26–1 Introduction to the Animal Kingdom

Of all the kingdoms of organisms, the animal kingdom is the most diverse in appearance. Some animals are so small that they live on or inside the bodies of other animals. Others are many meters long and live in the depths of the sea. They may walk, swim, crawl, burrow, or fly—or not move at all. As you will see, each major group, or phylum, has its own typical body plan.

What Is an Animal?

All members of the animal kingdom share certain characteristics. Animals are all heterotrophs, meaning that they obtain nutrients and energy by feeding on organic compounds from other organisms. Animals are multicellular, or composed of many cells. The cells that make up animal bodies are eukaryotic, meaning that they contain a nucleus and membrane-bound organelles. Unlike the cells of algae, fungi, and plants, animal cells do not have cell walls. **Animals, members of the kingdom Animalia, are multicellular, eukaryotic heterotrophs whose cells lack cell walls.**

The bodies of most animals contain tissues. Recall that a tissue is a group of cells that perform a similar function. Animals have epithelial, muscular, connective, and nervous tissues. Epithelial tissues cover body surfaces. The epithelial cells that line lung surfaces, for example, have thin, flat structures through which gases move in and out easily. The cells of muscle tissue contain proteins that enable the cells to contract, moving parts of animals' bodies. Connective tissue, such as bone and blood, support an animal's body and connect its parts. Cells embedded in bone tissue produce minerals that give strength and hardness to bone. Nervous tissue is composed of nerve cells, which have threadlike projections that act like telephone wires to carry information throughout the body.

Over 95 percent of all animal species are often grouped in a single, informal category: invertebrates. This group is defined in an odd way—by describing a characteristic that its members do *not* have. **Invertebrates** are animals that do not have a backbone, or vertebral column. They range in size from microscopic dust mites to the giant squid, which is more than 20 meters in length. They include groups as diverse as sea stars, worms, jellyfishes, and insects. The other 5 percent of animals, including fishes, amphibians, reptiles, birds, and mammals, are called **vertebrates,** because they have a backbone.

Guide for Reading

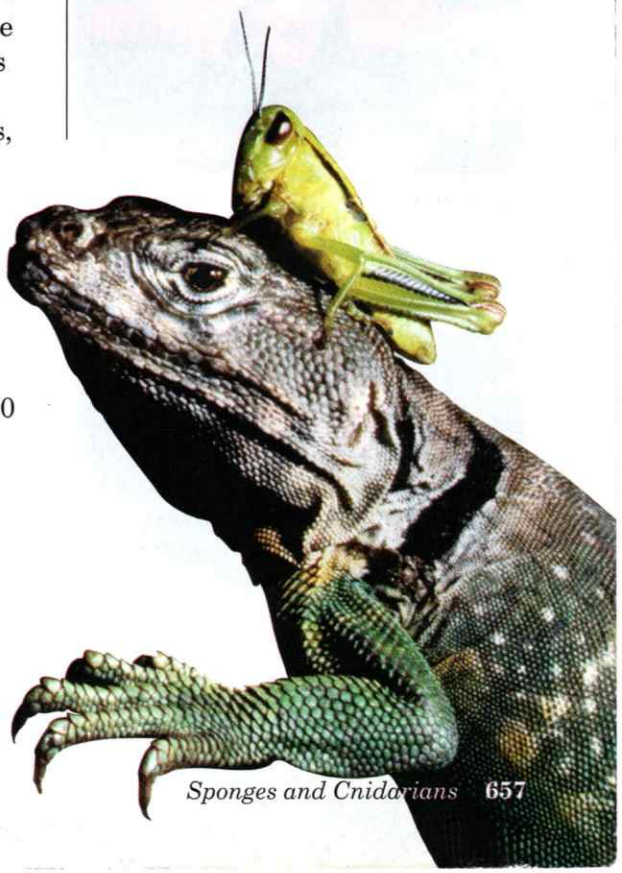
Key Concepts

- What characteristics do all animals share?
- What essential functions do animals carry out?
- What are the important trends in animal evolution?

Vocabulary

invertebrate • vertebrate
feedback inhibition
blastula • protostome
deuterostome • anus
endoderm • mesoderm
ectoderm • radial symmetry
bilateral symmetry
cephalization

Reading Strategy: Monitoring Your Understanding Before you read, write down what you already know about animals. After you have read this section, write down what you learned about animals.



▶ **Figure 26–1** The animal kingdom includes an incredible diversity of forms and lifestyles. **Despite their differences in appearance, both the collared lizard and the grasshopper are eukaryotic heterotrophs whose cells lack cell walls.**

What Animals Do to Survive

Animals carry out the following essential functions: feeding, respiration, circulation, excretion, response, movement, and reproduction. Over millions of years, animals have evolved in a variety of ways that enable them to do this. The study of the functions of organisms is called physiology. The structure, or anatomy, of an animal's body enables it to carry out physiological processes.

Many body functions help animals maintain homeostasis, or a relatively stable internal environment. Homeostasis is often maintained by internal feedback mechanisms called feedback loops. Most of these feedback loops involve **feedback inhibition,** in which the product or result of a process stops or limits the process. For example, when a dog becomes too hot, it pants. Panting releases heat, and the animal's body temperature decreases.

Feeding

Feeding Most animals cannot absorb food; instead, they ingest (or eat) it. Animals have evolved a variety of ways to feed. Herbivores eat plants; carnivores eat other animals; and omnivores feed on both plants and animals. Detritivores feed on decaying plant and animal material. Filter feeders are aquatic animals that strain tiny floating organisms from water.

Animals can also form symbiotic relationships, in which two species live in close association with each other. A parasite, for example, is a type of symbiont that lives within or on another organism, the host. The parasite feeds on the host, harming it.

Respiration

Respiration Whether they live in water or on land, all animals respire, which means that they take in oxygen and give off carbon dioxide. Because of their very simple, thin-walled bodies, some animals can rely on the diffusion of these substances through their skin. Most other animals, however, have evolved complex tissues and organ systems for respiration.

Circulation Many small aquatic animals, such as some aquatic worms, rely solely on diffusion to transport oxygen, nutrient molecules, and waste products among all their cells. Diffusion is sufficient because these animals are only a few cell layers thick. Larger animals, however, have some kind of circulatory system to move materials around within their bodies.

Circulation

Excretion

Excretion A primary waste product of cells is ammonia, a poisonous substance that contains nitrogen. A buildup of ammonia and other waste products would kill an animal. Most animals have an excretory system that either eliminates ammonia quickly or converts it into a less toxic substance that is removed from the body. By eliminating metabolic wastes, excretory systems help maintain homeostasis.

Response Animals respond to events in their environment using specialized cells called nerve cells. In most animals, nerve cells hook up together to form a nervous system. Some cells, called receptors, respond to sound, light, and other external stimuli. Other nerve cells process information and determine how the animal responds. The arrangement of nerve cells in the body changes dramatically from phylum to phylum.

Movement Some adult animals stay attached to a single spot. Most animals, however, are motile, meaning they can move. But both stick-in-the-muds and jet-setters usually have either muscles or musclelike tissues that generate force by becoming shorter. Muscle contraction enables motile animals to move around, usually by working in combination with a support structure called a skeleton. Muscles also help even sedentary animals feed and pump water and fluids through their bodies.

Reproduction Most animals reproduce sexually by producing haploid gametes. Sexual reproduction helps create and maintain genetic diversity in populations. It therefore helps improve species' abilities to evolve when the environment changes. Many invertebrates can also reproduce asexually. Asexual reproduction produces offspring that are genetically identical to the parent. It allows animals to increase their numbers rapidly.

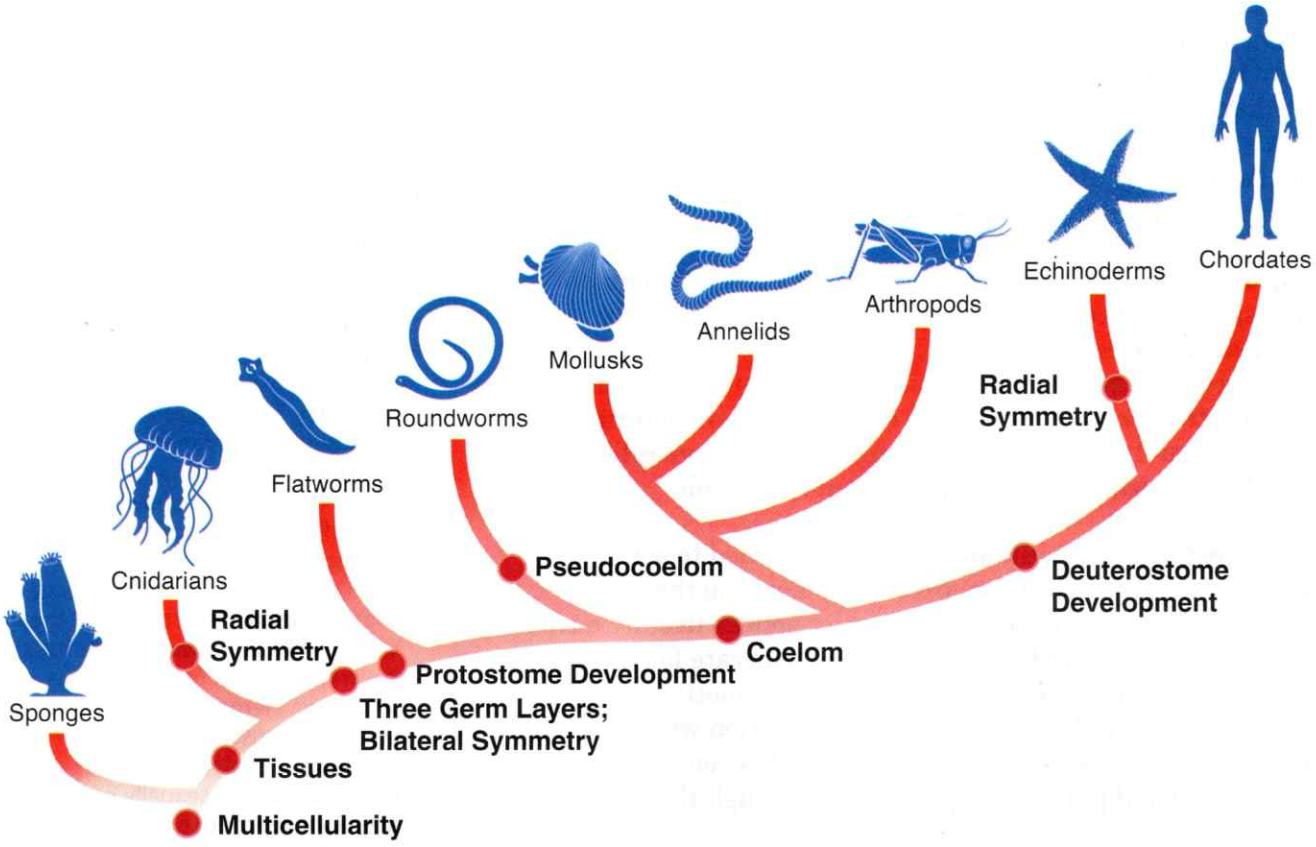
CHECKPOINT *How do sexual and asexual reproduction differ?*

Figure 26–2 **Animals carry out seven essential functions: feeding, respiration, circulation, excretion, response, movement, and reproduction.** Some snakes feed by constricting, or squeezing, their prey. Humans respire by breathing oxygenated air into lungs. A rabbit's circulatory system pumps blood through closed vessels, which are visible in its ears. Crabs rid their bodies of metabolic wastes by excreting fluid. Like many insects, moths respond to stimuli that they detect from the environment using specialized sense organs such as antennae. Herons move using a system of muscles attached to a low-density skeleton. Animals reproduce either sexually or asexually; lions reproduce sexually and have only a few offspring per litter.

Reproduction

Response

Movement



▲ **Figure 26–3** This diagram illustrates phylogenetic, or evolutionary, relationships among major groups of animals. Groups shown close together, such as echinoderms and chordates, are more closely related than groups that are shown farther apart, such as echinoderms and cnidarians. During the course of evolution that produced these different groups, important traits evolved. **Animals that are more complex typically have specialized cells, bilateral body symmetry, cephalization, and a body cavity.**

Trends in Animal Evolution

Your survey of the animal kingdom will begin with simple forms and move through more complicated ones. These different phyla are related to one another by a common evolutionary heritage. The diagram in **Figure 26–3** shows our most current understanding of phylogenetic relationships among groups of living animals. A comparison of the groups in the diagram shows important trends in animal evolution. **Complex animals tend to have high levels of cell specialization and internal body organization, bilateral body symmetry, a front end or head with sense organs, and a body cavity.** In addition, the embryos of complex animals develop in layers.

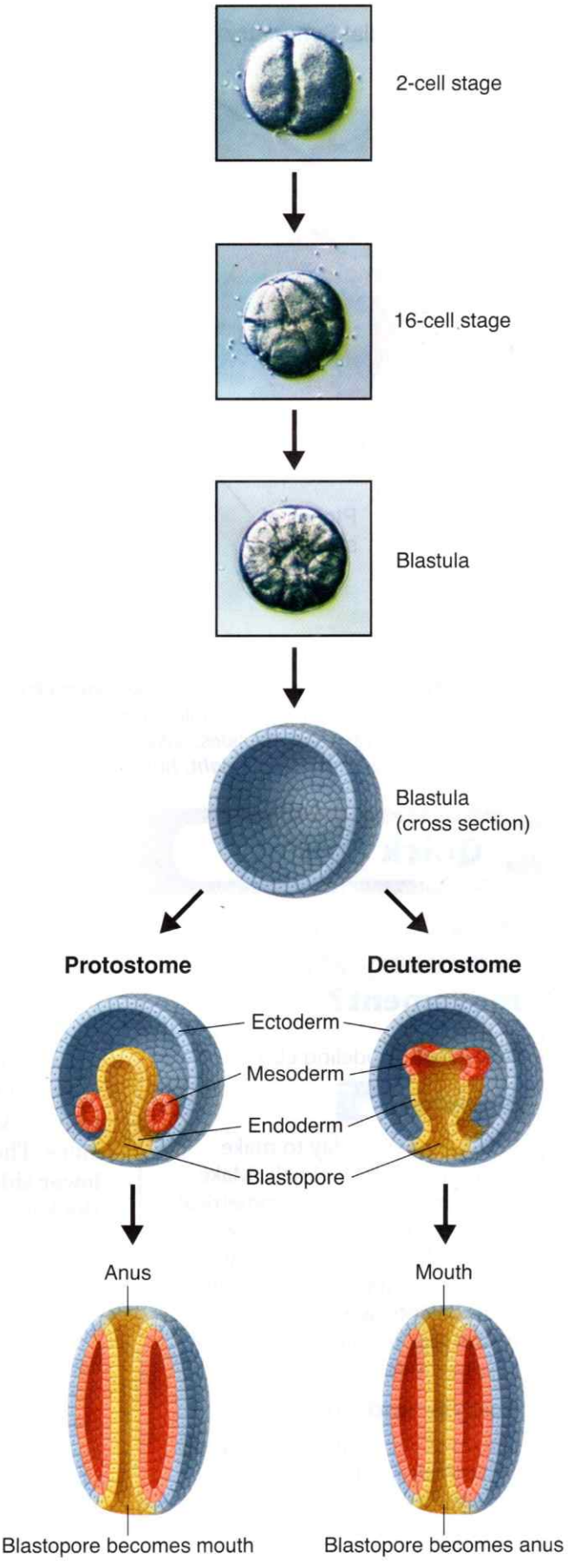
Cell Specialization and Levels of Organization As animals have evolved, by natural selection and other evolutionary processes, their cells have become specialized to carry out different functions, such as movement and response. Large animals need greater efficiency in body processes than do very small animals. Unicellular organisms, such as amoebas, move nutrients and waste products directly across their cell membranes. In multicellular organisms such as animals, however, each cell type has a structure and chemical composition that enable it to perform a specialized function. Groups of specialized cells form tissues. Tissues join together to form organs and organ systems—all of which work together to carry out a variety of complex functions.

Early Development Animals that reproduce sexually begin life as a zygote, or fertilized egg. **Figure 26–4** shows patterns of embryology, or development of the embryo after fertilization. The zygote undergoes a series of divisions to form a **blastula** (BLAS-tyoo-luh), which is a hollow ball of cells. The blastula folds in on itself, forming a single opening called a blastopore. The process of blastopore formation changes a simple ball of cells—similar to an inflated balloon—into an elongated structure with a tube inside, as if you were holding the balloon and pushing your thumbs toward the center.

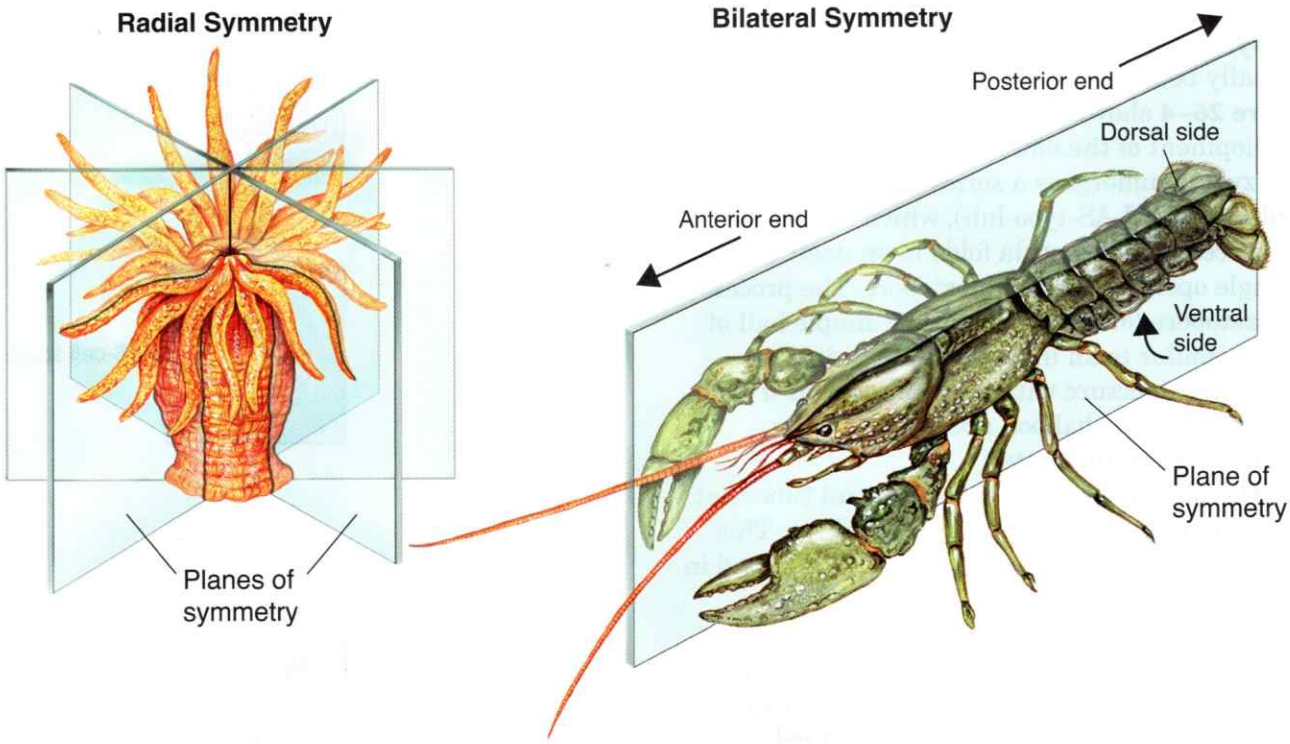
The blastopore leads into a central tube that runs the length of the developing embryo. This tube becomes the digestive tract and is formed in one of two ways. A **protostome** (PROH-tuh-stohm) is an animal whose mouth is formed from the blastopore. Most invertebrate animals are protostomes. A **deuterostome** (DOO-tur-uh-stohm) is an animal whose anus is formed from the blastopore. The **anus** is the opening through which wastes leave the digestive tract. The mouth is formed second, after the anus. Echinoderms and all vertebrates are deuterostomes. This similarity in embryology may indicate that vertebrates have a closer evolutionary relationship to echinoderms than to other invertebrates.

During early development, the cells of most animal embryos differentiate into three layers called germ layers. The cells of the **endoderm,** or innermost germ layer, develop into the linings of the digestive tract and much of the respiratory system. The cells of the **mesoderm,** or middle layer, give rise to muscles and much of the circulatory, reproductive, and excretory organ systems. The **ectoderm,** or outermost layer, gives rise to sense organs, nerves, and the outer layer of the skin.

CHECKPOINT *Which germ layer gives rise to the muscles?*



▶ **Figure 26–4** During the early development of animal embryos, cells divide to produce a hollow ball of cells called a blastula. An opening called a blastopore forms in this ball. In protostomes, the blastopore develops into the mouth. In deuterostomes, the blastopore forms an anus. **Interpreting Graphics** *Which cell layer lines the digestive tract in both protostomes and deuterostomes?*



▲ **Figure 26–5** Animals with radial symmetry have body parts that extend from a central point. Animals with bilateral symmetry have distinct anterior and posterior ends and right and left sides. **Interpreting Graphics** *How many planes of symmetry does the crayfish, above right, have?*

Quick Lab

How can body symmetry affect movement?

Material modeling clay

Procedure

1. Use modeling clay to make models of two animals. Make one model radially symmetrical and the other long, narrow, and bilaterally symmetrical.
2. Make grooves to divide each model into similar segments.
3. Add legs to some segments of your models.

Analyze and Conclude

1. **Inferring** Which type of body symmetry is more suited to walking forward?
2. **Using Models** How is bilateral symmetry an advantage to animals that walk or run?

Body Symmetry With the exception of sponges, every kind of animal exhibits some type of body symmetry in its anatomy, or body structure. Many simple animals, such as the sea anemone shown on the left in **Figure 26–5,** have body parts that repeat around the center of the body. These animals exhibit **radial symmetry,** similar to that of a bicycle wheel, in which any number of imaginary planes can be drawn through the center, each dividing the body into equal halves.

In animals with **bilateral symmetry,** such as the crayfish, only a single imaginary plane can divide the body into two equal halves. Animals with bilateral symmetry have left and right sides. They also usually have front and back ends and upper and lower sides. The anterior is the front end, and the posterior is the back end. The dorsal is the upper side, and the ventral is the lower side.

An anatomy with bilateral symmetry allows for segmentation, in which the body is constructed of many repeated and similar parts, or segments. Animals with bilateral symmetry, such as worms, insects, and vertebrates, typically have external body parts that repeat on either side of the body. The combination of bilateral symmetry and segmentation is found in two of the most successful animal groups—arthropods and vertebrates. Geneticists are learning how gene interactions during development control the growth and form of segments. Amazingly, the same controls are found in humans and insects!

CHECKPOINT *How do radial symmetry and bilateral symmetry differ?*

Figure 26–6 Animals with cephalization have the brain and other sense organs toward the front of the body. This end of the body comes into contact with the environment first, allowing animals to respond effectively to stimuli. **Inferring** *How might cephalization help animals to move quickly?*

Cephalization Animals with bilateral symmetry usually exhibit the anatomical characteristic called cephalization (sef-uh-lih-ZAY-shun). **Cephalization** is the concentration of sense organs and nerve cells at the front end of the body. Animals with cephalization, such as the dragonfly in **Figure 26–6,** respond to the environment more quickly and in more complex ways than simpler animals can. Animals with bilateral symmetry usually move with the anterior end forward, so this end comes in contact with new parts of the environment first. As sense organs such as eyes have evolved, they have tended to gather at the anterior end, as have nerve cells that process information and "decide" what the animal should do. In general, the more complex animals become, the more pronounced their cephalization. The anterior end is often different enough from the rest of the body that it is called a head.

Body Cavity Formation Most animals have a body cavity, which is a fluid-filled space that lies between the digestive tract and the body wall. A body cavity is important because it provides a space in which internal organs can be suspended so that they are not pressed on by muscles or twisted out of shape by body movements. Body cavities also allow for specialized regions to develop, and they provide room for internal organs to grow and expand. In some animals, body cavities contain fluids that are involved in circulation, feeding, and excretion.

26–1 Section Assessment

1. **Key Concept** What are the characteristics of members of the animal kingdom?
2. **Key Concept** Describe the seven essential functions performed by all animals.
3. **Key Concept** In what ways are complex animals different from simple animals?
4. How is the embryology of echinoderms similar to that of vertebrates? What might this similarity indicate about their evolutionary relationship?
5. How are body symmetry and cephalization related?
6. **Critical Thinking Applying Concepts** How is hunger an internal feedback mechanism for maintaining homeostasis?

Thinking Visually

Constructing a Chart
Make a two-column chart of the different functions that enable animals to survive and respond to the environment. In the first column, list each function. In the second column, include a drawing, photograph, or magazine clipping that illustrates an example of that function.

27–1 Flatworms

When most people think of worms, they think of long, squiggly earthworms. But there are many other kinds of worms. Some are the length of your body or as thick as your arm. Others look like glowing, furry blobs. Worms can flutter and glide, or climb around with paddlelike bristles. Still others are very small and live in tubes cemented to rocks.

How is their body shape beneficial to worms? A long, slender body allows an animal to move about more rapidly than a radially symmetrical body, like that of a cnidarian. Worms can move forward in a single direction rather than remaining stationary or drifting in currents. In addition, the mouth, sense organs, and brain (if there is one) are usually located at the head, or anterior end, of the body. This arrangement allows worms to locate food and respond to stimuli as they move. Many groups of organisms have worm-shaped bodies. The familiar earthworm is a segmented worm, which you will read about later in this chapter. The unsegmented worms include flatworms and roundworms. The simplest of these are the flatworms.

Guide for Reading

Key Concepts
- What are the defining features of flatworms?
- What are the characteristics of the three groups of flatworms?

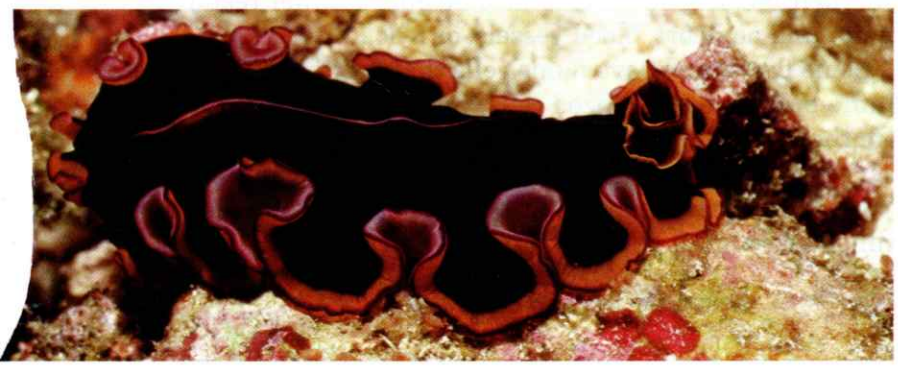
Vocabulary
acoelomate • coelom
pharynx • flame cell
ganglion • eyespot
hermaphrodite
fission • scolex
proglottid • testis

Reading Strategy: Outlining Before you read, use the headings of the section to make an outline about the characteristics of flatworms. As you read, fill in subtopics where they apply in the outline. Add phrases after each subtopic to provide key information.

What Is a Flatworm?

The phylum Platyhelminthes (plat-ih-hel-MIN-theez) consists of the flatworms. Most flatworms are no more than a few millimeters thick. **Flatworms are soft, flattened worms that have tissues and internal organ systems. They are the simplest animals to have three embryonic germ layers, bilateral symmetry, and cephalization.**

Flatworms are known as **acoelomates** (ay-SEE-luh-mayts), meaning "without coelom." A **coelom** (SEE-lum) is a fluid-filled body cavity that is lined with tissue derived from mesoderm. No coelom forms between the tissues of flatworms. **Figure 27–1** shows that the digestive cavity, which is lined with tissue derived from endoderm, is the only body cavity. Flatworms also have bilateral symmetry. This means that the animal has two well-formed sides that can be identified as left and right. Most flatworms exhibit enough cephalization to have what is called a head.



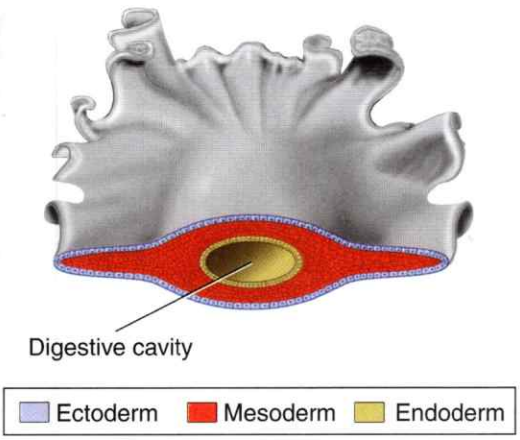


Figure 27–1 **Flatworms are the simplest animals to have three embryonic germ layers—ectoderm, endoderm, and mesoderm.** Shown here is the tropical, free-living flatworm *Pseudobiceros gloriosus*.

27–2 Roundworms

Members of the phylum Nematoda, also known as roundworms, are among the most numerous of all animals. It is difficult to imagine how many live around us. A single rotting apple can contain as many as 90,000 roundworms. A cubic meter of garden soil can be home to more than a million!

Guide for Reading

Key Concepts
- What are the defining features of roundworms?
- What roundworms are important in human disease?

Vocabulary
pseudocoelom
anus

Reading Strategy: Using Visuals As you read, write a statement explaining how each illustration or photograph reinforces or enhances the content of the section.

What Is a Roundworm?

Roundworms are slender, unsegmented worms with tapering ends. They range in size from microscopic to a meter in length. Most species of roundworms are free-living, inhabiting soil, salt flats, aquatic sediments, and water, from polar regions to the tropics. Many others are parasitic and live in hosts that include almost every kind of plant and animal.

Like flatworms, roundworms develop from three germ layers. However, roundworms have a body cavity between the endoderm and mesoderm tissues. Because this cavity is lined only partially with tissue derived from the mesoderm, it is called a **pseudocoelom** (soo-doh-SEE-lum), which means "false coelom." Observe the pseudocoelom in **Figure 27–7.**

Also, unlike most flatworms, roundworms have a digestive tract with two openings. This body plan is often called a tube-within-a-tube. The inner tube is the digestive tract, and the outer tube is the body wall. This arrangement makes digestion in roundworms very different from that in flatworms because food moves in one direction through the digestive tract. Any material in the food that cannot be digested leaves through the anus. The **anus** is the posterior opening of the digestive tract.

Roundworms are unsegmented worms that have pseudocoeloms and digestive systems with two openings—a mouth and an anus.

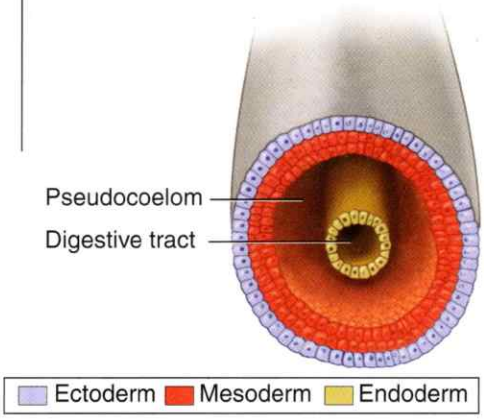


Figure 27–7 Roundworms such as hookworms are unsegmented worms that have a pseudocoelom and a digestive system with a mouth and an anus. Roundworms develop from three germ layers, and a pseudocoelom forms between the endoderm and mesoderm layers.