LAB TOPIC 18

Animal Diversity I: Porifera, Cnidaria, Platyhelminthes, Mollusca, and Annelida

Laboratory Objectives

After completing this lab topic, you should be able to:

1. Discuss characteristics of representative animals and phylogenetic relationships of selected phyla in the kingdom Animalia.
2. Compare the anatomy of the chosen animals, describing similarities and differences in organs and body form that allow each animal to carry out body functions.
3. Discuss the relationship between body form and the lifestyle or niche of the organism.

Introduction

Animals are classified in the domain **Eukarya,** kingdom **Animalia** (clade **Metazoa**). They are **multicellular** organisms and are **heterotrophic,** meaning that they obtain food by ingesting other organisms or their by-products. Careful study of comparative anatomy, embryology, and, most recently, genetic and molecular data reveals many similarities in structure and development. Collectively, this evidence implies an ancestral evolutionary relationship among all animals. The ancestor of all animals is thought to have lived somewhere between 675 and 800 million years ago, but most animal fossils range in age from 565 to 550 million years old, with most body forms appearing by the end of the Cambrian period (see Figure 14.3). In this and the following lab topic, you will investigate body form and function in examples of nine major groups of animals. You will use these investigations to ask and answer questions comparing general features of morphology and relating these features to the lifestyle of each animal.

Since the beginning of the scientific study of animals, scientists have attempted to sort and group closely related organisms, and categories used in classification schemes have changed over time. Based on the latest molecular evidence, current phylogenetic trees divide the metazoa into two major clades: the sponges in the phylum **Porifera,** and **Eumetazoa,** the clade that includes all other animals. This division is made because the body form of sponges is very different from that of other animals, leading most biologists to conclude that sponges are not closely related to any other animal groups.

Animals in Eumetazoa differ in basic physical characteristics, such as symmetry and body form. Animals may be **radially symmetrical** (parts arranged around a central axis) or **bilaterally symmetrical** (right and left halves are mirror images). Some animals have a saclike body form with only one opening into a digestive cavity. Others have two outer openings, a mouth, and an anus, and the digestive tract forms essentially a "tube within a tube." Differences in early developmental patterns have led to other important criteria for animal classification. You will learn more about animal development in Lab Topic 25. It will be helpful to read the "Overview of Stages of Early Development" in that lab topic before proceeding with this study of animal characteristics. Some differences in animal groups are based on the number of embryonic germ layers (layers of tissue that form early in development from which all the other tissues in the body arise). Most animals have three germ layers, ectoderm, mesoderm, and endoderm. Animals may also differ in the type of body cavity (coelom) that forms in the embryo, and the embryonic development of the digestive tract. The origin of the mouth and anus has led scientists to describe two developmental modes in bilaterally symmetrical animals, **protostome development** and **deuterostome development.** These two types of development differ in several basic characteristics, including the type of cleavage (early divisions of a fertilized egg), the manner of coelom formation, and the origin of the mouth and anus. An embryonic structure, the blastopore, develops into a mouth in the protostomes and into an anus in the deuterostomes.

In the study of the protists in Lab Topic 13, you learned that "traditional" phylogenetic trees have been challenged by the results of molecular studies, for example, evidence from analysis of DNA sequences of the gene coding for ribosomal RNA (rRNA). This is true not only for protists, but also for animals. Particularly in the protostomes, molecular studies have led to a regrouping of many traditionally established phylogenetic relationships. For example, for over 200 years zoology publications have assumed that annelids (segmented worms in the phylum Annelida) and arthropods (e.g., insects) are closely related based on their segmented bodies. Zoologists also noted, however, that annelids have developmental patterns similar to several groups that are not segmented. For example, annelids are like molluscs (e.g., clams) in having a developmental stage called the "trochophore larva." Recent molecular evidence helps to clarify this puzzle as it supports the hypothesis that annelids and molluscs are closely related, and separate from arthropods.

Molecular studies have led taxonomists to separate animals in Eumetazoa into two groups: those with radial symmetry and those with bilateral symmetry (clade **Bilateria**), and most phyla of animals are classified in one of the three clades of bilateral animals—**Deuterostomia, Lophotrochozoa,** and **Ecdysozoa.** Annelids (phylum Annelida), molluscs (phylum Mollusca), and several more phyla not studied in this lab topic are placed in the clade Lophotrochozoa. The name reflects the trochophore larvae found in annelids and molluscs. Also included in this clade are flatworms (phylum Platyhelminthes). Although flatworms lack such characteristics as a body cavity, the "tube-within-a-tube" body plan with mouth and anus, and elaborate internal organs that characterize the annelids and molluscs, recent molecular evidence indicates that they should be grouped with annelids and molluscs in the Lophotrochozoa clade. Evidence from ribosomal DNA sequences indicates that roundworms or nematodes (phylum Nematoda), arthropods (phylum Arthropoda), and several other phyla belong in the clade Ecdysozoa. Animals in this clade undergo molting (ecdysis), or the shedding of an outer body cover. In nematodes this covering is called the **cuticle.** In arthropods the covering is the **exoskeleton.**

Another surprising result of rRNA and other molecular evidence is that the nature of the body cavity may not be a characteristic that indicates major phylogenetic branching. A true coelom or pseudocoelom may have been independently gained or lost many times in evolutionary history. In traditional phylogenetic groupings, flatworms and nematodes were considered primitive, neither group having a "true" coelom. Ribosomal evidence has now moved nematodes to a different position with arthropods in the metazoan tree.

Figure 18.1 is a tree diagram representing the phylogeny of animal phyla based on the most recent molecular evidence. This phylogenetic tree represents a hierarchy of clades nested within larger clades. Much work remains to resolve the branching order within the lophotrochozoan and ecdysozoan clades. Scientists are collecting evidence from studies based on mitochondrial DNA sequencing, ribosomal genes, *Hox* genes, and genes coding for various proteins.

In addition to phylogenetic relationships among groups of organisms, there are two more unifying themes to be considered as you study the animals reviewed in lab topics 18 and 19. One theme is the relationship between *form and function*—how does the form (anatomy) of a structure relate to its function? A second theme is the relationship between *form and environment*—how does the form of a structure enable an organism to survive in its environment? The questions at the end of the lab topics will assist with this.

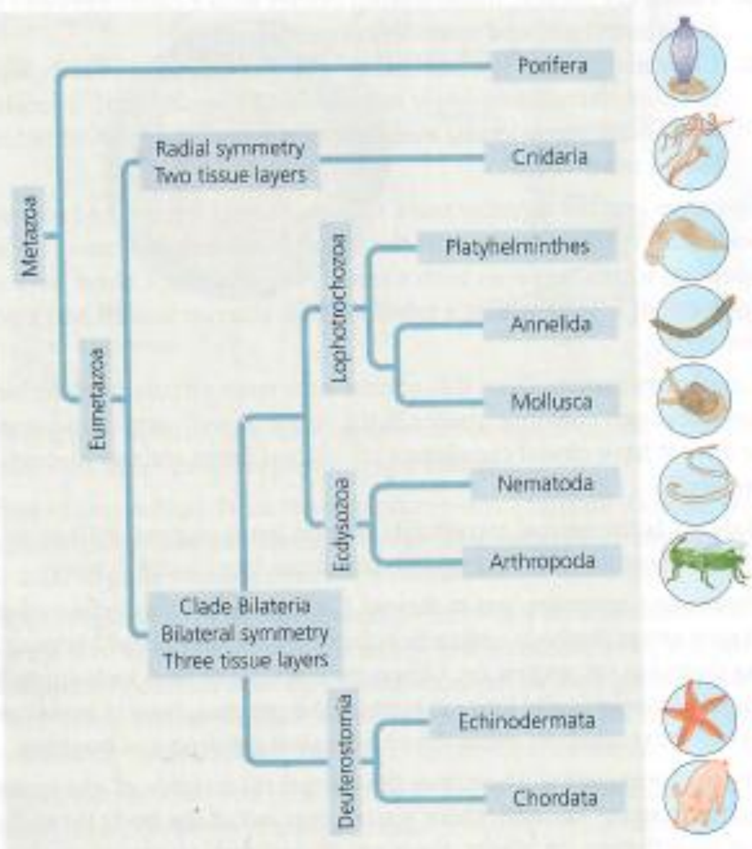

FIGURE 18.1
Phylogenetic organization of animals studied in this lab topic and Lab Topic 19 based on new molecular evidence. Animals with protostome development are assigned to one of two clades, Lophotrochozoa or Ecdysozoa.

The animals you will study in this lab topic are the sponge, the radially symmetrical hydra, and four examples of animals in the clade Lophotrochozoa: planaria, clamworm, earthworm, and clam (mussel). In Lab Topic 19 you will study three examples of Ecdysozoa (roundworm, crayfish, and grasshopper) and three examples of Deuterostomia (sea star, lancelet, and pig). All of the animals studied in these lab topics except the pig are **invertebrates,** animals that do not have a vertebral column (backbone). Only the pig is a **vertebrate** (has a backbone).

In your comparative study of these organisms, you will investigate 13 characteristics and you will be asked to describe these characteristics for each animal.

Before you begin the dissections, become familiar with the following characteristics and their descriptions:

1. *Symmetry.* Is the animal (a) radially symmetrical (parts arranged around a central axis), (b) bilaterally symmetrical (right and left halves are mirror images), or (c) asymmetrical (no apparent symmetry)?
2. *Tissue organization.* Are cells organized into well-defined tissue layers (structural and functional units)? How many distinctive layers are present?
3. *Body cavity.* Is a body cavity present? A body cavity—the space between the gut and body wall—is present only in three-layered organisms, that is, in organisms with the embryonic germ layers ectoderm, mesoderm, and endoderm. There are three types of body forms related to the presence of a body cavity and its type (Figure 18.2).
   a. Acoelomate, three-layered bodies without a body cavity. Tissue from the mesoderm fills the space where a cavity might be; therefore, the tissue layers closely pack on one another.
   b. Pseudocoelomate, three-layered bodies with a cavity between the endoderm (gut) and mesoderm (muscle).
   c. Coelomate, three-layered bodies with the coelom, or cavity, *within* the mesoderm (completely surrounded by mesoderm). In coelomate organisms, mesodermal membranes suspend the gut within the body cavity.
4. *Openings into the digestive tract.* Can you detect where food enters the body and digestive waste exits the body? Some animals have only one opening, which serves as both a mouth and an anus. Others have a body called a "tube within a tube," with an anterior mouth and a posterior anus.
5. *Circulatory system.* Does this animal have open circulation (the blood flows through coelomic spaces in the tissue as well as in blood vessels), or does it have closed circulation (the blood flows entirely through vessels)?
6. *Habitat.* Is the animal terrestrial (lives on land) or aquatic (lives in water)? Aquatic animals may live in marine (sea) or fresh water.
7. *Organs for respiration (gas exchange).* Can you detect the surface where oxygen enters the body and carbon dioxide leaves the body? Many animals use their skin for respiration. Others have special organs, including gills in aquatic organisms and lungs in terrestrial organisms. Insects have a unique system for respiration, using structures called *spiracles* and *tracheae.*
8. *Organs for excretion.* How does the animal rid its body of nitrogenous waste? In many animals, these wastes pass out of the body through the skin by diffusion. In others, there are specialized structures, such as

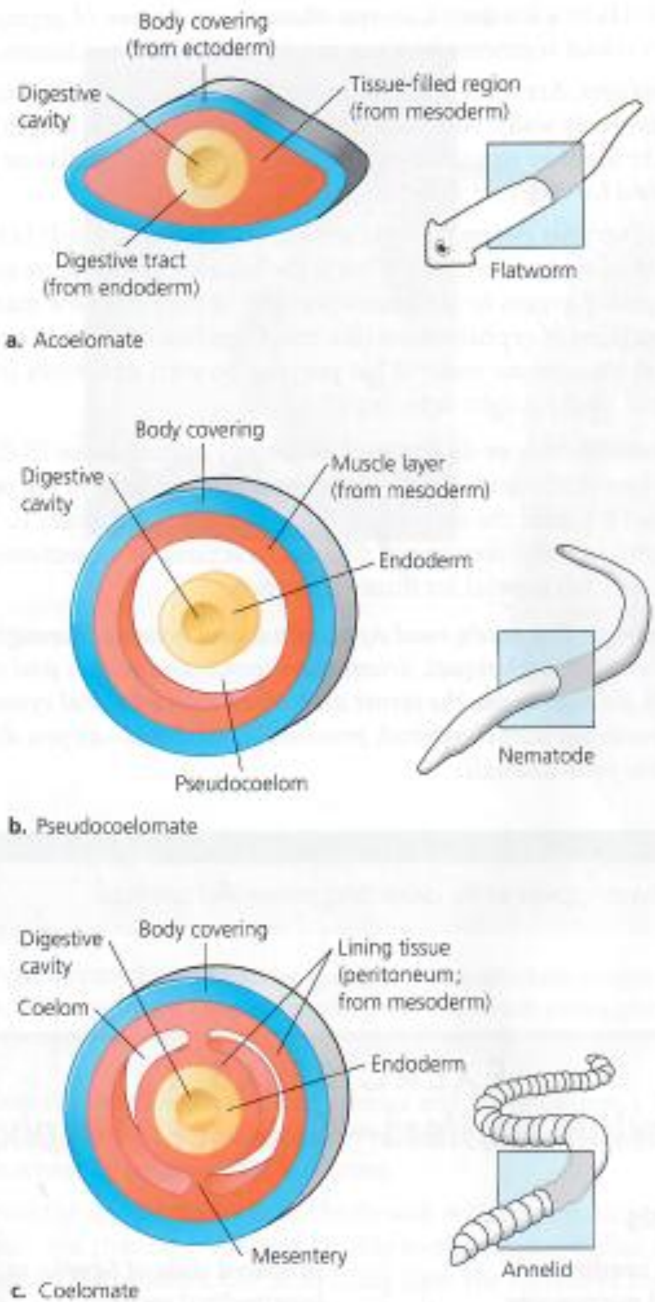

FIGURE 18.2

Three types of body cavities.

(a) In acoelomate animals, there is no body cavity and mesoderm fills the space where a cavity might be. (b) In pseudocoelomate animals, the body cavity lies between tissues derived from endoderm and mesoderm. (c) In coelomate animals, the body cavity is lined with mesoderm.

Malpighian tubules, lateral excretory canals, lateral canals with flame cells, structures called *nephridia,* and kidneys.

9. *Type of locomotion.* Does the organism swim, crawl on its belly, walk on legs, burrow in the substrate, or fly? Does it use cellular structures, such as cilia, to glide its body over the substrate?
10. *Support systems.* Is there a skeleton present? Is it an endoskeleton (inside the epidermis or skin of the animal), or is it an exoskeleton (outside the body wall)? Animals with no true skeleton can be supported by water: Fluid within and between cells and in body chambers such as a gastrovascular cavity or coelom provides a "hydrostatic skeleton."
11. *Segmentation.* Can you observe linear repetition of similar body parts? The repetition of similar units, or segments, is called *segmentation.* Segments can be more similar (as in the earthworm) or less

similar (as in a lobster). Can you observe any degree of segmentation? Have various segments become modified for different functions?

12. *Appendages.* Are there appendages (organs or parts attached to a trunk or outer body wall)? Are these appendages all along the length of the body, or are they restricted to one area? Are they all similar, or are they modified for different functions?
13. *Type of nervous system.* Do you see a brain and nerve cord? Is there more than one nerve cord? What is the location of the nerve cord(s)? Are sensory organs or structures present? Where and how many? Do you see signs of cephalization (the concentration of sensory equipment at the anterior end)? What purpose do such structures serve (for example, eyes for light detection)?

As you carefully study or dissect each organism, refer to these 13 characteristics, observe the animal, and record your observations in the summary table, Table 19.1, near the end of Lab Topic 19 Animal Diversity II. You may find it helpful to make sketches of difficult structures or dissections in the margin of your lab manual for future reference.

Before you begin this study, read Appendix E and become thoroughly familiar with dissection techniques, orientation terms, and planes and sections of the body. Be able to use the terms associated with bilateral symmetry—anterior, posterior, dorsal, ventral, proximal, and distal—as you dissect and describe your animals.

Wear gloves while dissecting preserved animals.

EXERCISE 18.1
Phylum Porifera—Sponges (*Scypha*)

Materials

dissecting needle
compound microscope
stereoscopic microscope
preserved and dry bath sponges
prepared slide of *Scypha* in longitudinal section
preserved *Scypha* in watch glass

Introduction

Within the animal kingdom, sponges are separated from all other animals because of their unique body form. You will observe the unique sponge structure by observing first a preserved specimen and then a prepared slide of a section taken through the longitudinal axis of the marine sponge *Scypha* (Figure 18.3). You will observe other more complex and diverse sponges on demonstration.

Procedure

1. Obtain the preserved sponge *Scypha* and observe its external characteristics using the stereoscopic microscope, comparing your observations with Figure 18.3a.

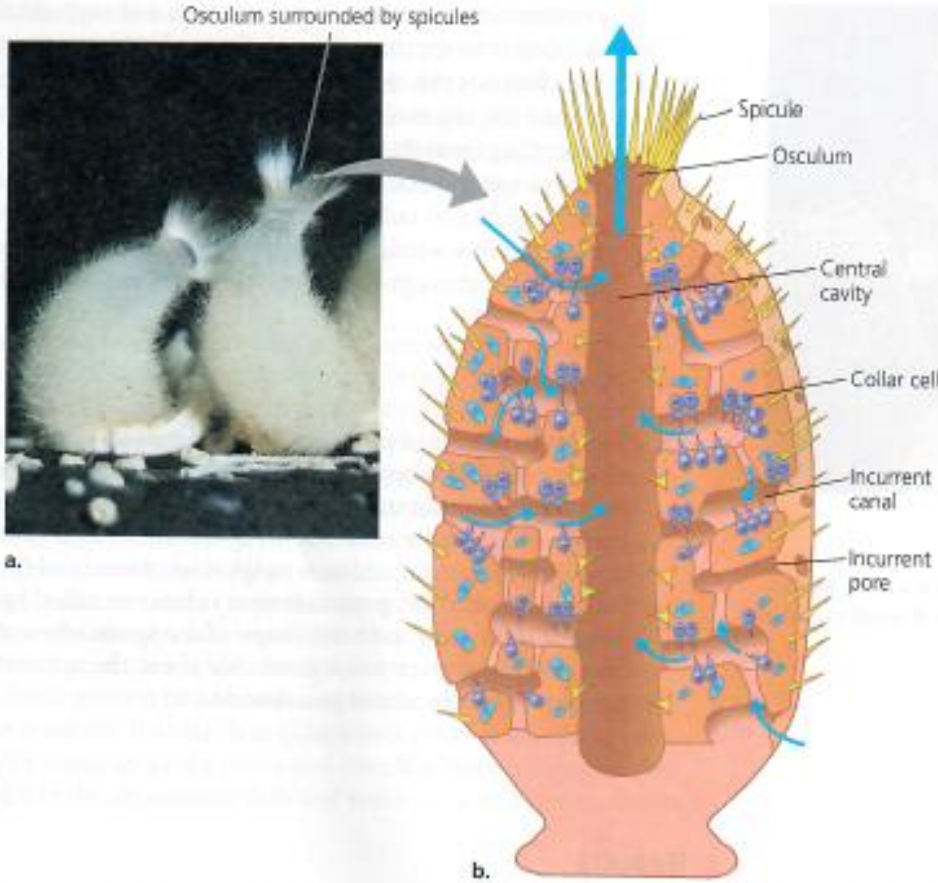

FIGURE 18.3

The sponge *Scypha*. (a) The entire sponge; (b) a longitudinal section through the sponge. Water passing through incurrent pores and canals passes into a central cavity, the spongocoel.

   a. Note the vaselike shape of the sponge and the **osculum,** a large opening to the body at one end. The end opposite the osculum attaches the animal to the substrate.
   b. Note the invaginations in the body wall, which form numerous folds and channels. You may be able to observe needlelike **spicules** around the osculum and protruding from the surface of the body. These spicules are made of calcium carbonate; they give support and protection to the sponge body and prevent small animals from entering the sponge's internal cavity.

2. Using the compound microscope, examine a prepared slide of a sponge body in longitudinal section and compare it with Figure 18.3b.
   a. Again, locate the osculum. This structure is not a mouth, as its name implies, but an opening used as an outlet for the current of water passing through the body wall and the **central cavity,** or **spongocoel.** The water enters the central cavity from channels and pores in the body. The central cavity is not a digestive tube or body cavity, but is only a channel for water.
   b. Note the structure of the body wall. Are cells organized into definite tissue layers (well-defined structural and functional units), or are they best described as a loose organization of various cell types? Various cells in the body wall carry out the functions of digestion,

FIGURE 18.4
Bath sponges have a body form consisting of large and small canals and chambers.

contractility, secretion of the spicules, and reproduction (some cells develop into sperm and eggs). One cell type unique to sponges is the **choanocyte,** or **collar cell.** These cells line the central cavity and the channels leading into it. Each collar cell has a flagellum extending from its surface. The collective beating of all flagella moves water through the sponge body. Small food particles taken up and digested by collar cells are one major source of nutrition for the sponge. How would you hypothesize about the movement of oxygen and waste throughout the sponge body and into and out of cells?

3. Observe examples of more complex sponges on demonstration and in Figure 18.4. The body of these sponges, sometimes called "bath sponges," contains a complex series of large and small canals and chambers. The same cells that were described in *Scypha* are present in bath sponges, but, in addition to spicules, there is supportive material that consists of a soft proteinaceous substance called **spongin.** These sponges often grow to fit the shape of the space where they live, and observing them gives you a good clue about the symmetry of the sponge body. How would you describe it?

Results

Complete the summary table, Table 19.1, near the end of Lab Topic 19, filling in all information for sponge characteristics in the appropriate row. This information will be used to answer questions in the Applying Your Knowledge section at the end of Lab Topic 19 Animal Diversity II.

EXERCISE 18.2
Phylum Cnidaria—Hydras (*Hydra*)

Materials

stereoscopic microscope
compound microscope
living *Hydra* culture
water flea culture
dropper bottles of water, 1% acetic acid, and methylene blue
prepared slide of *Hydra* sections
watch glass
depression slide
pipettes and bulbs
microscope slide and coverslip

Introduction

Cnidarians are a diverse group of organisms, all of which have a **tissue grade** of organization, meaning that tissues, but no complex organs, are present. Included in this group are corals, jellies, sea anemones, and Portuguese men-of-war. Most species are marine; however, there are a few freshwater species. Two body forms are present in the life cycles of many of these animals—an umbrella-like, free-swimming stage called a **medusa,** and a cylindrical, attached or stationary form called a **polyp.** The polyp forms often grow into colonies of individuals. Life cycles of most cnidarians include both polyp and medusa stages, but some species exist only as polyps or medusae. In this exercise you will observe some of the unique features of this group by observing the solitary freshwater organism *Hydra* (Figure 18.5).

Procedure

1. Place several drops of freshwater pond or culture water in a watch glass or depression slide. Use a dropper to obtain a living hydra from the class culture, and place the hydra in the drop of water. Hydra usually exist as single polyps that reproduce by budding, so occasionally you might see a smaller polyp growing from the side of a larger polyp. Using a stereoscopic microscope, observe the hydra structure and compare it with Figure 18.5a. Note any movement, the symmetry, and any body structures present. Note the **tentacles** that surround the "mouth," the only opening into the central cavity. Tentacles are used in capturing food and in performing a certain type of locomotion, much like a "handspring." To accomplish this motion, the hydra attaches its tentacles to the substrate and flips the basal portion of its body completely over, reattaching the base to a new position. If water fleas (*Daphnia*) are available, place one or two near the tentacles of the hydra and note the hydra's behavior. Set aside the hydra in the depression slide and return to it in a few moments.

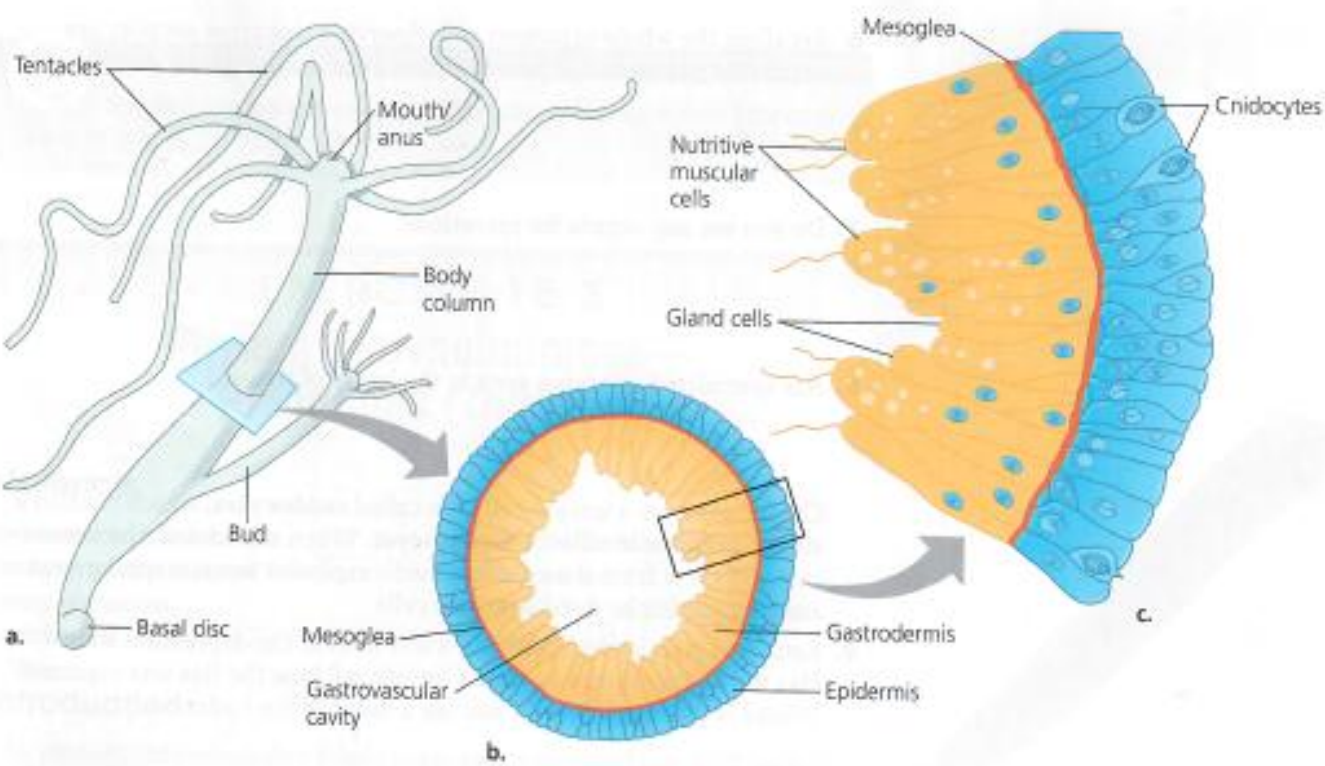

FIGURE 18.5

Hydra. (a) *Hydra* growing a new individual (a bud); (b) enlargement showing a cross section through the body wall, revealing two tissue layers; and (c) further enlargement showing details of specialized cells in the body wall, including cnidocytes.

2. Study a prepared slide of *Hydra* sections using the compound microscope and compare your observations with Figure 18.5b and 18.5c.

   Are definite tissue layers present? If so, how many?

   Given what you know of embryology, what embryonic layers would you guess give rise to the tissue layers of this animal's body?

3. Not visible with the microscope is a network of nerve cells in the body wall, which serves as the nervous system. There is no concentration of nerve cells into any kind of brain or nerve cord.
4. Observe the central cavity, called a **gastrovascular cavity.** Digestion begins in this water-filled cavity (**extracellular digestion**), but many food particles are drawn into cells in the **gastrodermis** lining the cavity, where **intracellular digestion** occurs.
5. Do you see signs of a skeleton or supportive system? How do you think the body is supported? Are appendages present?

6. Recalling the whole organism and observing this cross section, are organs for gas exchange present? How is gas exchange accomplished?

7. Do you see any organs for excretion?

8. Are specialized cell types seen in the layers of tissues?

   Cnidarians have a unique cell type called **cnidocytes,** which contain a stinging organelle called a **nematocyst.** When stimulated, the nematocyst will evert from the cnidocyte with explosive force, trapping food or stinging predators. Look for these cells.

9. Return to your living hydra and water fleas in the depression slide. Has the hydra captured a flea? Can you tell how the flea was captured? Where is the flea now—do you see a bulge in the hydra body?

10. To better observe cnidocytes and nematocysts in your living hydra, follow this procedure:

    a. Using a pipette, transfer the hydra to a drop of water on a microscope slide and carefully add a coverslip.

b. Use your microscope to examine the hydra, first on low, then intermediate, and finally on high powers, focusing primarily on the tentacles. The cnidocytes will appear as swellings. If your microscope is equipped with phase contrast, switch to phase. Alternatively, add a drop of methylene blue to the edge of the coverslip. Locate several cnidocytes with nematocysts coiled inside.

c. Add a drop of 1% acetic acid to the edge of the coverslip and, watching carefully using intermediate power, observe the rapid discharge of the nematocyst from the cnidocyte.

d. Using high power, study the discharged nematocysts that will appear as long threads, often with large spines, or barbs, at the base of the thread.

Results

Complete the summary table, Table 19.1, recording all information for *Hydra* characteristics in the appropriate row. You will use this information to complete Table 19.2 and to answer questions in the Applying Your Knowledge section at the end of Lab Topic 19 Animal Diversity II.

Discussion

What major differences have you detected between *Scypha* and *Hydra* body forms? List and describe them.

MB Student Media Videos—Ch. 33: *Hydra* Building; *Hydra* Eating *Daphnia*; Jelly Swimming; Thimble Jellies

EXERCISE 18.3
Phylum Platyhelminthes—Planarians (*Dugesia*)

Materials

stereoscopic microscope
compound microscope
living planarian
watch glass
prepared slide of whole mount of planarian
prepared slide of planarian cross sections

Introduction

The phylum Platyhelminthes (clade Lophotrochozoa) includes both parasitic and free-living flatworms with thin bodies that are *dorsoventrally* flattened. Tapeworms and flukes are well-known parasites of humans and other animals. In this exercise you will investigate an example of a free-living flatworm, a planarian, *Dugesia*. They are found under rocks, leaves, and debris in freshwater ponds and creeks. They move over these surfaces using a combination of muscles in the body wall and cilia on their ventral sides (Figure 18.6).

FIGURE 18.6
Dugesia, a freshwater planarian with two pigmented eyespots between the two auricles on its anterior end.

Procedure

1. Add a dropperful of pond or culture water to a watch glass. Use a dropper to obtain a living planarian from the class culture. Using your stereoscopic microscope, observe the planarian. Describe its locomotion. Is it directional? What is the position of its head? Does its body appear to contract?

   As you observe the living planarian, you will see two striking new features with regard to symmetry that you did not see in the two phyla previously studied. What are they?

2. Add a *small* piece of fresh liver to the water near the planarian. The planarian may approach the liver and begin to feed by extending a long tubular **pharynx** out of the **mouth,** a circular opening on the ventral side of the body. If the planarian feeds, it will curve its body over the liver and extend the pharynx, which may be visible in the stereoscopic microscope.

   After observing the planarian's feeding behavior, return it to the culture dish, if possible without the liver.

3. Using the lowest power on the compound microscope, observe the prepared slide of a whole planarian and compare it with Figure 18.7.

> Do not observe these slides using high power! The high power objective may crack the coverslip, resulting in damage to the lens.

   Examine the body for possible digestive tract openings. How many openings to the digestive tract are present?

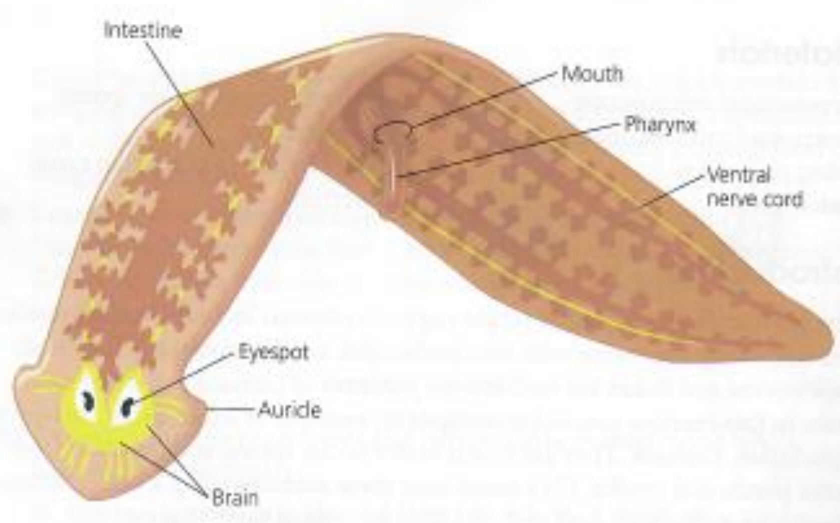

FIGURE 18.7

A planarian. The digestive system consists of a mouth, a pharynx, and a branched intestine. A brain and two ventral nerve cords (plus transverse nerves connecting them, not shown) make up the nervous system.

Observe again the pharynx and the mouth. The pharynx lies in a **pharyngeal chamber** inside the mouth. The proximal end of the pharynx opens into a dark-colored, branched intestine. If the intestine has been stained on your slide, you will see the branching more easily.

4. Continue your study of the whole planarian. The anterior blunt end of the animal is the head end. At each side of the head is a projecting **auricle.** It contains a variety of sensory cells, chiefly of touch and chemical sense. Between the two auricles on the dorsal surface are two pigmented **eyespots.** These are pigment cups into which retinal cells extend from the brain, with the photosensitive end of the cells inside the cup. Eyespots are sensitive to light intensities and the direction of a light source but can form no images. Beneath the eyespots are two cerebral ganglia that serve as the **brain.** Two ventral nerve cords extend posteriorly from the brain. These are connected by transverse nerves to form a ladderlike **nervous system.**
5. Study the prepared slide of cross sections of a planarian. You will have several sections on one slide. One section should have been taken at the level of the pharynx and pharyngeal chamber. Do you see a body cavity in any of the sections? (The pharyngeal chamber and spaces in the gut are not a body cavity.) What word describes this body cavity condition (see Figure 18.2a)?

   a. How many tissue layers can be detected? Speculate about their embryonic origin.

   Flatworms are the first group of animals to have three well-defined embryonic tissue layers, enabling them to have a variety of tissues and organs. Reproductive organs and simple excretory organs consisting of two lateral excretory canals and "flame cells" that move fluid through the canals are derived from the embryonic mesoderm. Respiratory, circulatory, and skeletal systems are lacking.

   b. How do you think the body is supported?

   c. How does gas exchange take place?

Results

1. In the space on the following page, diagram the flatworm as seen in a cross section at the level of the pharynx. Label the **epidermis, muscle** derived from **mesoderm,** the lining of the digestive tract derived from **endoderm,** the **pharynx,** and the **pharyngeal chamber.**

2. Complete the summary table, Table 19.1, recording all information for planarian characteristics in the appropriate row. You will use this information to complete Table 19.2 and answer questions in the Applying Your Knowledge section at the end of Lab Topic 19 Animal Diversity II.

Discussion

One of the major differences between Cnidaria and Platyhelminthes is radial versus bilateral symmetry. Discuss the advantage of radial symmetry for sessile (attached) animals and bilateral symmetry for motile animals.

EXERCISE 18.4
Phylum Mollusca—Clams

Materials

dissecting instruments
dissecting pan
preserved clam or mussel
disposable gloves

Introduction

Second only to the phylum Arthropoda in numbers of species, the phylum Mollusca (clade Lophotrochozoa) includes thousands of species living in many diverse habitats. Most species are marine. Others live in fresh water or on land. Many molluscs are of economic importance, being favorite human foods. Molluscs include such diverse animals as snails, slugs, clams, squids, and octopuses. Although appearing diverse, most of these animals share four characteristic features: (1) a hard external **shell** for protection; (2) a thin structure called the **mantle,** which secretes the shell; (3) a **visceral mass** in which most organs are located; and (4) a muscular **foot** used for locomotion.

In this exercise, you will dissect a clam, a molluscan species in the clade Bivalvia with a shell made of two parts called **valves.** Most clams are marine, although many genera live in freshwater lakes and ponds. You may have eaten molluscs, including clams, oysters, and scallops, which are all bivalves.

Wear gloves while dissecting preserved animals.

Procedure

1. Observe the external anatomy of the preserved clam. Certain characteristics will become obvious immediately. Can you determine symmetry, support systems, and the presence or absence of appendages? Are there external signs of segmentation? Record observations in Table 19.1.
2. Before you continue making observations, determine the dorsal, ventral, anterior, posterior, right, and left regions of the animal. Identify the two valves. The valves are held together by a **hinge** near the **umbo,** a hump on the valves. The hinge and the umbo are located **dorsally,** and the valves open **ventrally.** The umbo is displaced **anteriorly.** Hold the clam vertically with the umbo away from your body, and cup one of your hands over each valve. The valve in your right hand is the right valve; the valve in your left hand is the left valve. The two valves are held together by two strong **adductor** muscles inside the shell. Compare your observations with Figure 18.8.

Be cautious as you open the clam! Hold the clam in the dissecting pan in such a way that the scalpel will be directed toward the bottom of the pan.

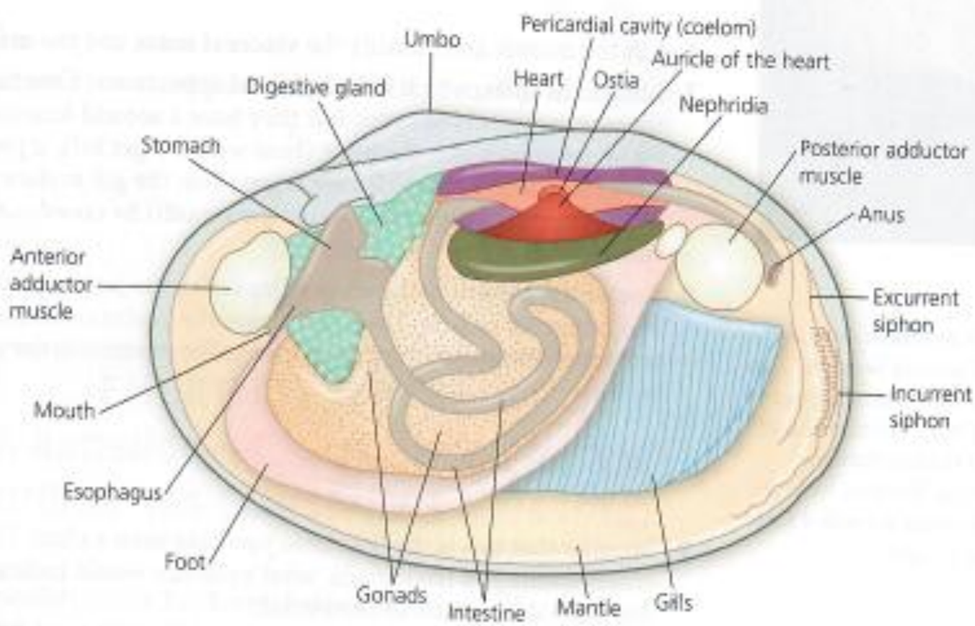

FIGURE 18.8

Anatomy of a clam. The soft body parts are protected by the shell valves. Two adductor muscles hold the valves closed. Most major organs are located in the visceral mass. In this diagram, the left mantle, the left pair of gills, and half of the visceral mass have been removed.

3. To study the internal anatomy of the clam, you must open it by prying open the valves. (A wooden peg may have been inserted between the two valves.) Insert the handle of your forceps or scalpel between the valves and twist it to pry the valves farther open. Place your clam in the dissecting pan with the clam's dorsal side supported on the pan bottom. This will allow you to make your cuts with the scalpel blade directed toward the pan bottom and not your hand. Carefully insert a scalpel blade, directed toward the dorsal side of the animal, into the space between the left valve and a flap of tissue lining the valve. The blade edge should be just ventral to (that is, below) the anterior adductor muscle (see Figure 18.8). The flap of tissue is the left **mantle.** Keeping the scalpel blade pressed flat against the left valve, carefully loosen the mantle from the valve and press the blade dorsally. You will feel the tough **anterior adductor muscle.** Cut through this muscle near the valve.
4. Repeat the procedure at the posterior end and cut the posterior adductor muscle. Lay the clam on its right valve and carefully lift the left valve. As you do this, use your scalpel to loosen the mantle from the valve. If you have been successful, you should have the body of the clam lying in the right valve. It should be covered by the mantle. Look for pearls between the mantle and the shell. How do you think pearls are formed?

FIGURE 18.9
Donax, a small bivalve often seen in the lower intertidal zone of beaches. Two tubular siphons are seen extending out of the shells. These siphons are more easily identified in *Donax* than in the clam that you are dissecting, but they have the same function. Notice the extended foot used for burrowing in sand.

5. Look at the posterior end of the animal where the left and right mantle come together. Hold the two mantle flaps together and note the two gaps formed. These gaps are called **incurrent** (ventral) and **excurrent** (dorsal) **siphons.** Speculate about the function of these siphons (see Figure 18.9).
6. Lift the mantle and identify the **visceral mass** and the **muscular foot.**
7. Locate the **gills,** which have a pleated appearance. One function of these structures is obvious, but they have a second function as well. As water comes into the body (how would it get in?), it passes through the gills, and food particles are trapped on the gill surface. The food is then moved anteriorly (toward the mouth) by coordinated ciliary movements.
8. Locate the **mouth** between two flaps of tissue just ventral to the anterior adductor muscle. Look just above the posterior adductor muscle and locate the **anus.** How is it oriented in relation to the excurrent siphon?
9. Imagine that this is the first time you have seen a clam. From the observations you have made, what evidence would indicate whether this animal is aquatic or terrestrial?

10. The **heart** of the clam is located in a sinus, or cavity, just inside the hinge, dorsal to the visceral mass (see Figure 18.8). This cavity, called the *pericardial cavity*, is a reduced **true coelom.** The single ventricle of the heart actually surrounds the **intestine** passing through this cavity. Thin auricles, usually torn away during the dissection, empty into the heart via openings called **ostia.** Blood passes from **sinuses** in the body into the auricles. What type of circulatory system is this?

11. Ventral to the heart and embedded in mantle tissue you will find a pair of greenish brown tissue masses, the **nephridia,** or kidneys. The kidneys remove waste from the pericardial cavity.
12. Open the visceral mass by making an incision with the scalpel, dividing the mass into right and left halves. Begin this incision just above the foot and cut dorsally. You should be able to open the flap produced by this cut and see organs such as the **gonads, digestive gland, intestine,** and **stomach.** Clam chowder is made by chopping up the visceral mass.
13. It is difficult to observe the nervous system in the clam. It consists of three ganglia, one near the mouth, one in the foot, and one below the posterior adductor muscle. These ganglia are connected by nerves.

    Now that you have dissected the clam, you should have concluded that there is no sign of true segmentation. Also, appendages (attached to a trunk or body wall) are absent.

Results

Complete the summary table, Table 19.1, recording all information for clam characteristics in the appropriate row. Use this information to complete Table 19.2 and to answer questions in the Applying Your Knowledge section at the end of Lab Topic 19 Animal Diversity II.

Discussion

List several features of clam anatomy that enable it to survive in a marine environment.

EXERCISE 18.5

Phylum Annelida—Clamworms (*Nereis*) and Earthworms (*Lumbricus terrestris*)

The phylum Annelida (clade Lophotrochozoa) includes a diverse group of organisms that have adapted to a variety of environments. Examples range in size from microscopic to several meters in length. Most species are marine, living free in the open ocean or burrowing in ocean bottoms. Others live in fresh water or in soils. Members of one group of annelids, the leeches, are parasitic and live on the blood or tissues of their hosts. The ability of annelids to inhabit such a wide range of environments is due in part to their segmented body design. In annelids, segmentation (the linear repetition of body segments) includes both external and internal structures of several systems. This is not true for two other phyla of animals that demonstrate segmentation, Arthropods and Chordates, studied in Lab Topic 19. In this exercise, you will study the clamworm, a marine annelid, and the earthworm, a terrestrial species. Keep in mind features that are adaptations to marine and terrestrial habitats as you study these organisms.

Lab Study A. Clamworms (*Nereis*)

Materials

dissecting tools
dissecting pan
preserved clamworm
disposable gloves
dissecting pins

Introduction

Species of *Nereis* (clamworms) are commonly found in mudflats and on the ocean floor. People who live near the ocean often use these worms for fishing bait much like earthworms are used inland. These animals burrow in sediments during the day and emerge to feed at night. As you observe the clamworm, note features that are characteristic of all annelids, as well as features that are special adaptations to the marine environment (Figure 18.10).

FIGURE 18.10
Nereis, a marine worm commonly found in mudflats and burrowing in the ocean floor.

Procedure

1. Observe the preserved, undissected clamworm and compare it with Figure 18.11. How would you describe the symmetry of this organism?

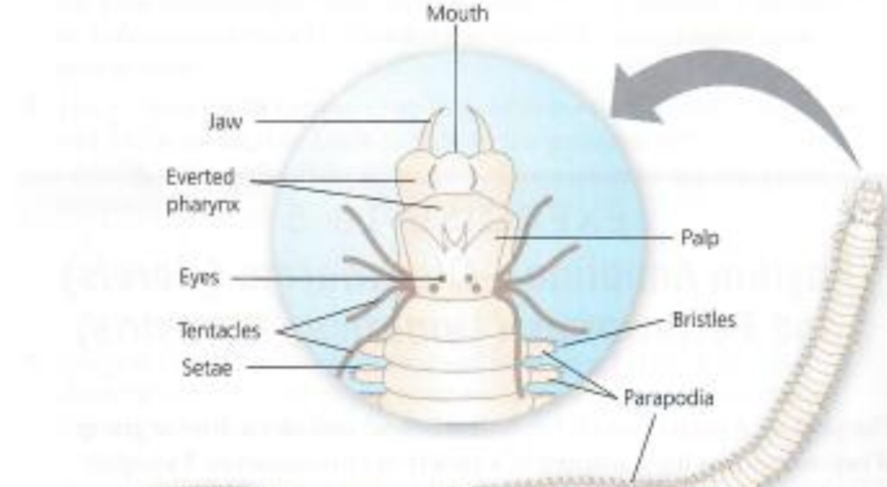

FIGURE 18.11
The clamworm, *Nereis.* The head has sensory appendages, and each segment of the body bears two parapodia with setae.

2. Determine the anterior and posterior ends. At the anterior end, the well-differentiated head bears **sensory appendages.** Locate the mouth, which leads into the digestive tract.
3. A conspicuous new feature of these organisms is the presence of **segmentation,** the division of the body along its length into segments. In annelids, segmentation includes both external and internal structures of several systems. Posterior to the head region, the segments bear fleshy outgrowths called **parapodia.** Each parapodium contains several terminal bristles called **setae.** In Lab Study B, you will see that the earthworm has setae but does not have parapodia. Suggest functions for parapodia and setae in the marine clamworm.
4. Holding the animal in your hand and using sharp-pointed scissors, make a middorsal incision the full length of the body. Carefully insert the tip of the scissors and lift up with the tips as you cut. Pin the opened body in the dissecting pan but do not put pins through the head region.
5. Locate the **intestine.** Do you see the "tube-within-a-tube" body plan?
6. Two **muscle layers,** one inside the skin and a second lying on the surface of the intestine, may be visible with the stereoscopic microscope. With muscle in these two positions, what kind of coelom does this animal have (see Figure 18.2c)?
7. Continuing your observations with the unaided eye and the stereoscopic microscope, look for **blood vessels,** particularly a large vessel lying on the dorsal wall of the digestive tract. This vessel is contractile and propels the blood throughout the body. You should be able to observe smaller lateral blood vessels connecting the dorsal blood vessel with another on the ventral side of the intestine. As you will see, in the earthworm these connecting vessels are slightly enlarged as "hearts" around the anterior portion of the digestive tract (around the esophagus). This is not as obvious in *Nereis.* What is this type of circulatory system, with blood circulating through continuous closed vessels?
8. Gas exchange must take place across wet, thin surfaces. Do you see any organs for gas exchange (gills or lungs, for example)? How do you suspect that gas exchange takes place?
9. Do you see any signs of a skeleton? What would serve as support for the body?

10. Clamworms and earthworms have a small bilobed brain (a pair of ganglia) lying on the surface of the digestive tract at the anterior end of the worm. You can see this more easily in an earthworm.

Lab Study B. Earthworms (*Lumbricus terrestris*)

Materials

dissecting instruments
compound microscope
stereoscopic microscope
preserved earthworm
prepared slide of cross section of earthworm

Introduction

Lumbricus species, commonly called *earthworms*, burrow through soils rich in organic matter. As you observe these animals, note features that are adaptations to the burrowing, terrestrial lifestyle.

Procedure

1. Obtain a preserved earthworm and identify its anterior end by locating the mouth, which is overhung by a fleshy dorsal protuberance called the **prostomium.** The anus at the posterior end has no such protuberance. Also, a swollen glandular band, the **clitellum** (a structure that secretes a cocoon that holds eggs), is located closer to the mouth than to the anus (Figure 18.12).

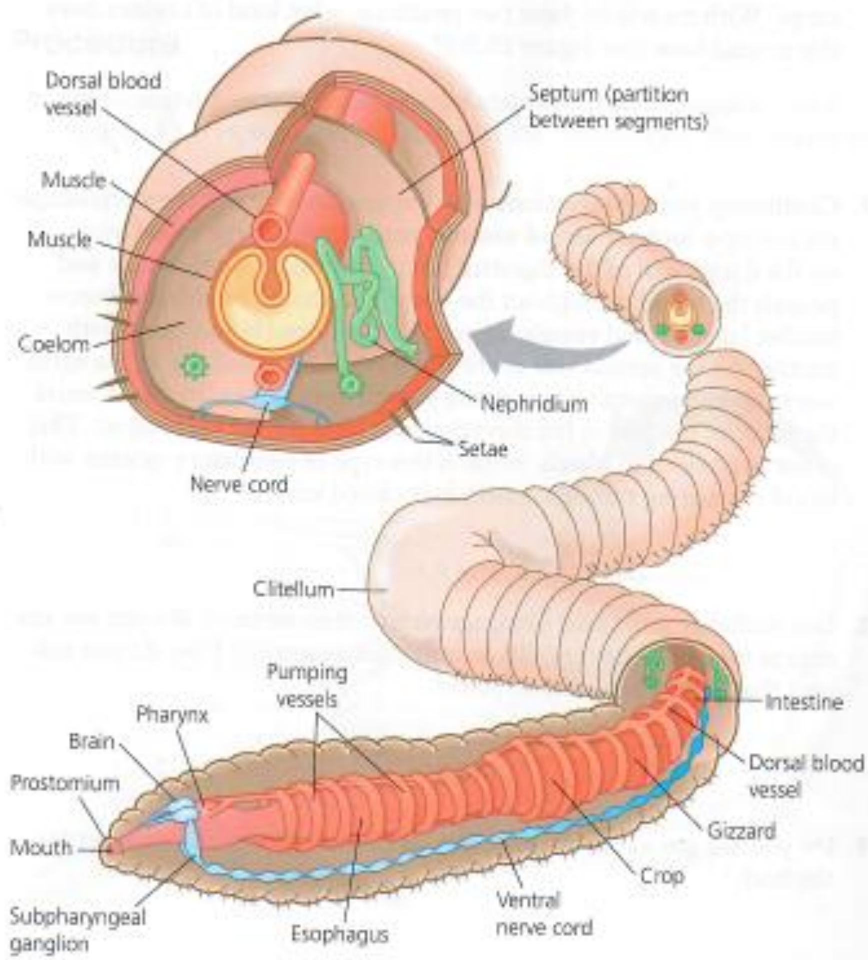

FIGURE 18.12
The earthworm. The small brain leads to a ventral nerve cord. A pair of nephridia lies in each segment.

a. Using scissors, make a middorsal incision along the anterior third of the animal, as you did for *Nereis.* You can identify the dorsal surface in a couple of ways. The prostomium is dorsal, and the ventral surface of the worm is usually flattened, especially in the region of the clitellum. Cut to the prostomium. Pin the body open in a dissecting pan near the edge. You may need to cut through the septa that divide the body cavity into segments.

b. Using a stereoscopic microscope or hand lens, look for the small **brain** just behind the prostomium on the surface of the digestive tract. Note the two nerves that pass from the brain around the pharynx and meet ventrally. These nerve tracts continue posteriorly as a **ventral nerve cord** lying in the floor of the coelom.

c. Look for the large **blood vessel** on the dorsal wall of the digestive tract. You may be able to see the enlarged lateral blood vessels (**hearts**) around the anterior portion of the digestive tract.

d. Identify (from anterior to posterior) the **pharynx, esophagus, crop** (a soft, swollen region of the digestive tract), **gizzard** (smaller and more rigid than the crop), and **intestine.**

e. Excretion in the clamworm and earthworm is carried out by organs called **nephridia.** A pair of these minute, white, coiled tubes is located in each segment of the worm body. Nephridia are more easily observed in the earthworm than in *Nereis* and should be studied here. To view these organs, cut out an approximately 2-cm-long piece of the worm posterior to the clitellum and cut it open along its dorsal surface. Cut through the septa and pin the piece to the dissecting pan near the edge to facilitate observation with the stereoscopic microscope. The coiled tubules of the nephridia are located in the coelomic cavity, where waste is collected and discharged to the outside through a small pore.

2. Using the compound microscope, observe the prepared slide of a cross section of the earthworm.

a. Locate the **thin cuticle** lying outside of and secreted by the **epidermis.** Recall the habitat of this organism and speculate about the function of the cuticle.

b. Confirm your decision about the type of coelom by locating **muscle layers** inside the epidermis and also lying on the surface of the **intestine** near the body cavity.

c. Locate the **ventral nerve cord,** lying in the floor of the coelom, just inside the muscle layer.

Results

Complete the summary table, Table 19.1, recording all information for clamworm and earthworm characteristics in the appropriate row. You will use this information to complete Table 19.2 and answer questions in the Applying Your Knowledge section at the end of Lab Topic 19 Animal Diversity II. Table 18.1, recording all information for clamworm and earthworm characteristics in the appropriate row.

MB Student Media Video—Ch. 33: Earthworm Locomotion

Discussion

A major new feature observed in the phylum Annelida is the segmented body. Speculate about possible adaptive advantages provided by segmentation.

By the end of today's laboratory period, you should have completed observations of all animals described in Animal Diversity I. The next lab topic, Animal Diversity II, is a continuation of this investigation and will present similar laboratory objectives. In Animal Diversity II, you will continue asking questions and making comparisons as you did in Animal Diversity I. By the end of the two lab topics, you should be able to use what you have learned about the animals to discuss and answer questions about the unifying themes of these laboratory topics.

Reviewing Your Knowledge

1. What are the characteristics of sponges that have led scientists to classify them in a group separate from the Eumetazoa?

2. Zoologists have described two modes of development in animals in the clade Bilateria, protostome development and deuterostome development. What criteria are used to distinguish between these two modes of development?

3. Molecular evidence has led taxonomists to group bilaterally symmetrical animals in one of three clades, Deuterostomia, Lophotrochozoa, or Ecdysozoa. Give one distinguishing characteristic of each of these groups other than molecular differences.

Applying Your Knowledge

1. A hydra (*Chlorophyra viridissima*) is bright green, and yet it does not synthesize chlorophyll. Think about the structure of the hydra and its feeding and digestive habits. What do you think is the origin of the green pigment in this species?

Investigative Extensions

1. Earthworms are among the most familiar inhabitants of soil. They play an important role in improving the texture of and adding organic matter to soil. You may have read Darwin's estimate that over 50,000 earthworms may inhabit one acre of British farmland. Earthworms are readily available from biological supply houses, or you may collect your own to use in experiments. Following are questions that you might investigate.
   - **a.** Why do earthworms come out of their burrows when it rains? Is it because they may drown in the water in their burrows? Does rain stimulate mating behavior, and the worms are coming to the surface to mate? Does the pH of the soil change as it rains, and is the burrow becoming too acidic or alkaline? What *is* the optimum pH range for earthworms? Does rain create conditions more favorable for migration to new habitats?
   - **b.** What effects do chemicals used in agriculture have on earthworm populations? Compare numbers and health of earthworms in containers of soil to which varying amounts of fertilizers, pesticides, or herbicides have been added.
   - **c.** Do earthworms in the soil stimulate plant growth? Compare the biomass of plants grown in containers with and without earthworms present.
2. An amazing diversity of organisms has evolved from the foot–mantle–visceral mass body plan of molluscs. Living terrestrial, freshwater, and marine snails and bivalves are available from biological supply houses, aquarium supply stores, or from ponds or terrestrial sites in your area. Consider the following questions that you might investigate. (A Google search for "snail experiments" yields over 1,140,000 entries, including experiments being performed in the International Space Station.)
   - **a.** What effect does sedimentation have on aquatic snail populations? Consider changes in water chemistry and/or substrate.
   - **b.** What effect does temperature have on the growth and/or reproduction of aquatic or terrestrial snails or slugs? Why would this question be of interest?
   - **c.** Invasive aquatic plants have become a major concern of scientists worldwide. For example, water hyacinth, introduced into ponds in

LAB TOPIC 19

Animal Diversity II: Nematoda, Arthropoda, Echinodermata, and Chordata

This lab is a continuation of observations of organisms in the animal kingdom (clade Metazoa) as discussed in Animal Diversity I. Return to Lab Topic 18 and review the objectives of the lab on page 467. Review the descriptions of the 13 characteristics you are investigating in the study and dissection of these animals (pp. 470–472).

In this lab topic you will study examples of two phyla included in the clade **Ecdysozoa,** Nematoda (Exercise 19.1) and Arthropoda (Exercise 19.2). These organisms have coverings on their body surfaces (exoskeletons) that they shed as they grow, a process called *ecdysis or molting.* In Exercises 19.3 and 19.4, you will study two phyla in the clade **Deuterostomia,** Echinodermata and Chordata.

As you continue your study of representative organisms, continue to record your observations in Table 19.1 at the end of this lab topic. Keep in mind the big themes you are investigating:

1. What clues do similarities and differences among organisms provide about phylogenetic relationships?
2. How is body form related to function?
3. How is body form related to environment and lifestyle?
4. What characteristics can be the criteria for major branching points in producing a phylogenetic tree (representing animal classification)?

EXERCISE 19.1
Phylum Nematoda—Roundworms (*Ascaris*)

Materials

dissecting instruments
dissecting pan
dissecting pins
compound microscope
disposable gloves
preserved *Ascaris*
prepared slide of cross section of *Ascaris*
hand lens (optional)

the southern United States, chokes ponds and waterways, in some cases hindering human and fish navigation. Ponds may become so choked that they dry up, destroying habitat for alligators, turtles, fish, and other native species. Design a greenhouse experiment to test the efficacy of aquatic snails in controlling the growth of invasive aquatic plants.

3. Review regeneration in planaria in the lab activity found at http://www.hhmi.org/biointeractive/activities/planaria/planaria_regen_activity.pdf. Use this as the basis for designing an independent investigation of regeneration in planaria.

Student Media: BioFlix, Activities, Investigations, and Videos

www.masteringbiology.com (select Study Area)

Activities—Ch. 32: Animal Phylogenetic Tree; Ch. 33: Characteristics of Invertebrates

Investigations—Ch. 32: How Do Molecular Data Fit Traditional Phylogenies?

Videos—Ch. 33: *Hydra* Budding; *Hydra* Eating *Daphnia*; *Hydra* Releasing Sperm; Jelly Swimming; Thimble Jellies; Earthworm Locomotion; Discovery Videos: Ch. 33: Invertebrates

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Balavoine, G. "Are Platyhelminthes Coelomates Without a Coelom? An Argument Based on the Evolution of *Hox* Genes." *American Zoologist,* 1989, vol. 38, pp. 843–858.

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Halanych, K. M. "The New View of Animal Phylogeny." *Annual Review of Ecology, Evolution, and Systematics,* 2004, vol. 35, pp. 229–256.

Mallatt, J. and C. Winchell. "Testing the New Animal Phylogeny: First Use of Combined Large-Subunit and Small-Subunit rRNA Sequences to Classify Protostomes." *Molecular Biology and Evolution,* 2002, vol. 19, pp. 289–301.

Websites

Encyclopedia of Life—an online reference source and database for all known species: http://www.eol.org

Planaria as a model organism for understanding stem cell biology: http://www.hhmi.org/biointeractive/stemcells/planarian_regen.html

The Tree of Life Web project provides information on all major groups of organisms, including invertebrates: http://tolweb.org/Animals/2374

University of Michigan Museum of Zoology, Animal Diversity Web. Includes descriptions of many invertebrates and vertebrates, links to insect keys, and references: http://animaldiversity.ummz.umich.edu/site/index.html

Introduction

Roundworms, or nematodes (clade Ecdysozoa), are among the most abundant and widely distributed organisms on earth. One species of roundworm, *Caenorhabditis elegans*, has become a model research organism in biology. NASA has used *C. elegans* in experiments to test the effects of space flight on human physiology. The resilience of these organisms became apparent when *C. elegans* specimens survived the Space Shuttle *Columbia* disaster in February, 2003. In 2006, the Nobel Prize in Medicine was awarded to two scientists for their studies of gene regulation using this soil worm as their research organism, and *C. elegans* continues to be important in many disciplines of biological research around the world. *Caenorhabditis elegans* is a small roundworm—only 1 millimeter in length. *Ascaris*, the roundworm you will study in this exercise, is considerably larger.

Recall that ecdysozoans secrete exoskeletons that must be shed as the animal grows. Nematodes are covered with a proteinaceous **cuticle** that sheds periodically. *Ascaris* lives as a parasite in the intestines of mammals such as horses, pigs, and humans. Most often these parasites are introduced into the mammalian body when food contaminated with nematode eggs is eaten. Keep in mind the problem of adaptation to a parasitic lifestyle as you study the structure of this animal.

Wear disposable gloves while dissecting preserved animals.

Procedure

1. Wearing disposable gloves, obtain a preserved *Ascaris* and determine its sex. Females are generally larger than males. The posterior end of the male is sharply curved.
2. Use a hand lens or a stereoscopic microscope to look at the ends of the worm. A mouth is present at the anterior end. Three "lips" border this opening. A small slitlike **anus** is located ventrally near the posterior end of the animal.
3. Open the animal by making a middorsal incision along the length of the body with a sharp-pointed probe or sharp scissors. Remember that the anus is slightly to the ventral side (Figure 19.1). Be careful not to go too deep. Once the animal is open, pin the free edges of the body wall to the dissecting pan, spreading open the body. Pinning the animal near the edge of the pan will allow you to view it using the stereoscopic microscope. As you study the internal organs, you will note that there is a **body cavity.** This is not a true coelom, however, as you will see shortly when you study microscopic sections. From your observations, you should readily identify such characteristics as symmetry, tissue organization, and digestive tract openings.
   a. The most obvious organs you will see in the dissected worm are **reproductive organs,** which appear as masses of coiled tubules of varying diameters.
   b. Identify the flattened **digestive tract,** or intestine, extending from mouth to anus. This tract has been described as a "tube within a tube," the outer tube being the body wall.
   c. Locate two pale lines running laterally along the length of the body in the body wall. The excretory system consists of two longitudinal tubes lying in these two **lateral lines.**

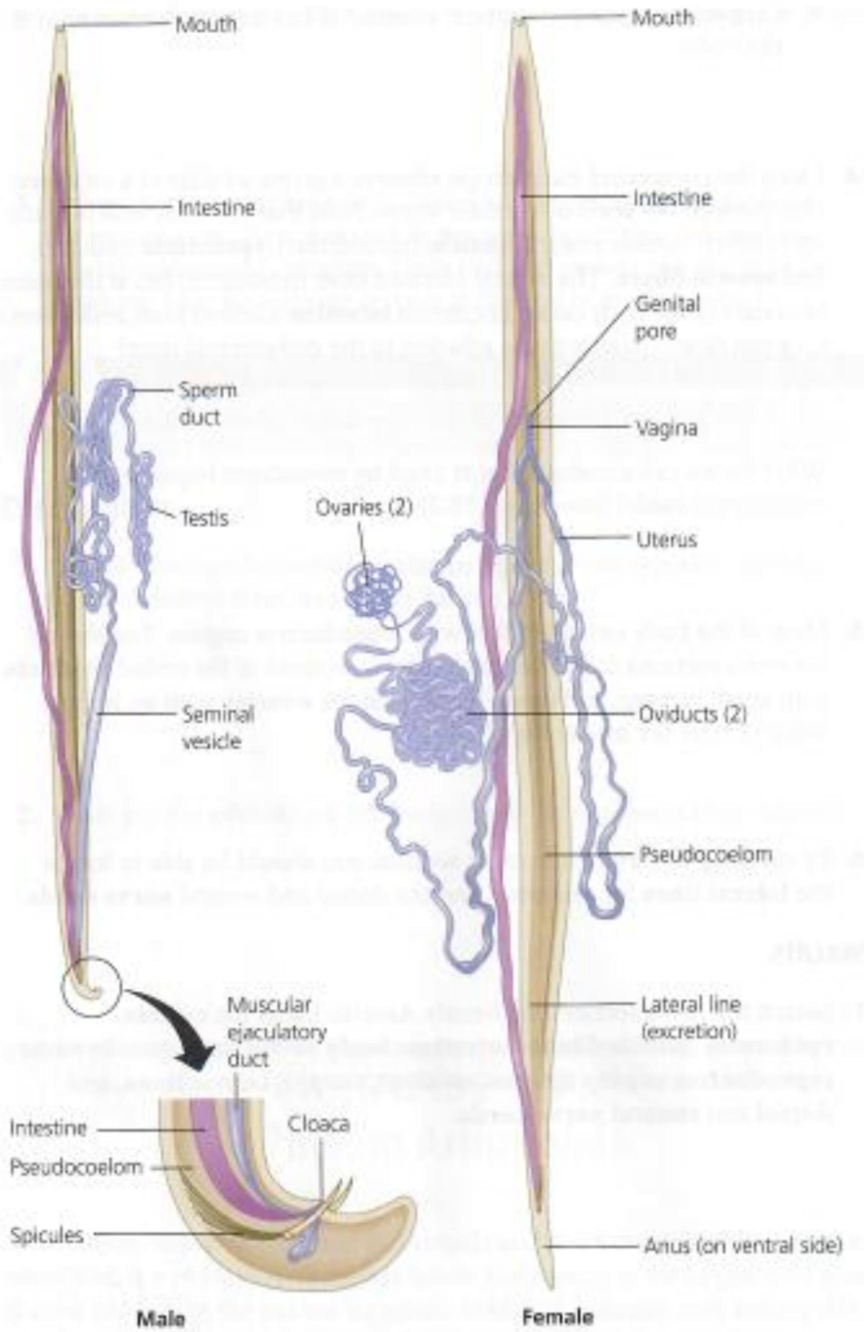

FIGURE 19.1

Male and female *Ascaris*. The digestive tract originates at the mouth and terminates in the anus. Reproductive structures fill the body cavity.

d. There are no organs for gas exchange or circulation. Most parasitic roundworms are essentially anaerobic (require no oxygen).

e. How would nourishment be taken into the body and be circulated?

f. The nervous system consists of a ring of nervous tissue around the anterior end of the worm, with one dorsal and one ventral nerve cord. These structures will be more easily observed in the prepared slide.

g. Do you see signs of segmentation in the body wall or in the digestive, reproductive, or excretory systems?

h. Do you see signs of a support system? What do you think supports the body?

4. Using the compound microscope, observe a prepared slide of a cross section through the body of a female worm. Note that the body wall is made up of (from outside inward) **cuticle** (noncellular), **epidermis** (cellular), and **muscle fibers.** The muscle (derived from mesoderm) lies at the outer boundary of the body cavity. Locate the **intestine** (derived from endoderm). Can you detect muscle tissue adjacent to the endodermal layer?

   What do we call a coelom that is lined by mesoderm (outside) and endoderm (inside) (see Figure 18.2b)?

5. Most of the body cavity is filled with reproductive organs. You should see cross sections of the two large **uteri,** sections of the coiled **oviducts** with small lumens, and many sections of the **ovaries** with no lumen. What do you see inside the uteri?

6. By carefully observing the cross section, you should be able to locate the **lateral lines** for excretion and the dorsal and ventral **nerve cords.**

Results

1. Sketch the cross section of a female *Ascaris.* Label the **cuticle, epidermis, muscle fibers, intestine, body cavity** (give specific name), **reproductive organs (uterus, oviduct, ovary), lateral lines,** and **dorsal** and **ventral nerve cords.**

2. List some features of *Ascaris* that are possible adaptations to parasitic life.

3. Complete the summary table, Table 19.1, recording all information for roundworm characteristics in the appropriate row. You will use this information to complete Table 19.2 and answer questions in the Applying Your Knowledge section at the end of this lab topic.

MB Student Media Video—Ch. 33: *C. elegans* Crawling

Discussion

1. Discuss the significance of an animal's having two separate openings to the digestive tract, as seen in *Ascaris*.

2. What are the advantages of a body cavity being present in an animal?

EXERCISE 19.2
Phylum Arthropoda

With astronomical numbers of individuals and more than a million species identified, the phylum Arthropoda (clade Ecdysozoa) is the largest and most diverse phylum in the animal kingdom. Evidence indicates that arthropods first lived on Earth over half a billion years ago. They can be found in almost every imaginable habitat: marine waters, fresh water, and almost every terrestrial niche. Many species are directly beneficial to humans, serving as a source of food. Others make humans miserable by eating their homes, infesting their domestic animals, eating their food, and biting their bodies. These organisms have an exoskeleton that periodically sheds as they grow. In this exercise, you will observe the morphology of two arthropods: the crayfish (an aquatic arthropod) and the grasshopper (a terrestrial arthropod).

Lab Study A. Crayfish (*Cambarus*)

Materials

dissecting instruments
dissecting pan
preserved crayfish
disposable gloves

Introduction

Crayfish live in streams, ponds, and swamps, usually protected under rocks and vegetation. They may walk slowly over the substrate of their habitat, but they can also swim rapidly using their tails. The segmentation seen in annelids is seen also in crayfish and all arthropods; however, you will see that the segments are grouped into functional units.

Procedure

1. Obtain a preserved crayfish, study its external anatomy, and compare your observations with Figure 19.2. Describe the body symmetry, supportive structures, appendages, and segmentation, and state the adaptive advantages of each characteristic.
   a. body symmetry

   b. supportive structures

   c. appendages

   d. segmentation

2. Identify the three regions of the crayfish body: the **head, thorax** (fused with the head), and **abdomen.** Note the appendages associated with each region. Speculate about the functions of each of these groups of appendages.

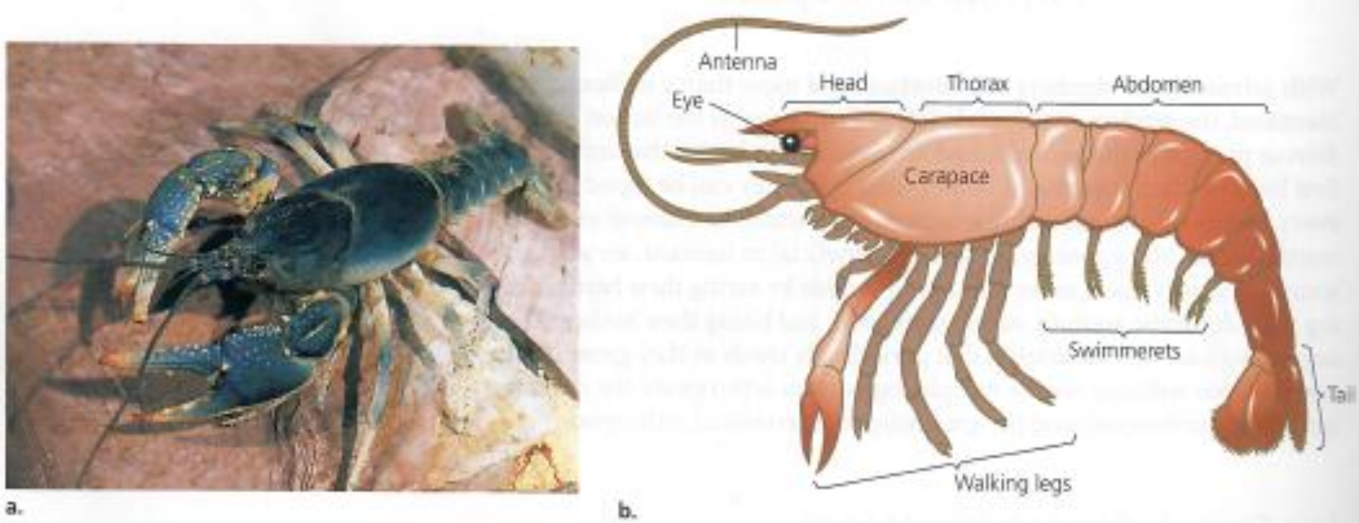

FIGURE 19.2

An aquatic arthropod. (a) *Cambarus*, a freshwater crayfish. (b) External anatomy of a crayfish. The body is divided into head, thorax, and abdominal regions. Appendages grouped in a region perform specific functions.

a. head appendages

b. thoracic appendages

c. abdominal appendages

3. Feathery **gills** lie under the lateral extensions of a large, expanded exoskeletal plate called the **carapace** (see Figure 19.2). To expose the gills, use scissors to cut away a portion of the plate on the left side of the animal. What is the function of the gills? Speculate about how this function is performed.

4. Remove the dorsal portion of the carapace to observe other organs in the head and thorax. Compare your observations with Figure 19.3.
   a. Start on each side of the body at the posterior lateral edge of the carapace and make two lateral cuts extending along each side of the thorax and forward over the head, meeting just behind the eyes. This should create a dorsal flap in the carapace.
   b. Carefully insert a needle under this flap and separate the underlying tissues as you lift the flap.
   c. Observe the **heart,** a small, angular structure located just under the carapace near the posterior portion of the thorax. (If you were not successful in leaving the tissues behind as you removed the carapace, you may have removed the heart with the carapace.)

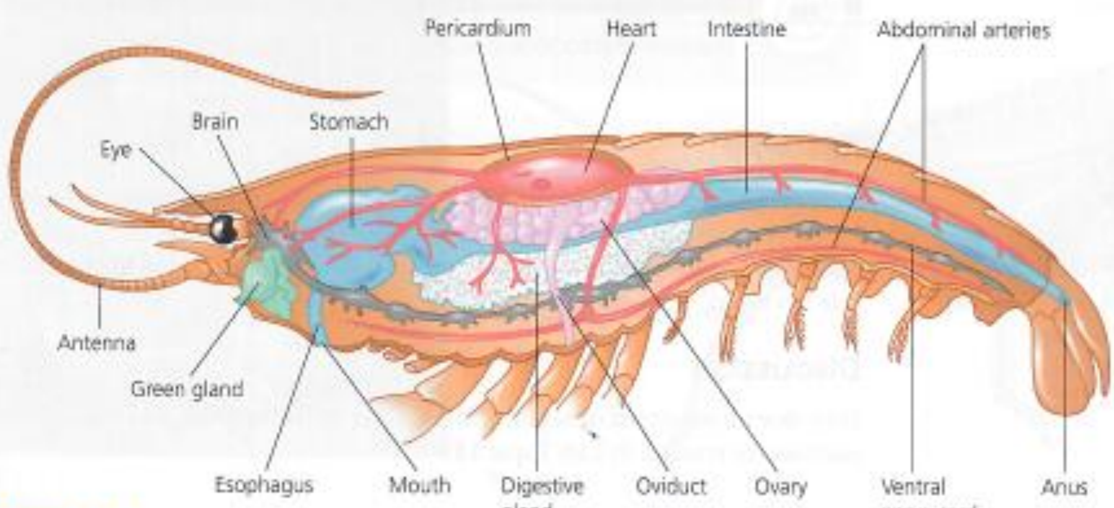

FIGURE 19.3

Internal anatomy of the crayfish. Large digestive glands fill much of the body cavity. The intestine extends from the stomach through the tail to the anus. The green glands lie near the brain in the head.

Thin threads leading out from the heart are **arteries.** Look for holes in the heart wall. When blood collects in **sinuses** around the heart, the heart relaxes, and these holes open to allow the heart to fill with blood. The holes then close, and the blood is pumped through the arteries, which distribute it around the body. Blood seeps back to the heart, since no veins are present. What is the name given to this kind of circulation?

d. Locate the **stomach** in the head region. It is a large, saclike structure. It may be obscured by the large, white **digestive glands** that fill the body cavity inside the body wall. Leading posteriorly from the stomach is the **intestine.** Make longitudinal cuts through the exoskeleton on either side of the dorsal midline of the abdomen. Lift the exoskeleton and trace the intestine to the anus. (When shrimp are "deveined" in preparation for eating, the intestine is removed.) Given all of the organs and tissues around the digestive tract and inside the body wall in the body cavity, what kind of coelom do you think this animal has?

e. Turn your attention to the anterior end of the specimen again. Pull the stomach posteriorly (this will tear the esophagus) and look inside the most anterior portion of the head. Two **green glands** (they do not look green), the animal's excretory organs, are located in this region. These are actually long tubular structures that resemble nephridia but are compacted into a glandular mass. Waste and excess water pass from these glands to the outside of the body through pores at the base of the antennae on the head.

f. Observe the **brain** just anterior to the green glands. It lies in the midline with nerves extending posteriorly, fusing to form a **ventral nerve cord.**

MB Student Media Video—Ch. 33: Lobster Mouth Parts

Results

Complete Table 19.1, recording all information for crayfish characteristics in the appropriate row. You will use this information to complete Table 19.2 and answer questions in the Applying Your Knowledge section at the end of this lab topic.

Discussion

How does the pattern of segmentation differ in the crayfish and the earthworm studied in Lab Topic 18?

Lab Study B. Grasshoppers (*Romalea*)

Materials

dissecting instruments
dissecting pan
preserved grasshopper
disposable gloves

Introduction

The grasshopper, an insect, is an example of a terrestrial arthropod (Figure 19.4a). Insects are the most successful and abundant of all land animals. They are the principal invertebrates in dry environments, and they can survive extreme temperatures. They are the only invertebrates that can fly. As you study the grasshopper, compare the anatomy of this terrestrial animal with that of the aquatic crayfish, just studied. This comparison should suggest ways that terrestrial animals have solved the problems of life out of water.

Procedure

1. Observe the external anatomy of the grasshopper. Compare your observations with Figure 19.4a and b.
   a. Note the symmetry, supportive structures, appendages, and segmentation of the grasshopper.
   b. Observe the body parts. The body is divided into three regions: the **head,** the **thorax** (to which the legs and wings are attached), and the **abdomen.** Examine the appendages on the head, speculate about their functions, and locate the mouth opening into the digestive tract.
   c. Turning your attention to the abdomen, locate small dots along each side. These dots are **spiracles,** small openings into elastic air tubes, or **tracheae,** that branch to all parts of the body and constitute the respiratory system of the grasshopper. This system of tubes brings oxygen directly to the cells of the body.

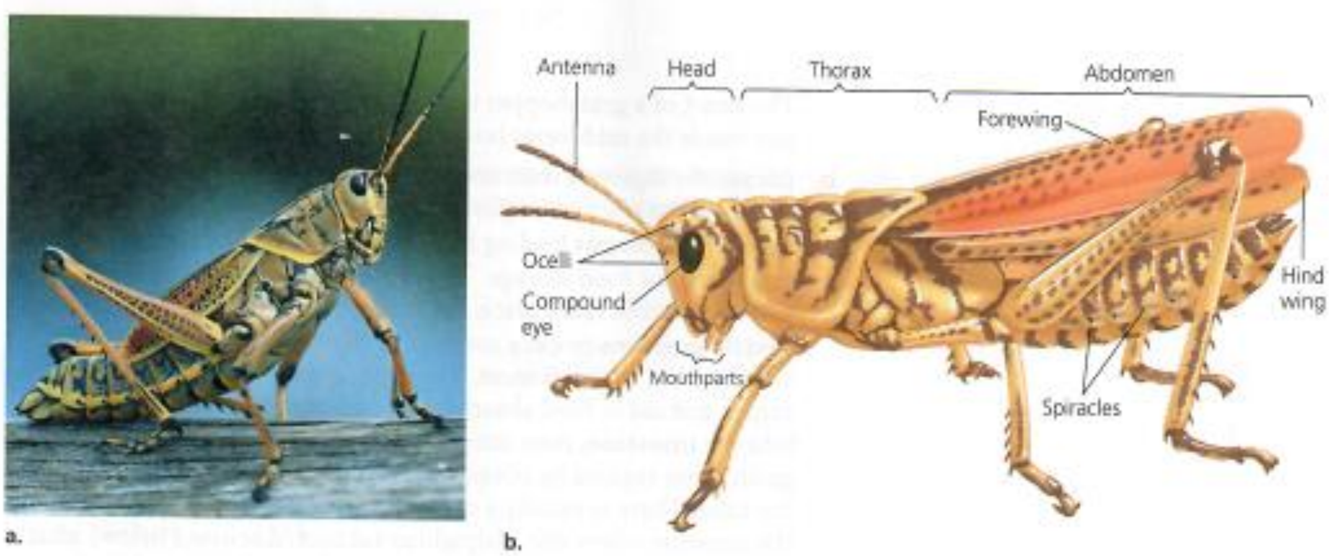

FIGURE 19.4
A terrestrial arthropod. (a) A grasshopper with segmented body and jointed appendages. (b) External anatomy of the grasshopper. The body is divided into head, thorax, and abdominal regions. Wings and large legs are present. Small openings, called *spiracles,* lead to internal tracheae, allowing air to pass into the body.

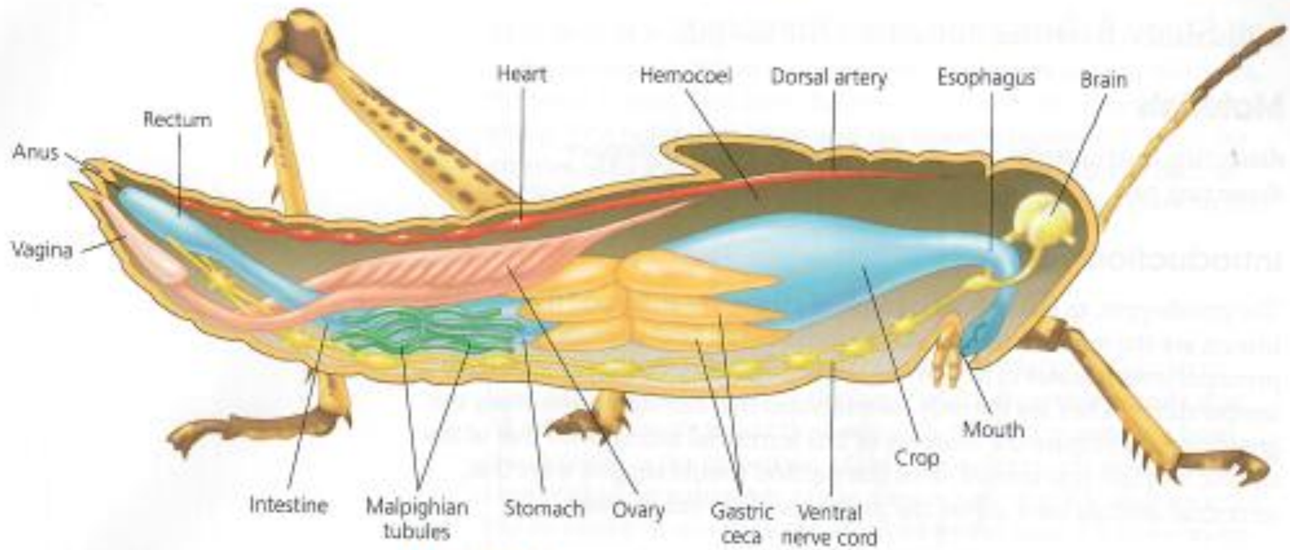

FIGURE 19.5

Internal anatomy of the grasshopper. The digestive tract, extending from mouth to anus, is divided into specialized regions: the esophagus, crop, stomach, intestine, and rectum. Gastric ceca attach at the junction of the crop and the stomach. Malpighian tubules empty excretory waste into the anterior end of the intestine.

2. Remove the exoskeleton. First take off the wings and, starting at the posterior end, use scissors to make two lateral cuts toward the head. Remove the dorsal wall of the exoskeleton and note the segmented pattern in the muscles inside the body wall. Compare your observations with Figure 19.5 as you work.

   a. A space between the body wall and the digestive tract, the **hemocoel** (a true coelom), in life is filled with colorless blood. What type of circulation does the grasshopper have?

   The heart of a grasshopper is an elongate, tubular structure lying just inside the middorsal body wall. This probably will not be visible.

   b. Locate the digestive tract and again note the mouth. Along the length of the tract are regions specialized for specific functions. A narrow **esophagus** leading from the mouth expands into a large **crop** used for food storage. The crop empties into the **stomach,** where digestion takes place. Six pairs of fingerlike extensions called **gastric pouches** or **ceca** connect to the digestive tract where the crop and the stomach meet. These pouches secrete digestive enzymes and aid in food absorption. Food passes from the stomach into the **intestine,** then into the **rectum,** and out the **anus.** Distinguish these regions by observing constrictions and swellings along the tube. There is usually a constriction between the stomach and the intestine where the Malpighian tubules (discussed below) attach. The intestine is shorter and usually smaller in diameter than the stomach. *The intestine expands into an enlarged rectum that absorbs excess water from any undigested food, and relatively dry excrement passes out the anus.*

c. The excretory system is made up of numerous tiny tubules, the **Malpighian tubules,** which empty their products into the anterior end of the intestine. These tubules remove wastes and salts from the blood. Locate these tubules.

d. Push aside the digestive tract and locate the **ventral nerve cord** lying medially inside the ventral body wall. Ganglia are expanded regions of the ventral nerve cord found in each body segment. Following the nerve cord anteriorly, note that branches from the nerve cord pass around the digestive tract and meet, forming a brain in the head.

Results

Complete Table 19.1, recording all information for grasshopper characteristics in the appropriate row. You will use this information to complete Table 19.2 and answer questions in the Applying Your Knowledge section at the end of this lab topic.

Discussion

1. Describe how each of the following external structures helps the grasshopper live successfully in terrestrial environments.

   a. Exoskeleton

   b. Wings

   c. Large, jointed legs

   d. Spiracles

2. Describe how each of the following internal structures helps the grasshopper live successfully in terrestrial environments.

   a. Tracheae

   b. Malpighian tubules

   c. Rectum

EXERCISE 19.3
Phylum Echinodermata—Sea Star

Echinodermata is one of three phyla in the clade Deuterostomia. You will study another deuterostome phylum in Exercise 19.4, phylum Chordata. The third phylum, Hemichordata, will not be studied. Examples of echinoderms include the sea star, sea urchin, sea cucumber, and sea lily. Some of the most familiar animals in the animal kingdom are in the phylum Chordata—fish, reptiles, amphibians, and mammals. Take a look at a sea star (starfish) in the saltwater aquarium in your lab or in a tidal pool on a rocky shore. What are the most obvious characteristics of this animal? Then imagine a chordate—a fish, dog, or even yourself. You might question why these two phyla are considered closely related phylogenetically. The most obvious difference is a very basic characteristic—the sea star has radial symmetry and most chordates that you imagine have bilateral symmetry. The sea star has no head or other obvious chordate features and it crawls around using hundreds of small suction cups called tube feet. Most chordates show strong cephalization and move using appendages. Your conclusion from the superficial observations might be that these two phyla are not closely related. Your observations are a good example of the difficulty faced by taxonomists when comparing animals based only on the morphology of adults. Taxonomists must collect data from studies of developmental and molecular similarities before coming to final conclusions.

In this and the following exercise, you will examine an echinoderm, the adult sea star, and two chordates, asking questions about their morphology and adaptation to their habitats. You may not be convinced of their phylogentic relationships, however, until you complete Lab Topic 25 Animal Development, when you will study early development in sea urchins and sea stars. In that lab topic, you will see that chordates and echinoderms have similar early embryonic developmental patterns, including the formation of the mouth and anus and the type of cleavage.

Materials

preserved sea stars
fine-tipped scissors and other dissecting instruments
dissecting pan
disposable gloves

Introduction

The sea star (also called starfish) is classified in the phylum Echinodermata. They are marine animals with an endoskeleton of small, spiny calcareous plates bound together by connective tissue. Their symmetry is radial pentamerous (five-parted). They have no head or brain and few sensory structures. All animals in this phylum have a unique **water-vascular system** that develops from mesoderm and consists of a series of canals carrying water that enters the body through an outer opening, the **madreporite.** The canals are located inside the body and include a ring around the central disk of the body and tubes or canals that extend out into each arm. The canals then terminate in many small structures called **tube feet** visible along the groove on the oral side of each arm. Each tube foot ends blindly in an attachment disk (podium) that extends to the outside of the body. A small canal connects each podium to a small spherical sac (ampulla) inside the body. Using a combination of muscle contraction and adhesive chemicals, a sea star can extend and attach the feet to hard surfaces such as the surface of a clamshell, or rocks on the ocean shore (Figure 19.6).

FIGURE 19.6

Sea star. The radial symmetry of echinoderm adults is evident in this deuterostome.

Procedure

1. Observe the external anatomy of a sea star. Compare your observations with Figure 19.7a and b. Locate the **aboral** surface—the "upper" surface away from the mouth (Figure 19.7a). The downside is the **oral** surface where the mouth is located (Figure 19.7b).
2. Count the number of arms that extend out from the **central disk.** Echinoderms are usually pentamerous, meaning that their arms are in multiples of five. Occasionally a sea star with six arms will be found. Arms that are damaged or lost can be regenerated, and an extra arm may regenerate.
3. Observe the animal's aboral surface (Figure 19.7a). Locate the **madreporite,** a small porous plate displaced to one side of the central disk that serves to take water into the water vascular system.

   Notice that the surface of the animal's body is spiny. The spines project from calcareous plates of the **endoskeleton.** The endoskeleton is derived from the embryonic germ layer mesoderm. In life, the entire surface of the body is covered with an **epidermis** derived from ectoderm that may not be visible with the naked eye.
4. Observe the animal's oral surface (Figure 19.7b). The **mouth,** surrounded by spines, is located in the central disk with grooves extending from the mouth out into each arm. **Tube feet** lie along these grooves.
5. Open the body of the sea star to observe the internal structures. (Figure 19.7c) Use fine-tipped scissors to cut off and discard about 1/2 inch from the tip of the arm opposite the madreporite (see Figure 19.7a). Then carefully cut along each side of this arm to where it joins the central disk. Cut across the top of the arm at the margin of the disk and remove this portion of the body wall. Observe the inside surface of the removed piece to see the endoskeleton and its calcareous plates.

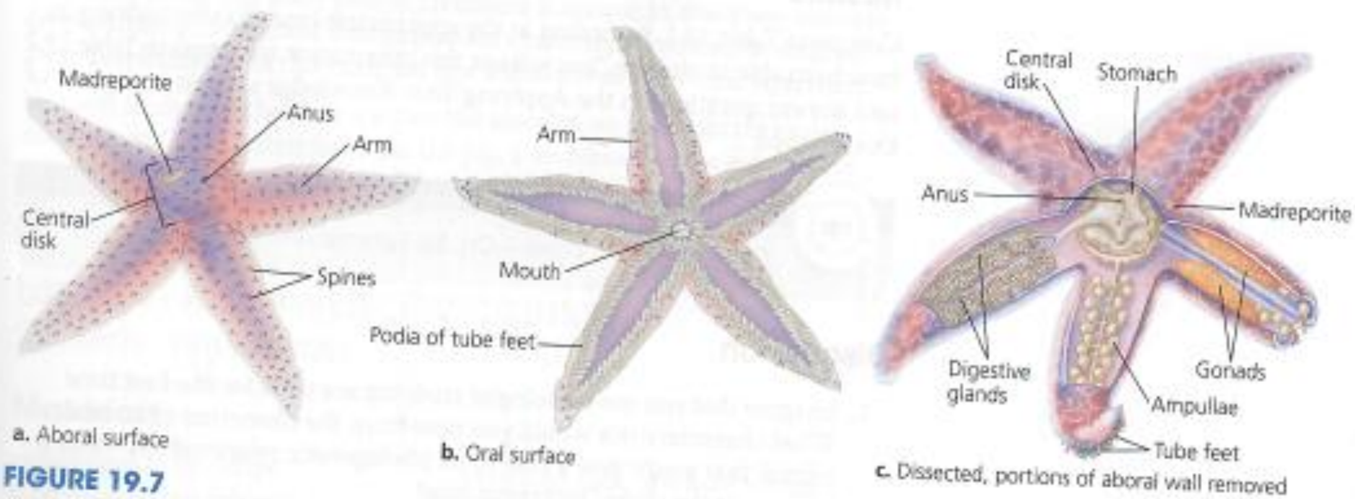

FIGURE 19.7

Anatomy of a sea star. (a) Aboral surface. (b) Oral surface. (c) Dissected sea star with portions of the aboral wall removed.

6. Continue using the scissors to carefully cut through the body wall along the side of each arm, and then around the central disk, but leave the madreporite in place by carefully cutting around it. This will allow you to remove the entire aboral surface of the body (excluding the madreporite).
7. Inside the body the organs are located in a **true body cavity** that in life is filled with coelomic fluid that carries oxygen and absorbed food to various parts of the body. Small delicate projections of the body cavity protrude between the plates of the endoskeleton to the outside of the body. These projections, covered with epidermis, are called **skin gills** or dermal branchiae, and function in the exchange of oxygen and carbon dioxide with the water bathing the animal's body. In addition, nitrogenous waste passes through these skin gills into the surrounding water; these structures thus have both respiratory and excretory functions.
8. Refer to Figure 19.7c as you locate the following structures in your dissected sea star. The central disk contains the folded **stomach,** a portion of which can be everted through the mouth on the oral side of the animal. A small anus is located on the aboral body surface (now removed), although very little fecal material is ejected here. Most digestion takes place in the stomach, which may be everted into the body of a clam. The digested broth is then sucked up into the sea star body. After feeding, the sea star draws in its stomach by contracting its stomach muscles.
9. Conspicuous organs in the coelom of the animal's arms are **digestive glands** lying on top of **gonads.** Push aside the digestive glands to observe the gonads. Then look along the inside of the arm below the gonads to observe small fleshy **ampullae** lying along the grooves extending from the central disk into each arm. Each ampulla connects with a podium of a tube foot, as described in the Introduction above. Other systems cannot be easily observed in this preparation. A reduced circulatory system (hemal system) exists, but its function is not well defined. It consists of tissue strands and unlined sinuses. The nervous system includes a nerve ring around the mouth and radial nerves with epidermal nerve networks. There is no central nervous system.

Results

Complete Table 19.1, recording in the appropriate row all information you have been able to observe. You will use this information to complete Table 19.2 and answer questions in the Applying Your Knowledge section at the end of this lab topic.

MB Student Media Video—Ch. 33: Echinoderm Tube Feet

Discussion

1. Imagine that you are a zoologist studying sea stars for the first time. What characteristics would you note from the dissection of an adult animal that might give a clue to its phylogenetic relationships—that it belongs in the clade Deuterostomia?

2. What structures have you observed that appear to be unique to echinoderms?

3. How would you continue your study to obtain more information that might help in classifying these animals?

4. Given the fact that other deuterostomes are bilaterally symmetrical, what is one explanation for the radial symmetry of most adult echinoderms?

EXERCISE 19.4
Phylum Chordata

Up to this point, all the animals you have studied in Lab Topics 18 and 19 are commonly called **invertebrates,** a somewhat artificial designation based on the absence of a backbone. The phylum Chordata studied in this exercise includes two subphyla of invertebrates and a third subphylum, Craniata, that includes those animals called **vertebrates.** Animals in this subphylum have an endoskeleton of cartilage or bone and a head and skull. Craniates with a vertebral column are called vertebrates. Chordates inhabit terrestrial and aquatic (freshwater and marine) environments. One group has developed the ability to fly. The body plan of chordates is unique in that these animals demonstrate a complex of four important characteristics at some stage in their development. In this exercise, you will discover these characteristics.

You will study two chordate species: the lancelet, an invertebrate in the subphylum Cephalochordata, and the pig, a vertebrate in the subphylum Craniata. The third subphylum, Urochordata, will not be studied.

Lab Study A. Lancelets (*Branchiostoma*, formerly *Amphioxus*)

Materials

compound microscope
stereoscopic microscope
preserved lancelet in watch glass
prepared slide of whole mount of lancelet
prepared slide of cross section of lancelet

FIGURE 19.8
Branchiostoma. The lancelet is a small chordate that lives in coastal waters.

Introduction

Lancelets are marine animals that burrow in sand in tidal flats. They feed with their head end extended from their burrow. They resemble fish superficially, but their head is poorly developed, and they have unique features not found in fish or other vertebrates. They retain the four unique characteristics of chordates throughout their life cycle and are excellent animals to use to demonstrate these features. In this lab study, you will observe preserved lancelets, prepared slides of whole mounts, and cross sections through the body of a lancelet (Figure 19.8).

Procedure

1. Place a preserved lancelet in water in a watch glass and observe it using the stereoscopic microscope. Handle the specimen with care and *do not dissect it*. Note the fishlike shape of the slender, elongate body. Locate the anterior end by the presence at that end of a noselike **rostrum** extending over the mouth region, surrounded by small tentacles. Notice the lack of a well-defined head. Look for the segmented muscles that surround much of the animal's body. Can you see signs of a tail? If the animal you are studying is mature, you will be able to see two rows of 20 to 25 white gonads on the ventral surface of the body.
2. Return the specimen to the correct container.
3. Observe the whole mount slide of the lancelet and compare your observations with Figure 19.9.

⚠ Use only the lowest power on the compound microscope to study this slide.

a. Scan the entire length of the body wall. Do you see evidence of segmentation in the muscles or in other organs or structures?

yes

b. Look at the anterior end of the animal. Do you see evidence of a sensory system? Describe what you see.

Yes, Tentacles

c. Locate the mouth of the animal at the anterior end. See if you can follow a tube from just under the rostrum into a large sac with numerous gill slits. This sac is the **pharynx with gill slits,** a uniquely chordate structure. Water and food pass into the pharynx from the mouth. Food passes posteriorly from the pharynx into the intestine, which ends at the anus on the ventral side of the animal, several millimeters before the end. The extension of the body beyond the anus is called a **postanal tail.** Think of the worms you studied in

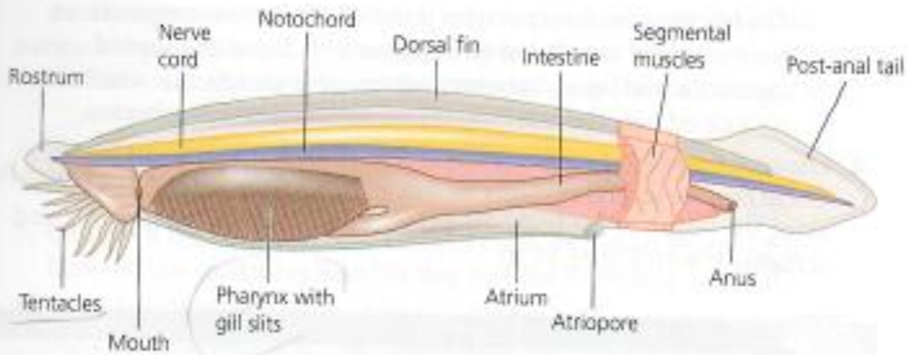

FIGURE 19.9

The lancelet, whole mount. The rostrum extends over the mouth region. The pharynx, including the pharyngeal gill slits, leads to the intestine, which exits the body at the anus. Note that a tail extends beyond the anus. Structures positioned from the dorsal surface of the body inward include a dorsal fin, the nerve cord, and the notochord.

Lab Topic 18 Animal Diversity I. Where was the anus located in these animals? Was a postanal region present? Explain.

d. Water entering the mouth passes through the gill slits and collects in a chamber, the **atrium,** just inside the body wall. The water ultimately passes out of the body at a ventral pore, the **atripore.** Surprisingly, the gill slits are not the major gas exchange surface in the lancelet body. Because of the great activity of ciliated cells in this region, it is even possible that blood leaving the gill region has less oxygen than that entering the region. The function of gill slits is simply to strain food from the water. The major site for gas exchange is the body surface.

e. Now turn your attention to the dorsal side of the animal. Beginning at the surface of the body and moving inward, identify the listed structures and speculate about the function of each one.

dorsal fin:

nerve cord: signals for movement.

like mini skeleton

notochord: body support

The nerve cord is in a dorsal position. Have you seen only a dorsal nerve cord in any of the animals previously studied?

The notochord is a cartilage-like rod that lies ventral to the nerve cord and extends the length of the body. Have you seen a notochord in any of the previous animals?

The lancelet circulatory system is not visible in these preparations, but the animal has **closed circulation** with dorsal and ventral aortae, capillaries, and veins. Excretory organs, or nephridia (not visible here), are located near the true coelom, which surrounds the pharynx.

4. Observe the slide of cross sections taken through the lancelet body. There may be several sections on this slide, taken at several positions along the length of the body. Find the section through the pharynx and compare it with Figure 19.10.

> Study this slide on the lowest power.

In cross section, it is much easier to see the structural relationships among the various organs of the lancelet. Identify the following structures and label them on Figure 19.10.

a. *Segmental muscles.* They are located on each side of the body, under the skin.

b. *Dorsal fin.* This projects upward from the most dorsal surface of the body.

c. *Nerve cord.* You may be able to see that the nerve cord contains a small central canal, thus making it hollow. The nerve cord is located in the dorsal region of the body, ventral to the dorsal fin between the lateral bundles of muscle.

d. *Notochord.* This is a large oval structure located just ventral to the nerve cord.

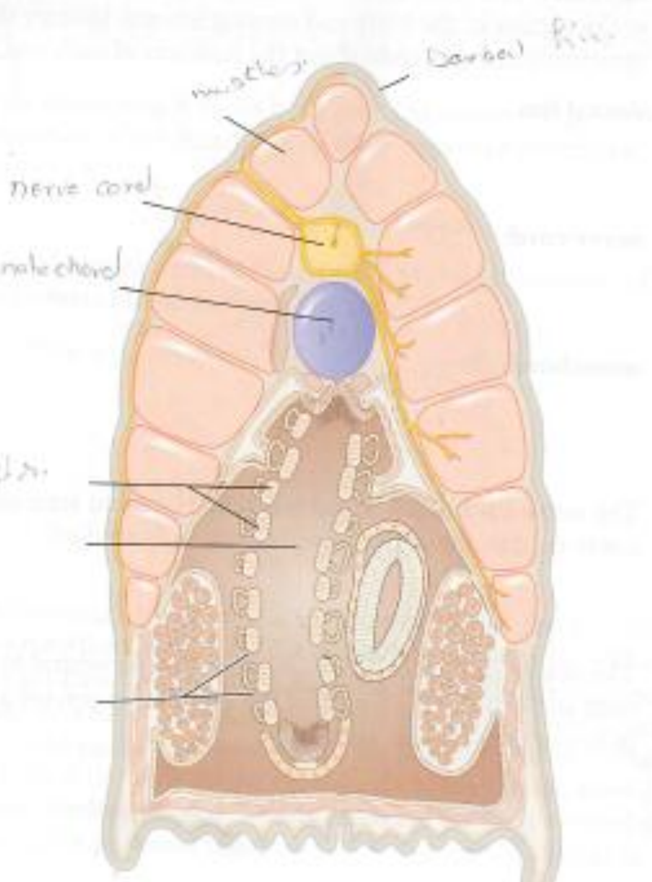

FIGURE 19.10
Cross section through the pharyngeal region of the lancelet.

e. *Pharynx with gill slits.* This structure appears as a series of dark triangles arranged in an oval. The triangles are cross sections of **gill bars.** The spaces between the triangles are **gill slits,** through which water passes into the surrounding chamber.

Results

1. Complete the diagram of the lancelet cross section in Figure 19.10. Label all the structures listed in step 4 of the Procedure section.
2. Complete Table 19.1, recording all information for lancelet characteristics in the appropriate row. You will use this information to complete Table 19.2 and answer questions in the Applying Your Knowledge section at the end of this lab topic.

Discussion

Describe the uniquely chordate features that you have detected in the lancelet that were not present in the animals previously studied.

Lab Study B. Fetal Pigs (*Sus scrofa*)

Materials

preserved fetal pig
dissecting pan
disposable gloves

Introduction

The pig is a terrestrial vertebrate. You will study its anatomy in detail in Lab Topics 22, 23, and 24. In this lab study, working with your lab partner, you will observe external features only, observing those characteristics studied in other animals in previous exercises. Compare the organization of the vertebrate body with the animals previously studied. As you dissect the pig in subsequent labs, come back to these questions and answer the ones that cannot be answered in today's lab study.

Procedure

1. Obtain a preserved fetal pig from the class supply and carry it to your desk in a dissecting pan.

Use disposable gloves to handle preserved animals.

2. With your lab partner, read each of the following questions. Drawing on observations you have made of other animals in the animal diversity lab studies, predict the answer to each question about the fetal pig. Then examine the fetal pig and determine the answer, if possible. Give evidence for your answer based on your observations of the pig, your knowledge of vertebrate anatomy, or your understanding of animal phylogeny.

   a. What type of symmetry does the pig body have?

      Prediction:

      Evidence:

   b. How many layers of embryonic tissue are present?

      Prediction:

      Evidence:

   c. Are cells organized into distinct tissues?

      Prediction:

      Evidence:

   d. How many digestive tract openings are present? Would you describe this as a "tube within a tube"?

      Prediction:

      Evidence:

   e. Is the circulatory system open or closed?

      Prediction:

      Evidence:

f. What is the habitat of the animal?

Prediction:

Evidence:

g. What are the organs for respiration?

Prediction:

Evidence:

h. What are the organs for excretion?

Prediction:

Evidence:

i. What is the method of locomotion?

Prediction:

Evidence:

j. Are support systems internal or external?

Prediction:

Evidence:

k. Is the body segmented?

Prediction:

Evidence:

l. Are appendages present?

Prediction:

Evidence:

m. What is the position and complexity of the nervous system?

Prediction:

Evidence:

Results

Complete Table 19.1, recording all information for pig characteristics in the appropriate row. You will use this information to complete Table 19.2 and answer questions in the Applying Your Knowledge section that follows.

Reviewing Your Knowledge—Lab Topics 18 and 19

1. Complete the summary table, Table 19.1, recording in the appropriate row information about characteristics of all animals studied.
2. Using Table 19.1, complete Table 19.2. Categorize all animals studied based on the 13 basic characteristics discussed in Lab Topic 18. Use this information to answer questions in the Applying Your Knowledge section that follows.

Applying Your Knowledge

1. Using specific examples from the animals you have studied in Lab Topics 18 and 19, describe ways that organisms have adapted to specific environments.
   a. Compare organisms adapted to aquatic environments with those from terrestrial environments.
   b. Compare adaptations of the parasitic *Ascaris* with the earthworm or clamworm, free-living organisms.
2. In Lab Topic 18 you studied the free-living flatworm, *Planaria*. The phylum Platyhelminthes also includes many examples of parasitic flatworms, for example, tapeworms and trematodes (flukes). Using Web resources, choose an example of a parasitic flatworm and compare morphological differences between this organism and the planarian that reflect specific lifestyle adaptations.

3. In your studies of animal phyla, you observed segmentation in widely diverse clades, for example, annelids (Lophotrochozoa), arthropods (Ecdysozoa), and chordates (Deuterostomia). How can you explain this in terms of their evolutionary history?

4. Upon superficial examination, the body form of certain present-day animals might be described as simple, yet these animals may have developed specialized structures, perhaps unique to their particular phylum. Illustrate this point using examples from some of the simpler organisms you have dissected.

5. From Lab Topics 18 and 19, one might conclude that certain trends can be detected, trends from ancestral features (those that arose early in the evolution of animals) to more derived traits (those that arose later). However, animals with ancestral characteristics still successfully exist on Earth today. Why is this so? Why have the animals with derived traits not completely replaced the ones with ancestral traits? Use examples from the lab to illustrate your answer.

6. A major theme in biology is the relationship between form and function in organisms. Select one of the major characteristics from Table 19.1, and illustrate the relationship of form and function for this characteristic using examples from the organisms studied.

7. Will, a student in the Coastal Biology course, has found an animal he cannot identify in the lower beach sand of Jekyll Island. What are some questions that he should ask to help determine the phylum of the animal?

8. As you review the information you have recorded in Tables 19.1 and 19.2, do you see a relationship between *symmetry* and (1) the organization of the nervous system and (2) the number of tissue layers?

TABLE 19.1 Summary Table of Animal Characteristics

Animal	Symmetry	Tissue Organization	Type of Body Cavity	Digestive Openings	Circulatory System	Habitat	Respiratory Organs
Sponge 							
Hydra 							
Planarian 							
Clam 							
Clamworm/ earthworm 							
Roundworm 							
Crayfish 							
Grasshopper 							
Sea star 							
Lancelet 							
Pig 							

TABLE 19.1 Summary Table of Animal Characteristics (*continued*)

Animal	Excretory System	Locomotion	Support System	Segmentation	Appendages	Nervous System Organization
Sponge 						
Hydra 						
Planarian 						
Clam 						
Clamworm/ earthworm 						
Roundworm 						
Crayfish 						
Grasshopper 						
Sea star 						
Lancelet 						
Pig