examine the prepared slides of the sponge body and examine it with the light microscope.

Using Fig. 7.4, view the structure of the body wall, making note of the manner in which the cells are organized. Find the flagellated **collar cells (choanocytes)** that line the central cavity. The collective beating of the flagella of these cells generates an inward current through the sponge body and the collar cells trap and digest small food particles from the water.

Needlelike **spicules** composed of calcium carbonate surround the osculum and protrude from the surface of the body. These structures give support and protection to the sponge and prevent small animals from entering the sponge's internal cavity.

3. Examine a slide of spicules under the light microscope. Compare to Fig. 7.6
4. Fill in the information about sponges in Table 1.

Phylum Cnidaria—Hydras, Jellyfish, and Sea Anemones:

Cnidarians are the simplest animals that possess true tissues. These animals have sac-like bodies consisting of just two tissue layers. The central digestive compartment, the **coelenteron (gastrovascular cavity)**, has a single opening that serves as both the mouth and the anus (Fig. 7.9,

7.36). These carnivorous animals use **tentacles** arranged in a ring around the mouth to capture and ingest prey. The tentacles possess a unique feeding cell type called **cnidocytes**, which contain a stinging thread capsule called a nematocyst. When stimulated, the nematocyst turns inside out of the cnidocyte with explosive force, releasing a long thread that entangles prey. Most cnidarians are marine; however, a few live in freshwater. Included among the freshwater species is the microscopic, solitary organism, *Hydra*, the specimen you will examine today.

Examination of Hydra:

1. Using a dissecting microscope, observe the Hydra's structure and compare with Fig. 7.10-11. Note the symmetry of the Hydra body plan.

- Tap the edges of your Petri dish. Observe and compare the rate of elongation and the rate of contraction of this organism.
- Find the mouth with its surrounding tentacles. Watch to see if a hydra catches any prey. In addition to their function in acquiring food, the tentacles are used in a type of locomotion that resembles a hand-spring. The hydra can attach its tentacles to the substrate and flip its body completely over, reattaching the base to a new position.

2. Study the prepared slides of hydra using the light microscope. Compare the sections with Fig. 7.12-14. Find the **bud, basal disk, gastrodermis, and epidermis**.

Observe the tissue organization of the hydra body. Can you see two distinct tissue layers? What are these layers? Although you will not be able to see it, hydra do have a simple nervous system. The slow movements of *Hydra* are coordinated by a microscopic *nerve net* present in the body wall. Cnidarians lack a brain and nerve cord.

3. Think about how the body of the hydra is supported. How might the gastrovascular cavity provide support? Complete the characteristics of hydra in Table 1.

Examination of sea anemone:

Metridium senile is a common anemone in the northeastern United States and in northern Europe. It inhabits shallow, subtidal water and lives attached to rocks.

1. Find the **tentacles, mouth, pharynx, gastrovascular cavity, and pedal disk** (Fig. 7.36).

Phylum Platyhelminthes—Flatworms, Flukes, and Tapeworms:

Platyhelminths have bilaterally symmetrical bodies that are *dorsoventrally flattened*. These so-called "flatworms" have several evolutionary developments compared to cnidarians. Along with the evolution of bilateral symmetry came moderate cephalization and the ability for unidirectional movement. Flatworms also are triploblastic, a condition that has contributed to the development of true muscle and several other organs that are not present in the radiata. There are about 20,000 species of flatworms, grouped into three classes. Flatworms are free-living carnivores found under rocks, leaves, and debris in freshwater ponds and creeks. They move over these surfaces using a combination of muscles in their body wall and cilia on their ventral side.

1. Using a dissecting microscope, observe a live flatworm and compare to Fig 7.45-46. Note the mode of locomotion through the water. What does it do if you touch it with the tip of a probe? What does this indicate? Shine light from a pen light or flashlight onto the planarian, and describe its response. Find the **head**, **eyespot**, and **gastrovascular cavity**.

Response to Touch:

Response to Light:

Examine a whole mount of *Planaria* using a light microscope and compare it with Fig 7.46. Examine the body for possible digestive tract openings. How many openings to the digestive tract can you see? The mouth is at the end of a muscular, protrusible **pharynx** that extends from the middle of the ventral side of the planarian. Find the pharynx and **mouth**. The proximal end of the pharynx opens into a branched **gastrovascular cavity**. The blunt end of the animal is the anterior or head region. Look for the pair of pigmented **eyespot**s on the dorsal side of the head. These sensory organs are sensitive to light intensities and the direction of a light source, but cannot form images.

Lateral to the eyespots are flaps called **auricles** that function for smell. Beneath the eyespots are two cerebral ganglia that serve as a simple **brain**. Two ventral nerve cords extend posteriorly from the ganglia, running the entire length of the body. The two cords are connected by transverse nerves to form a *ladder-like nervous system*.

2. Examine the prepared slide of a whole mount and cross-section of *Planaria* (Fig. 7.45).

The evolution of *three well-defined embryonic tissue layers* has enabled flatworms to have a variety of tissues and organs, including reproductive organs and excretory organs. The mesodermally-derived excretory system consists of two *lateral excretory canals* and *flame cells* that move fluid through the canals. Respiratory, circulatory, and skeletal systems are lacking in the flatworm. How do you think the body of the worm is supported? How and where do you think gas exchange takes place?

3. Fill in the characteristics of the flatworm in Table 1.

Examination of tapeworms (*Taenia*):

Cestodes, or tapeworms, are highly specialized internal parasites and with few exceptions the adults inhabit the intestine of a vertebrate such as dogs. The tapeworm body consists of an anterior, head-like scolex and the trunk, or strobila, consisting of a linear series of segments, or proglottids. The scolex attaches the worm to the gut wall of the host.

1. Using Fig. 7.58-62, find the **scolex**, **suckers**, and **proglottids**. Where is the **mouth**?

Phylum Annelida: Earthworms, Tubeworms, and Leeches:

Annelids are a diverse group of animals that live in marine, freshwater, and moist terrestrial habitats. One group, the leeches, comprises blood-sucking parasites. Annelids range in size from microscopic

to several meters in length. These animals share a number of features with nematodes (*e.g.*, bilateral symmetry, three distinct tissue layers, a complete digestive tract), but have several new adaptations.

EARTHWORM DISSECTION (pp. XXX-XXX of your photo atlas):

1. Examine the live earthworm (*Lumbricus terrestris*) and compare it with Fig 7.85. Earthworms burrow through rich organic soils. As you observe these animals, note features that are adaptations to the burrowing, terrestrial lifestyle.

Identify the anterior end of the worm by locating the **mouth**. The mouth is overhung by a fleshy dorsal protuberance called the prostomium. The **anus** at the posterior end lacks this protuberance. A swollen glandular band, the clitellum, is located closer to the mouth than to the anus and also can be used to identify the anterior end.

Note the segmented appearance of the earthworm. The posterior segments of the earthworm have four pairs of **setae**. Rub your fingers along the outer surface of the worm to feel the setae. What function might the setae have? Think of how the earthworm moves.

2. Your lab instructor will show you how to anesthetize your earthworm. Afterward, place your worm on a dissecting tray and pin the head and anus. Carefully cut open the body wall moving from the head to the anus. As you cut, pin back the body wall to expose the internal organs. Examine the dissected earthworm and compare to Fig. 7.86-91.

Locate the digestive tract and its many specialized regions: the **pharynx**, **esophagus**, **crop**, **gizzard**, and **intestine**.

Using the dissecting microscope, locate the **longitudinal** and **circular muscle** layers that line the body cavity. What advantage will these two muscle layers provide for locomotion?

Look for the **large blood vessel** on the dorsal wall of the digestive tract. You may be able to see the five pairs of enlarged lateral blood vessels (**hearts**) around the anterior portion of the digestive tract. These lateral vessels connect the dorsal vessel to another large ventral vessel and also pump blood through the circulatory system.

A pair of small, white coiled tubes called **metanephridia** are located in body cavity of each segment of the worm's body. These organs remove wastes from the blood and from fluid within the body cavity. Look for the small **brain** just behind the prostomium on the surface of the digestive tract. Locate the two nerves that pass from the brain around the pharynx. These nerve tracts fuse ventrally and continue posteriorly as a **ventral nerve cord** with segmented ganglia.

3. Using a microscope, observe a prepared slide of a cross-section of an earthworm (Fig. 9.72).

Locate the thin **cuticle** lying outside the epidermis. Speculate about its function in a terrestrial habitat. Locate the **ventral nerve cord**, usually lying embedded in muscle.

4. Fill in the characteristics of the earthworm in Table 1.

Phylum Arthropoda: Insects, Crustaceans, Spiders, Ticks, and Mites:

Arthropods are segmented coelomates with *jointed appendages* and a rigid *exoskeleton* comprised of *chitin*. Arthropods are the largest group of invertebrates, as well as the most diverse group of organisms on Earth with over 1 million described species: 2 out of every 3 described species on the planet is an arthropod. Arthropods are found in almost every type of environment. They show a greater degree of complexity than most other invertebrates, including highly developed sensory and nervous systems, a hard chitinous exoskeleton, and specialization of groups of body segments and their associated appendages into multiple functions. This process is known as *tagmatization*. In addition, arthropods are the only invertebrates to have evolved flight, which is one of the adaptations that has allowed the insects to become the most speciose group of animals. Arthropods also show some of most extensive cephalization of all the invertebrates. The arthropods share many features of their annelid ancestors, including segmentation. As you will see, arthropods have expanded on the segmented body plan, evolving many specialized appendages. *What characteristic separates this phylum from the segmented worms, such as the earthworm?*

CRAYFISH DISSECTION (pp. 166-168 of your photo atlas):

Examine the body plan of the crayfish including symmetry, segmentation, and arrangement of appendages. As for the grasshopper, the body of the crayfish can be divided into three main regions: the **head**, the **thorax** (which is fused with the head --cephalothorax) and the **abdomen**. The head is distinguishable by its two pairs of antennae, a pair of eyes, and the hard mandibles that are used for eating. Four long pairs of **walking legs** are present on the thorax. The abdomen is equipped with 5 pairs of small **swimmerets**, and ends in a long jointed tail or uropod.

1. Note the tough outer cuticle of the crayfish. It is constructed from protein and the polysaccharide **chitin**. Locate the large exoskeletal plate or carapace that covers the thorax. What is the function of the tough outer cuticle of these organisms?

2. Using a pair of scissors on a preserved specimen, cut away a portion of the carapace on the left side of the animal. Locate the feathery **gills** that lie just beneath the carapace. What is the function of these structures in the crayfish?

3. Again, using your scissors, remove the dorsal portion of the carapace to expose other organs of the head and thorax. Starting at the posterior lateral edge of the carapace, make two lateral cuts extending along each side of the thorax and forward over the head. The cuts should meet just behind the eyes, creating a dorsal flap in the carapace. Carefully lift the flap by inserting a needle under it and separating the underlying tissues as you lift.

4. Locate the **heart**. It is a small, angular structure located just under the carapace near the posterior portion of the thorax. If you do not see it, it may have been removed with the carapace. Thin, threadlike arteries that distribute blood around the body lead out of the heart. No veins are present. Instead blood collects in sinuses around the heart. Small holes (ostia) in the heart open to allow the

blood to seep back into the heart. Try to locate these holes. What is the name of this kind of circulation?

5. Locate the large, saclike **stomach** in the head region. If it is not immediately obvious, it may be hidden by the large, creamy colored **digestive gland** that fills much of the body. Leading posteriorly from the stomach is the **intestine**. Follow the path of the intestine to the **anus** by making a longitudinal cut through the exoskeleton on each side of the dorsal midline of the abdomen. Lift and remove the exoskeleton to view the intestine.

6. Turning your attention back to the anterior region of the digestive tract, pull the stomach posteriorly. This will tear the esophagus and allow you to look inside the most anterior portion of the head. Two compact **green glands** (cream or orangy color) are located in this region. These are actually long tubular structures that resemble nephridia, but are compacted into a glandular mass. Waste materials and excess water pass from these glands to the outside of the body through pores at the base of antennae.

7. Locate the **brain** (or ganglion) just dorsal and anterior to the green glands. It lies in the midline and nerves extend posteriorly from it, fusing to form the ventral nerve cord.

8. Fill in the characteristics of the flatworm in Table 1.

APPLYING YOUR KNOWLEDGE

1. One of the major differences between cnidaria and the various worms examined in this exercise is radial versus bilateral symmetry. What is the advantage of radial symmetry for sessile (attached) animals and bilateral symmetry for mobile animals? What major evolutionary trend accompanies bilateral symmetry?

2. What is the adaptive significance of an animal having two separate openings to the digestive tract, as seen in annelids and arthropods?

3. What anatomical features are adaptations to a parasitic lifestyle? Which are adaptations to an aquatic lifestyle? To a terrestrial lifestyle?

4. A major new feature observed in the phyla Annelida and Arthropoda is a segmented body. Speculate about the advantages provided by segmentation.

Table 1. Summary of 12 characteristics for comparative study of Kingdom Animalia

Organism	Symmetry	Tissue Organization (No. of layers)	Digestive Openings	Circulatory System	Habitat	Locomotion
Sponge						
Hydra						
Flatworm						
Earthworm						
Crayfish						

Organism	Excretory System	Respiratory System	Support System	Segmentation	Nervous System Organization	Appendages
Sponge						
Hydra						
Flatworm						
Earthworm						
Crayfish						

