LESSON 28.2

Getting Started

Objectives

28.2.1 Describe the three types of skeletons in animals.

28.2.2 Explain how muscles produce movement in animals.

Student Resources

Study Workbooks A and B, 28.2 Worksheets

Spanish Study Workbook, 28.2 Worksheets

BIOLOGY.com Lesson Overview • Lesson Notes
- Activities: InterActive Art, Art in Motion
- Assessment: Self-Test, Lesson Assessment

For corresponding lesson in the **Foundation Edition,** see pages 674–677.

Build Background

Partially fill an oblong balloon with water. Explain that the balloon represents an invertebrate's gastrovascular cavity and the water represents fluids within that cavity. Then, squeeze parts of the balloon to show how the movement of the fluid changes the shape of the balloon. Point out that squeezing the balloon is similar to the way an invertebrate uses contractile cells in its body wall to move fluids around and change its shape. Explain that the water balloon is a model of a hydrostatic skeleton.

28.2 Movement and Support

Key Questions

What are the three types of skeletons?

How do muscles enable movement?

Vocabulary

hydrostatic skeleton • exoskeleton • molting • endoskeleton • joint • ligament • tendon

Taking Notes

Compare/Contrast Table As you read, create a table comparing and contrasting the three types of skeletons.

THINK ABOUT IT As a dragonfly hovers over a stream, a trout leaps out of the water to catch it. An earthworm wriggles through leaf litter nearby. A falcon streaks overhead, hunting a mouse scampering across a field. All these invertebrates and vertebrates face similar challenges as they move through air or water, or over land. In order to move, animals use different structures that work in similar ways.

Types of Skeletons

What are the three types of skeletons?

To move efficiently, all animals must do two things. First, they must generate physical force. Then, they must somehow apply that force against air, water, or land in order to push or pull themselves around.

Skeletal Support An animal's ability to move efficiently is greatly enhanced by rigid body parts. Legs push against the ground. Bird wings push against air, and fins or flippers apply force against water. Each of these body parts is supported by some sort of skeleton. **Animals have three main kinds of skeletal systems: hydrostatic skeletons, exoskeletons, and endoskeletons.**

▶ ***Hydrostatic Skeletons*** Some invertebrates, such as cnidarians and annelids, have hydrostatic skeletons. The **hydrostatic skeleton** of a cnidarian such as a hydra, for example, consists of fluids held in a gastrovascular cavity that can alter the animal's body shape drastically by working with contractile cells in its body wall. When a hydra closes its mouth and the cells encircling its body wall constrict, the animal elongates and its tentacles extend, as shown in the left photo of **Figure 28–8.** Because water is not compressible, constricting the cavity elongates the animal, somewhat like a water balloon that has been squeezed. A hydra often sits in this position for hours, waiting for prey to swim by. If it is disturbed, its mouth opens, allowing water to flow out, and longitudinal cells in its body wall contract, shortening the body, as in the right photo of **Figure 28–8.**

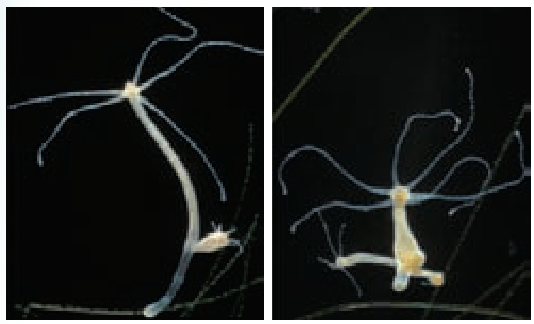


FIGURE 28–8 Hydrostatic Skeleton Some invertebrates, such as this hydra, have hydrostatic skeletons. When a hydra closes its mouth, water trapped in its body causes it to elongate (left). When it opens its mouth again, water is released, and it becomes shorter (right).

NATIONAL SCIENCE EDUCATION STANDARDS

UNIFYING CONCEPTS AND PROCESSES

I, V

CONTENT

C.5.d

INQUIRY

A.1.b, A.2.a

UbD Teach for Understanding

ENDURING UNDERSTANDING Animals have evolved diverse ways to carry out basic life processes and maintain homeostasis.

GUIDING QUESTION How are different animals adapted to move through their environments?

EVIDENCE OF UNDERSTANDING *After students have completed the lesson, assign the following assessment to show their understanding of different types of animal skeletons.* Ask students to work in pairs to make a labeled drawing that identifies an organism, names the type of skeleton it has, and shows how its skeleton provides support. Ask students to share their drawings with the class.

▶ ***Exoskeletons*** Many arthropods have exoskeletons, as do most mollusks, such as snails and clams. The **exoskeleton,** or external skeleton, of an arthropod is a hard body covering made of a complex carbohydrate called chitin. Most mollusks have exoskeletons, or shells, made of calcium carbonate.

Jointed exoskeletons enable various arthropods to swim, fly, burrow, walk, crawl, and leap. They can also provide watertight coverings that enable some arthropods to live in Earth's driest places. An exoskeleton can also provide physical protection from predators—as you know if you have ever tried to crack a crab or lobster shell or seen a mollusk withdraw into its shell. Mollusks with two-part shells are called bivalves. Bivalves such as clams can also close their shells to avoid drying out.

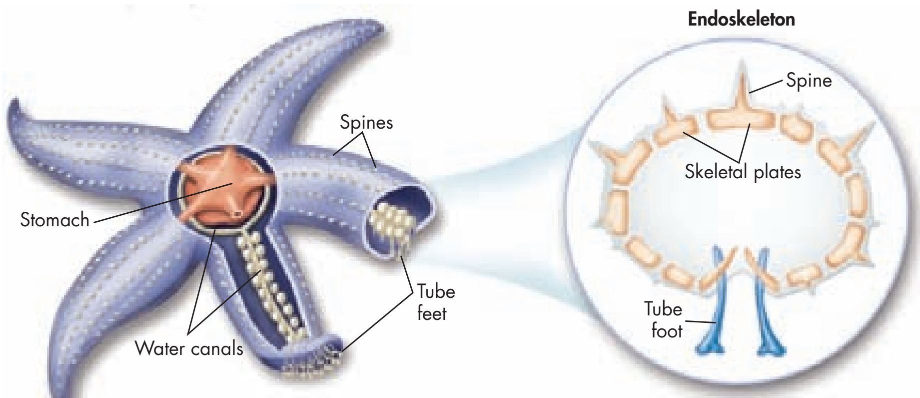
But exoskeletons have disadvantages. An external skeleton poses a problem when the animal it belongs to needs to grow. To increase in size, arthropods break out of their exoskeleton and grow a new one, in a process called **molting,** shown in **Figure 28–9.** Exoskeletons are also relatively heavy. The larger arthropods get, the heavier their skeletons become in proportion to their body weight. This is one reason that some science-fiction monsters could never exist. The legs of an elephant-size spider would collapse under the spider's weight!

FIGURE 28–9 Exoskeleton Arthropods such as this cicada periodically "grow out" of their exoskeletons and have to break out of them in order to grow new ones. **Infer** ***How might molting be a dangerous inconvenience?***

▶ ***Endoskeletons*** Echinoderms and vertebrates have endoskeletons. An **endoskeleton** is a structural support system within the body. Sea stars and other echinoderms have an endoskeleton made of calcified plates, as you can see in **Figure 28–10.** These skeletal plates support and protect echinoderms, and also give them a bumpy texture.

Vertebrates have an endoskeleton made of cartilage or a combination of cartilage and bone. Sharks and some other fishes have skeletons made almost entirely of cartilage. In other vertebrates, most of the skeleton is bone. Four-limbed vertebrates also have structures called limb girdles that support limbs and allow the animal to move around.

FIGURE 28–10 Endoskeleton Not every endoskeleton looks like yours! Some invertebrates, including echinoderms such as this sea star, have rigid internal body supports. These supports are not, however, made of bone.



BIOLOGY.com Search Lesson 28.2 GO • InterActive Art

Teach

Use Visuals

Use **Figures 28–9** and **28–10** to compare and contrast exoskeletons and endoskeletons.

Ask What are two advantages of an exoskeleton? *(It provides a watertight covering and protects the animal's soft body.)*

Ask Are endoskeletons always made of bone? *(No, the endoskeletons of echinoderms are not bone, and the endoskeletons of cartilaginous fishes are made of cartilage.)*

DIFFERENTIATED INSTRUCTION

ELL **English Language Learners** Explain that the prefix *exo-* means "outer," and the prefix *endo-* means "inside." Ask English language learners to use those meanings to write definitions of *exoskeleton* and *endoskeleton* in their notebook. Suggest students add drawings next to their definitions to help them remember.

LPR **Less Proficient Readers** To help students who have difficulty absorbing information they read, set up a classroom display of examples of exoskeletons for them to observe. You might display a variety of mollusk shells, such as clam, nautilus, and snail shells. Display a cicada exoskeleton that has been left behind by a molting insect. If possible, show students a live lobster, crab, or crayfish.

BIOLOGY.com The **InterActive Art: Sea Star Water Vascular System** shows how sea stars move, feed, circulate nutrients, and get rid of wastes.

Quick Facts

MOLLUSK SHELLS

Mollusk shells occur in such a variety of shapes and sizes that they serve as the main means of identification for many mollusk species. The obvious advantage of a hard exterior shell is the protection it provides for the animal's soft body. Like the exoskeletons of arthropods, exterior shells have one major disadvantage: Because shells do not consist of living, dividing cells, mollusks outgrow them. Many mollusks, however, have evolved shell designs that allow them to build onto the shell to accommodate their increased body size. The shell is not continuously added to but is expanded periodically as needed. Another disadvantage of shells is that they reduce mobility. Most mollusks, such as snails, lumber along under the load of their heavy shells. Other mollusks, such as clams, are largely stationary throughout their adult lives.

Answers

FIGURE 28–9 Right after molting, the exoskeleton is soft, which makes the arthropod vulnerable to predators.

LESSON 28.2

Teach continued

Lead a Discussion

Make sure students understand the relationships between skeletons, joints, ligaments, tendons, and muscles.

Ask What connects bones to other bones at a joint? *(ligament)*

Ask What connects a muscle to a bone? *(tendon)*

DIFFERENTIATED INSTRUCTION

L1 **Struggling Students** Provide each student with a **T-Chart,** and suggest they write the terms *joints, ligaments,* and *tendons* in the left column. In the right column, they can add descriptions, examples, and drawings that will help them remember what these vocabulary terms mean.

Study Wkbks A/B, Appendix S30, T-Chart. **Transparencies,** GO15.

L3 **Advanced Students** If school policy permits, obtain a whole bony fish, and have a small group of students dissect it. Provide dissecting tools, and instruct them to wear goggles, lab apron, and disposable plastic gloves. Ask them to observe and make drawings of muscle blocks on the fish's back as well as the features of the skeleton. Have the group report to the class what they observed.

BIOLOGY.com Students can use the **Art in Motion: Muscles and Joints** animation to compare exoskeletons and endoskeletons.

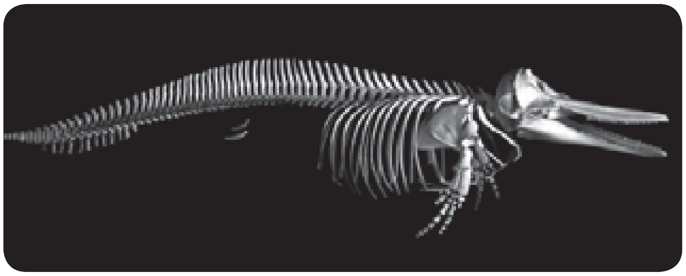


FIGURE 28–11 Vertebrate Skeleton A typical vertebrate skeleton, such as that of this dolphin, is made up mostly of bone.

Evolution has produced a wide range of variations of the vertebrate endoskeleton that enables these animals to swim, fly, burrow, walk, crawl, or leap, but they all provide strong, lightweight support. Of course, because an internal skeleton does not surround the body, it cannot protect an animal the way that an exoskeleton can. On the other hand, an internal skeleton can grow as an animal grows, so the animal does not need to molt. Because endoskeletons are lightweight in proportion to the bodies they support, even land-dwelling vertebrates can grow very large.

Joints If an animal's rigid skeleton were made of one piece, or if its parts were rigidly attached to each other, the animal couldn't move. Arthropods and vertebrates can move because their skeletons are divided into many parts that are connected by **joints.** Joints are places where parts of a skeleton are held together in ways that enable them to move with respect to one another. In vertebrates, bones are connected at joints by strong connective tissues called **ligaments.** Most joints are formed by a combination of ligaments, cartilage, and lubricating joint fluid that enables bones to move without painful friction.

> **Quick Lab** GUIDED INQUIRY
>
> **What Are Some Adaptations of Vertebrae?**
>
> 1. Obtain a chicken neck from your teacher. Bend the neck back and forth and from side to side.
> 2. Insert a dissecting probe into the opening at the top of the neck. What do you observe? **CAUTION:** *Use care with sharp instruments.*
>
> **Analyze and Conclude**
>
> **1. Infer** How is the structure of the chicken's neck related to its function?
>
> **2. Predict** What would happen if the chicken's neck were just one vertebra with no central opening?
>
> **3. Draw Conclusions** How would you expect the vertebrae in an elephant's neck to differ from those in the chicken's neck? Explain your answer.

Muscles and Movement

How do muscles enable movement?

Muscles are specialized tissues that produce physical force by contracting, or getting shorter, when they are stimulated. Muscles can relax when they aren't being stimulated, but they cannot actively get longer. That presents a problem. Think about how animals move. Fishes swim by moving their bodies back and forth, and by pushing against the water with their fins. Your legs work by swinging backward and forward, pushing against the ground as you walk. But how can animals move limbs backward and forward or push against water or land if muscles generate force in only one direction?

In many animals, muscles work together in pairs or groups that are attached to different parts of a supporting skeleton. Muscles are attached to bones around the joints by tough connective tissue called **tendons.** Tendons are attached in such a way that they pull on bones when muscles contract. Typically, muscles are arranged in groups that pull parts of the skeleton in opposite directions. Here's how muscles and parts of a skeleton work together.

 BIOLOGY.com Search Lesson 28.2 GO • Art in Motion

Quick Lab

PURPOSE Students infer how the structure of vertebrae is related to the function of vertebrae.

MATERIALS chicken neck, dissecting probe

SAFETY Warn students to handle the dissecting probe carefully. Have them wear disposable, plastic gloves as they dissect the chicken neck and then wash their hands thoroughly when finished.

PLANNING Obtain fresh chicken necks from a butcher. Soak the necks in bleach, and then rinse thoroughly. Practice before the lab so you can demonstrate inserting the dissecting probe into the hole for the spinal cord. You may want to cut away the skin from around the neck to better view the vertebrae.

ANALYZE AND CONCLUDE

1. The many bones of the neck allow for a wide range of motion. The opening in each vertebra surrounds and protects the spinal cord.
2. The chicken would have a rigid, inflexible body, and the vertebra could not support or protect its spinal cord.
3. Sample answer: They would be larger so they could support a larger skull.

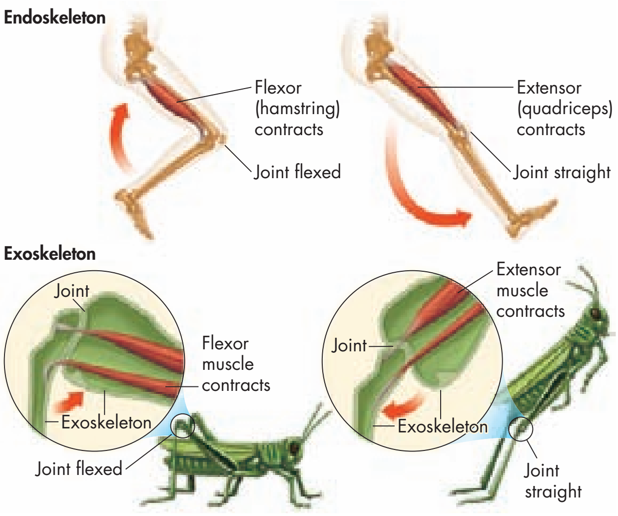


FIGURE 28–12 Muscles and Joints The diagrams show how muscles work with a vertebrate endoskeleton and an arthropod exoskeleton to bend and straighten joints. **Compare and Contrast** *To what structure are arthropod muscles attached? To what structure are vertebrate muscles attached?*

Movement Arthropod muscles are attached to the inside of the exoskeleton. Vertebrate muscles are attached around the outside of bones. In both cases, different pairs or groups of muscles pull across joints in different directions. As you can see in **Figure 28–12,** when one muscle group contracts, it bends, or flexes, the joint. When the first group relaxes and the second group contracts, the joint straightens.

Vertebrate Muscular and Skeletal Systems An amazing variety of complex combinations of bones, muscle groups, and joints have evolved in vertebrates. In many fishes and snakes, muscles are arranged in blocks on opposite sides of the backbone. These muscle blocks contract in waves that travel down the body, bending it first to one side and then to the other. As these waves of movement travel down the body, they generate thrust. The limbs of many modern amphibians and reptiles stick out sideways from the body, as though the animals were doing push-ups. If you watch these animals move, you will see that many use sideways movements of their backbone to move their limbs forward and backward.

Most mammals stand with their legs straight under them, whether they walk on two legs or four. Mammalian limbs have evolved in ways that enable many different kinds of movement, as you can see in **Figure 28–13** on the next page. The shapes and relative positions of bones and muscles, and the shapes of joints, are linked very closely to the functions they perform. Limbs that are specialized for high-speed running or long-distance jumping have very differently shaped bones, muscles, and joints than limbs adapted for flying, swimming, or manipulating objects. In fact, paleontologists can reconstruct the habits of extinct animals by studying the joints of fossil bones and the places where tendons and ligaments once attached.

UbD Check for Understanding

FOLLOW-UP PROBES

Ask Why must muscles work together in pairs? *(Muscles produce physical force by contracting, or getting shorter. So, a joint bends when a muscle or a group of muscles contracts in one direction, and then the joint straightens when a second muscle or group contracts in a different direction.)*

ADJUST INSTRUCTION

If students have difficulty answering the question, have them review the information in the subsection, **Movement,** and **Figure 28–12.** Then, call on students at random to explain why muscles in both invertebrates and vertebrates work in pairs or groups.

Use Visuals

After students have read **Muscles and Movement** and reviewed **Figure 28–12,** have them discuss how muscles work with skeletons to produce movement in different kinds of animals. Explain that most animals, including invertebrates, have muscle tissues.

Ask What is the difference in how muscles are attached in animals with exoskeletons and animals with endoskeletons? *(In animals with exoskeletons, muscles are attached to the inside of the exoskeleton. In animals with endoskeletons, muscles are attached around the outside of bones.)*

Emphasize that muscles move a joint by working in opposing pairs or groups. As an example, point out that biceps and triceps are opposing muscles in the human upper arm. Ask what happens when a student contracts the biceps. *(The arm bends at the elbow joint.)* Ask what contracts to straighten the arm again. *(the triceps muscle)*

DIFFERENTIATED INSTRUCTION

L1 Struggling Students Have students work in small groups, and challenge each group to choose one type of animal and make a model that shows how it moves. Students can use any common materials, such as rubber bands, paper clips, straws, suction cups, and craft sticks. Suggest students use library or online sources to find out more about how their animal moves. After all models have been built, invite each group to present its model to the class.

ELL Focus on ELL: Access Content

ALL SPEAKERS Set up a **Gallery Walk** about animal movement and support by writing *hydrostatic skeleton, exoskeleton,* and *endoskeleton* on separate pieces of chart paper. Post the pieces of chart paper at different places on the classroom wall and have three groups rotate among them. At each poster, each group should write what they know about the type of skeleton, using a pen color different from that of the other groups. Remind students to include information about how muscles work with each skeleton. As each group rotates to a poster, its members should add to the previous group's comments and correct mistakes. When groups return to their first poster, have members summarize information about that skeleton for the class.

Study Wkbks A/B, Appendix S6, Gallery Walk.

Answers

FIGURE 28–12 the exoskeleton; bones

LESSON 28.2

Assess and Remediate

EVALUATE UNDERSTANDING

Call on students at random to explain the differences among the three main kinds of animal skeletons. Then, have students complete the 28.2 Assessment.

REMEDIATION SUGGESTION

L1 **Struggling Students** If students have difficulty answering **Question 1b,** review with them the advantages and disadvantages of endoskeletons.

BIOLOGY.com Students can check their understanding of lesson concepts with the **Self-Test** assessment. They can then take an online version of the **Lesson Assessment.**

FIGURE 28–13 Vertebrate Musculoskeletal Systems A great variety of bones, muscle groups, and joints have evolved in vertebrates. For instance, differently shaped bones and muscles form limbs adapted for manipulating objects (raccoons), climbing through trees (sloths), long-distance jumping (frogs), and flying through the air (birds).

28.2 Assessment

Review Key Concepts

1. a. **Review** What body structures generate force? With what other body structure do these structures work to enable movement?
   b. **Infer** Why are the largest land animals vertebrates?
2. a. **Review** What characteristics are common to the skeletons of all vertebrates?
   b. **Form a Hypothesis** Suppose that you were to find a vertebrate fossil that showed a joint structure with muscle and tendon relationships similar to that of a squirrel. For which kinds of movement would you predict the animal had been best adapted?

Apply the Big idea

Structure and Function

3. Create a model of a vertebrate or invertebrate joint. Make sure the muscles are attached to the same skeletal structures they would be attached to in a real animal and that the muscles and skeletal structure allow the joint to bend and flex.

BIOLOGY.com Search Lesson 28.2 GO • Self-Test • Lesson Assessment

Assessment Answers

1a. Muscles generate force, and they work with skeletons to enable movement.

1b. Vertebrates and a few invertebrates have endoskeletons, which grow as the animal grows. Because endoskeletons are lightweight in proportion to the bodies they support, land-dwelling vertebrates can grow very large.

2a. Vertebrates have an endoskeleton made of cartilage and/or bone, and endoskeletons are lightweight in proportion to the bodies they support.

2b. Sample answer: running and climbing

3. Big idea Models will vary. To build these models, students might use slender dowels for the bones or tongue depressors for the exoskeleton, and rubber bands for the muscles.