UNIT 8

Animals

CHAPTER

23 Invertebrate Diversity

KEY CONCEPTS

23.1 Animal Characteristics
Animals are diverse but share common characteristics.

23.2 Animal Diversity
More than 95 percent of all animal species are invertebrates.

23.3 Sponges and Cnidarians
Sponges and cnidarians are the simplest animals.

23.4 Flatworms, Mollusks, and Annelids
Flatworms, mollusks, and annelids belong to closely related phyla.

23.5 Roundworms
Roundworms have bilateral symmetry and shed their outer skeleton to grow.

23.6 Echinoderms
Echinoderms are on the same evolutionary branch as vertebrates.

Online BIOLOGY CLASSZONE.COM

Animated BIOLOGY
View animated chapter concepts.
- Digestive Tract Formation
- Shared Body Structures

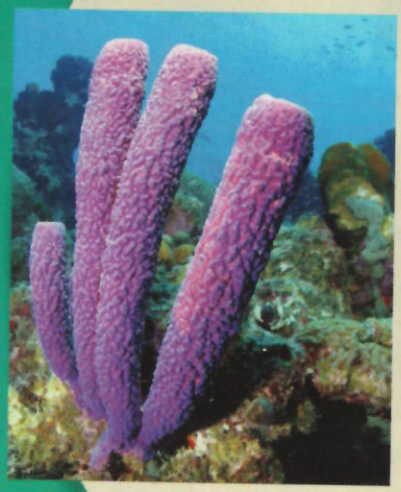
BIOZINE
Keep current with biology news.
- News feeds
- Bio Bytes
- Polls

RESOURCE CENTER
Get more information on
- Sponges and Cnidarians
- Worms
- Mollusks

How is this sea slug similar to a spider?

Both sea slugs and spiders are invertebrates. Invertebrates, which are animals without backbones, account for the vast majority of animals on Earth. You are surrounded by invertebrates on a daily basis, whether you are aware of them or not. Invertebrates exist in a wide variety of shapes and sizes and live in many different habitats—including your body!

Connecting CONCEPTS



Adaptation Because adult sea slugs do not have shells, they must use other methods to avoid being eaten. Some sea slugs eat sponges. Sponges (left) have chemicals that make them taste bad. Sea slugs have the ability to overcome the foul taste and are able to incorporate the chemicals into their body. These chemicals, in turn, give the sea slugs a bad taste, helping them to avoid predation.

23.1 Animal Characteristics

KEY CONCEPT Animals are diverse but share common characteristics.

MAIN IDEAS

- Animals are the most physically diverse kingdom of organisms.
- All animals share a set of characteristics.

VOCABULARY

collagen, p. 697
homeotic, p. 698
homeobox, p. 698

REVIEW AT CLASSZONE.COM

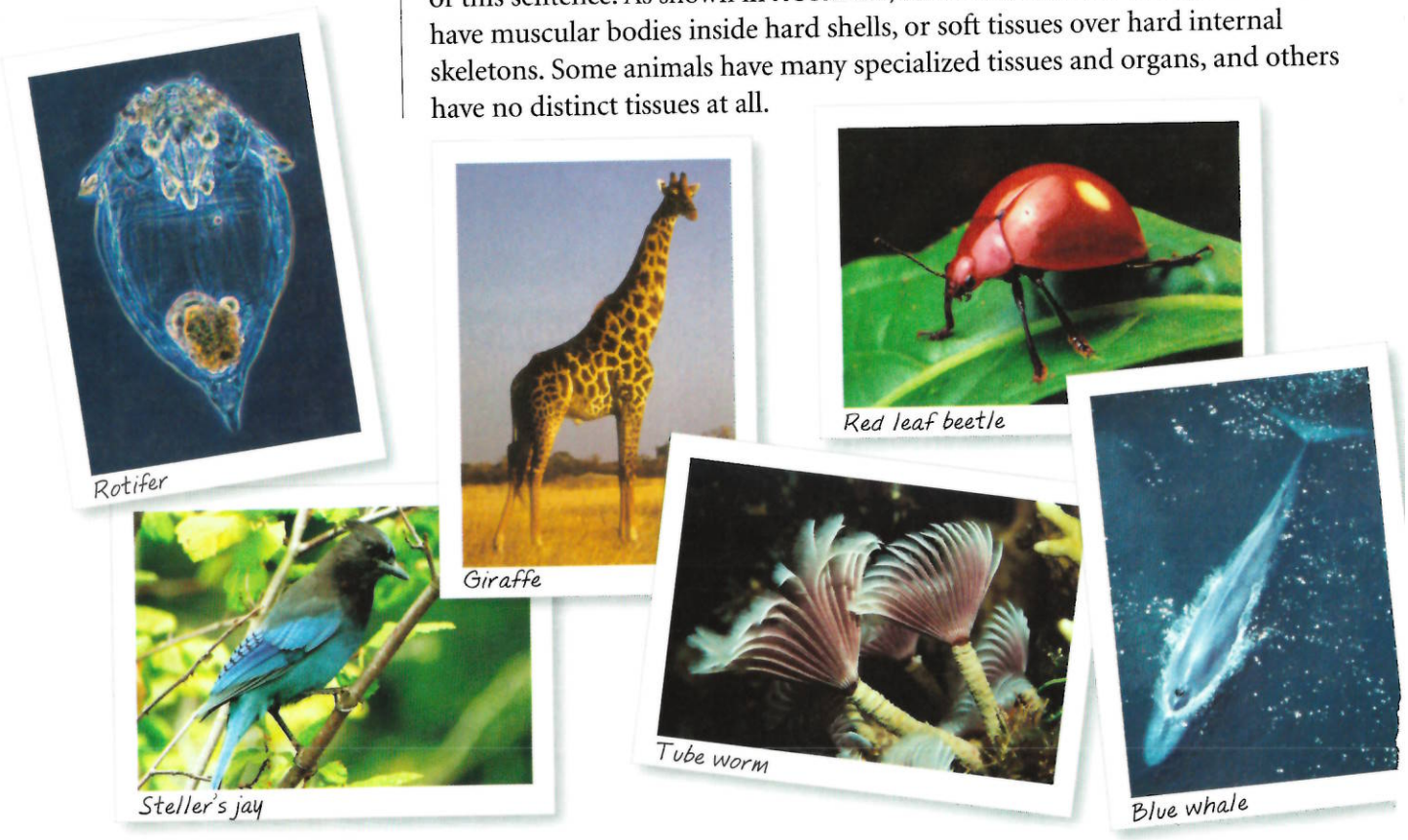
Connect We are animals. So are jellyfish, squid, cockroaches, tapeworms, sea stars, and the family dog. Animals live in nearly every environment on Earth, from high in the atmosphere to the deepest sea trench. While they come in a huge variety of shapes and sizes, they all share a common ancestry and a set of common physical and genetic characteristics.

MAIN IDEA

Animals are the most physically diverse kingdom of organisms.

More than 1 million species of animals have been described so far, and scientists predict that tens of millions more have yet to be discovered. Animals are a remarkably diverse group of organisms. They range in size from blue whales twice the length of a school bus to rotifers smaller than the period at the end of this sentence. As shown in **FIGURE 23.1**, some look like soft tubes, and others have muscular bodies inside hard shells, or soft tissues over hard internal skeletons. Some animals have many specialized tissues and organs, and others have no distinct tissues at all.

FIGURE 23.1 Animal body plans vary widely in shape and size, from microscopic rotifers (colored SEM; magnification 170×) to blue whales 24 meters in length.



Animals are found nearly everywhere on Earth, including places where plants and fungi do not live. They are the dominant herbivores, predators, and detritivores in most ecosystems. Some walk, burrow, swim, fly, or slide along on mucus trails in search of food. Others spend their whole adult lives fixed to a single spot, endlessly straining water to collect microscopic particles of food.

Connect **What ecological factors determine where certain animals are found?**

Connecting CONCEPTS

Niches Recall from **Chapter 14** that an ecological niche includes all of the factors a species needs to survive, thrive, and reproduce.

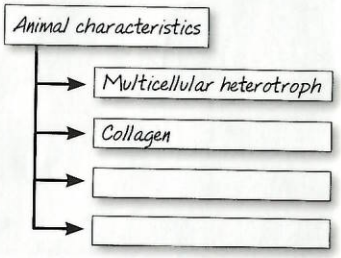
MAIN IDEA

All animals share a set of characteristics.

Given the huge physical diversity among animals, what characteristics distinguish animals from other organisms? All animals share a set of derived characters, or heritable features, that set them apart from other eukaryotes. These characteristics suggest that all animals are the descendants of a single common ancestor.

TAKING NOTES

Use a diagram to take notes on the unique characteristics of animals.



All Animals Are Multicellular Heterotrophs

Animals must eat. Their cells lack the chloroplasts that let photosynthetic organisms make their own food. All animals are heterotrophs, meaning they eat other organisms to gain the nutrients they need to survive. Any organic compound an animal uses in cellular respiration has to come from an outside source. Single-celled protists also eat other organisms. But because even the simplest animal is built of many specialized cells, all animals can ingest and process larger food particles than a single cell can engulf.

Animals are not the only eukaryotes that are both heterotrophic and multicellular. Fungi are also multicellular and use organisms for food. But cells of fungi do not have the same diversity of functions that animal cells have. Although animals and fungi share heterotrophic ancestors, it is likely that they evolved the trait of multicellularity independently.

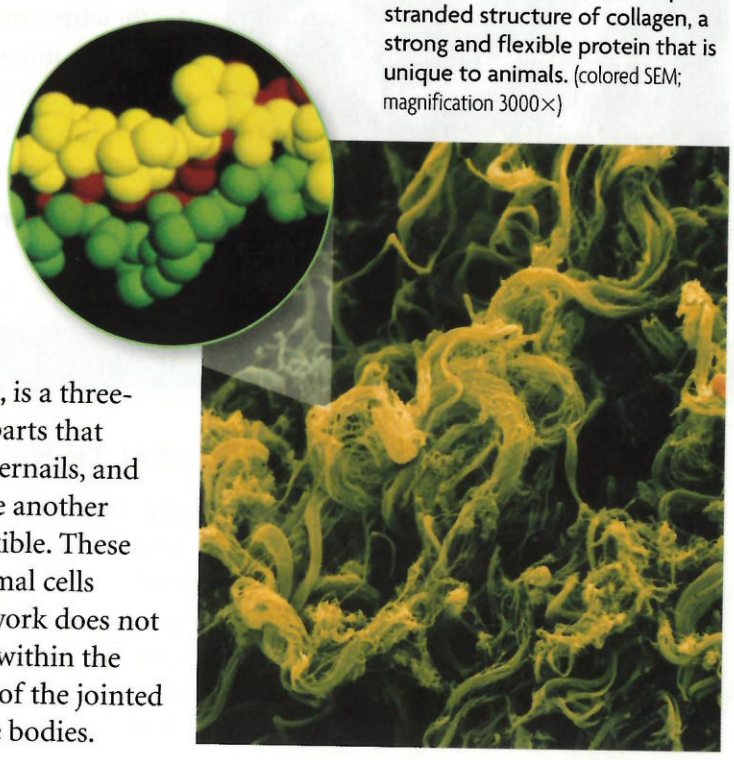


FIGURE 23.2 This molecular model and SEM show the triple-stranded structure of collagen, a strong and flexible protein that is unique to animals. (colored SEM; magnification 3000×)

Animal Cells Are Supported by Collagen

Unlike the cells of plants and fungi, animal cells lack rigid cell walls. Therefore, animals are the only multicellular organisms with no cellular structure to support their cells. What component carries out these functions in animals?

Collagen (KAHL-uh-juhn), shown in **FIGURE 23.2**, is a three-stranded protein unique to animals. Animal body parts that contain collagen include skin, bone, ligaments, fingernails, and hair. Individual collagen proteins combine with one another to form ropelike fibers that are both strong and flexible. These fibers form an extracellular network that many animal cells use for support. Unlike a cell wall, the collagen network does not glue cells in place, so it is possible for cells to move within the animal's body. Collagen also forms an integral part of the jointed skeleton that many animals use to move their entire bodies.

Animals Are Diploid and Usually Reproduce Sexually

Animals are the only multicellular organisms that do not alternate between free-living diploid and haploid stages. In all animal species, the individuals that reproduce are diploid (meaning they have one set of chromosomes from each parent), and they produce offspring that are also diploid. Some kinds of animals can reproduce both asexually and sexually. For example, a *Hydra* can clone itself by budding. These species have male and female sexual organs and also reproduce sexually. A few animals have become completely asexual. All whiptail lizards, for example, are females, and all their offspring are clones of the mother. But these animals evolved from sexual species, and their asexual habits are derived characters.

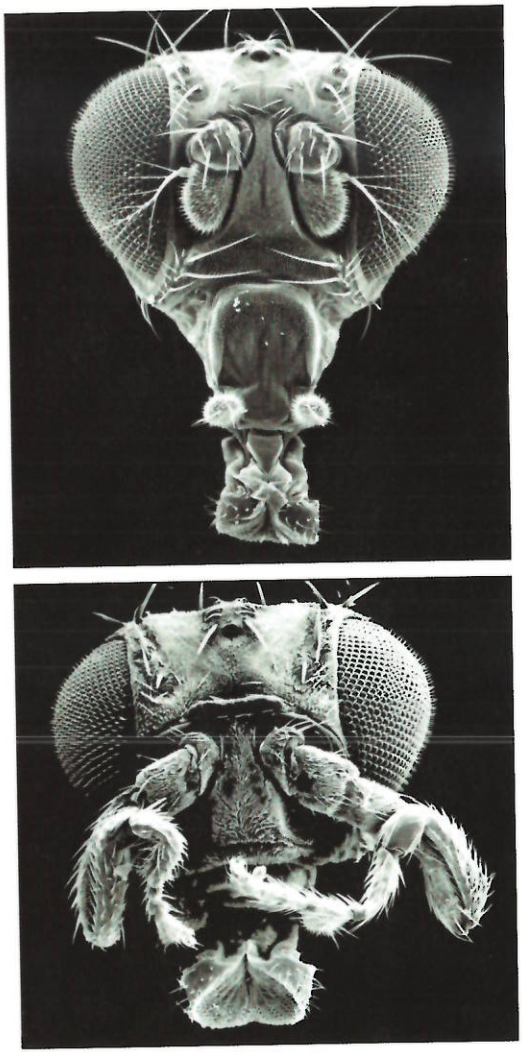


FIGURE 23.3 In the wildtype fly (top), the antennae develop normally. In the mutant fly (bottom), a mutation causes legs to form in place of the antennae. (SEMs; magnification 70×)

Most Animals Have *Hox* Genes

Most of the animals that scientists have studied so far share a group of genes called homeotic genes. **Homeotic** (HOH-mee-AH-tihk) genes are a class of genes that control early development in animals. Every homeotic gene has a specific sequence of 180 nucleotides called **homeobox** (HOH-mee-uh-BAHKS), or *Hox*, genes. *Hox* genes define the head-to-tail pattern of development in animal embryos. Homeotic genes create segments in a larva or embryo that develop into specific organs and tissues. The *Hox* genes within these segments determine the position of cell differentiation and development by switching certain genes "on" or "off."

A mutation in a homeotic gene leads to the development of a body structure in the wrong position. For example, the effect of a mutation in a homeotic gene, *Antennapedia,* determines whether an insect body segment will grow antennae or legs. As shown in **FIGURE 23.3,** in the wildtype fly (top), antennae develop normally. In the fly with a mutation in its homeotic genes (bottom), legs develop where the antennae should be. However, the rest of the fly develops normally. Although the misplaced legs look normal in structure, they are not functional for the fly. Flies with homeotic mutations usually do not live very long.

Analyze **How are homeotic and *Hox* genes related?**

23.1 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. In what ways are animals physically diverse? Give three examples.
2. List and describe the derived characters that all animals share.

CRITICAL THINKING

3. **Apply** How does the structure of animal cells allow animals to move?
4. **Hypothesize** Animals are heterotrophs. How might this have contributed to such great animal diversity?

Connecting CONCEPTS

5. **Genetics** How does the genome of an offspring resulting from sexual reproduction differ from that of an offspring resulting from asexual reproduction?

23.2 Animal Diversity

KEY CONCEPT More than 95 percent of all animal species are invertebrates.

MAIN IDEAS

- Each animal phylum has a unique body plan.
- Animals are grouped using a variety of criteria.
- A comparison of structure and genetics reveals the evolutionary history of animals.

VOCABULARY

vertebrate, p. 699
invertebrate, p. 699
phylum, p. 699
bilateral symmetry, p. 701
radial symmetry, p. 701
protostome, p. 702
deuterostome, p. 702

REVIEW AT CLASSZONE.COM

Connect When you think of an animal, something familiar such as a dog or a snake probably comes to mind. Both of these animals are vertebrates, a group that represents one small subset of animals. However, most animals are invertebrates and look nothing like your mental picture. To understand the vast diversity of animal life, biologists look for unique characteristics that help them sort animals into distinct groups and arrange those groups into a family tree.

MAIN IDEA

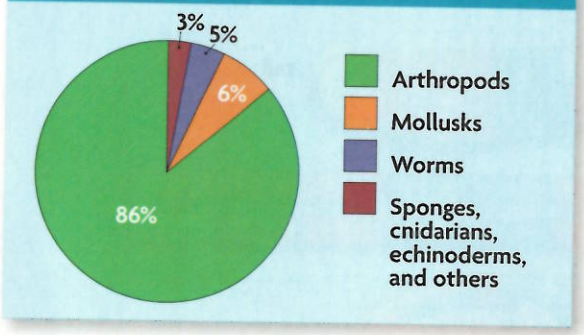
Each animal phylum has a unique body plan.

Connecting CONCEPTS

Classification Recall from **Chapter 17** that in the Linnaean system of classification, phylum is the first level below kingdom. As you learned earlier, all animals are classified in the kingdom Animalia.

A **vertebrate** (VUR-tuh-briht) is an animal with an internal segmented backbone. Vertebrates are the most obvious animals around us, and we are vertebrates, too. But vertebrates make up less than five percent of all known animal species. All other animals are invertebrates. **Invertebrates** (ihn-VUR-tuh-brihts) are animals without backbones. Early animal classifications divided all animals into vertebrates and invertebrates. But because invertebrates are not defined by a set of shared derived characters, the division is considered outdated. Many invertebrates are not closely related to one another.

FIGURE 23.4 INVERTEBRATE SPECIES BY GROUP



Animal Phyla

Scientists now use shared characters to divide animals into more than 30 major groups. Each group, or **phylum** (FY-luhm) (plural, *phyla*), of animals is defined by structural and functional characteristics that are different from every other animal group. Each animal phylum has a unique body plan and represents a different way that a multicellular animal is put together.

Every animal phylum has a unique set of anatomical characteristics. These unique characteristics are true of both the largest and smallest phyla. Some phyla, such as mollusks, have tens of thousands of species, ranging from land snails to marine octopuses. Others are much less diverse. Phyla such as Arthropoda contain species that look very different from one another. In other phyla, such as Nematoda, all of the species look very similar. The relative amount of invertebrate species per group is shown in **FIGURE 23.4.**

Homeobox Genes and Body Plans

If you take a look at the animals that you might see on a walk through the park, you may notice how different their body plans are. The swimming fish in a park pond have sets of fins, the flying birds have pairs of wings, and the squirrels chasing one another have four legs.

Differences in body plans result from differences in the expression of homeobox genes. As shown in **FIGURE 23.5**, homeobox genes tell embryonic cells which part of the body they are going to become, such as the head, middle, or tail. These instructions start a chain reaction that turns on all other genes that define the adult form—where limbs go, how many eyes will develop, the location of the gut, and so on. For this reason, a mutation in a *Hox* gene can change an animal's entire body plan. Scientists think that mutations in these genes led to the vast diversity of animal species.

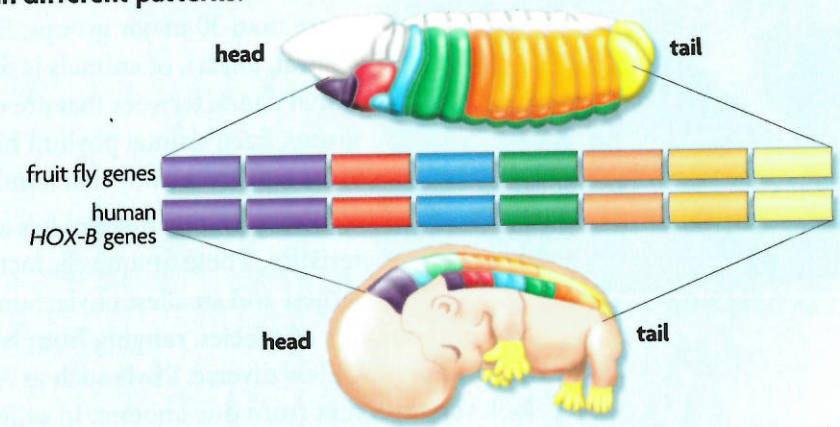
All the animal phyla now known first appeared during the Cambrian explosion. How did so many unique body plans appear in such a short time? The trigger may have been an increase in oxygen levels in the atmosphere that began about 700 million years ago. As oxygen levels rose, eukaryotic organisms could become more active and begin to occupy different niches within more complex ecosystems.

The Cambrian explosion was only possible because animals had already evolved *Hox* genes. These genes became a toolkit that changed animal bodies through duplication and loss. For example, a sponge is a simple animal that has at least one *Hox* gene, while an arthropod has eight. This difference suggests that over time, mutations have caused the original *Hox* gene to be copied repeatedly, forming a series of similar genes along a chromosome. Every time a gene is duplicated, one of the copies can keep doing its original job in the organism, leaving the other free to mutate and take on new roles.

Analyze **How are *Hox* genes related to the diversity of body plans?**

FIGURE 23.5 *Hox* Gene Expression

The genes that determine a fruit fly's body plan are variations of the same genes that determine a human's, but they are expressed in different patterns.



Analyze **In both fruit flies and humans, *Hox* genes occur in a similar order on chromosomes. How does the illustration emphasize this point?**

MAIN IDEA

Animals are grouped using a variety of criteria.

Like other organisms, animals are placed in separate groups based on certain characteristics. Three criteria used to categorize animals are body plan symmetry, number of tissue layers, and developmental patterns.

Body Plan Symmetry

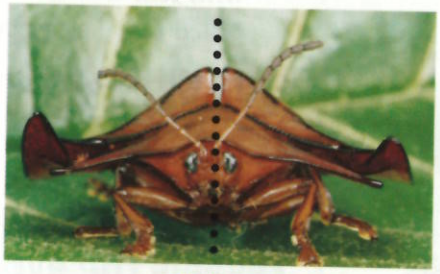
Symmetry refers to how similar an object is across a central axis. For example, if you draw a line down the middle of a square, both sides are equal in shape and size. An object is asymmetrical if the two sides are not mirror images of one another. Most animal body plans fall into one of two types of symmetry.

- Animals with **bilateral symmetry** can be divided equally along only one plane, which splits an animal into mirror-image sides.
- Animals with **radial symmetry** have body parts arranged in a circle around a central axis.

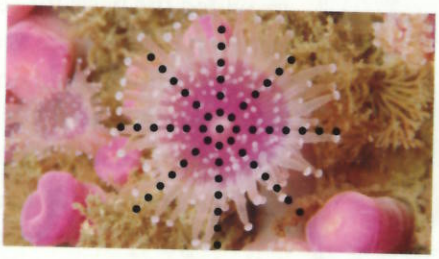
Bilateral animals have distinct heads and tails, which are called the anterior (head) and posterior (tail) ends. These animals also have distinct backs and bellies, which are called the dorsal (back) and ventral (belly) surfaces. Each of these regions can become specialized. For example, structures that an animal uses to move, such as legs, are usually found on its ventral surface. Active hunters that often travel in one direction in search of food have a head region with a concentration of nervous tissue that forms a brain and with sensory organs such as eyes.

VISUAL VOCAB

Animals with **bilateral symmetry** can be divided equally along only one plane, which splits an animal into mirror-image sides.



Animals with **radial symmetry** have body parts arranged in a circle around a central axis.



TAKING NOTES

Draw a simple sketch of an animal in your notes. Mark its symmetry, then label its anterior, posterior, dorsal, and ventral sides.

Tissue Layers

Bilateral animals have three distinct layers of tissue. Animals with three tissue layers are triploblastic. These layers are the ectoderm, endoderm, and mesoderm. The ectoderm is the outer layer that develops into both the skin and the brain and nervous system. The endoderm is an inner layer that lines the animal's gut. The mesoderm is a middle layer that develops into internal tissues and organs. Complex organ systems resulted from the evolution of this third tissue layer.

Most radial animals have only two distinct layers of tissue. These layers are an inner endoderm and an outer ectoderm. Radial animals do not have a mesoderm layer, and therefore they lack the complex internal tissues and organs found in triploblastic animals.

VOCABULARY

The following Greek word parts can help you remember the names of tissue layers.

- *-derm* comes from a word meaning "skin"
- *ecto-* means "outer"
- *endo-* means "inner"
- *meso-* means "middle"

Animated BIOLOGY

Compare how protostome and deuterostome digestive tracts form at ClassZone.com.

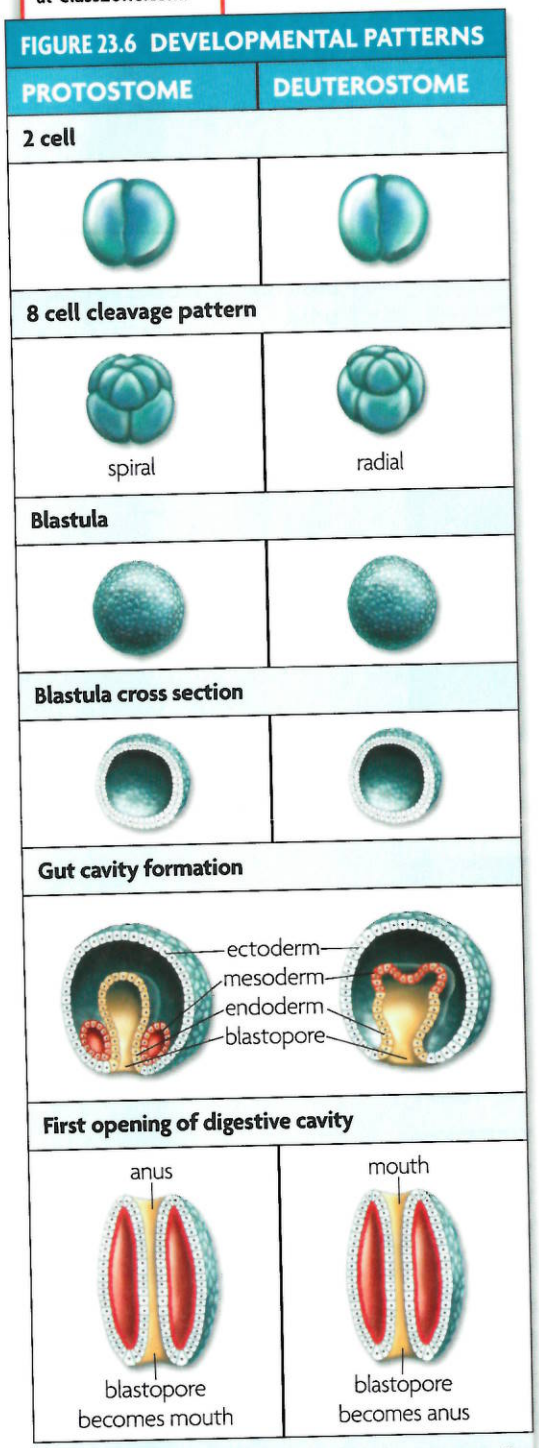
Developmental Patterns

Animals are separated into two major divisions: the protostomes and the deuterostomes. As shown in **FIGURE 23.6**, protostome and deuterostome development differs in a number of ways:

- **First opening of the digestive cavity** The major difference between protostomes and deuterostomes is the structure that develops from the first opening of the digestive cavity. In **protostomes** (PROH-tuh-STOHMZ), the mouth is formed first, and the anus second. In **deuterostomes** (DOO-tuh-roh-STOHMZ), the first opening forms the anus, and the mouth is formed second.
- **Gut cavity formation** In protostomes, the gut cavity is formed from separations in the mesoderm. In deuterostomes, the gut cavity forms from pouches created by the folds in the gut tube.
- **Cleavage pattern** In most protostomes, early cell divisions lead to an eight-celled embryo in a twisted arrangement called spiral cleavage. In deuterostomes, cells divide into eight-celled embryos with cells that are lined up one atop the other in an arrangement called radial cleavage.

Connect **Is the symmetry of the human body bilateral or radial?**

FIGURE 23.6 DEVELOPMENTAL PATTERNS



Contrast **How does the development of protostomes and deuterstomes differ?**

MAIN IDEA

A comparison of structure and genetics reveals the evolutionary history of animals.

Work by the American zoologist Libbie Hyman in the mid-1900s provided the basis for scientists' understanding of the relationships between invertebrate species. Hyman based her phylogeny, or evolutionary history, on major events in development. The ability to compare ribosomal DNA and *Hox* genes has helped to both confirm and rearrange some relationships among invertebrate animal groups.

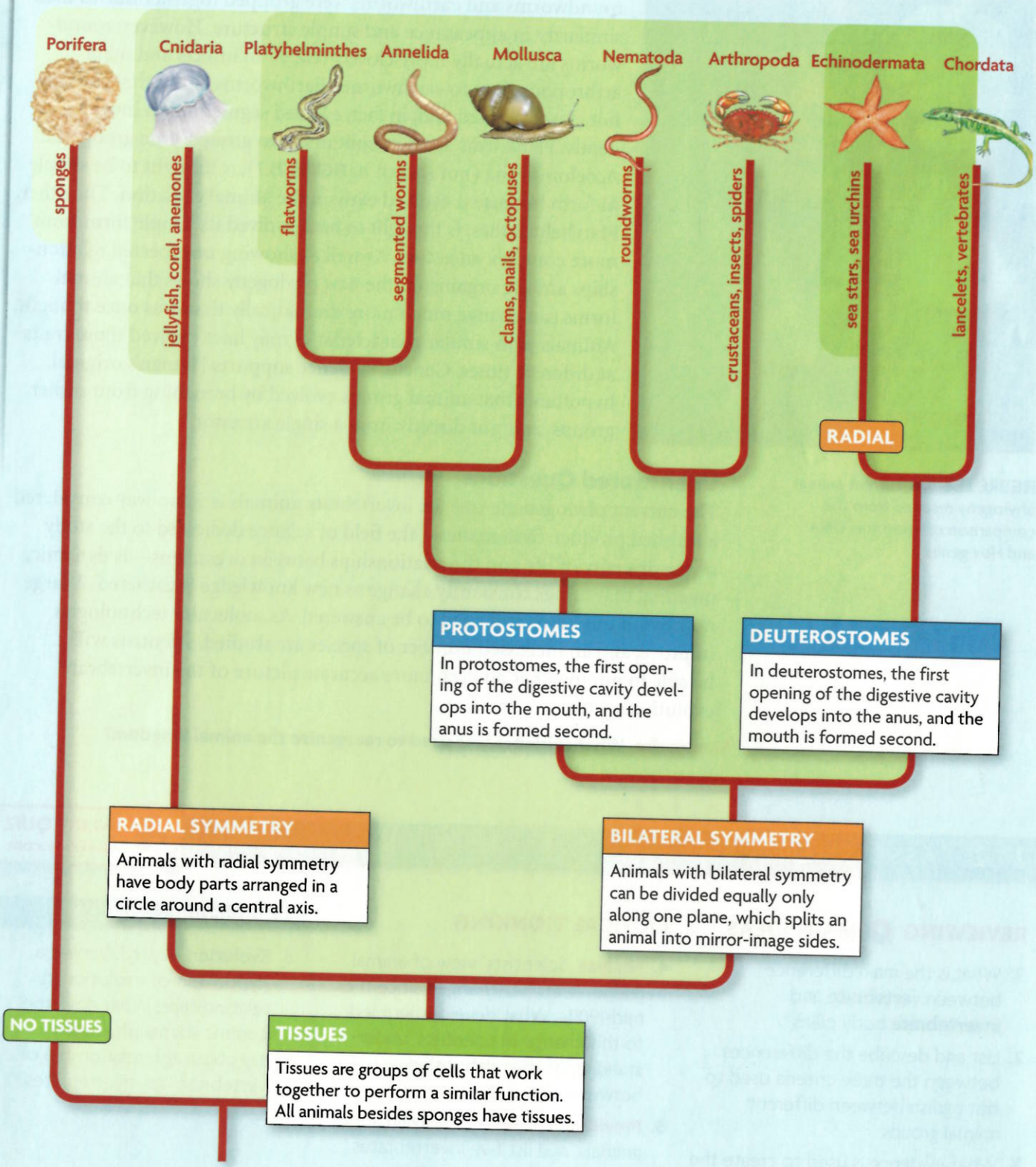
The presence of tissues is one characteristic that separates one animal group from another. Sponges, which lack tissues, are the simplest members of the animal kingdom, followed by animals with two tissue layers, such as jellyfish and corals. Whether an animal has radial or bilateral symmetry is another defining characteristic. As shown in **FIGURE 23.7**, the two major radiations, or phylogenetic branches, are the protostomes and the deuterostomes.

Protostomes Protostomes are further divided into the Lophotrochozoa (flatworms, annelids, and mollusks) and Ecdysozoa (roundworms and arthropods). All members of the Lophotrochozoa have either a specialized feeding structure made of hollow tentacles or a free-swimming ciliated larval form. Members of the Ecdysozoa must shed their outer skin to grow.

Deuterostomes Deuterostomes include members of the Echinodermata (such as sea stars and sand dollars) and the Chordata (such as birds, mammals, and all other vertebrates). As a member of the Chordata, you are a deuterostome.

FIGURE 23.7 Phylogeny of Animals

Comparisons of genetic sequences were used to modify the phylogenetic tree of animals.



CRITICAL VIEWING **Which phylum is most closely related to humans, which are chordates?**

FIGURE 23.8 The current animal phylogeny resulted from the comparison of ribosomal DNA and *Hox* genes.

Unexpected Evolutionary Relationships

The new organization of the animal kingdom shows relationships between animals that were previously unexpected. Originally, roundworms and earthworms were grouped together due to their similarity in appearance and simple structure. However, roundworms are actually more closely related to insects and other arthropods than to earthworms. Earthworms and arthropods are not closely related and, in fact, evolved segmentation independently. Flatworms are now split into two groups. One group, the Acoelomorpha (not shown in **FIGURE 23.7**), is thought to be simple in form because it evolved early in the animal radiation. The other, Platyhelminthes, is thought to have evolved its simple form from more complex ancestors. As well as showing unexpected relationships among organisms, the new phylogeny shows that animal forms can change much more dramatically than was once thought. Animals with similar characteristics may have evolved those traits at different times. Genetic evidence supports Hyman's original hypothesis that animal groups evolved by branching from earlier groups, and not directly from a single ancestor.

Unanswered Questions

The current phylogenetic tree for invertebrate animals is in no way considered a finished product. Systematics—the field of science dedicated to the study of the diversity of life and the relationships between organisms—is dynamic, meaning that things constantly change as new knowledge is gathered. A large number of questions still need to be answered. As molecular technologies improve, and an increased number of species are studied, scientists will be able to put together an even more accurate picture of the invertebrate evolutionary tree.

Summarize **What evidence was used to reorganize the animal kingdom?**

23.2 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. What is the main difference between **vertebrate** and **invertebrate** body plans?
2. List and describe the differences between the three criteria used to distinguish between different animal groups.
3. What evidence is used to create the phylogenetic tree for animals?

CRITICAL THINKING

4. **Analyze** Scientists' view of animal relationships has changed since the mid-1900s. What development led to this change in scientists' understanding of the relationships between animals?
5. **Provide Examples** Think again about animals, and list five invertebrates that might live in your neighborhood. To which **phylum** does each invertebrate belong?

Connecting CONCEPTS

6. **Evolution** A phylogeny is a hypothesis of evolutionary relationships. What does the current animal phylogeny say about the relationship of vertebrates to invertebrates?

23.3 Sponges and Cnidarians

KEY CONCEPT Sponges and cnidarians are the simplest animals.

MAIN IDEAS

- Sponges have specialized cells but no tissues.
- Cnidarians are the oldest existing animals that have specialized tissues.

VOCABULARY

sessile, p. 705
filter feeder, p. 706
polyp, p. 707
medusa, p. 707
mesoglea, p. 707
nematocyst, p. 707
gastrovascular cavity, p. 708

REVIEW AT CLASSZONE.COM

Connect Imagine you are snorkeling beneath the clear blue waters surrounding Australia's Great Barrier Reef. In addition to schools of tropical fish and sharks, covering the ocean floor are brightly colored sponge and coral species. Sponges and corals are members of two of the simplest animal phyla, the Porifera and the Cnidaria.

MAIN IDEA

Sponges have specialized cells but no tissues.

VOCABULARY

Sessile comes from a Latin word meaning "to sit." The opposite of sessile is mobile. *Mobile* comes from a Latin word meaning "to move."

Sponges have long been considered the most primitive animals on Earth because their body plan is much like what scientists would expect for an early multicellular organism. Two lines of recent evidence have strengthened this hypothesis.

- Sponge fossils more than 570 million years old were found in Australia, making sponges one of the most ancient groups of known animals.
- Molecular evidence confirms that sponges are closely related to a group of protists called choanoflagellates. Choanoflagellates are very similar in size and shape to certain cells found within a sponge. These protists are considered the most likely ancestors of all animals.

FIGURE 23.9 Sponges are among the simplest animals that still exist today.

Sponge Characteristics

Sponges lack muscle and nerve cells. So not surprisingly, they are **sessile,** meaning they are unable to move from where they are attached. As **FIGURE 23.9** shows, sponges attach to hard surfaces. They secrete toxic substances that prevent other sponges from growing into their area and also protect them from hungry predators and parasites. Some of these chemicals have been used in the development of medicines to treat forms of cancer such as lymphoma.

Sponge Reproduction

Sponges reproduce both sexually and asexually. In sexual reproduction, some species release eggs and sperm into the water, and fertilization occurs there. In other species, sperm is released into the water, and the egg is fertilized within the female sponge. The fertilized egg develops into a free-swimming larva that attaches to a surface, where it remains and develops into its adult form.

Some sponges reproduce asexually by budding. Buds break off from the adult sponge and float in the water until they attach to an underwater surface, where they grow into their adult form.

Sponge Anatomy

Sponges do not have mouths. As you can see in **FIGURE 23.10**, their cells are arranged around a network of channels that let water flow directly through the sponge's body. Water is pulled into the sponge though tiny pores in its body wall, and used water is ejected from a larger hole at the top of the sponge called the osculum. Of the thousands of known species of sponges, most are marine filter feeders. **Filter feeders** eat by straining particles from the water.

Sponges can be found in many colors and shapes. Some sponges are shaped like tubes, while others lie flat against the ocean floor. Regardless of their shape, all sponge bodies are made up of two layers of cells that cover a framework of collagen-like fibers, called spongin. The skeleton is usually reinforced with hard calcium- or silicon-based crystals called spicules. While sponges do not have tissues, they do have several types of specialized cells.

- **Pinacocytes** These thin and leathery cells form the sponge's outer layer.
- **Choanocytes** These cells, also called "collar cells," form the inner layer of the sponge. Each has a long flagellum surrounded by a collar of tiny hairlike structures called microvilli. These cells pull water through the sponge by beating their flagella. As the water passes the choanocytes, tiny food particles are trapped in the mucus on the microvilli.
- **Amoebocytes** These are mobile cells found in the jellylike material sandwiched between the two cell layers. Amoebocytes absorb and digest the food particles caught by the choanocytes and move the nutrients to other parts of the sponge. They also transport oxygen and wastes in the sponge. Because of their mobility, amoebocytes are important to a sponge's growth and repair of injuries.

Summarize **What characteristics make sponges the simplest animals?**

Connecting CONCEPTS

Symbiosis Recall from Chapter 14 that symbiosis is a close relationship between two or more species living in close contact. Sponges form symbiotic relationships with many different animals. Shrimps, crabs, and worms have been found living within the cavities of a sponge.

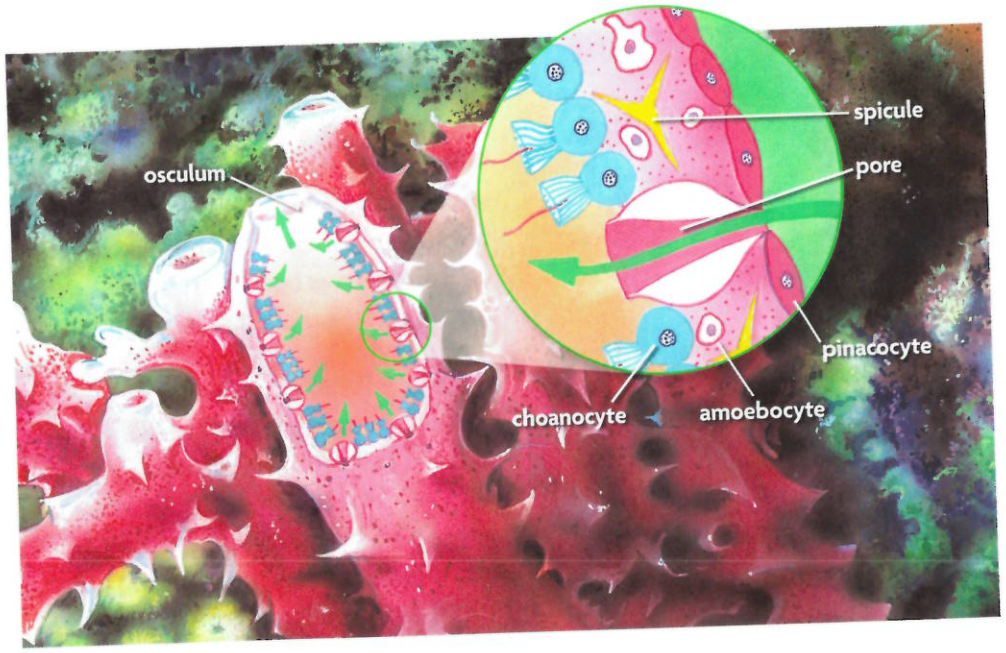


FIGURE 23.10 Sponges are animals that have specialized cells but lack tissues. This cutaway shows the internal organization of the sponge.

MAIN IDEA

Cnidarians are the oldest existing animals that have specialized tissues.

In contrast to sponges, cnidarians (ny-DAIR-ee-uhnz) can move. A jellyfish pulsing through the water and an anemone waving its tentacles make deliberate movements using simple nerves and muscles.

Cnidarian Characteristics

Cnidarians have two body forms: the polyp and the medusa, both of which are shown in **FIGURE 23.11.** **Polyps** (PAHL-ihps) are cylindrical tubes with mouth and tentacles facing upward. This form is characteristic of cnidarians such as corals. **Medusas** are umbrella-shaped, with their mouth and tentacles on the underside. This form is characteristic of free-swimming cnidarians such as the jellyfish. Many cnidarian species alternate between the two forms during their life cycle. Both polyps and medusas have radial symmetry, a characteristic of all cnidarians.

Cnidarian Reproduction

A cnidarian may reproduce both asexually and sexually during its life cycle. Polyps reproduce asexually by budding. This method produces genetically identical offspring. In the medusa form, cnidarians reproduce sexually by releasing gametes into the water. The fertilized egg develops into a free-swimming larva, called a planula. The planula then develops into the polyp stage.

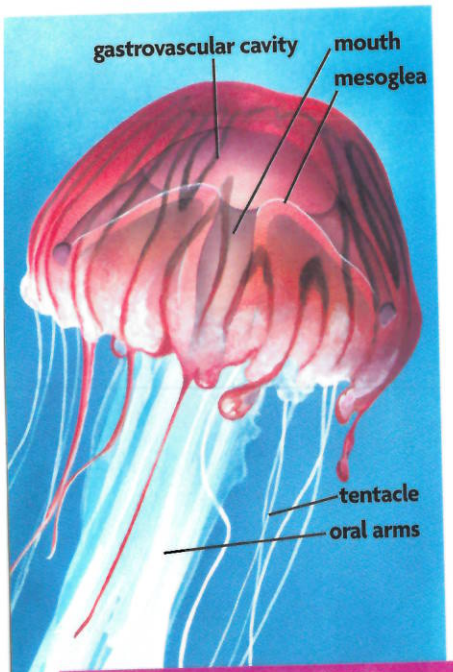
Cnidarian Anatomy

Cnidarian bodies have two tissue layers separated by a non-cellular jellylike material called **mesoglea** (MEHZ-uh-GLEE-uh). The outer layer of tissue is made up of three types of cells.

- **Contracting cells** Contracting cells cover the surface of the cnidarian and contain muscle fibers.
- **Nerve cells** Nerve cells interconnect and form a network over the entire animal. They send sensory information around the animal and coordinate muscular contractions. Cnidarians do not have brains.
- **Cnidocytes** (NY-duh-SYTS) Cnidocytes are specialized cells that contain stinging structures used for defense and capturing prey. They are unique to cnidarians. Cnidocytes are found all over a cnidarian's body, but most of them are on the tentacles.

One type of stinging structure found in both sea anemones and jellyfish is the nematocyst. A **nematocyst** (NEHM-uh-tuh-SIHST) is a capsule containing a thin, coiled, harpoon-shaped tubule with a poisonous barb at one end.

FIGURE 23.11 In the polyp form of a coral (top), the tentacles and mouth face upward. In the medusa form of a jellyfish (bottom), the tentacles and mouth face downward.



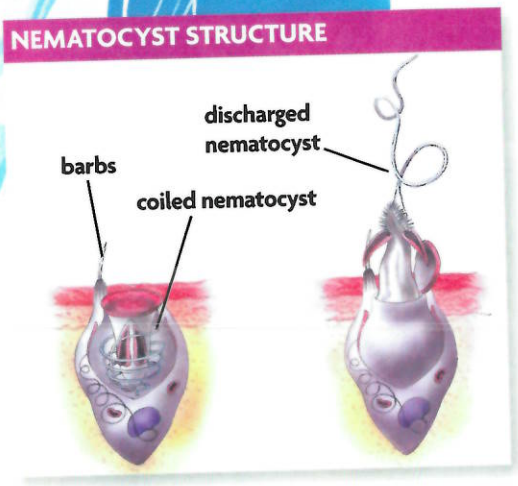


FIGURE 23.12 Cnidarians such as this jellyfish use nematocysts, a type of stinging structure found on their tentacles, to both capture prey and defend themselves against predators.

Nematocysts, shown in **FIGURE 23.12**, usually do not fire on contact unless a chemical signals the presence of prey or a predator. When they fire, nematocysts uncoil rapidly to spear and poison prey. Prey captured by nematocysts on the tentacles are stuffed through the animal's mouth into a saclike digestive space called the **gastrovascular cavity.** The cavity is lined with the cnidarian's inner tissue layer, which has cells that secrete digestive enzymes and absorb nutrients. Cnidarians do not have an anus, which in other animals is a separate exit for wastes. In cnidarians, wastes are pushed out through the mouth.

The gastrovascular cavity also moves oxygenated water to internal cells. When the animal's mouth is closed, water in the cavity becomes pressurized and provides skeletal support to the tissue, similar to a balloon full of water. Muscular contractions can work against the pressurized fluid and change the animal's shape.

Cnidarian Classes

There are four major groups, or classes, of cnidarians. Each class is defined in part by which body form is dominant during the animals' lives.

- **Anthozoa** (AN-thuh-ZOH-uh) include sea anemones and corals. The polyp form is dominant in these animals. There is no medusa stage.
- **Hydrozoa** (HY-druh-ZOH-uh) include fire corals, the Portuguese man-of-war, and hydras. These animals alternate between polyp and medusa forms. Medusas reproduce sexually, producing gametes that fuse to produce larvae. Larvae settle to the seafloor and grow into polyps. Most polyps are asexual.
- **Scyphozoa** (SY-fuh-ZOH-uh) are jellyfish. The medusa form is dominant in these animals. Some species have either a very short polyp stage or none at all.
- **Cubozoa** (KYOO-buh-ZOH-uh) include the tropical box jellyfish and sea wasps. These animals also have a dominant medusa form. Unlike the Scyphozoa, they have a cube-shaped body and well-developed eyes with retinas, corneas, and lenses—though how an animal with no brain interprets visual data is still unknown.

Contrast How do the polyp and medusa forms differ?

23.3 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. What is the main function of each of the three types of cells that make up a sponge's body?
2. What are the functions of the inner and outer tissue layers in a cnidarian?

CRITICAL THINKING

3. **Infer** What are the advantages of a **gastrovascular cavity** to the body functions of a cnidarian?
4. **Contrast** How do sponges and cnidarians defend themselves against predators? What is different about the methods used by each?

Connecting CONCEPTS

5. **Evolution** Some sponges have the remarkable ability to reassemble themselves after they are experimentally broken down into individual cells. What might this suggest about the origin of multicellularity in animals?

MATERIALS

- 2 large eyedroppers
- culture of *Hydra*
- petri dish
- drop of bottled spring water
- hand lens or dissecting microscope
- toothpick
- culture of *Daphnia magna*

PROCESS SKILLS

- **Observing**
- **Collecting Data**

Feeding *Hydra*

Hydra (LM; magnification 20×)

Hydra **belong to the phylum Cnidaria, which includes jellyfish and coral. These animals have thin body walls that are only a few cells thick. They eat small groups of microorganisms, called plankton, that include single-celled animals and protists. In this investigation, you will observe the *Hydra*'s anatomy, responses to touch, and feeding behavior.**

PROBLEM What are the behaviors of a *Hydra*?

PROCEDURE

1. Using the eyedropper, place a drop of water from the culture containing a *Hydra* into a petri dish. Be careful not to damage the *Hydra*. Cover the *Hydra* with spring water.
2. Observe the *Hydra* using a hand lens or dissecting microscope. Draw the *Hydra* and label its parts.
3. Using a toothpick, gently touch the side of the *Hydra* and note its response. Record your observations in your lab notebook.
4. Using a toothpick, gently touch the tentacles of the *Hydra* and note its response. Record your observations in your lab notebook.
5. Using a new eyedropper, transfer a drop of water containing *Daphnia* to the petri dish with the *Hydra*. Note all the events that happen as the *Hydra* catches and eats the *Daphnia*. Write all of your observations in your lab notebook. Wash your hands when you are finished with your work.

ANALYZE AND CONCLUDE

1. **Analyze** Did the *Hydra* have a head or tail end? If so, explain how you could tell the difference.
2. **Describe** Where was the *Hydra's* mouth?
3. **Infer** How do you think a *Hydra* removes wastes from its body? Explain your answer.
4. **Analyze** What was the most sensitive part of the *Hydra*? Why do you think this part was sensitive?
5. **Analyze** Describe the feeding behavior of the *Hydra*. How did it react to the presence of *Daphnia*?
6. **Apply** From your observations of the *Hydra's* feeding behavior, what do you think the small, rounded cells on the *Hydra's* tentacles do? Explain your answer.

23.4 Flatworms, Mollusks, and Annelids

KEY CONCEPT Flatworms, mollusks, and annelids belong to closely related phyla.

MAIN IDEAS

- Flatworms are simple bilateral animals.
- Mollusks are diverse animals.
- Annelids have segmented bodies.

VOCABULARY

complete digestive tract, p. 712
radula, p. 712
hemocoel, p. 712
segmentation, p. 714
coelom, p. 714

REVIEW AT CLASSZONE.COM

Connect Imagine if you had no stomach or lungs. Just like a flatworm, you would have to be rather flat and thin in order to get the oxygen and food you need to survive. While some flatworms can grow up to 20 meters long, they are never more than a few millimeters thick.

MAIN IDEA

Flatworms are simple bilateral animals.

Based on molecular studies, most flatworms, mollusks, and annelids are classified together as members of the Lophotrochozoa. These animals have either a feeding structure made of hollow tentacles called a lophophore, or a distinctive free-swimming ciliated larva called a trochophore. The name Lophotrochozoa is taken from these two anatomical features.

Flatworms have a solid body and an incomplete or absent gut. A flatworm's shape is the direct result of having no circulatory system. Flatworms can only move oxygen to their cells by diffusion, so all their cells must be close to the outside environment. Complex characters such as gut tubes were probably lost at a later stage of evolution, often as the flatworms became parasitic on other animals. The three classes of flatworms include the planarians, flukes, and tapeworms.

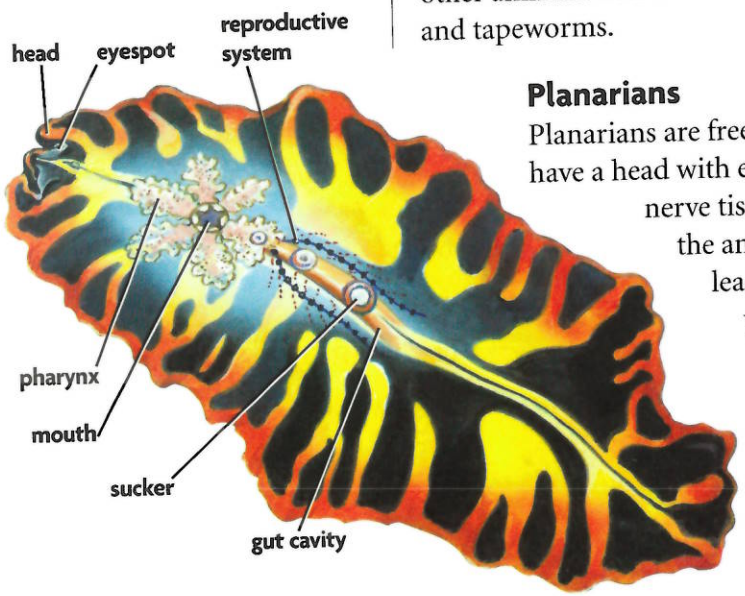


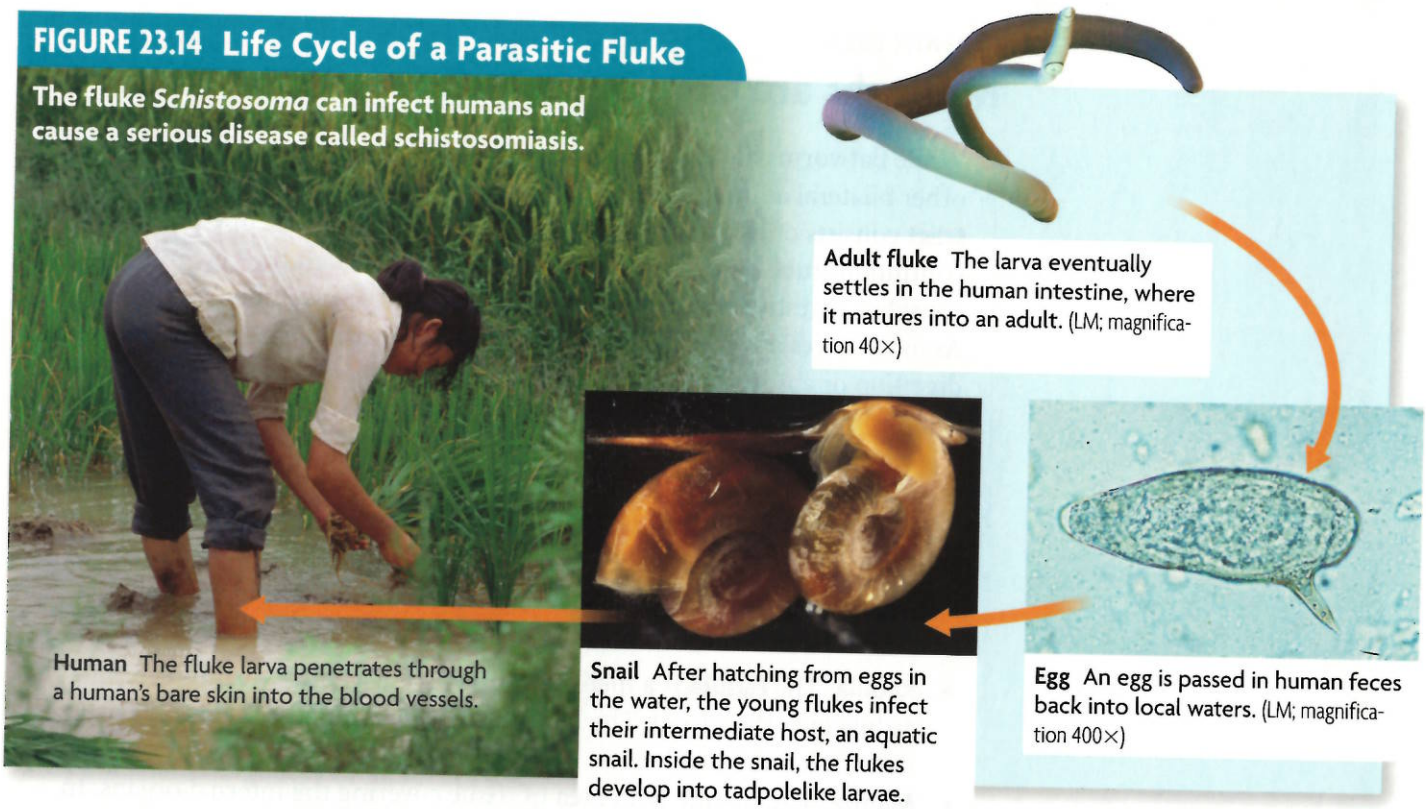
FIGURE 23.13 Planarians, such as this zebra flatworm, have a solid body that lacks a complete gut.

Planarians

Planarians are free-living, nonparasitic flatworms. Planarian worms have a head with eyespots and a simple brain built of a cluster of nerve tissue. As shown in **FIGURE 23.13**, the mouth is found on the animal's ventral surface rather than in its head, and it leads to a gut cavity. A muscular tube called the pharynx extends from the mouth to collect food. These worms actively hunt for food using chemoreceptors to detect odors in the water or in the air. They usually move using the cilia on their ventral surface, but they also have bands of muscle that let them twist their bodies.

FIGURE 23.14 Life Cycle of a Parasitic Fluke

The fluke *Schistosoma* can infect humans and cause a serious disease called schistosomiasis.



Adult fluke The larva eventually settles in the human intestine, where it matures into an adult. (LM; magnification 40×)

Egg An egg is passed in human feces back into local waters. (LM; magnification 400×)

Snail After hatching from eggs in the water, the young flukes infect their intermediate host, an aquatic snail. Inside the snail, the flukes develop into tadpolelike larvae.

Human The fluke larva penetrates through a human's bare skin into the blood vessels.

Flukes

Flukes are parasites that feed on the body fluids of other animals. Flukes have a mouth with a pharynx that opens into a gut cavity. They are found in both invertebrate and vertebrate hosts. Many species of flukes have life cycles that involve more than one host. **FIGURE 23.14** shows the life cycle of one fluke, *Schistosoma* (SHIHS-tuh-SOHM-uh), which can infect humans and cause a serious disease called schistosomiasis. This disease affects about 200 million people in areas such as Africa and Southeast Asia. The disease is contracted by wading in or drinking fresh water contaminated with fluke larvae. Symptoms of the disease include the onset of fever and muscle pain within one to two months of infection. The disease is treated by an anti-parasitic medicine.

Tapeworms

Tapeworms are parasites that live in vertebrate guts. They have a small head with suckers or hooks used to attach to the host. Their long ribbonlike body has no gut. Instead of swallowing food, these animals absorb nutrients from the digested food in which they live. An adult tapeworm's body is made up of segments containing both male and female sexual organs. When these segments fill with fertilized eggs, they break off and are excreted with the host's feces.

Many tapeworms have complex life cycles involving multiple hosts. The life cycle of a dog tapeworm begins when an egg is passed with a dog's feces. A flea eats the egg, and the egg develops into a larva within the flea's body. The tapeworm infects another dog when it accidentally eats the infected flea while licking its fur. The tapeworm develops into an adult within the dog's intestines, and the cycle begins again.

Connecting CONCEPTS

Structure and Function The simple structure of a tapeworm reflects that as an adult it does not have to move or digest food. The lack of complex internal systems allows for a simpler body plan.

Contrast **How are planarians different from flukes and tapeworms?**

MAIN IDEA

Mollusks are diverse animals.

While flatworms have a digestive sac with only one opening, mollusks and all other bilateral animals have a complete digestive tract. A **complete digestive tract** consists of two openings—a mouth and an anus—at opposite ends of a continuous tube. Because food moves one way through the gut, animals with complete digestive tracts can turn their guts into disassembly lines for food. As food moves down the gut, it travels through areas that are specialized for digestion or absorption. Animals with complete digestive tracts can eat continuously. This efficient and frequent digestion allows animals to be more active.

Mollusk Anatomy

Mollusks include animals as different-looking as oysters, garden snails, and giant squid. Mollusks may be sessile filter feeders, herbivores that graze on algae, or predators. Despite this variety of form and lifestyle, all mollusks share at least one of three features, shown in **FIGURE 23.15.**

- **Radula** The **radula** is a filelike feeding organ. Mollusks eat by scraping the radula over their food. The hard teeth of the radula pick up tiny particles that the animal swallows.
- **Mantle** The mantle is an area of tissue covering the internal organs. In most mollusks, the mantle secretes a hard calcium-based shell that protects the animal from predators.
- **Ctenidia** (tih-NIHD-ee-uh) The ctenidia are flat gills found in a pocket of the mantle tissue called the mantle cavity. The gills absorb oxygen from water that enters this cavity. In the land-dwelling snail shown below, the gills have been lost, and oxygen is absorbed from air rather than from water in the cavity.

While the gills contain blood vessels, blood is also pumped through the hemocoel. The **hemocoel** (HEE-muh-SEEL) consists of spaces between cells within the animal's tissues. This circulatory system extends into a large muscular foot. Snails and slugs crawl on the foot, while clams and scallops dig with the foot. In cephalopods, such as squids and octopuses, the foot forms a muscular siphon, parts of the tentacles, and head.

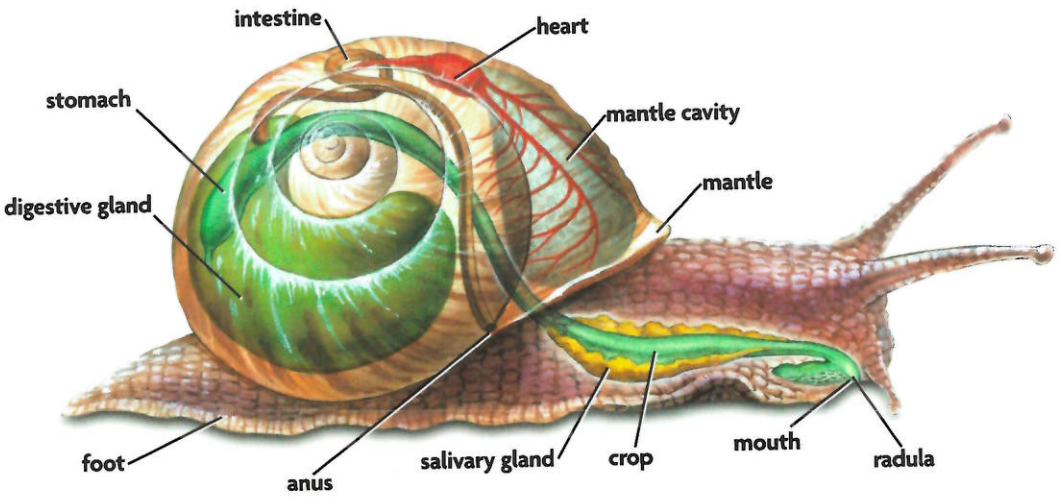


FIGURE 23.15 The anatomy of a common garden snail includes a radula and a mantle, both of which are features shared by most mollusks.

Classes of Mollusks

There are seven classes of mollusks. The majority of species, however, are found within three classes: the gastropods, pelecypods (bivalves), and cephalopods.

- **Gastropoda** This class includes snails, nudibranchs, abalones, and limpets. This class includes over half of the species found in the Mollusk phylum. Gastropods live in both land and aquatic ecosystems. This class includes species that are herbivores, carnivores, and scavengers.
- **Pelecypoda** This class includes clams, oysters, mussels, and scallops. Pelecypods, which are also called bivalves, have a soft body that is protected by two hard shells that are hinged together. Most bivalves are filter feeders that live in marine ecosystems.
- **Cephalopoda** This class includes squid, as shown in **FIGURE 23.16**, octopuses, nautiluses, and cuttlefish. Among the mollusks, the nervous system and eye of the cephalopod are the most well-developed. Cephalopods are carnivores that eat animals such as crustaceans, fish, and other mollusks.
- **Scaphopoda** This class is also called the tusk shells, so named because their shells resemble the shape of an elephant's tusks. These mollusks live at the bottom of water bodies, where they feed on detritus.
- **Polyplacophora** This class is also called the chitons, which are animals that have a shell with overlapping plates. These marine mollusks spend most of their lifetime clinging to rocks, where they feed by using their radula to scrape algae and plant matter from the rocks.
- **Aplacophora** This class includes small wormlike animals that, unlike most mollusks, do not have shells. These mollusks live in deep water. Some feed on small marine invertebrates, while others are parasites of coral.
- **Tryblidia** This class of mollusks was once believed to be extinct, but they were rediscovered in 1952. Little is known about these marine mollusks that live in deep water.

FIGURE 23.16 The Humboldt, or jumbo, squid may grow to nearly 2 meters (6 ft) in length.

Connecting CONCEPTS

Convergent Evolution Much like the human eye, the cephalopod eye is made up of a lens, retina, iris, and pupil. However, the evolution of cephalapod and human eyes occurred independently. Recall from **Chapter 11** that convergent evolution is the evolution of similar structures in unrelated species.

Mollusk Reproduction

Mollusks use a variety of reproductive strategies. Garden snails, for example, are hermaphrodites. Hermaphrodites are organisms that have both male and female reproductive organs. Reproduction usually involves cross-fertilization. Just before mating, the impregnating snail fires a "love dart" into the other. This calcium-rich, mucus-covered dart causes the recipient snail's reproductive system to store more sperm. During mating, a packet of sperm is transferred into the recipient snail. This packet of sperm is used to fertilize the eggs. These eggs are laid in underground nests. After a period of two to four weeks, juvenile snails hatch from the eggs.

Summarize **What common features are shared by mollusks?**

QUICK LAB OBSERVING

Anatomy of a Clam

A clam is a bivalve mollusk. In this lab, you will explore the parts and systems of a clam.

PROBLEM What are the internal organs and systems of a clam?

PROCEDURE

1. Place the clam in the dissecting tray and follow the instructions on the drawing to carefully open the shell.
2. Look for the gills, and use your probe to study them.
3. Observe and note the shape of the foot. Locate the palps.
4. Follow the instructions to peel away the muscle layer to see the internal organs.
5. Locate the reproductive organs, and then find the digestive system.
6. Dispose of your specimen as instructed by your teacher.

ANALYZE AND CONCLUDE

1. **Infer** What organ does the clam use to breathe?
2. **Infer** The clam is a filter feeder. Based on your observations of the digestive system, how does the clam eat?
3. **Infer** The arteries and veins are not attached to each other. How might the circulatory system work?

MATERIALS

- preserved clam specimen
- dissecting tray
- Anatomical Clam Drawing
- screwdriver
- scalpel
- probe
- scissors
- forceps
- 12 dissecting pins
- hand lens
- paper towels

MAIN IDEA

Annelids have segmented bodies.

All annelids share more similarities in their body plans than mollusks do. Three groups of annelids—earthworms, marine worms, and leeches—are characterized by segmentation. **Segmentation** refers to the repeated sections of an annelid's long body that contain a complex set of body structures.

Annelid Anatomy

The features of an annelid's segmented body are shown in **FIGURE 23.17.** A typical annelid segment contains part of the digestive tract, nerve cord, and blood vessels that carry blood to the worm's tissues. Annelids have a closed circulatory system, where blood travels in a closed circuit inside blood vessels. Each body segment also contains organs that collect and excrete wastes, bands of longitudinal and circular muscle, and a coelom.

VOCABULARY

Coelom comes from a Greek word meaning "cavity." *Septum* comes from a Latin word meaning "partition."

The **coelom** (SEE-luhm) is a fluid-filled space that is completely surrounded by muscle. The coelom is divided by partitions called septa (singular, *septum*). The fluid inside the coelom acts as a hydrostatic skeleton. To understand how a hydrostatic skeleton works, think of a water balloon. When you squeeze one end, the water moves to the opposite end. An annelid uses its hydrostatic skeleton in a similar way to move from one place to another. When the longitudinal muscles contract, the segment shortens. When circular muscles contract, the segment lengthens. Alternating waves of contractions move from head to tail, producing the worm's characteristic crawling motion.

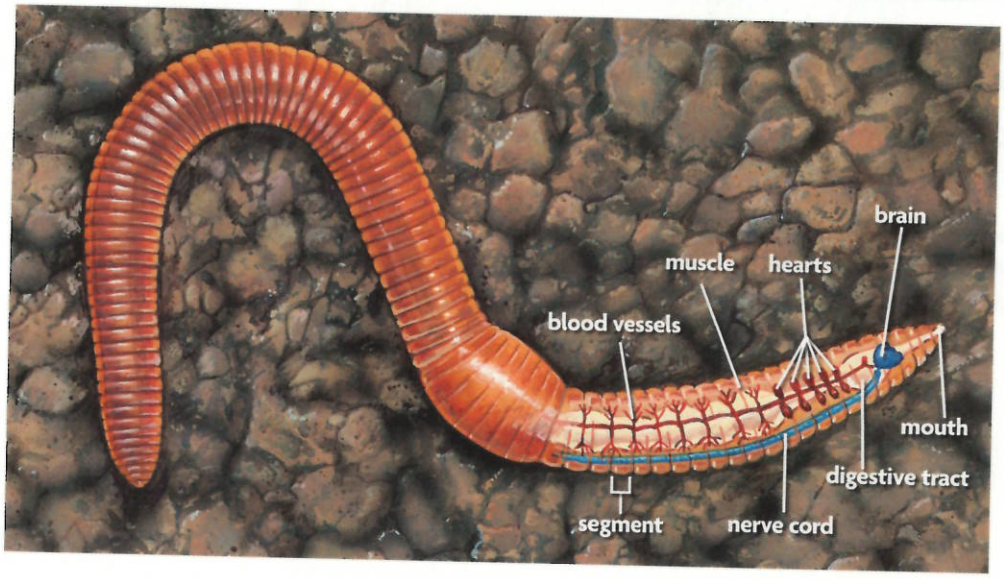


FIGURE 23.17 Annelids, such as earthworms, have similar body plans, characterized by segmentation.

Annelid Diet

Earthworms and marine worms eat organic waste material. Earthworms excrete digested material, called castings, into the soil. Castings help maintain a nutrient-rich soil. While most people think of leeches as blood-feeders, a number of leech species are actually predators that feed on invertebrates such as snails and aquatic insect larvae.

Annelid Reproduction

Annelid reproduction may be either asexual or sexual. Asexual reproduction results from fragmentation. In this method, a portion of the posterior end of the annelid breaks off and forms a new individual. Some annelids, such as earthworms, are hermaphrodites. Just as in land snails, reproduction occurs by cross-fertilization. Other annelids, such as marine worms, have separate males and females. Fertilized eggs of marine annelids initially develop into free-swimming larvae. Larvae grow in size by the formation of new segments.

Contrast **In what ways are annelids different from mollusks?**

23.4 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING ▶ MAIN IDEAS

1. Describe the characteristics that separate the three groups of flatworms.
2. What is the function of a mollusk's **radula**?
3. What are the three groups of annelids? Describe their body plan, using the word **coelom.**

CRITICAL THINKING

4. **Apply** How might a community prevent *Schistosoma* infections?
5. **Infer** What adaptations might mollusks without shells use to defend against predators?

Connecting CONCEPTS

6. **Evolution** Free-living flatworms have pairs of sensory organs in their heads. What might make two sense organs set on either side of the head more adaptive than a single central organ?

23.5 Roundworms

KEY CONCEPT Roundworms have bilateral symmetry and shed their outer skeleton to grow.

MAIN IDEAS

- Roundworms shed their stiff outer skeleton as they grow.
- Many roundworms are parasites.

VOCABULARY

cuticle, p. 716
pseudocoelom, p. 716

REVIEW AT CLASSZONE.COM

Connect Imagine grabbing a handful of soil. In that single handful, there may be thousands of roundworms. These animals are found in nearly every ecosystem on Earth, including mountaintops and deep ocean trenches. They are also found within extreme environments such as hot springs and Arctic ice.

MAIN IDEA

Roundworms shed their stiff outer skeleton as they grow.

Roundworms, also called nematodes, are one of the most numerous kinds of animals, in terms both of numbers and of species diversity. The more than 15,000 species of roundworms vary in size from less than a millimeter to over 10 meters in length.

Roundworms are part of the group Ecdysozoa, which also includes arthropods—crustaceans, spiders, and insects. Like mollusks and annelids, members of the Ecdysozoa are protostomes and have bilateral symmetry. All Ecdysozoans have a tough exoskeleton called a cuticle. The **cuticle** (KYOO-tih-kuhl) is made of chitin, and must be shed whenever the animal grows larger. When the animal sheds its cuticle, its soft body is exposed to predators until its new skeleton hardens.

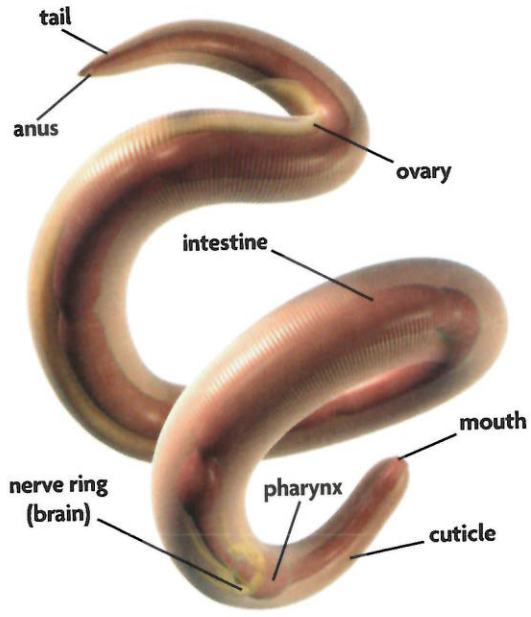


FIGURE 23.18 Roundworms have a cylindrical shape and must shed their tough outer cuticle to grow in size.

Roundworm Anatomy

As shown in **FIGURE 23.18,** a roundworm is cylindrical, with a blunt head and tapered tail. It is covered with a tough cuticle that lies over a layer of muscle. Muscle in the roundworm is laid out lengthwise. This arrangement means that a roundworm moves by bending its body side-to-side. Rather than crawling like other types of worms, a roundworm's movement is more whiplike.

Muscle within the roundworm is separated from the central gut tube by a fluid-filled space. This fluid-filled space is called a **pseudocoelom** (soo-duh-SEE-luhm) because it is not completely lined by muscle. (The prefix *pseudo-* means "false.") Roundworms do not have circulatory or respiratory systems. However, they do have a digestive system, which includes a mouth, pharynx, intestine, and anus. Food that is eaten, such as plant matter, algae, or bacteria, travels the length of the roundworm, from the mouth at one end to the anus at the other.

Roundworm Reproduction

Most roundworms reproduce sexually. In some cases, female roundworms bear live young after eggs hatch within the female's reproductive tract. In most cases, however, larvae develop from eggs laid by the female. Roundworms grow into their adult form by molting.

Contrast **How does growth differ in a roundworm and in a human?**

MAIN IDEA

Many roundworms are parasites.

Roundworms are parasites of nearly every plant and animal species. These animals cause a lot of damage to the crop species they infect. Such a widespread loss of crops can seriously harm the economy of farming communities. Other roundworms infect humans. These roundworms include hookworms, pinworms, and Guinea worms.

- **Hookworms** A hookworm is found within the digestive tract of its host. This parasite feeds on its host's blood. A hookworm infects its human host when a person walks barefoot over contaminated soil. Over 1 billion people are infected with hookworms. Such infections are common in the tropics and subtropics.
- **Pinworms** A pinworm is found in the gut of its host. Pinworm infections often occur when the host accidentally swallows eggs picked up from contaminated surfaces.
- **Guinea worms** Guinea worms are found in the guts and connective tissues of their hosts. Guinea worm infections occur when a person drinks contaminated water. Work by global health organizations has helped to eliminate this disease from most of the world.

"So much for being the early bird, you've got worms."

Source: CartoonStock.com

Infer **Why might most parasitic roundworms live in the gut of their host?**

23.5 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. Why do roundworms molt? Use the term **cuticle** in your answer.
2. What are three parasitic roundworms that infect human hosts?

CRITICAL THINKING

3. **Contrast** How are earthworm and roundworm body cavities different?
4. **Apply** How might Guinea worm infections be prevented?

Connecting CONCEPTS

5. **Parasitism** Many species of roundworms are parasites of plants and animals. How is a roundworm's body plan related to its function as a parasite?

23.6 Echinoderms

KEY CONCEPT Echinoderms are on the same evolutionary branch as vertebrates.

MAIN IDEAS

- Echinoderms have radial symmetry.
- There are five classes of Echinoderms.

VOCABULARY

ossicle, p. 718
water vascular system, p. 718

REVIEW AT CLASSZONE.COM

Connect If you have ever seen a tide pool, you may have noticed several creatures clinging to the pool's rocky bottom and sides. Brightly colored sea stars and spiky sea urchins are just two of the echinoderms that are often found in these habitats.

MAIN IDEA

Echinoderms have radial symmetry.

Adult echinoderms are slow-moving marine animals that have radial symmetry. In contrast, echinoderm larvae have bilateral symmetry. This difference suggests that echinoderms had bilateral ancestors and that radial symmetry is a derived character.

Echinoderm Anatomy

The anatomy of a sea star is shown in **FIGURE 23.19.** Note that each arm of a sea star contains both digestive glands and reproductive glands. For clarity, they are shown separately in different arms in the illustration.

All echinoderms have an internal skeleton made up of many tiny interlocking calcium-based plates called **ossicles.** These ossicles are embedded within the skin. The plates are joined together by a unique catch connective tissue with adjustable stiffness. Catch connective tissue allows echinoderms to change their consistency, going from very flexible to very stiff in a matter of seconds. The combination of a firm skeleton and a surface covered with spiny projections (often poisonous) helps to fend off predators.

Echinoderms have a **water vascular system,** which is a series of water-filled radial canals that extend along each arm from the ring canal surrounding the central disk. The radial canals store water that is used for circulation and for filling tiny suckerlike appendages along the arms called tube feet. Changes in water pressure extend and retract the tube feet. On its own, a tube foot is small, but many of them working together can exert large forces. Tube feet are used to grab objects and to move around.

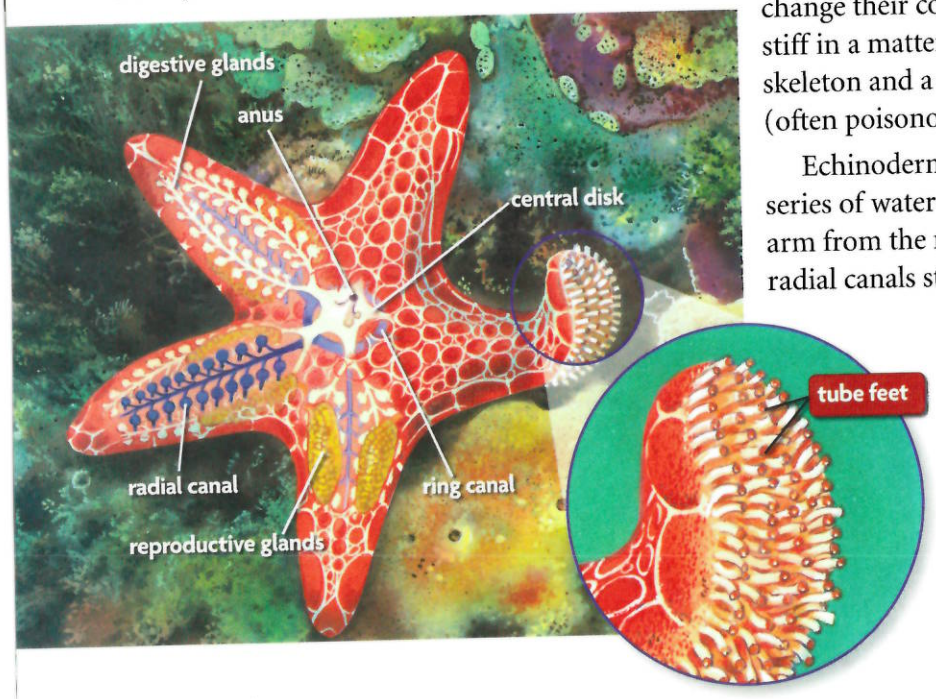


FIGURE 23.19 Echinoderms, such as sea stars, are radially symmetrical animals with an internal skeleton made of interlocking plates embedded under the skin. Three arms of this sea star have been "cut away" to show internal anatomy.

A sea star has a complete digestive system made up of a mouth, stomach, a small length of intestine, and an anus. To eat a clam, a sea star grabs hold of the clam with its tube feet and uses pressure to pull apart the clam's shell. Sea stars are able to push their stomach out of their mouths. The stomach enters the narrow space between the two shells of a clam, and digestive juices from the digestive glands dissolve the clam's body. The clam is completely digested in the stomach. Waste material exits out the anus.

Echinoderms such as sea stars can regenerate, or regrow, their limbs, as shown in **FIGURE 23.20**. Sea cucumbers can regenerate a portion of their digestive system, which they sometimes eject when disturbed. For regeneration to occur, certain body parts, such as a portion of a sea star's central disk, must still remain.

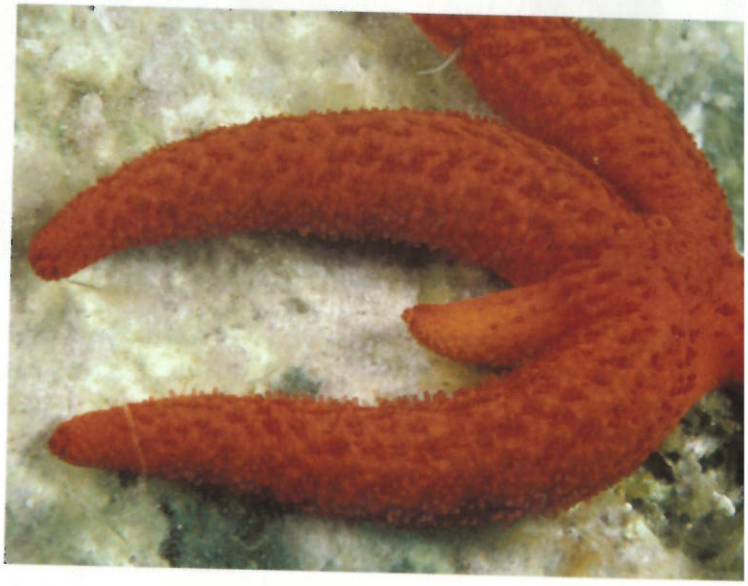


FIGURE 23.20 Sea stars and other echinoderms are able to regenerate, or regrow, limbs.

Echinoderm Reproduction

Most echinoderms reproduce sexually. Adult sea stars, for example, release sperm and eggs from the reproductive glands in their arms into the water. The fusion of these gametes results in fertilization of the egg. The fertilized egg develops into a free-floating, planktonic larva that matures in the water. As it matures, an echinoderm undergoes a complex series of changes into its adult form. The left side of its body begins to form the tube feet, while the right side forms the ossicle plates that will protect its outer surface. Eventually, the echinoderm settles onto the ocean floor, where it develops into an adult.

Connect **A sea star specimen has bilateral symmetry. Is it an adult or a larva? Why?**

MAIN IDEA

There are five classes of Echinoderms.

Echinoderms have a variety of body plans, ranging from the spiny round sea urchin to the oblong and the well-named sea cucumber.

Feather Stars and Sea Lilies

Feather stars and sea lilies are members of the class Crinoidea (kry-NOY-dee-uh). A feather star, shown in **FIGURE 23.21**, can move with its arms, but it is usually attached to a surface. Sea lilies are sessile. They are attached to the ocean bottom by a stalk on one side of their bodies. These animals filter feed by using the tube foot–like extensions covering their arms to collect and transfer food to the mouth.

Sea Stars

Sea stars are members of the class Asteroidea (as-tuh-ROY-dee-uh). Some sea stars are filter feeders, while others are opportunistic feeders, meaning that they will eat whatever food source they happen to come upon. Other sea stars are carnivorous predators.

FIGURE 23.21 Feather stars are members of the class Crinoidea. These animals are filter feeders.

FIGURE 23.22 Basket stars (left) use their long, branched arms to capture plankton. Sea urchins (middle) are covered in long, sharp spines that protect them from predators. Sea cucumbers (right) are fleshy animals that live on the ocean floor.

Brittle Stars and Basket Stars

Brittle stars and basket stars are both members of the class Ophiuroidea (AHF-ee-yuh-ROY-dee-uh). Brittle stars have long spindly arms and are fast movers. Because their tube feet lack suckers, brittle stars use their arms to move. Some brittle stars are scavengers that feed on detritus on the ocean floor. Others are predators. Basket stars, shown in **FIGURE 23.22**, also have long arms, although with many branches. Basket stars filter feed by capturing plankton with their arms.

Sea Urchins, Sea Biscuits, and Sand Dollars

Sea urchins, sea biscuits, and sand dollars are all members of the class Echinoidea (EHK-uh-NOY-dee-uh). The bodies of sea biscuits and sand dollars are covered with tiny projections, which the animals use for movement and for burrowing on the ocean floor. Sea urchins, which do not burrow, do not have these projections. Instead, these animals are covered in long, sharp spines. Burrowing animals feed on waste matter on the ocean floor. Most sea urchins graze on algae by trapping it on sticky tentacles found on their ventral side.

Sea Cucumbers

Sea cucumbers are the only members of the class Holothuroidea (HAHL-uh-thu-ROY-dee-uh). Sea cucumbers are fleshy animals that have a long, bilateral shape. Instead of arms, sea cucumbers have thick, fleshy tentacles. These tentacles are used to capture particles of food, which the animal eats by pulling its tentacles through its mouth. Sea cucumbers, which live on the ocean floor, are also sediment feeders. These animals absorb food items in their digestive tract, and eject nonfood particles through their anus.

Contrast **How do feeding behaviors differ between sea stars and sea cucumbers?**

NSTA SCILINKS scilinks.org

For more information on echinoderms, visit scilinks.org. Keycode: MLB023

23.6 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. How does the **water vascular system** enable echinoderms to move?
2. Describe the differences in body plans between the five classes of echinoderms.

CRITICAL THINKING

3. **Contrast** How do the feeding habits of sessile echinoderms differ from those that are mobile?
4. **Infer** How does an echinoderm benefit from the ability to regenerate limbs?

Connecting CONCEPTS

5. **Bioindicators** Sea urchins live on rock- and sand-covered areas of the ocean floor. What changes in an ocean ecosystem might be indicated by an increase in the sea urchin population?

DATA ANALYSIS
ClassZone.com

Correlations Among Invertebrate Data

A **scatterplot** is a type of graph used to identify a trend or a correlation between two variables.

- The independent variable is usually graphed on the *x*-axis.
- The dependent variable is usually graphed on the *y*-axis.
- The data points are plotted but not connected.

Three types of correlations between variables can be shown on a scatterplot.

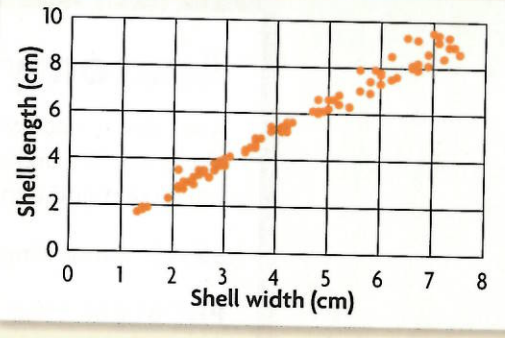
- Positive—as one variable increases or decreases, the other variable increases or decreases respectively.
- Negative (inverse)—as one variable increases, the other decreases.
- No correlation—there is no change in one variable as the other variable either increases or decreases.

EXAMPLE

Graph 1, a scatterplot of butter clam shell length and width, shows that as the width of the clam's shell increases, the length of the shell increases as well. This is a positive correlation, because as width increases, length increases. If it were an inverse correlation, one of the variables would increase as the other decreased.

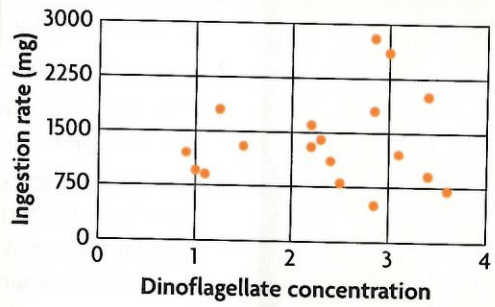
Graph 2, a scatterplot of zooplankton feeding rates, shows no correlation between the feeding rates of zooplankton and the concentration of dinoflagellates. You can infer that there is no correlation from the graph, because the data is scattered across the graph and does not form a pattern.

GRAPH 1. PUGET SOUND BUTTER CLAMS



Source: Seattle Central Community College

GRAPH 2. ZOOPLANKTON FEEDING RATE



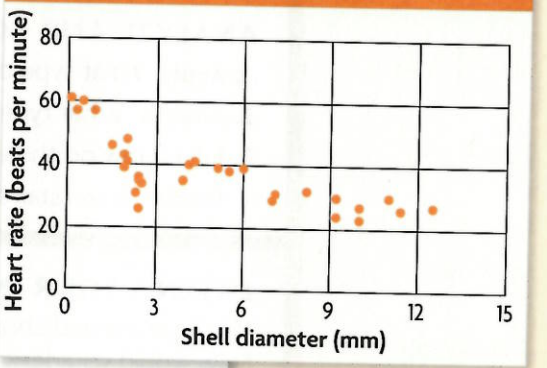
Source: Calbet, A. et al. *Journal of Aquatic Microbial Ecology* 26

ANALYZE A SCATTERPLOT

Scientists measured the heart rate and shell diameter of snails. These data are shown in the graph at the right. Use the graph to answer the following three questions.

1. **Analyze** Describe the correlation between the shell diameter and the heart rate in this species of snail.
2. **Predict** If a snail shell were to grow past 14 mm, what do you think would happen to the snail's heart rate?
3. **Infer** Suggest a possible explanation for the correlation between heart rate and shell diameter.

GRAPH 3. SNAIL HEART RATE



Source: Iowa State University

Use these inquiry-based labs and online activities to deepen your understanding of invertebrates.

INVESTIGATION

Anatomy of a Sea Star

A sea star is a saltwater echinoderm in the same phylum as sea urchins and sand dollars. In this lab, you will dissect and explore the parts of a sea star.

SKILL Observing

PROBLEM What organs and systems are inside a sea star?

MATERIALS

- preserved sea star specimen
- dissecting tray
- scissors
- forceps
- dissecting needle
- 12 dissecting pins
- hand lens or dissecting microscope
- paper towels
- Anatomical Sea Star Drawing

PROCEDURE

1. Remove the sea star from its container and place it in the dissecting tray.
2. Examine the external anatomy of the sea star.
3. Follow the instructions on the sea star drawing as you complete steps 4–8.
4. Use scissors to cut off the end of one ray about one inch from the tip. Use the scissors to cut a long circular flap of skin along the length of one ray to expose the organs underneath. Look closely in the ray on either side of the groove.
5. With forceps and scissors, lift and cut the skin closer to the center (within half an inch). There, on either side of the groove, you will see the gonads, or reproductive organs, of the sea star.
6. The water-filled space in each ray is called the coelom. Notice that the sea star has no heart or circulatory system.
7. When finished, dispose of your sea star according to instructions from your teacher. Be sure to wash your hands thoroughly before leaving the lab.

ANALYZE AND CONCLUDE

1. **Apply** What type of symmetry does the sea star have?
2. **Analyze** What type of texture does the dorsal surface have? What is it covered with?
3. **Infer** How do the eyespots compare with eyes of other animals?
4. **Predict** A sea star does not have teeth. How does it eat?

EXTEND YOUR INVESTIGATION

You have learned about the different structures and their functions within a sea star. How would you design an experiment to determine what food items sea stars prefer? Use the library or Internet to research which food items sea stars eat, and then design your experiment. Include in your experimental design your control, independent variables, and dependent variables.

INVESTIGATION

Anatomy of an Annelid

The California blackworm (*Lumbriculus variegatus*) lives in sediments and organic debris on the edges of freshwater ponds, marshes, and lakes. In this investigation, you will observe a blackworm's anatomy and behavior, and observe and measure blood flow.

SKILL Observing

PROBLEM What are the features of an annelid?

MATERIALS

- 6–10 filter paper disks
- forceps
- petri dish
- 10 mL spring water
- California blackworm
- eyedropper
- dissecting microscope

PROCEDURE

1. Place a filter paper disk in the petri dish and moisten it with water at room temperature.
2. Carefully transfer a blackworm to the petri dish using the eyedropper.
3. Observe the blackworm at low (40×) and high (400×) powers with the microscope.
4. Draw what you see. What structures can you identify? How many segments does the blackworm have? Can you see the large blood vessels running along the worm? Draw them.
5. Observe the blood vessels more closely. Do they change over time? If so, what happens?

ANALYZE AND CONCLUDE

1. **Analyze** Does the worm have a head end and tail end? Explain.
2. **Infer** What causes blood to flow in the worm?
3. **Experimental Design** Write a procedure to measure the blood flow using a ruler and a watch.

Online BIOLOGY CLASSZONE.COM

ANIMATED BIOLOGY

Shared Body Structures

Animals that look very different can have similar body structures. Compare structures and organs of four different invertebrates to explore shared characteristics.

WEBQUEST

Parasites. Just the word can make your skin crawl. In this WebQuest, you will explore one parasite, the tapeworm. You will learn about its lifecycle and how to keep from becoming a host yourself! (colored SEM; magnification 40×)

BIOZINE

Stories about invertebrates—such as "Sea Snails' Slime Holds Healing Properties" and "Designer Dogs: Get the Mix You Want"—are often in the headlines. Read the latest news about animals in the BioZine.

CHAPTER 23

Interactive Review @ CLASSZONE.COM

KEY CONCEPTS | Vocabulary Games | Concept Maps | Animated Biology | Online Quiz

23.1 Animal Characteristics

Animals are diverse but share common characteristics. Animals are the most physically diverse kingdom of organisms. All animals share a set of characteristics.

- All animals are multicellular heterotrophs.
- Animal cells are supported by collagen.
- Animals that reproduce are diploid and usually reproduce sexually.
- Most animals have *Hox* genes.

23.2 Animal Diversity

More than 95 percent of all animal species are invertebrates. Each animal phylum has a unique body plan. Scientists have constructed an invertebrate phylogenetic tree supported by anatomy comparisons and molecular evidence.

Bilateral symmetry Radial symmetry

23.3 Sponges and Cnidarians

Sponges and cnidarians are the simplest animals. Sponges are aquatic animals that have specialized cells but lack tissues. These animals were among the first to evolve during the Cambrian explosion. Cnidarians, which include jellyfish, corals, and sea anemones, are the most primitive animals still in existence today with specialized tissues.

23.4 Flatworms, Mollusks, and Annelids

Flatworms, mollusks, and annelids belong to closely related phyla. Flatworms are simple bilateral animals. They include planarians, flukes, and tapeworms. Mollusks share at least one feature in common: a radula, a mantle, or ctenidia. Common mollusks include snails, bivalves such as clams, and squid. Annelids have segmented bodies and include earthworms, leeches, and marine polychaete worms.

23.5 Roundworms

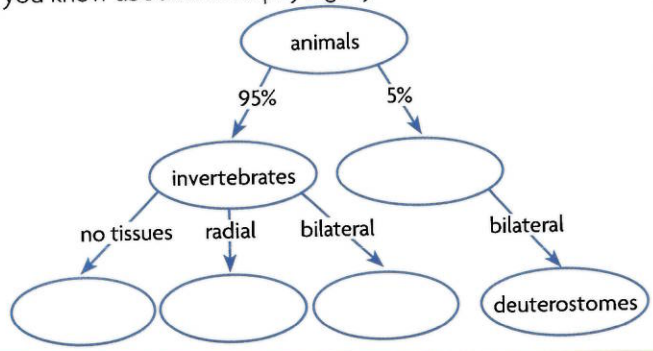
Roundworms have bilateral symmetry and shed their outer skeleton to grow. Roundworms are cylindrical, with a blunt head and tapered tail. They are covered with a tough cuticle that lies over a layer of muscle. Roundworms may be free-living or parasitic. Common human parasites include hookworms, pinworms, and Guinea worms.

23.6 Echinoderms

Echinoderms are on the same evolutionary branch as vertebrates. Echinoderms and vertebrates are both deuterostomes. Like cnidarians, echinoderms have radial symmetry. These animals have body parts arranged in a circle around a central axis and use a water vascular system to move and transport nutrients. Some echinoderms can regenerate portions of their body, and sometimes they use regeneration as a way to produce offspring.

Synthesize Your Notes

Concept Map Use a concept map to summarize what you know about animal phylogeny.



Content Frame Use a table to synthesize notes on the characteristics of the different invertebrate phyla.

Phyla	Features	Symmetry	Examples
Cnidaria	Tissues	Radial	Jellyfish, coral
Flatworms			

Chapter Assessment

Chapter Vocabulary

23.1 collagen, p. 697
homeotic, p. 698
homeobox, p. 698

23.2 vertebrate, p. 699
invertebrate, p. 699
phylum, p. 699
bilateral symmetry, p. 701
radial symmetry, p. 701
protostome, p. 702
deuterostome, p. 702

23.3 sessile, p. 705
filter feeder, p. 706
polyp, p. 707
medusa, p. 707
mesoglea, p. 707
nematocyst, p. 707
gastrovascular cavity, p. 708

23.4 complete digestive tract, p. 712
radula, p. 712
hemocoel, p. 712
segmentation, p. 714
coelom, p. 714

23.5 cuticle, p. 716
pseudocoelom, p. 716

23.6 ossicle, p. 718
water vascular system, p. 718

Reviewing Vocabulary

Visualize Vocabulary

For each word or word pair below, use simple shapes, lines, or arrows to illustrate the meaning. Label each picture, and write a short caption.

1. collagen
2. segmentation
3. mesoglea
4. gastrovascular cavity
5. polyp, medusa
6. radial symmetry, bilateral symmetry
7. radula
8. hemocoel

Greek and Latin Word Origins

Using the Greek or Latin word origins of the terms below, explain how the meaning of the root relates to the definition of the term.

9. The word *phylum* comes from the Greek word *phūlon*, which means "class."

10. The word *sessile* comes from the Latin word *sedere*, which means "to sit."

11. The word *segment*, as in *segmentation*, comes from *segmentum*, from the Latin word *secāre*, which means "to cut."

12. The word *radula* comes from the Latin word *radere*, which means "to scrape."

13. The word *pseudocoelom* comes from the Greek words *pseudes*, which means "false," and *koilos*, which means "hollow."

Reviewing MAIN IDEAS

14. What four characteristics are common to members of the animal kingdom?

15. What is the difference between an invertebrate and a vertebrate?

16. Describe three different criteria used to classify animals into groups.

17. What types of evidence are used to put together the evolutionary history of the animal kingdom?

18. What characteristic makes sponges the simplest animals?

19. Describe the two general body forms of cnidarians, which include jellyfish and corals.

20. What are the three types of flatworms? Describe the main features of each.

21. Mollusks have a complete digestive tract. What is one benefit of having this feature?

22. Describe what a segmented body plan looks like. Which phylum includes animals with segmented bodies?

23. Why must roundworms shed their outer skeleton?

24. Several species of roundworms are parasites with human hosts. Name one and explain how it affects human health.

25. What is the function of an echinoderm's water vascular system?

26. How does the ability to regenerate help an echinoderm escape from predators?

Critical Thinking

27. **Analyze** How are the functions of *Hox* genes related to the diversity of body plans and characteristics within the animal kingdom?

28. **Contrast** How is development different for an echinoderm and a mollusk? Use a table to summarize their different development patterns.

29. **Infer** While both sponges and cnidarians are simple animals, cnidarians have specialized tissues. What might be some advantages of having specialized tissues?

30. **Infer** Why is the ability to secrete toxic substances important to the survival of a sponge?

31. **Synthesize** How has molecular biology played a critical role in our understanding of animal relationships and phylogeny?

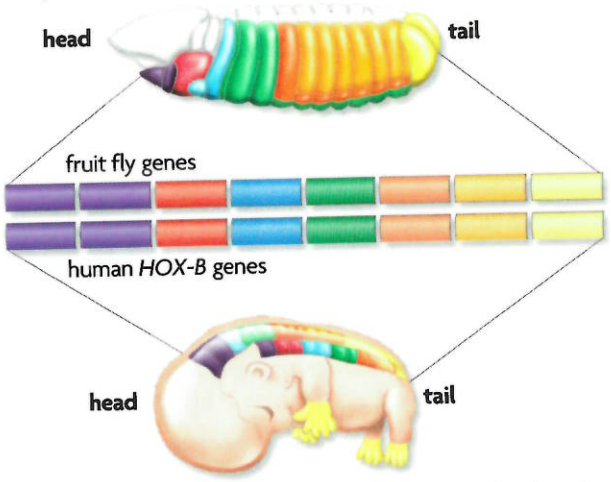
32. **Infer** Even when an annelid is cut in half, it can often still survive. What anatomical feature enables an annelid to remain alive when half of its body is gone?

33. **Apply** What is the function of an echinoderm's catch connective tissue?

34. **Compare and Contrast** Animals exhibit variety in their digestive systems. What do you think are the advantages and disadvantages of having a gastrovascular cavity compared with a complete digestive tract?

Interpreting Visuals

Use the *Hox* gene diagram below to answer the next two questions.



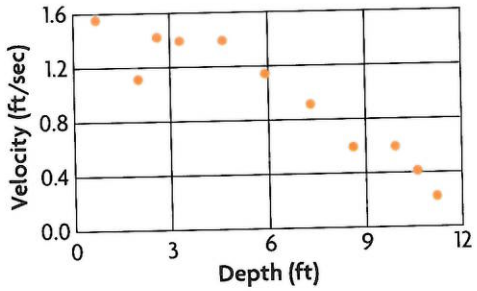
35. **Apply** How do the two organisms above display the pattern seen in all *Hox* genes?

36. **Synthesize** How does the diagram support the idea that all animals share a common ancestor?

Analyzing Data

Scientists measured the depth and velocity of water in the Columbia River in Washington. These data are shown on the scatterplot graph below. Use the graph to answer the next three questions.

COLUMBIA RIVER DEPTH AND VELOCITY



Source: USGS

37. **Analyze** What type of relationship exists between the depth and the velocity of the water? Explain your answer.

38. **Predict** Make a prediction about the velocity of the water if the depth were 14 feet.

39. **Infer** In what way might a species adapted to living at lower depths differ from a species adapted to living in shallow water?

Connecting CONCEPTS

40. **Write a Travel Brochure** Imagine you are an advertising director for a travel agency. Choose an invertebrate from this chapter, and create a brochure to entice your chosen invertebrate to visit a vacation spot. Remember that each invertebrate species has specific requirements for survival. In your brochure, include a description of the location (and why it is the perfect place for your invertebrate), the menu of local restaurants, and other features that would make your chosen invertebrate feel at home.

41. **Connect** In addition to storing poisonous chemicals from their food, nudibranchs also are very colorful. In other colorful animals, such as birds, fish, and insects, colors are important for a variety of reasons. What might be the adaptive advantage of a nudibranch's bright coloration?