The Evolution of Animal Diversity 18

Human beings are animals, and our species evolved in an environment filled with animal life. Even now, when many humans live in cities, other species of animals affect our lives in many ways. We eat some animals, such as clams, chickens, and cattle, and make useful products from their shells, hides, fur, and bones. Bees make honey, and their cousins the mosquitoes make us miserable. Animals still work for humans in many parts of the world, tilling fields and carrying heavy loads. Worms enrich the soil, and coral animals build reefs that protect harbors. We choose some animals to live with us as pets. We marvel at the beauty of tropical fish and rain forest butterflies and at the size and strength of whales and crocodiles. Only in the last century have humans begun to appreciate the evolutionary relationships among all these fascinating animals and our own place in this story. The evolution of animal life is the subject of this chapter.

Organizing Your Knowledge

Exercise 1 (Module 18.1)

This module describes how we "draw the line" between animals and other organisms. Five major groups of living things are listed below. Use colored pens or pencils to draw lines separating the groups on the basis of the following characteristics.

1. Draw a black line between organisms that have simple cells and those that have complex cells (with organelles). Write "simple cells" on one side of the line and "complex cells" on the other.
2. Draw a blue line between organisms that are primarily unicellular and those that are multicellular. Label these groups.
3. Separate heterotrophic and autotrophic multicellular organisms with a green line, and label each group.
4. Draw a red line between those heterotrophs that ingest their food and then digest it, and those that digest food outside their bodies and then absorb the nutrients. Label each. On the animal side of the line, also note that animals have unique extracellular proteins and intercellular junctions, lack cell walls, are diploid (except for eggs and sperm), have unique embryonic stages, and most have muscle and nerve cells.

Plants Fungi Animals

Protists

Prokaryotes

Exercise 2 (Module 18.2)

Using Module 18.2 as a guide, sketch and briefly describe how animals may have evolved from colonial protists.

Exercise 3 (Modules 18.3 - 18.4)

Sponges and cnidarians are the simplest animals. Complete the following description of these two phyla by filling in the blanks.

Sponges, phylum [1]_____, and cnidarians, phylum [2]_____, are both simple animals. Most sponges and cnidarians live in the [3]_____, but some are found in fresh water. Many sponges and all cnidarians are characterized by [4]_____ symmetry. This means their body parts are arranged in a circle around a central axis.

Sponges are by far the simpler of the two animals. A sponge is a simple tube perforated by tiny [5]_____. The body wall consists of [6]_____ layers of cells. The outer layer functions to protect the sponge. A gelatinous middle layer contains wandering amoebocytes and a skeleton made of flexible spongin or more rigid mineral-containing particles. The sponge's inner layer consists of cells called choanocytes bearing [7]_____, which move to create a current of water that [8]_____ the sponge through the small pores and [9]_____ through a large central opening. The choanocytes trap [10]_____ from the water and then engulf them by phagocytosis. The amoebocytes pick up food from the choanocytes and distribute it to other cells. They also make the [11]_____ fibers.

Unlike other animals, sponges lack both [12]_____ and muscles. In fact, their cells are relatively unspecialized, so the cell layers are not considered true [13]_____. It is likely that sponges are early offshoots of ancient colonial [14]_____ called choanoflagellates.

Cnidarians—animals such as [15]_____, sea anemones, and corals—are a bit more complicated. They have a [16]_____ cavity, muscles, and a [17]_____ system that enables them to respond to stimuli and coordinate muscle action. Unlike sponges, their cells are organized into [18]_____, groups of cells adapted to perform specific functions. But unlike more complex animals, they have only [19]_____ tissue layers, and most of their activities are carried out at the tissue level, not by the organs and [20]_____ of more complex creatures.

Cnidarians are radially symmetrical and come in two shapes. A [21]_____ is a tube with tentacles radiating from one end. It is usually fixed in place. A [22]_____ is a disk with a fringe of tentacles on the edge. [23]_____ are medusas and are able to move about in the water. Some cnidarians, such as the freshwater form called a [24]_____, illustrated in the text, exist only in the polyp form; some cnidarians exist only as medusae. Others have both medusa and polyp stages in their life cycles.

A cnidarian captures small prey and pushes it into its mouth with its [25]_____. Special cells called [26]_____ on the tentacles (characteristic only of cnidarians) sting and entangle the prey. The mouth of a polyp is on top of the body, in the center of the tentacles. A jelly's mouth is [27]_____, in the center of the umbrella. The mouth leads to a digestive sac called the [28]_____ cavity. Food is digested here, and fluid in the cavity circulates food particles around the body. The fluid in the cavity also keeps the flimsy body "inflated" and gives the cnidarian its shape. Because the gastrovascular cavity has only one opening, [29]_____ are expelled through the mouth. This arrangement is called an [30]_____ digestive system.

Exercise 4 (Module 18.5)

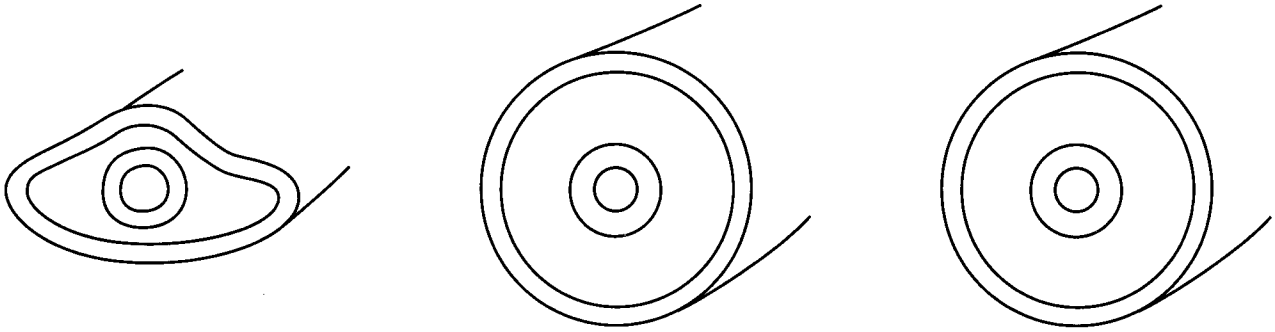
The development of bilateral symmetry was a major step in animal evolution. Compare animals having bilateral symmetry with those having radial symmetry by completing the following table.

Animals with Radial Symmetry	*Animals with Bilateral Symmetry*
Examples: some sponges, cnidarians	1.
2.	Right and left sides
3.	Dorsal and ventral surfaces
No anterior or posterior end	4.
No distinct head	5.
6.	Move actively through environment

Exercise 5 (Module 18.7)

Most animals have a body cavity, a space between the digestive tract and the body wall. (There are many advantages to having a body cavity; these are reviewed in the "Testing Your Knowledge" section.) There are two kinds of body cavities: A pseudocoelom is in direct contact with the digestive tract, and a middle layer derived from mesoderm lines the body covering. A coelom is a space within the mesoderm-derived layer, which covers the digestive tract and lines the body wall. The diagrams below show the body covering and the digestive tract of three animals. Complete the diagrams by sketching in the middle (mesoderm-derived) tissue layer. Label the layers and color the *body covering* blue, the *digestive tract* yellow, and the *middle tissue layer* red.

○ Body covering (from ectoderm) ○ Digestive tract (from endoderm) ○ Middle tissue layer (from mesoderm)



Flatworm Roundworm Earthworm

Exercise 6 (Modules 18.4, 18.6, 18.8)

Review and compare the structures and lifestyles of cnidarians, flatworms, and roundworms by completing this chart.

	Cnidarians	*Flatworms*	*Roundworms*
1. Phylum name			
2. Examples			
3. Type of body symmetry			
4. Body shape(s)			
5. Body cavity			
6. Digestive tract			
7. Where they live			
8. Importance to humans			

Exercise 7 (Module 18.9)

This module discusses several of the structural and functional characteristics of mollusks. Match each of the statements on the right with a body structure on the left.

A. Coelom
B. Radula
C. Gill
D. Foot
E. Mantle
F. Circulatory system
G. Shell

____ 1. Modified to form a lung in land snails
____ 2. Secretes the shell
____ 3. Used by a clam to capture food
____ 4. Divided into hinged halves in bivalves
____ 5. Functions in locomotion in most mollusks
____ 6. Extracts oxygen from the water
____ 7. Rasping organ used to scrape up food
____ 8. Distributes nutrients, water, and oxygen around the body
____ 9. Missing or internal in squids and octopuses
____ 10. Outgrowth of the body surface that drapes over the animal
____ 11. Modified to form tentacles in cephalopods
____ 12. Small cavities around heart, kidney, and reproductive organs
____ 13. Long projections on the back of a sea slug
____ 14. "Crawling" movements of this structure propel gastropods
____ 15. Used by a clam for digging and anchoring in mud or sand
____ 16. Shoots out a jet of water to propel a squid
____ 17. Eyes of a scallop are along the edge of this structure
____ 18. A one-piece coiled structure in snails
____ 19. Lacking in terrestrial snails and slugs
____ 20. The chambered nautilus has this, but the octopus does not

Exercise 8 (Modules 18.10 - 18.11)

These two modules discuss the importance of segmentation and annelids, the segmented worms. Read the modules and review them by filling in the blanks.

The next time you dig up an earthworm, or see one wriggling on the sidewalk, pause to appreciate its beauty and complexity. Earthworms are segmented worms of the phylum [1]_____. The name, which means "ringed," refers to the repeating ringlike [2]_____ that make up the worm's body. There are three main groups of annelids. Most live in the [3]_____, but many species live in [4]_____ and moist soil.

The most distinctive external characteristic of annelids is segmentation. Internally, each segment is separated from adjacent ones by [5]_____. The [6]_____ system includes clusters of nerve cells in each segment. There are blood vessels serving each segment, and [7]_____ structures, which dispose of fluid wastes, are also repeated. The main blood vessels and the [8]_____ system are unsegmented.

What are the advantages of a segmented body? It probably is an adaptation to facilitate [9]_____. It gives the body greater [10]_____ and [11]_____. This enables an earthworm to burrow, obtaining nutrients from the soil that passes through its digestive tract. Earthworms stir up the soil, and their [12]_____ improve its texture.

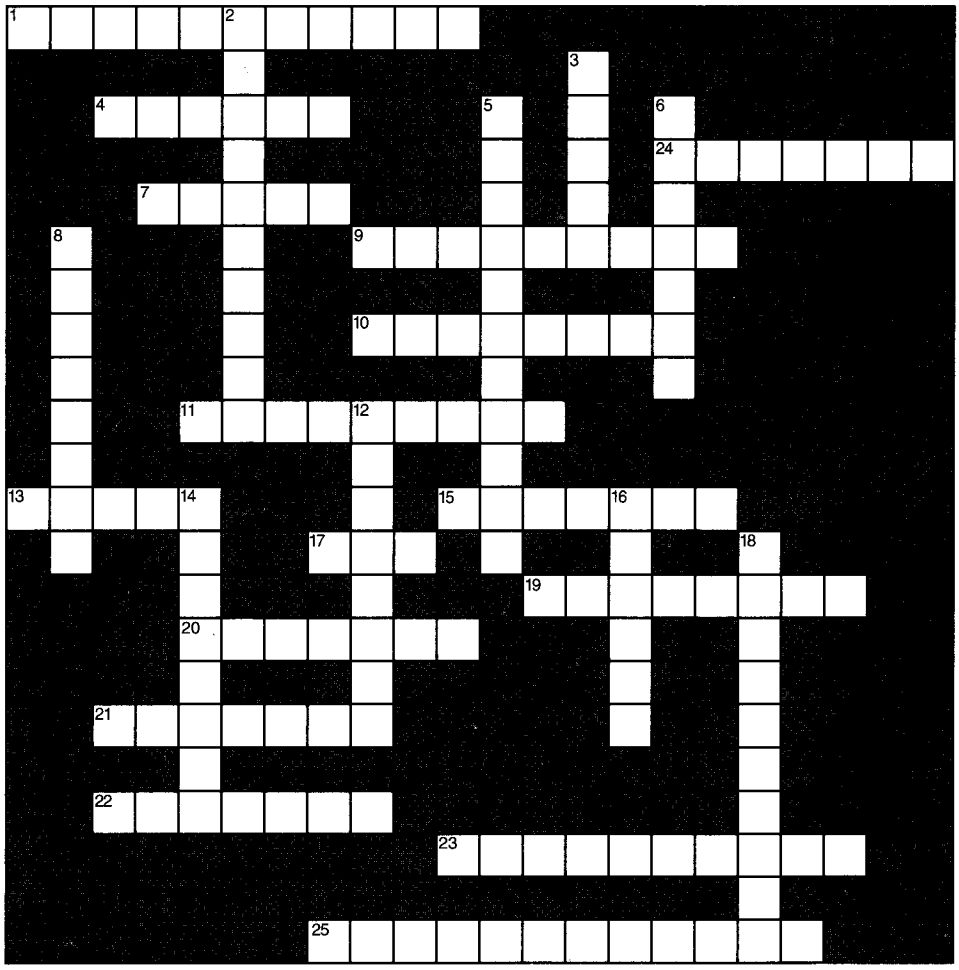
The largest group of annelids are the [13]_____. Most of these worms live in the [14]_____, where they wriggle along the bottom, burrow in the mud, or construct protective [15]_____. The mobile polychaetes move by means of segmental [16]_____. In tube-dwellers, these appendages are modified for [17]_____.

The third group of annelids are the [18]_____. Some suck [19]_____, but most are free-living [20]_____ that eat small animals. Most leeches live in [21]_____, but there are some land dwellers. Leeches have sharp [22]_____, and they secrete an anesthetic that enables them to slice painlessly through the skin and an anticoagulant that keeps blood flowing freely. The latter substance may be useful in preventing [23]_____.

Annelids are not the only segmented animals. [24]_____ are segmented; this is seen clearly in the abdomen and in the thorax, where wings and legs are repeated. Animals with backbones are also segmented. In humans, segmentation is most clearly seen in the backbone, formed from a series of bones called [25]_____, and in the abdominal [26]_____. How did segmentation evolve? The new field of [27]_____ seeks to understand the changes in developmental genes that might answer this question.

Exercise 9 (Modules 18.12 – 18.13)

These modules concern phylum Arthropoda, a large and important group of invertebrates. Review your knowledge of arthropods by completing the crossword puzzle.



Across

1. Crabs and lobsters are ____.
4. The arthropod exoskeleton is made of ____ and protein.
7. An insect has ____ pairs of legs.
9. The ____ crab is a "living fossil" related to spiders.
10. ____ are sensory appendages on the head.
11. ____ are marine filter-feeding crustaceans.
13. Insects are the only invertebrates with ____.
15. Arthropods have ____ appendages.
17. A spider might hunt insects or catch them in a ____.
19. The ____ is an arachnid with pincers and a sting at the end of its tail.
20. ____ is shedding the old exoskeleton and growing a larger one.
21. A lobster uses its ____ for defense.
22. The ____ are the most diverse group of arthropods.
23. ____ are multilegged carnivores.
24. ____ are the largest order of animals.
25. An ____ is a biologist who study insects.

Down

2. Crabs, grasshoppers, and tarantulas are all representatives of phylum ____.
3. Scorpions, spiders, ____, and mites are all arachnids.
5. Every arthropod has a hard external skeleton called an ____.
6. An insect's body consists of head, thorax, and ____.
8. Many people are ____ to dust mites.
12. Arthropods were thought to be closely related to ____, but these two phyla probably evolved from different bilateral ancestors.
14. The arthropod body consists of groups of ____.
16. An insect's wings and legs are attached to its ____.
18. ____ are wormlike plant-eaters with many short legs.

Exercise 10 (Module 18.14)

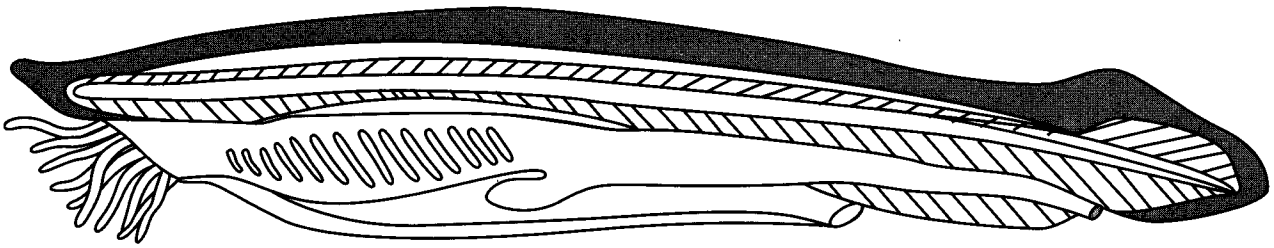
Web/CD Activity 18A *Characteristics of Invertebrates*

Echinoderms are a unique animal phylum. Circle the statements below that relate to echinoderms, and cross out statements that are not relevant to echinoderms.

1. Adults have radial symmetry
2. Live in salt water and fresh water
3. Larvae have radial symmetry
4. Have spines embedded under the skin
5. Most closely related to cnidarians
6. Lack segmentation
7. Bend jointed appendages to move
8. Good at regeneration
9. Have a water vascular system
10. Move and feed with tube feet
11. Adults have bilateral symmetry
12. Examples: sea urchins and sea stars
13. Live only in salt water
14. Larvae have bilateral symmetry
15. Have an endoskeleton
16. Most closely related to chordates
17. Are segmented
18. Examples: clams and snails

Exercise 11 (Module 18.15)

Like all vertebrates, we are chordates, but so are some very simple animals that are not vertebrates—the lancelets and tunicates. All chordates, from tunicates to truck drivers, share four key chordate characteristics. Label these four characteristics on the drawing of a lancelet below.



Exercise 12 (Modules 18.16 - 18.22)

Web/CD Activity 18B *Characteristics of Chordates*

Vertebrates have a skull and backbone made of bone or cartilage. Most have appendages with bony supports. These modules discuss the seven major groups of vertebrates. Match each statement below with the proper group(s) of vertebrates. A few questions have more than one answer.

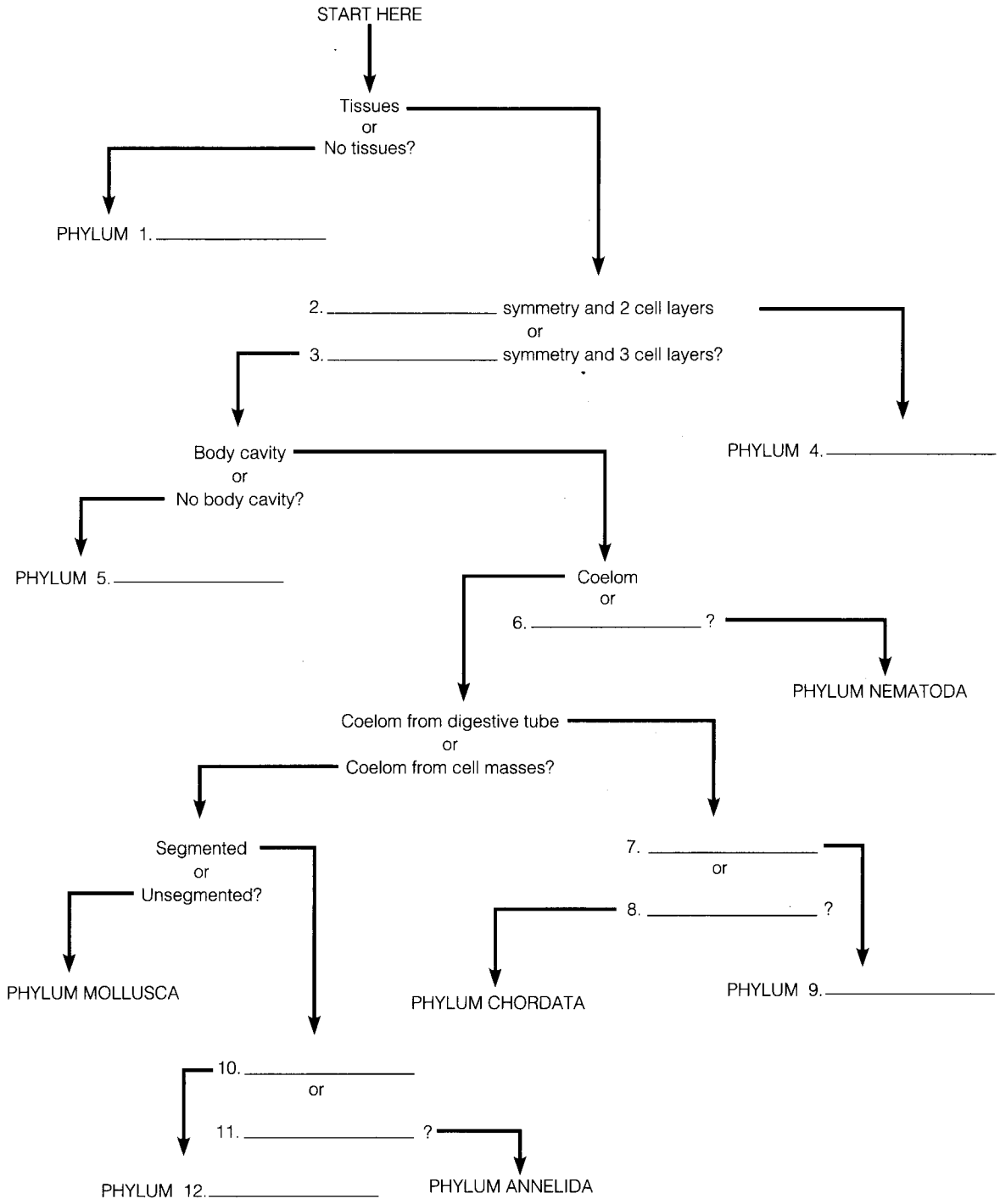
A. Agnathans
B. Cartilaginous fishes
C. Bony fishes
D. Amphibians
E. Reptiles
F. Birds
G. Mammals

____ 1. The first vertebrates on land
____ 2. Two endothermic groups of vertebrates
____ 3. First vertebrates with amniotic eggs
____ 4. Have tadpole larvae
____ 5. Gave rise to the reptiles
____ 6. Have hair
____ 7. Lack jaws
____ 8. Have an operculum that helps pump water over their gills
____ 9. Three groups that are aquatic
____ 10. Proliferated after the dinosaurs died out
____ 11. Trout, bass, and perch
____ 12. The first vertebrates with legs
____ 13. Feed their young milk
____ 14. Two groups that evolved from reptiles
____ 15. Sharks and rays
____ 16. Class Aves
____ 17. Live mostly on land but lay eggs in the water
____ 18. Have a swim bladder that provides buoyancy
____ 19. The young of most in this group develop inside their mothers
____ 20. Probably evolved from a kind of dinosaur
____ 21. Two groups with paired fins
____ 22. The most primitive vertebrates
____ 23. Placentals, marsupials, and monotremes
____ 24. The majority of vertebrates are in this group
____ 25. Human beings are in this group
____ 26. Populations are dramatically declining around the world
____ 27. The largest land animals ever were in this group
____ 28. Lampreys
____ 29. Class Chondrichthyes
____ 30. Frogs and salamanders

Exercise 13 (Module 18.23 and Summary)

Web/CD Activity 18C *Animal Phylogenetic Tree*

Module 18.23 summarizes the evolutionary relationships and characteristics of the major phyla of animals. Suppose you found an animal and wanted to know to which phylum it belonged. You could use what biologists call a "key," a series of questions that leads you to the animal's identity. Such a key is given below, in the form of a flowchart. Before you can use this key, you will need to complete it. Some questions and phylum names are given; others are missing. Using information from this chapter, complete the key. (You may then want to try it out by "keying out" an animal.)



Testing Your Knowledge

Multiple Choice

1. You would expect to find the greatest number of phyla of animals ____ and the greatest number of species of animals ____ .
   a. on land . . . in the sea
   b. in fresh water . . . in the sea
   c. in the sea . . . on land
   d. in the sea . . . in fresh water
   e. on land . . . in fresh water

2. Which of the following is *not* a characteristic of all animals?
   a. They are multicellular.
   b. They have tissues, organs, and organ systems.
   c. They are eukaryotes.
   d. They ingest their food.
   e. They are heterotrophic.

3. Animals probably evolved from colonial protists. How do animals differ from these protist ancestors?
   a. The protists were prokaryotic.
   b. Animals have more specialized cells.
   c. The protists were heterotrophic.
   d. The protists were autotrophic.
   e. Animals are able to reproduce.

4. A ____ is the simplest animal discussed in this chapter to have ____ .
   a. sponge . . . bilateral symmetry
   b. flatworm . . . a body cavity
   c. roundworm . . . a complete digestive tract
   d. jelly . . . a complete digestive tract
   e. snail . . . a body cavity

5. Which of the following animals does *not* have a body cavity?
   a. flatworm
   b. ant
   c. mouse
   d. clam
   e. earthworm

6. Which of the following phyla include numerous parasites and pests?
   a. roundworms and flatworms
   b. mollusks and roundworms
   c. annelids and flatworms
   d. annelids and roundworms
   e. mollusks and flatworms

7. Which of the following animals is *not* segmented?
   a. leech
   b. snail
   c. human being
   d. lobster
   e. salmon

8. Phylum _____ includes the largest number of species.
   a. Mollusca
   b. Arthropoda
   c. Annelida
   d. Chordata
   e. Echinodermata

9. The water vascular system of a sea star functions in
   a. movement of the tube feet.
   b. circulation of nutrients around the body.
   c. pumping water for swimming movements.
   d. waste disposal.
   e. keeping all parts of the body moist at low tide.

10. A ____ is a chordate but not a vertebrate.
    a. lamprey
    b. shark
    c. lancelet
    d. sea star
    e. frog

11. How do lampreys differ from other vertebrates?
    a. They have a skeleton made of flexible cartilage.
    b. They do not have jaws.
    c. They do not have paired appendages (fins or legs).
    d. all of the above
    e. b and c only

12. The first vertebrates to live on land were
    a. agnathans.
    b. reptiles.
    c. amphibians.
    d. cartilaginous fishes.
    e. mammals.

13. There are three major groups of mammals, categorized on the basis of their
    a. size.
    b. habitat.
    c. method of locomotion.
    d. teeth and digestive system.
    e. method of reproduction.

14. Zoologists have traditionally placed chordates and echinoderms on one major branch of the animal phylogenetic tree, and mollusks, annelids, and arthropods on another major branch. Which of the following is the basis for this separation into two branches?
    a. whether or not the animals have a skeleton
    b. type of symmetry
    c. whether or not the animals have a body cavity
    d. how the body cavity is formed
    e. whether or not the animals are segmented
15. Which of the following are most numerous and successful on land?
    a. mollusks and chordates
    b. annelids and arthropods
    c. arthropods and chordates
    d. annelids and chordates
    e. mollusks and arthropods
16. Which of the following is *not* a hypothesis suggested to explain the Cambrian explosion of animal diversity?
    a. increase in atmospheric oxygen levels
    b. development of more complex predator-prey relationships
    c. evolution of new regulatory/developmental genes
    d. movement of animals onto land
    e. All of the above are hypothesis suggested to explain the Cambrian explosion

Essay

1. Describe the characteristics that separate animals from the other kingdoms of living things.
2. Describe some of the characteristics that biologists consider important when deciding the phylum into which an animal should be classified.
3. What kinds of animals have a body cavity? What kinds lack a body cavity? Describe some of the advantages of having a body cavity.
4. Describe how the mantle, mantle cavity, and shells of snails, clams, and squids are modified for their different ways of life.
5. In terms of numbers of individuals and numbers of species, it could be argued that insects are the most successful creatures on Earth. What are some characteristics that have made them so successful?
6. The spadefoot toad of the southwestern United States is an unusual amphibian; it is capable of surviving in the desert. Few amphibians can tolerate dry desert conditions, but many reptiles—horned toads, rattlesnakes, and desert tortoises—thrive in hot, arid regions. In what ways are reptiles better adapted to life in the desert than amphibians?
7. Describe adaptations of birds for flight.

Applying Your Knowledge

Multiple Choice

1. Compare the two phylogenetic trees in Module 18.23. The tree based on molecular data greatly revises which of the following relationships?
    a. cnidaria and all other phyla
    b. annelids and mollusks
    c. sponges and all other phyla
    d. annelids and arthropods
    e. chordates and echinoderms
2. Which of the following includes the largest number of species?
    a. animals that are segmented
    b. animals with radial symmetry
    c. animals with a body cavity
    d. animals that are unsegmented
    e. animals with a backbone
3. Which of the following is radially symmetrical?
    a. a doughnut
    b. an automobile
    c. a spoon
    d. a peanut butter sandwich
    e. a wristwatch
4. A marine biologist dredged up a small animal from the bottom of the ocean. It was uniformly segmented, with short, stiff appendages and soft, flexible skin. It had a complete digestive system and a circulatory system but no skeleton. Based on this description, this animal sounds most like
    a. a lancelet.
    b. a crustacean.
    c. a mollusk.
    d. a roundworm.
    e. an annelid.

5. "Pill bugs" or "sow bugs," often found under rocks and logs in moist places, are perhaps most noticed for their ability to roll up into a ball when disturbed. Sow bugs are really crustaceans, not insects. Therefore, a sow bug does *not* have
   a. an exoskeleton.
   b. gills.
   c. three pairs of legs.
   d. antennae.
   e. jointed appendages.
6. Which of the following is thought to be most closely related to you?
   a. sea star
   b. snail
   c. earthworm
   d. jelly
   e. ant
7. There are only a few species of cartilaginous fishes, compared with the bony fishes. Cartilaginous fishes are mostly limited to a lifestyle of swimming fast in open water. Bony fishes have adapted to many different lifestyles—clinging to seaweed, hiding in crevices, even burrowing in the bottom. This could probably be attributed to the fact that bony fishes
   a. have more rigid skeletons.
   b. are smaller than cartilaginous fishes.
   c. have operculums and swim bladders.
   d. have lateral line systems and paired fins.
   e. are endothermic.
8. Which of the following is *not* thought to be in the lineage that led to human beings?
   a. an amphibian
   b. a dinosaur
   c. a jawless vertebrate
   d. a colonial protist
   e. a lungfish
9. Which of the following is *not* shared by birds and reptiles?
   a. endothermic metabolism
   b. amniotic eggs
   c. backbone of vertebrae
   d. scales made of keratin
   e. gill structures in embryo
10. Imagine that you are a paleontologist (a scientist who studies fossils of ancient life forms). In a recent dig, you unearthed bones of all of the following. Which could you have found in the oldest sediments?
    a. amphibians
    b. placental mammals
    c. dinosaurs
    d. birds
    e. marsupials

Essay

1. Sponges have no muscles and cannot move. They have no nerve cells and cannot sense the environment around them. Why are they considered animals?
2. A flattened creature called *Trichoplax,* in phylum Parazoa (a small phylum not discussed in this chapter), is the simplest known animal. Its body consists of a simple ciliated outer layer over a core of unspecialized cells. It has no digestive tract, but it crawls over food and hunches its "back" to form a temporary hollow that serves as a digestive sac. What does this animal suggest about the early evolution of animals?
3. Imagine that you are a Peace Corps volunteer assigned to a small African village where many people are infected with pork tapeworms, which are spread from pig to pig and from pigs to people by eating infected meat. Resources are scarce; the poor villagers cannot afford expensive medicines. If these worms have life cycles like other tapeworms, suggest three ways the villagers could interrupt the worm's life cycle and prevent themselves from becoming infected.
4. Name what you consider to be a successful phylum of animals. What are your criteria for choosing these animals? What makes them successful?
5. Zoologists have found that certain marine snails and polychaete worms have similar ciliated swimming larvae. What does this evidence suggest about the evolution of annelids and mollusks? Is this reflected in the animal phylogenetic trees given in this chapter? Explain.

6. How do you know that a dog is a chordate? A vertebrate? Are all chordate and vertebrate characteristics seen in the adult dog? If not all are seen in the adult, what makes the dog a chordate?
7. Nearly all the land vertebrates in the Arctic and Antarctic are birds and mammals—polar bears, walruses, and penguins, for example. Why do you think there are so many birds and mammals, but virtually no reptiles or amphibians, in these regions?

Extending Your Knowledge

1. Learning more about the evolution of animals makes a visit to a zoo or museum much more rewarding. Many large cities have zoos, nature centers, aquariums, and natural history museums. You might enjoy examining the invertebrates of a coral reef up close in an aquarium exhibit, comparing placentals and marsupials at the zoo, and reliving the age of dinosaurs at a natural history museum. If you want a real close-up experience, many museums, zoos, and aquariums train volunteers to act as guides and "explainers."
2. If you are interested in learning about, observing, and protecting wildlife, there are several organizations you can join. Three of the largest are National Audubon Society, 950 Third Avenue, New York, NY 10022; National Wildlife Federation, 1400 16th St. NW, Washington, DC 20036; and World Wildlife Fund, 1250 24th St. NW, Washington, DC 20037. Find them on the Web at www.audubon.org, www.nwf.org, and www.wwf.org.