LABORATORY 27

Diversity—Phylum Chordata

OVERVIEW

The phylum to which we, *Homo sapiens,* belong is the Chordata. All representatives of this group have, or are clearly related to forms that have, each of the following characteristics: (1) a flexible but incompressible supporting skeletal rod called the **notochord,** from which comes the name Chordata; (2) a **dorsal tubular nerve cord** lying above the notochord; (3) **pharyngeal pouches,** also called visceral or "gill" pouches, located in the pharynx (an anterior region of the gut); and (4) a **post-anal tail.**

The phylum Chordata includes two groups (subphyla), the tunicates and sea lancelets, that do not have backbones, and it is closely related to another phylum, the Hemichordata, containing pterobranchs and acorn worms (acorn worms were previously classified with the chordates). However, the hemichordates do not possess all of the features of chordates and probably represent an early offshoot of the line leading to the chordates. All of these "invertebrate" chordates (tunicates and sea lancelets) and the Hemichordata are referred to as **protochordates.**

A third group (subphylum) of the phylum Chordata contains organisms that have a *backbone,* a bony spinal or vertebral column that replaces most of the notochord and encases the nerve cord, and a *skull* surrounding the brain, an anterior expansion of the nerve cord. These organisms are called **vertebrates.** There are seven vertebrate classes with living representatives. The classification of hemichordates and chordates is summarized below:

- Phylum Hemichordata (Stomochordata)
  - Class Pterobranchia: pterobranchs
  - Class Enteropneusta: acorn worms
- Phylum Chordata
  - Subphylum Urochordata (Tunicata): sea squirts and relatives
  - Subphylum Cephalochordata (Acraniata): sea lancelets
  - Subphylum Vertebrata: vertebrates
    - Class Agnatha: jawless fishes
    - Class Placodermi (extinct)
    - Class Chondrichthyes: cartilaginous fishes
    - Class Osteichthyes: bony fishes
    - Class Amphibia: frogs, salamanders, and others
    - Class Reptilia: turtles, snakes, lizards, crocodiles, and others
    - Class Aves: birds
    - Class Mammalia: mammals

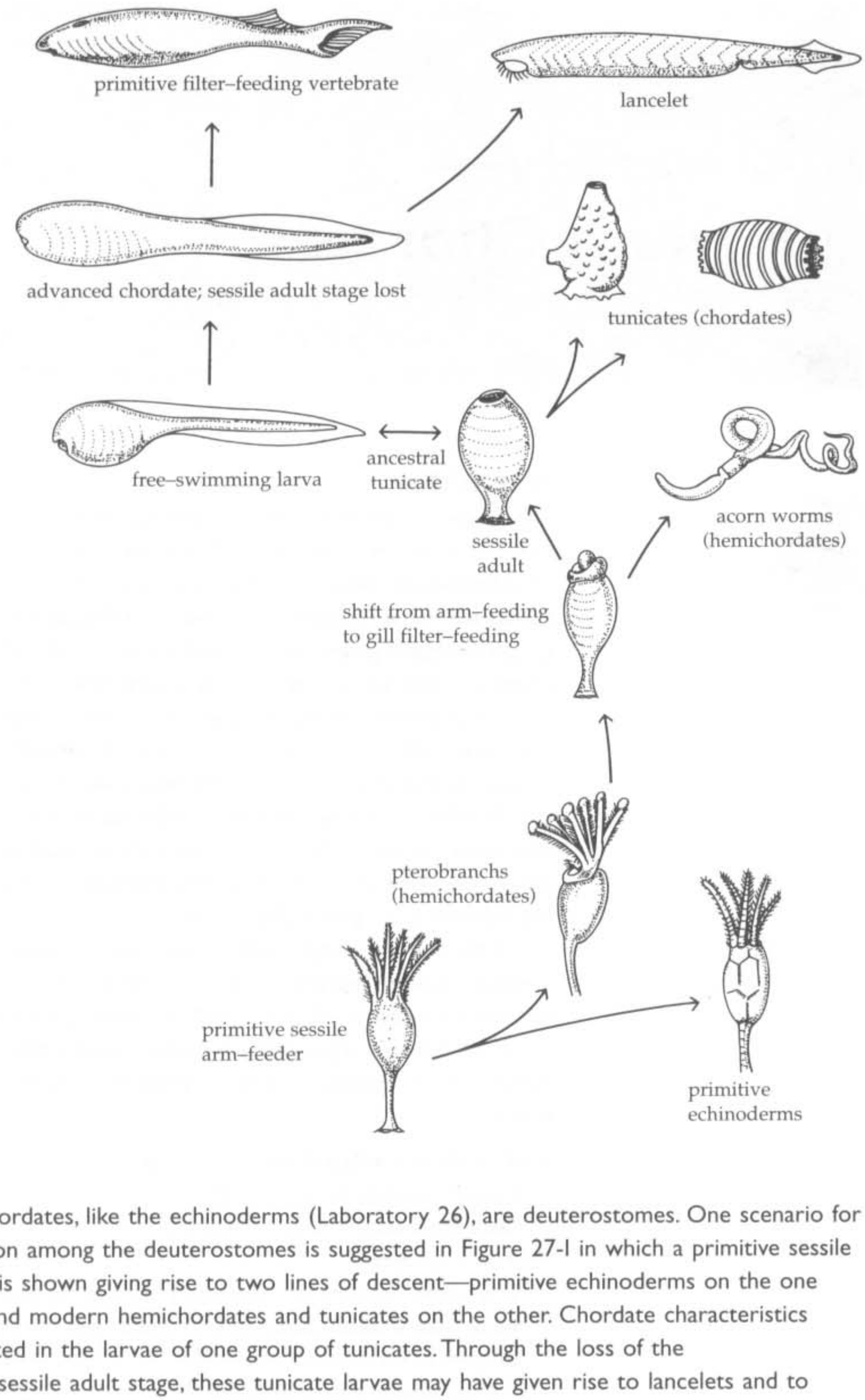

Figure 27-1 *Chordates may have evolved as follows: A primitive sessile filter-feeder with ciliated tentacles may have given rise to primitive echinoderms such as sea lilies and to modern hemichordates. In the hemichordate line, multiplication of gill slits and replacement of tentacles by the pharyngeal basket as the primary feeding mechanism distinguished tunicates from their hemichordate ancestors. Chordate characteristics originated in the larvae of one line of tunicates. In a process called* paedomorphosis *(retention of juvenile characteristics by the adult), this group lost the typical adult sessile stage and gave rise to the lancelets and more advanced free-swimming chordates. (After Alfred S. Romer and Thomas S. Parsons,* The Vertebrate Body, *6/e, p. 34, CBS, New York, 1983.)*

Chordates, like the echinoderms (Laboratory 26), are deuterostomes. One scenario for evolution among the deuterostomes is suggested in Figure 27-I in which a primitive sessile feeder is shown giving rise to two lines of descent—primitive echinoderms on the one hand, and modern hemichordates and tunicates on the other. Chordate characteristics originated in the larvae of one group of tunicates. Through the loss of the typical sessile adult stage, these tunicate larvae may have given rise to lancelets and to more advanced, free-swimming chordates, including the vertebrates.

Evolutionary relationships among the vertebrate groups are shown in Figure 27-II.

STUDENT PREPARATION

Prepare for this laboratory by reading the text pages indicated by your instructor. Familiarizing yourself in advance with the information and procedures in this laboratory will give you a better understanding of the material and will improve your efficiency.

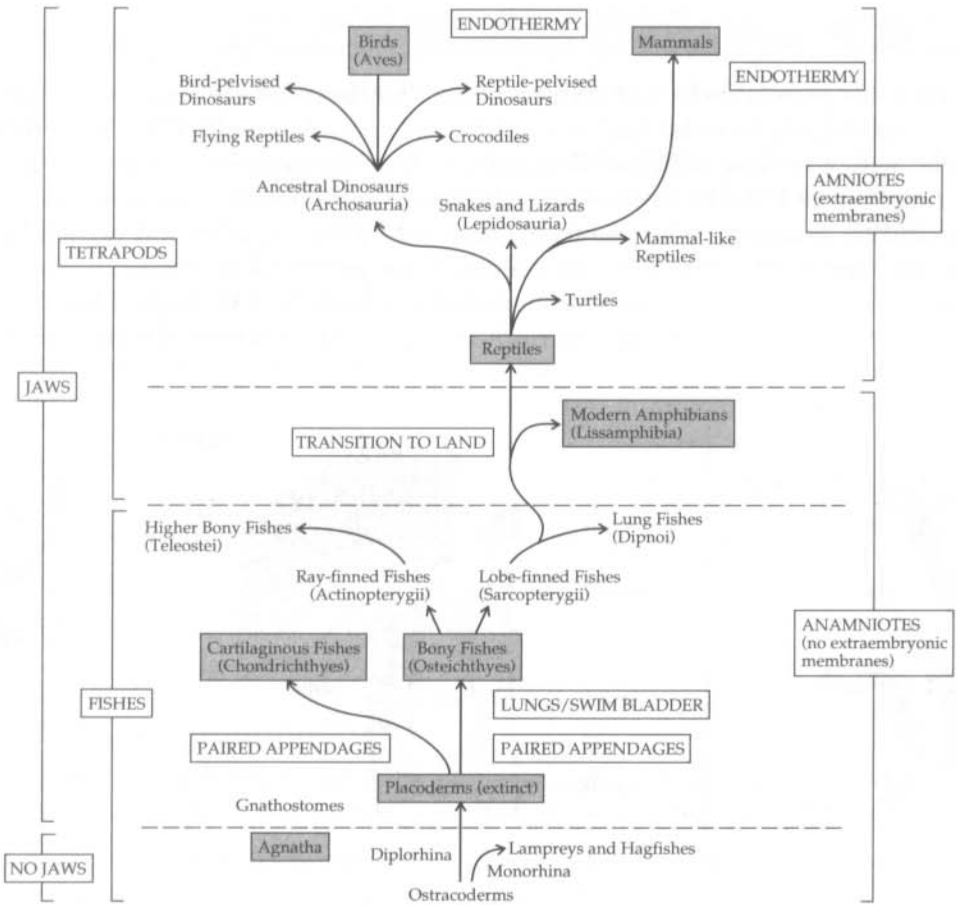

Figure 27-II *There are seven classes of vertebrates with living representatives. The first class, the* ***Agnatha****, includes extinct jawless fishes, the* ***ostracoderms****, and their specialized and aberrant living descendants, the lampreys and hagfishes. Note that modern agnathans have only a single nostril—they and their ancestors are grouped with the* ***Monorhina****. Other agnathans, all extinct, had two nostrils and are classified as* ***Diplorhina****—this is the line that must have given rise to higher vertebrates, but the transition is obscured by time. The remaining vertebrates all have jaws and can be called* ***gnathostomes*** *(gnatho-, jaw).*

We can group together a class of diverse extinct fishes called ***placoderms*** *and their descendants, the* ***Chondrichthyes****—sharks, skates, and rays, the second class of living vertebrates. In members of this group, bony tissues have generally been replaced with less dense cartilage, reducing the amount of energy required for remaining afloat.*

The third class includes the bony fishes, or ***Osteichthyes****. This line developed a lung/swim bladder, a gas-containing sac used in respiration in some members and also in maintaining neutral buoyancy so that continuous swimming is not required to remain afloat. Two lines of evolution are evident in the group. The* ***ray-finned fishes*** *include the higher bony fishes or* ***teleosts****, a group containing the majority of vertebrate species and most of the fishes with which we are familiar. The* ***lobe-finned fishes*** *developed fleshy appendages with bone structures apparently homologous to those of the higher vertebrates. This line of bony fishes led to four-legged animals* ***(tetrapods)*** *and life on land.*

Amphibians *are the fourth class of living vertebrates. Modern representatives (frogs, salamanders, and caecilians) are the rather specialized descendants of diverse fossil forms that first invaded land. Although many adults in this group leave the water, eggs and larvae require an aquatic environment (or a reasonable substitute) for development. Thus amphibians are not completely terrestrial.*

The fifth class of vertebrates, ***Reptilia****, made the transition to land with the development of an egg containing the nutritional reserves required for development and extraembryonic structures necessary for food utilization, waste storage, and gas exchange. Reptiles once counted among their members dinosaurs, flying pterosaurs, swimming ichthyosaurs, and other familiar but extinct species. Several lines survive today; of these, the best known are turtles, snakes and lizards, and alligators.*

Birds*, the sixth class of vertebrates, are thought to have originated from small carnivorous dinosaurs or their ancestors. Recent evidence, however, suggests that birds may actually predate dinosaurs. The seventh class,* ***mammals****, originated from a different line of running carnivorous reptiles and diversified into forms familiar to us today.*

✓ EXERCISE A Hemichordates

This phylum contains pterobranchs and acorn worms. **Pterobranchs** are small, sedentary, colonial marine organisms with individuals (zooids) held in a gelatinous mass (Figure 27A-1a). Each individual has a *proboscis*, a *collar* with a feeding structure (lophophore) bearing tentacles, and a body *trunk* held within a secreted covering (Figure 27A-1b). Each of these body sections contains a coelomic cavity. Food is filtered from the surrounding seawater by a mucous net secreted by the tentacles and carried by ciliary movements to the mouth. The mouth, located between the proboscis and collar, opens into a pharynx (with a pair of pharyngeal slits in some pterobranchs) that leads to a **U**-shaped digestive tract with the anus opening near the mouth. Extending anteriorly into the proboscis from the pharynx is a strand of tissue

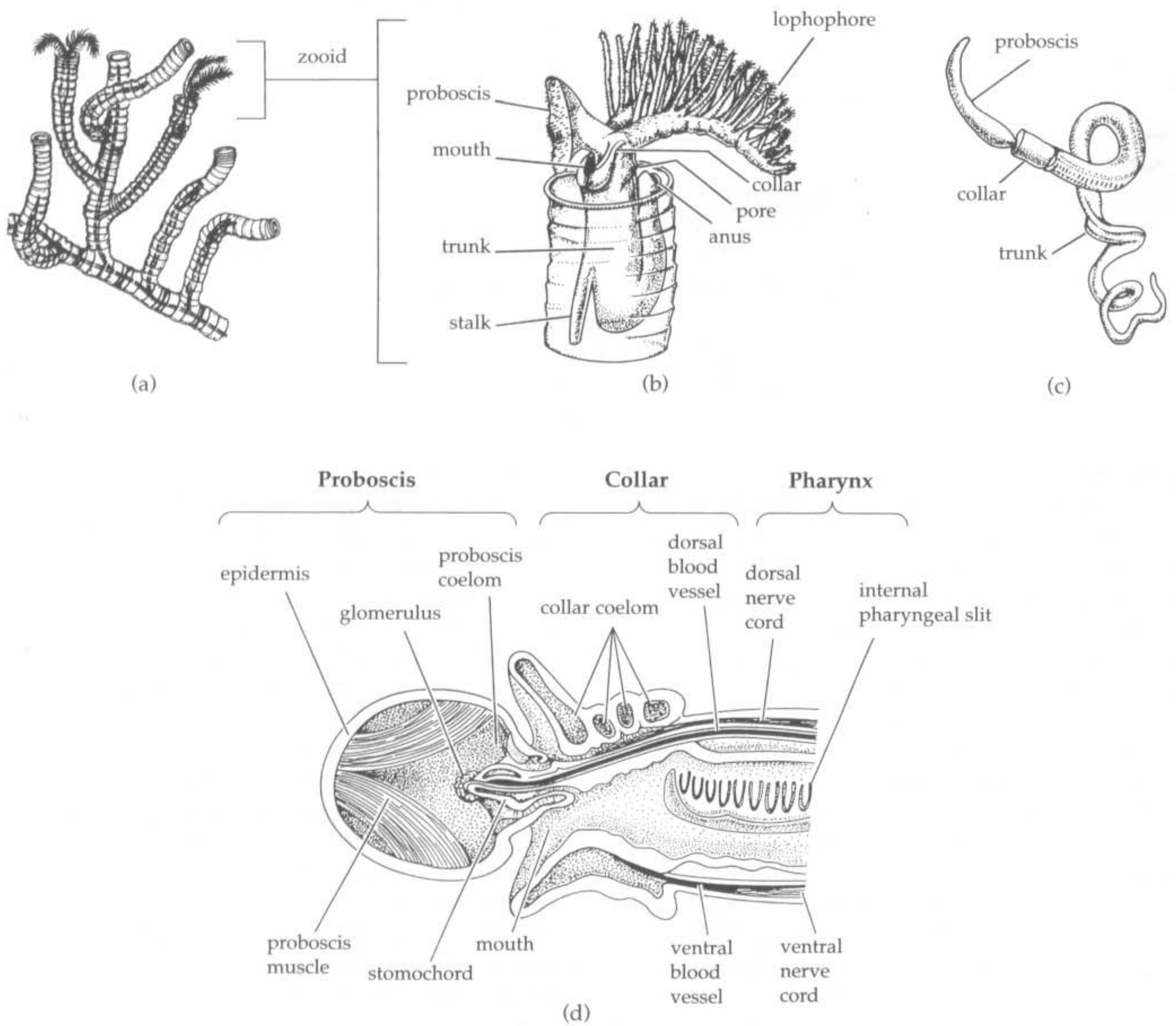

Figure 27A-1 *(a) Part of a pterobranch colony. (b) An individual pterobranch zooid* (Rhabdopleura). *(c) An acorn worm* (Balanoglossus). *(d) A mid-sagittal section of an acorn worm. [(a) (b) (c) after Alfred S. Romer and Thomas S. Parsons,* The Vertebrate Body, *6/e, p. 25, CBS, New York, 1983; (d) after Saul Wischnitzer,* Atlas and Dissection Guide for Comparative Anatomy: Lab Manual, *p. 11, W. H. Freeman, New York, 1979.]*

that resembles the notochord of chordates. However, this skeletal element originates from endodermal (not mesodermal) tissues and does not extend the length of the body as does a true notochord. Thus, it is not currently regarded as homologous to the notochord. Because of its origin near the mouth, this structure is called a **stomochord.**

Acorn worms (Figure 27A-1c, d), marine burrowing animals from 2 cm to 2 m in length, also have a stomochord, but have lost the lophophore. The proboscis has become muscular and assists in burrowing. Cilia on the surface of the proboscis collect food in a mucous net and move it to the mouth. The mouth can also be used to gather detritus from the ocean bottom. As in pterobranchs, the body is divided into three sections: the proboscis, collar (lacking the lophophore), and trunk, each with its own coelomic cavity. The anus is at the end of the body.

Although these organisms are not now placed in the phylum Chordata, the presence of pharyngeal gill slits and other developmental similarities clearly suggest a relationship with the echinoderm-chordate line.

Objectives

- ☐ Describe the organization of pterobranchs and acorn worms.
- ☐ Relate the evolution of hemichordates to that of chordates.

Procedure

1. Study the diagrams of pterobranchs in Figure 27A-1a, b. Compare the structural features of an individual zooid with those of an acorn worm, as seen in Figure 27A-1c, d.
2. Examine a preserved acorn worm (preserved or plastic mount). Note the three regions of the body: the proboscis, used in burrowing and feeding; the collar; and the trunk. The anterior section of the body also bears a number of pharyngeal slits.
3. Examine a median longitudinal section of the anterior end of an acorn worm. Identify as many of the structures shown in Figure 27A-1d as possible. The collar serves as an anchor for extension and contraction of the proboscis during burrowing. The surface of the proboscis is ciliated and is used in feeding. Try to identify the stomochord which projects into the proboscis coelom. At the anterior end of this structure is a tissue mass known as the glomerulus (it may have some excretory function). The nervous system consists of a nerve net with dorsal and ventral nerve cords—there is no real "cerebral" expansion and there are no special sensory organs. Acorn worms have a circulatory system in which blood flows anteriorly in dorsal vessels and posteriorly in ventral vessels; the blood is colorless.

   a. *What features suggest that pterobranchs and acorn worms are related?*

   ____

   ____

   b. *What structures link the hemichordates to the chordates?* ____________________

   ____

✓ EXERCISE B Tunicates

Tunicates or **urochordates** are a relatively diverse group of marine filter-feeders. They are solitary or colonial and may be either attached to the substrate or free-floating. The most familiar forms are **ascidians** or **sea squirts.** Adult sea squirts can be found attached to pilings or rocks in the intertidal zone of our coasts. Larvae of solitary forms, however, are free-swimming, bilaterally symmetrical "tadpoles" with characteristic chordate features—a notochord extending into a post-anal tail, a dorsal tubular nerve cord, and pharyngeal pouches (Figure 27B-1a). These larvae locate an appropriate substrate, attach with a sucker at their head end, and undergo metamorphosis during which most of the characteristics of the chordate are lost. Great interest has focused on this larva because it is a "typical" chordate, whereas adult sea squirts bear little resemblance to any other representative of the phylum.

Objectives

☐ Describe the structures of the larva and the adult form of solitary sea squirts and relate these structures to chordate characteristics.

Procedure

1. Obtain a slide of the tadpole larva of a tunicate and examine it under low power (10×), or study Figure 27B-1a if slides are not available.

   The larva has a tail with a **notochord** that may be visible. A **nerve cord** lies above this supporting element, directing the activities of muscle cells alongside the notochord. Anteriorly, the nerve cord expands to form a hollow cephalic vesicle with a simple light-sensitive structure and a gravity receptor.

   A mouth (which may not be open at this stage) leads into a pharynx, perforated by several gill slits. These open into a surrounding pocket called the **atrium**, which exits dorsally. An incomplete intestine is present. On a separate sheet of paper, sketch those features you can identify. Metamorphosis includes reabsorption of the tail and a rotation of the body so that the mouth opens opposite the site of attachment to the substrate.

2. Observe an adult sea squirt on demonstration (Figure 27B-1b). The outer body is covered by a **test** or "tunic." This structure contains **tunicin,** a cellulose-like material that is unique in the animal world. Your specimen is probably relatively soft and pigmented.

   Directly opposite the point of attachment is the mouth, which leads into a pharynx perforated by many pharyngeal slits. Water, propelled by cilia lining the pharyngeal basket, passes through a mucous net where food particles are trapped. This net is coiled by ciliary action then passed into a simple **U**-shaped intestine where digestion takes place. Wastes are voided through the anus into the atrium, the chamber surrounding the pharynx. Filtered water and feces are expelled from the atrium through the atrial siphon near the mouth. If a dissected specimen is available, locate the mouth and pharyngeal basket.

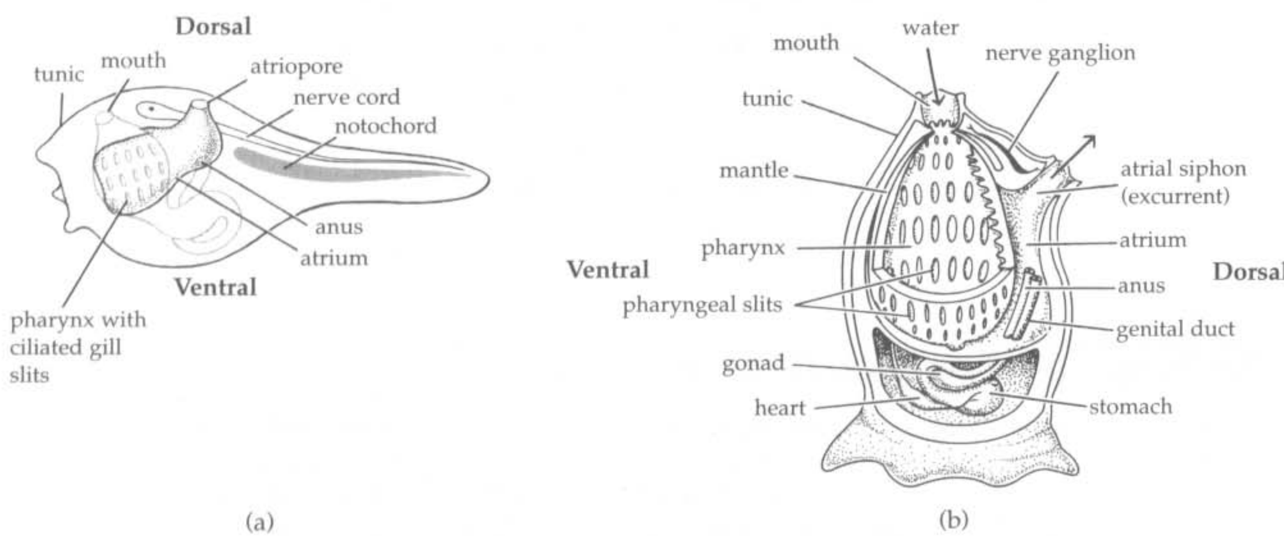

Figure 27B-1 *(a) The tunicate larva. (b) The adult form.*

Gonads may also be apparent near the base of the organism. Tunicates are hermaphroditic—individuals possess both testes and ovaries. Ducts lead to the atrium where gametes are shed at the appropriate season.

A fascinating feature of the tunicate "heart," an open tube located below the pharynx, is that it can reverse the flow of blood from dorsal to ventral and from ventral to dorsal every two or three minutes. Blood cells in some tunicates contain pigments with vanadium or niobium, rare elements concentrated from the surrounding ocean. However, these pigments probably have no respiratory function. Tunicates were once believed to have no coelom, but it is now thought that the hemocoel may represent this structure in adults.

If a sea squirt is disturbed, longitudinal muscles contract, pulling the organism toward the site of attachment and expelling a jet of water from the siphon as the pharynx collapses.

a. What feature does the adult tunicate retain that is typical of all chordates?

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✓ EXERCISE C Sea Lancelets

A second small subphylum of chordates, the **cephalochordates (Acraniata),** contains small, bilaterally symmetrical marine organisms with all of the characteristic features of chordates. However, unlike all other representatives of the phylum, in cephalochordates the notochord extends all the way to the front of the head, beyond the anterior end of the dorsal nerve tube. In other chordates, the notochord ends behind the expanded part of the dorsal nerve tube or cerebral vesicle (behind the forebrain in vertebrates). Thus the name cephalochordate (*cephalo-*, head) is appropriate for this group. The most commonly studied cephalochordate is *Branchiostum lanceolatum* (formerly known as *Amphioxus*).

This group is of particular interest because it is representative of the types of organisms that could have evolved from the tunicate larva.

Objectives

☐ Describe the structure of a lancelet and relate features of this organism to those of other chordates.

Procedure

1. Place a preserved lancelet in a small watch glass under your dissecting microscope or obtain a whole-mount prepared slide for study. On a separate sheet of paper, sketch and label the features you are able to identify. Use Figure 27C-1a as a reference.
2. Examine the external body plan of a lancelet.

   a. What kind of symmetry is exhibited by the lancelet? ____________________

3. The integument in adult lancelets is covered with a cuticle secreted by the outer layer of cells. In larvae, the integument is ciliated. These features may not be apparent in your specimen.
4. Try to find the **notochord.** It may be visible as a homogeneous column of tissue extending the length of the animal and located just above the pharyngeal basket. This incompressible rod is flexible.
5. The **nerve cord** is located above the notochord. If you have a whole mount, you may be able to see small pigmented areas along the side of the cord. These "eye spots" function in the reception of light but cannot form images. Anteriorly, the nerve cord is not expanded; it terminates behind the anterior end of the notochord, where a small pigmented spot may be found.
6. Above the nerve cord is a series of **dorsal fin rays** that support the dorsal fin. Along the length of the body you can find the chevron-shaped **myomeres,** clusters of longitudinal

muscle separated by sheets of tissue (myosepta). It is the contraction of these muscles on alternate sides of the larva that flexes the notochord and propels the larva through the water.

b. Why is it important that the notochord is incompressible? (Hint: What happens when the myomeres contract?) ____

____

7. Find the **buccal cirri** projecting around the mouth; these guard the opening of the mouth against sand and large detritus that could damage the delicate pharynx. The **wheel organ** is a ciliated structure on the inner lateral and dorsal walls of the vestibule (mouth or buccal cavity). The cilia of the wheel organ direct a vortex of water toward the mouth. The mouth leads into the pharynx which is perforated by about 200 **pharyngeal slits** leading to the atrium, a cavity surrounding the pharynx. These slits are covered by a mucous net secreted by cells lining the pharynx and, as water passes through the net directed by cilia on the walls of the pharynx, food is filtered from the water, wrapped in the mucus, and moved to the intestine. Note that a branch of the gut, the **hepatic diverticulum** (named because of some similarities with the vertebrate liver), protrudes anteriorly into the atrium, lying alongside the pharynx. Digestive wastes are voided through the anus which may be seen ventrally, near the base of the caudal fin. Water filtered through the pharyngeal slits and into the atrium leaves the body through the **atriopore,** anterior to the anus.

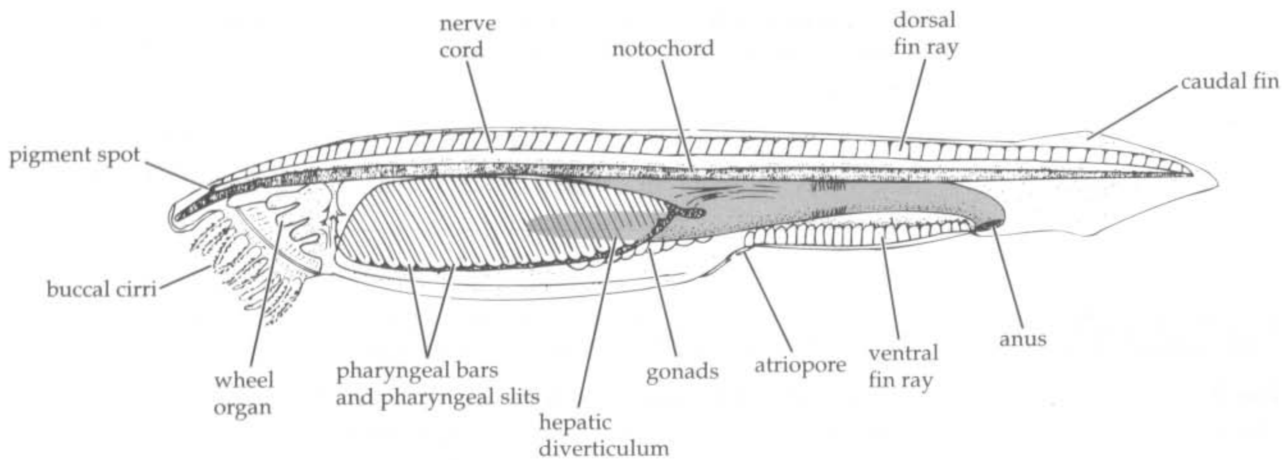
8. Obtain a slide of a cross section through the pharyngeal region of a lancelet and study it under scanning power (4×) using your compound microscope. Identify the structures labeled on Figure 27C-1b. Note the fin ray supporting the dorsal fin. Beneath this is the nerve cord lying over the larger notochord. Laterally, you can see sections through the chevron-shaped body musculature (myomeres), separated by connective tissue septa. Ventrolaterally, there is a **metapleural fold** on each side of the body. These folds and the dorsal fin help the lancelet control roll, pitch, and yaw when swimming (the caudal fin provides the major propulsive thrust).

9. Projecting from the lateral wall of the body into the atrium are gonads. Male and female gonads are found in separate organisms. Gametes are shed into the atrium and carried to the outside with the water passing through the pharynx to the atriopore. You may also note a section of the hepatic diverticulum in your specimen.

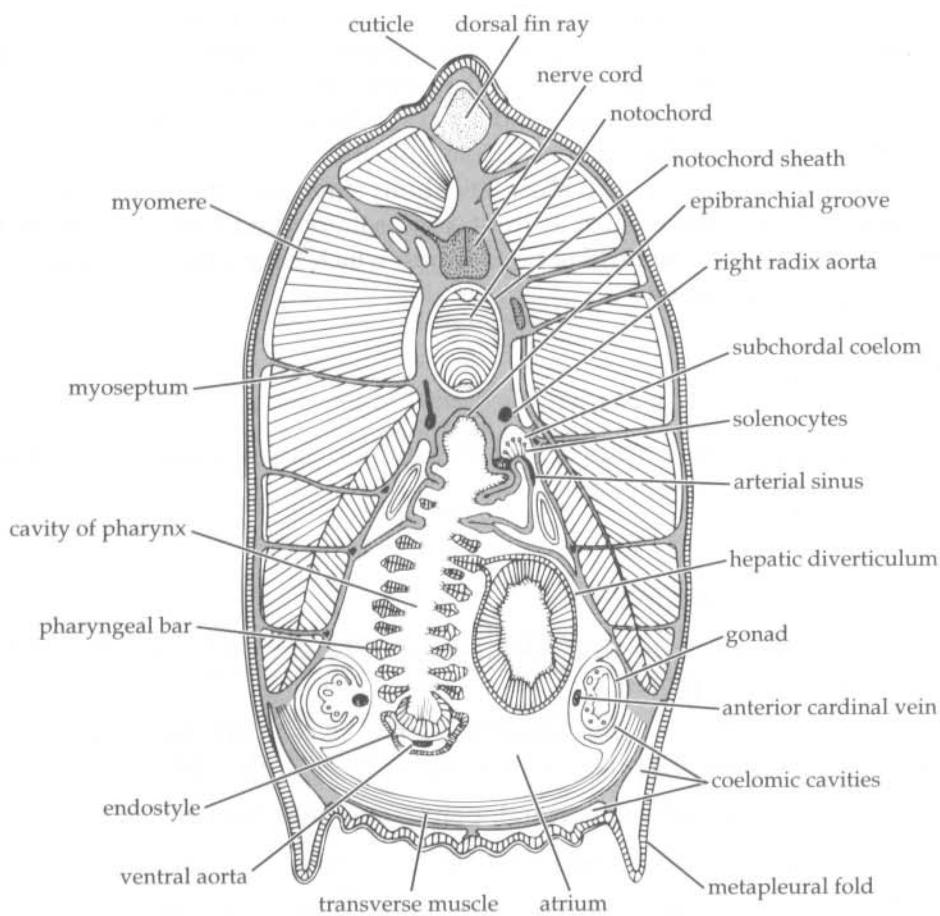
10. In the middle of the atrium, you will observe the pharynx tissue. The **pharyngeal bars** or "gill" bars of the pharynx bound the pharyngeal or "gill" slits used in filter-feeding. The pharynx is attached to the body in the mid-dorsal line but hangs free into the atrial cavity. Ventrally, the pharyngeal bars attach to the **endostyle.** Because of the delicate nature of the pharynx, lancelets attempt to keep larger particles out of the pharynx—when they are unsuccessful, "cough" reflexes mediated by giant nerve fibers are used to eject detritus from the mouth.

11. Relate the structures you find in the cross section to those seen in your whole mount. Be sure that you understand the spatial relations of the pharynx and atrium and how water is passed through these structures.

    In the cross section, you may be able to identify several vessels of the circulatory system. This is a closed system with large sinuses but without true capillaries. The blood is acellular and oxygen is carried in solution rather than bound to a blood pigment. There is no "heart" as such, but several major vessels, including the "ventral aorta," located under the endostyle, pulsate and assist a series of contractile bulbules (found at the base of alternate pharyngeal bars) to pass blood dorsally where it is collected by two vessels (**radices**) that join to form the "dorsal aorta." These vessels, coupled with a lateral return system of sinuses and vessels surrounding the gut and the hepatic diverticulum, suggest a circulatory pattern very similar to that of vertebrates. Near the dorsal vessels, clusters of excretory



(a)



(b)

Figure 27C-1 *(a) Internal anatomy of a lancelet. These animals are filter-feeders that spend most of their lives buried in the bottom sediment of shallow marine environments. Only the "head" and mouth protrude above the bottom. Seawater taken into the pharynx passes through the pharyngeal slits. Oxygen from the seawater diffuses into the pharyngeal bars, which are richly supplied with blood vessels. A mucous net between the pharyngeal bars collects particles of debris and small organisms that are then passed from the pharynx into the gut. (b) A cross section through the pharyngeal region of a lancelet. (After Malcolm Jollie,* Chordate Morphology, *p. 7, Krieger, Melbourne, FL, 1973.)*

structures contain nephridia with flagella. These structures, called **solenocytes,** are intermediate between the protonephridia found in some larvae of smaller invertebrates and the metanephridia of larger animals.

c. *Cephalochordates show no signs of an enlargement of the nerve tube and associated sense organs usually found in the anterior end of the chordate nervous system. Why might this be so?*

✓ EXERCISE D Vertebrates—Fishes

The three groups of vertebrates you will study in this exercise are all fishes: the Agnatha, Chondrichthyes, and Osteichthyes. Some of the features that characterize these groups can be demonstrated by a study of the external morphology of a lamprey, a shark, and a teleost (bony fish). Also see Laboratory 37, Table 37-1, for a summary of structural and functional adaptations of vertebrates, including fishes.

The class Agnatha includes all jawless fishes. According to the fossil record, these are the oldest known fish. At one time, they had bony skeletons, but the skeletons of modern representatives, the lampreys and lungfishes, are composed of cartilage. Lampreys feed upon their prey by attaching to the skin and sucking blood from soft tissues—that is, the adult forms are parasites.

Modern Chondrichthyes include the rays and sharks (Selachii), of which the dogfish shark, *Squalus,* is one of the smallest members, and the chimeras (Holocephali).

The Osteichthyes include modern fish. Most have **bony endoskeletons.** The class includes many popular marine and freshwater fishes such as trout, bass, salmon, and tuna—all members of the higher bony fishes, the Teleostei. Unlike the cartilaginous fishes, which have external gill slits, osteichthyans have gills covered by a flap, or **operculum.**

Objectives

☐ State several distinguishing characteristics of each of the three classes of aquatic vertebrates by examining some features of their external morphology.

Procedure

1. Examine the lamprey, dogfish shark, and teleost fishes on display in the laboratory. Complete Table 27D-1 as you proceed.
2. Use a hand lens to study the skin (integument) of each specimen. Describe the surface features that characterize the skin and record these in the table.
3. Identify the **dorsal, caudal, pectoral, pelvic,** and **anal fins** on your specimens.

   a. *Which fishes have paired fins?* ______________________

   b. *How does the structure of the fins in the dogfish shark differ from the fin structures of the other two classes?* ______________________

   ____

4. Examine the head of each specimen. Look for the **external nares** (nostrils) of the dogfish shark. How are they arranged? Probe one of the nostrils with a dissecting needle. You should be able to feel a short passageway that makes no connection with the pharynx. The nares of fish are not used in respiratory gas exchange, but instead detect the presence of dissolved chemicals in the water—their role is in olfaction, the sense of smell.
5. Look for a single nostril on the surface of the head of the lamprey. Find the external nares of the teleost fish. In Table 27D-1, describe the arrangement of nares on the head of each fish.

Table 27D-1 Comparison of the External Morphology of Three Fishes

	Lamprey	Dogfish	Teleost
Features of the integument			
Number of fins (paired or unpaired)			
Location of fins			
Number of external nares			
Position of external nares			
Texture, size, and shape of the teeth			
Position of the teeth inside the mouth			
Number of gill slits			
Location of gill slits (covered or uncovered)			
Other distinguishing features observed			

6. In the adult lamprey, one set of "teeth" is on the lateral walls of the large funnel at the anteroventral end of the organism. The lamprey uses these teeth to penetrate the skin of its prey. Additional teeth surround the mouth at the rear of the funnel, and another set of teeth is on the tongue, which is rolled up inside the mouth. Feel these "horny" teeth composed of cornified epidermal cells and describe their size and shape in Table 27D-1.
7. Compare the teeth of the lamprey with the teeth of the dogfish shark.
8. Examine the teeth of the teleost fish. The teeth of both the dogfish shark and the teleost fish are made of **dentine,** a type of bone not supplied with blood vessels.

   c. *How can the relative positions of the nares and the mouth in a lamprey and a dogfish be explained in terms of their method of feeding?* ______________________________

   ____

9. External gill slits in cartilaginous fishes occur in a lateral series near the back of the head. Water is taken in through the mouth, passed over the gills, and expelled through the gill slits. Record the number of these slits in the lamprey and the dogfish shark. In the dogfish shark, the first gill slit is reduced to a small opening, the **spiracle,** located above the angle of the jaw. In higher vertebrates, this gill slit becomes the outer and middle ear and the eustachian tube.
10. Using a blunt probe, gently move aside the operculum of the teleost fish. Sketch the arrangement of the gills in the space below.

11. When your data table is complete, and you are finished with the three specimens, cover the specimens with wet paper towels so they will not dry out.

✓ EXERCISE E Amphibians and Reptiles

Amphibians are incompletely adapted to terrestrial environments. Even in those species that possess lungs, some gas exchange must occur through the skin. This requires that the skin be kept moist, a condition that prevents amphibians from living in a strictly terrestrial environment.

Amphibians also depend on water for reproduction. In many amphibians, such as the frog, eggs are laid in freshwater ponds or streams and are fertilized externally. The tadpole larva is a swimming stage that undergoes metamorphosis into an adult frog. Frogs may live on land, but they must return to the water to lay their eggs.

Unlike amphibians, most reptiles lead strictly terrestrial lives. Their tough, horny skin need not be kept moist and actually retards water loss. Reptilian eggs have hard or leathery shells and contain all the food and water needed for complete embryonic development.

See Laboratory 37, Table 37-1, for a summary of structural and functional adaptations of vertebrates, including amphibians and reptiles.

Objectives

☐ Compare amphibian and reptilian adaptations to living on land.

Procedure

1. Feel the skins of amphibians and reptiles on display (use live specimens if they are available).
   a. How would you describe them? ______________________________

   ____

   b. Which type of skin offers more protection from desiccation in a terrestrial environment?

   ____

   c. The integument of reptiles is formed from a number of epidermal plates or scales. What is the general shape of these scales? ______________________________

   d. In what regions of the reptile's body do the scales become very small and numerous?

   ____

   e. What are the advantages of this arrangement for mobility? ______________________________

   ____

2. Compare the limbs and feet of the amphibians and reptiles on display.
   f. What are the general differences? ______________________________

   ____

   g. What structures of amphibian limbs betray their aquatic heritage?

   ____

   h. How are the amphibian and reptilian limbs oriented with respect to the sides of the body?

   ____

   i. For what locomotor activities would such an arrangement be best suited?

   ____

3. Compare the arrangement of bones in the forelimbs of the turtle and the frog shown in Figure 27E-1a, b.

j. How do the two forelimbs differ in number and kinds of bones present?

____

k. How does the angle of the joint between the upper and lower part of the leg differ between the frog and the turtle? ____

____

4. Compare the arrangement of bones of the hindlimbs of the frog and turtle as shown in Figure 27E-1c, d.

l. How do the hindlimbs differ in number and kinds of bones present?

____

m. What is the major difference between the hindlimbs of these two animals?

____

n. How is the difference in the angle of their hindlimbs related to the difference in the locomotor behavior of frogs and turtles? ____

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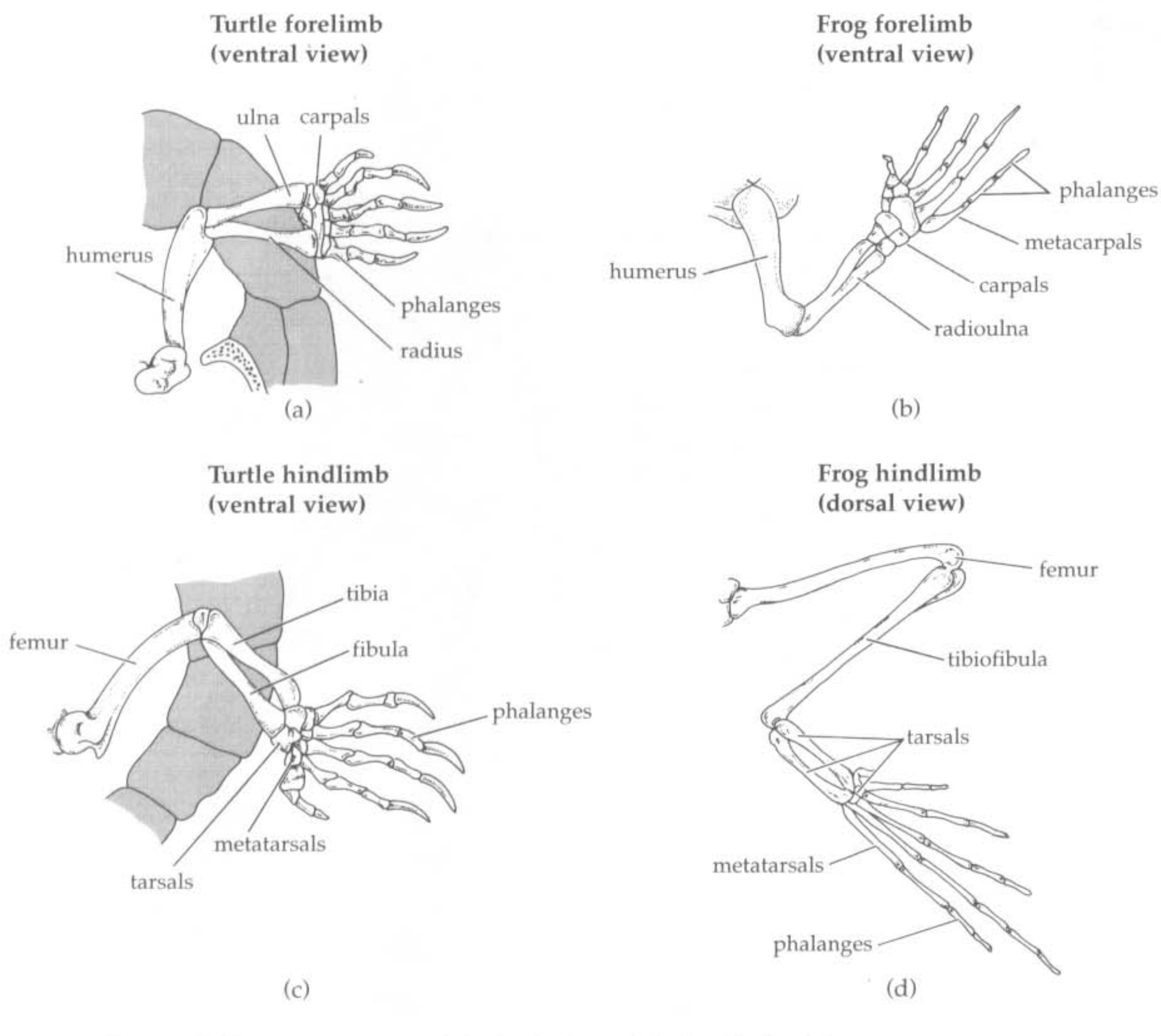


Figure 27E-1 *Comparison of the forelimbs and the hindlimbs of the turtle and the frog.*

5. If amphibian and reptile eggs are available, examine them under the dissecting microscope.

o. How do they differ in size and texture? ____________________

p. What surrounds and protects the frog egg? ____________________

q. How do the types of egg laid by amphibians and reptiles relate to the mode of fertilization and the type of environment in which the egg must hatch? ____________________

____

✓ EXERCISE F The Avian and Mammalian Skeletal Systems

Birds and mammals trace their ancestry to groups within the class Reptilia. Inferences about these relationships are supported by observations of similar skeletal structures—many of the elements in both groups are **homologous,** or related by descent. Of course, the avian skeleton shows many specializations and constraints related to flight, and the mammalian skeleton is more generalized and adaptable to different modes of locomotion.

See Laboratory 37, Table 37-1, for a summary of structural and functional adaptations of vertebrates, including birds and mammals.

Figure 27F-1 *(a) Human skeleton. (b, opposite) Skeleton of a bird.*

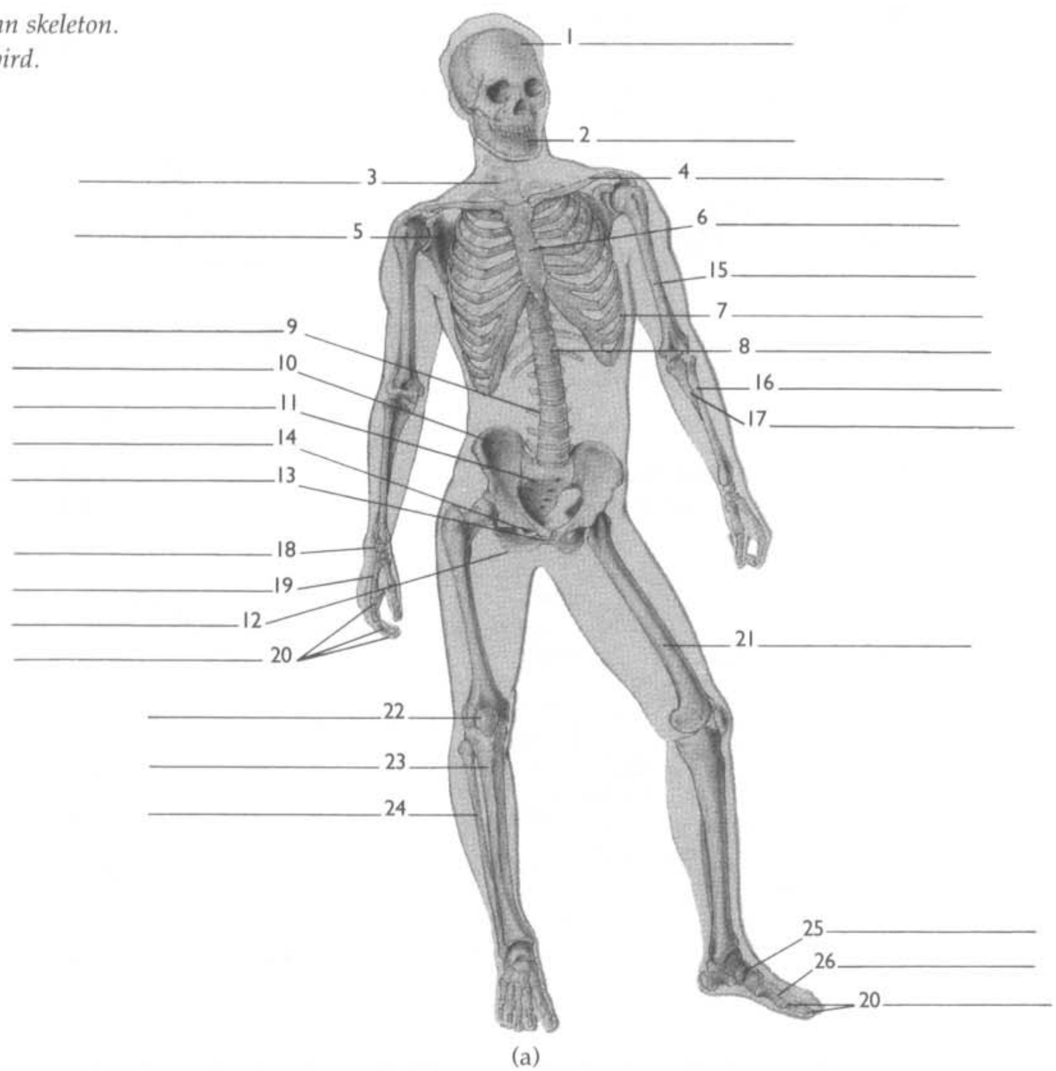
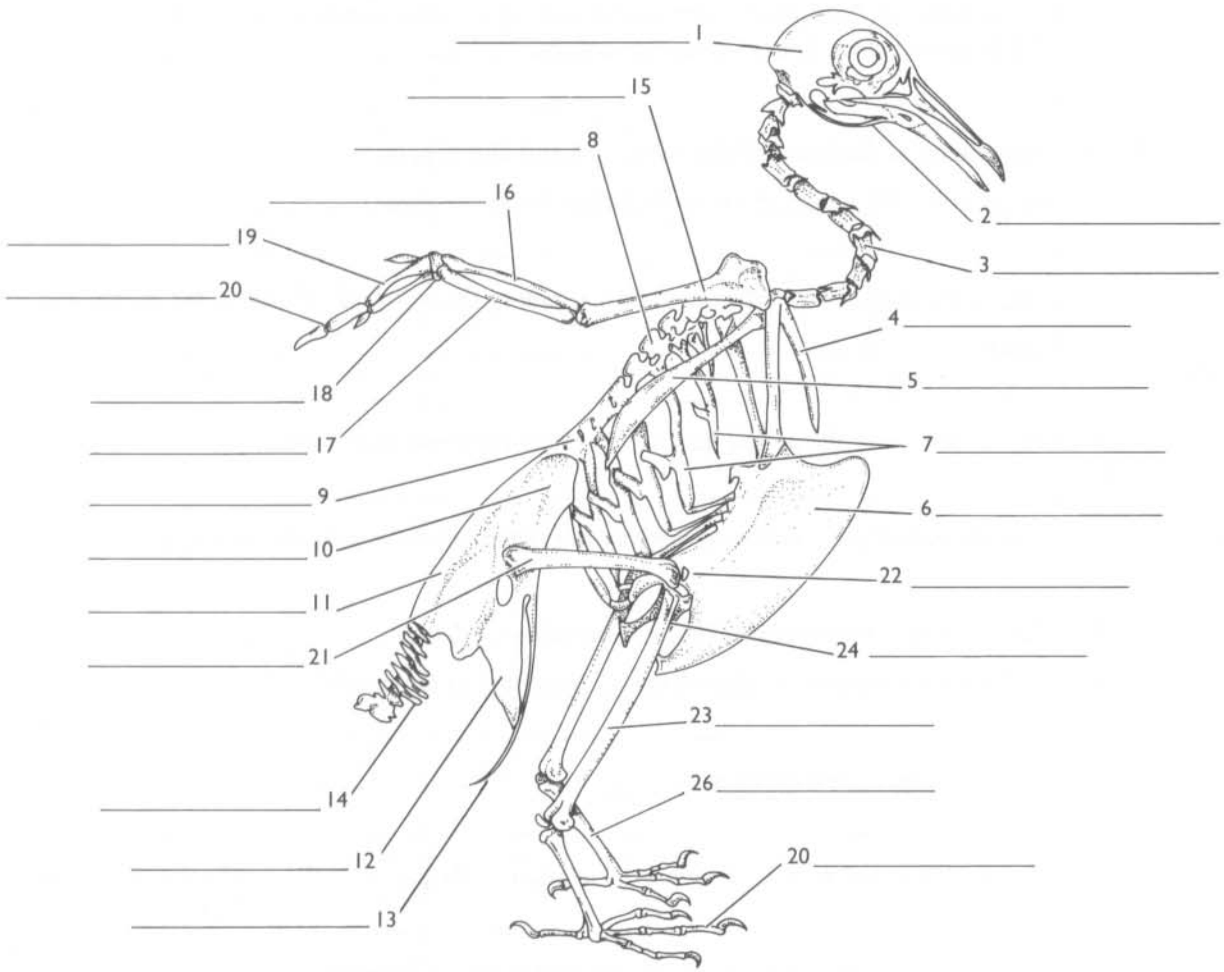


Table 27F-1 Bones of the Mammalian and the Avian Skeletons

The Axial Skeleton			
1	Skull	8	Thoracic vertebra
2	Mandible	9	Lumbar vertebra
3	Cervical vertebra	10	Ilium
4	Clavicle	11	Sacral vertebra (synsacrum in bird)
5	Scapula	12	Ischium
6	Sternum	13	Pubis
7	Ribs	14	Coccyx in human (caudal vertebrae in bird and in cat)
The Appendicular Skeleton			
15	Humerus	21	Femur
16	Radius	22	Patella
17	Ulna	23	Tibia (tibiotarsus in bird)
18	Carpal	24	Fibula
19	Metacarpal (carpometacarpal in bird)	25	Tarsal (for bird, see tibiotarsus)
20	Phalanges	26	Metatarsal (tarsometatarsus in bird)



(b)

Objectives

- ☐ Compare a representative avian skeleton with that of a representative mammal.
- ☐ Relate the skeletal morphology in birds and mammals to a single ancestral pattern.

Procedure

1. Study a mammalian skeleton (cat or human) and an avian skeleton (pigeon). If skeletons are not available, refer to Figure 27F-1 throughout this exercise.
2. Locate all of the bones listed in Table 27F-1 in both skeletons. Note that vertebrate skeletal systems are divided into (1) the **axial skeleton,** including the skull and spinal column, and the rib cage and sternum, and (2) the **appendicular skeleton,** including the bones of the forelimbs and hindlimbs and their connections to the axial skeleton.
3. Compare the size of the skulls of the pigeon and the mammal.
   a. Do they appear to differ in size relative to the size of each animal's entire skeleton?

   ____
4. Compare a cut bone from a pigeon (or chicken) with that of a mammal. Use bones of approximately the same diameter and length.
   b. Which appears to be lighter in weight? ______________ *Explain.*

   ____

   c. Certain bones in the pigeon contain extensions of air sacs, which are part of the respiratory system. What feature of avian bones makes this possible? ______________

   ____
5. Examine the axial skeleton of the mammal and the pigeon.
   d. List, in order, the names of the major categories of vertebrae. ______________

   ____

   e. Compare the number of vertebrae in each region of the vertebral column in the pigeon and the cat or human. ______________

   ____

   f. Why do you think the pigeon has more cervical vertebrae than a mammal?

   ____

   g. Name the fused bones in the pigeon that are commonly known as the wishbone.

   ____

   h. Where are these bones located in the mammalian skeleton? ______________

   i. What are the names of the three bones of the pelvis in mammals?

   ____

   Name the homologous bones in the pigeon ______________

   ____

   j. Describe the orientation of the femur in relation to the pelvis in the mammal and the bird.

   ____

   k. How does this difference relate to the different modes of locomotion? ______________

   ____

6. Locate the bones of the pigeon's wing that correspond to the carpals, metacarpals, and phalanges in mammals. Compare the numbers of such bones in the two groups. The reduced number of bones in the pigeon's wing results from the fusion of adjacent bones.

   l. Why would this arrangement be of advantage to the pigeon? ______________________

   ____

Subphylum or Class	Chordate Characteristics Present	Chordate Characteristics Missing	Invertebrate or Vertebrate	Distinguishing Characteristics	Adaptations to Environment
Urochordata					
Cephalochordata					
Agnatha					
Chondrichthyes					
Osteichthyes					
Amphibia					
Reptilia					
Aves					
Mammalia					

7. Locate the bones of the pigeon's hindlimb that correspond to the mammalian tarsals, metatarsals, and phalanges. Note that the number of these bones is reduced in the bird.

   m. Suggest why the pattern of hindlimb structure in birds differs from that in mammals.

   ____

   ____

Laboratory Review Questions and Problems

1. Define "homologous structure." Give three examples of homologous structures studied in the laboratory.

2. Complete the table on page 27-17. List representative organisms under the appropriate group in the left-most column.