Chapter 13

Bones and Muscles

CALIFORNIA Standards Preview

S 7.5 The anatomy and physiology of plants and animals illustrate the complementary nature of structure and function. As a basis for understanding this concept:

- **a.** Students know plants and animals have levels of organization for structure and function, including cells, tissues, organs, organ systems, and the whole organism.
- **c.** Students know how bones and muscles work together to provide a structural framework for movement.

S 7.6 Physical principles underlie biological structures and functions. As a basis for understanding this concept:

- **h.** Students know how to compare joints in the body (wrist, shoulder, thigh) with structures used in machines and simple devices (hinge, ball-and-socket, and sliding joints).
- **i.** Students know how levers confer mechanical advantage and how the application of this principle applies to the musculoskeletal system.

No matter your age or ability level, playing sports is fun and healthful.

Video Preview
Discovery Channel School
Bones, Muscles, and Skin

S 7.6.i

Focus on the BIG Idea

How do the physical principles of forces and machines relate to the functions of your muscles and skeleton?

Check What You Know

A cat sleeps on one end of a see-saw, while a mouse crouches on the other end. The cat wakes up and walks away. How will the forces acting on the ends change? How will the forces change if the cat runs across the board toward the mouse?

Build Science Vocabulary

The images shown here represent some of the Key Terms in this chapter. You can use this vocabulary skill to help you understand the meaning of some Key Terms in this chapter.

Vocabulary Skill

Latin Word Origins

Many English words come from Latin. In Chapter 2 you learned that the Latin prefix re- means "back" or "against." In this chapter you will learn the term *resistance*. Resistance comes from the Latin prefix *re-* and the Latin word *sistere*, which means "to stand." So *resistance* means "the act of standing against." The table below shows Latin words that are sources of some Key Terms in this chapter.

Latin Word	Meaning of Latin Word	Key Term
in-	not	**involuntary muscle** Type of muscle that is not under a person's conscious control
ligare	to tie	**ligament** Connective tissue that holds bones together
porus	a tiny opening or hole	**osteoporosis** A condition in which bones lose minerals, develop larger openings than normal bones, and become weak
resistere	to place against	**resistance force** The force that a lever exerts against an object
voluntas	free will	**voluntary muscle** Type of muscle that is under a person's conscious control

Apply It!

1. How does the meaning of the Latin word *ligere* help you to understand what a ligament is?
2. What two key terms in the table come from the Latin word *voluntas*? What does this Latin word mean?


cardiac muscle


striated muscle


smooth muscle

Chapter 13 Vocabulary

Section 1 (page 508)

- muscle tissue
- nervous tissue
- connective tissue
- epithelial tissue
- organ system
- digestion
- kidney
- nephron
- urinary bladder
- pathogen
- antibody
- immunity
- homeostasis
- stress

Section 2 (page 518)

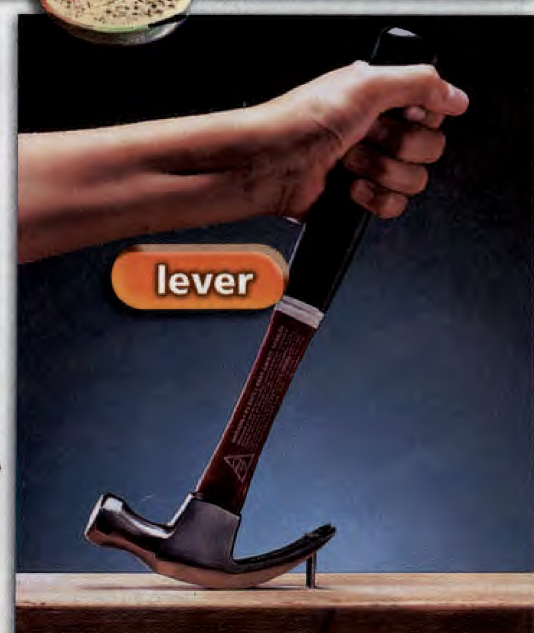
- skeleton
- vertebrae
- joint
- ligament
- cartilage
- compact bone
- spongy bone
- marrow
- osteoporosis

Section 3 (page 526)

- involuntary muscle
- voluntary muscle
- skeletal muscle
- tendon
- striated muscle
- smooth muscle
- cardiac muscle

Section 4 (page 532)

- force
- work
- machine
- lever
- fulcrum
- effort force
- effort distance
- resistance force
- resistance distance
- mechanical advantage
- effort arm
- resistance arm



Interactive Textbook

Build Science Vocabulary *Online*

Visit: PHSchool.com

Web Code: cvj-4130

How to Read Science

Reading Skill

Take Notes

When you take notes, you write important ideas in shortened form.

1. Use a red or blue heading as the title of your notes.
2. Create a two-column note-taking organizer similar to the sample below. In the left column, write questions about the text that follows the heading. The questions should ask for important information.
3. Write the answers in the right column.
4. Write a summary statement that expresses the main idea.

See the sample notes below on part of Section 1 of this chapter.

Questions	Notes: Cells
What is a cell?	The basic unit of structure and function in a living thing
What is the structure of a cell?	See Figure 1. Cell membrane—outside boundary of cell Nucleus—directs cell's activities; contains DNA, which contains information determining cell's structure and function Cytoplasm—everything inside cell except nucleus; contains organelles
What are the functions of cells?	Carry on processes that let organisms live, grow, and reproduce
	Summary Statement: Organisms are made of cells. Cells carry on important functions in organisms.

Apply It!

1. Review the notes in the right column. What are two important ideas found in the notes?
2. According to the summary, what is the main idea of this text?
3. As you read Section 1, take notes on the rest of the section. When you read Section 3, take notes on the whole section.

Lab zone

Standards Investigation

S 7.5.c, 7.6.h

A Not-So-Simple Machine

A prosthesis is an artificial device that replaces a human body part. Designing artificial replacements, such as prosthetic hands, can be a challenging task. This is because even a simple act, such as picking up a pen, involves a complex interaction of body parts. If you study the movements of your hand, you may see how some of its movements are like simple machines, such as levers and hinges. You can use the physical principles behind these and other simple machines to build a prosthetic hand.

Your Goal

To design, build, and test a replacement for a human hand

Your prosthesis must

- grasp and lift a variety of objects
- be activated by pulling a cord or string
- spring back when the cord is released
- be built following the safety guidelines in Appendix A

Plan It!

Before you design your prosthetic hand, study the human hand. Watch how the fingers move to pick up objects. Make a list of tools, machines, or other devices that mimic the ability of the hand to pick up objects. Examples include tongs, tweezers, pliers, and chopsticks. Then, choose materials for your hand and sketch your design. When your teacher has approved your design, build and test your prosthetic hand.

Section 1

Organ Systems and Homeostasis

CALIFORNIA **Standards Focus**

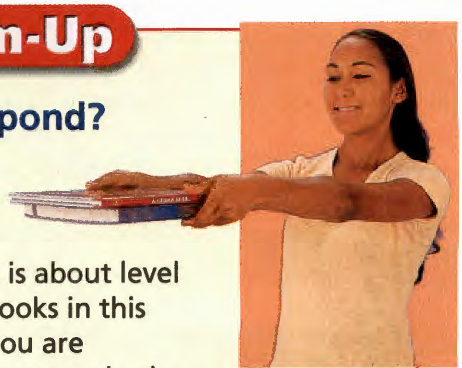
S 7.5.a Students know plants and animals have levels of organization for structure and function, including cells, tissues, organs, organ systems, and the whole organism.

- What are the levels of organization in the body?
- What systems are in the human body, and what are their functions?
- What is homeostasis?

Key Terms

- muscle tissue
- nervous tissue
- connective tissue
- epithelial tissue
- organ system
- digestion
- kidney
- nephron
- urinary bladder
- pathogen
- antibody
- immunity
- homeostasis
- stress

Lab zone **Standards Warm-Up**



How Does Your Body Respond?

1. Stack one book on top of another one.
2. Lift the two stacked books in front of you so the lowest book is about level with your shoulders. Hold the books in this position for 30 seconds. While you are performing this activity, note how your body responds. For example, how do your arms feel at the beginning and toward the end of the 30 seconds?
3. Balance one book on the top of your head. Walk a few steps with the book on your head.

Think It Over

Inferring List all the parts of your body that worked together as you performed the activities in Steps 1 through 3.

The bell rings—lunchtime! You hurry down the noisy halls to the cafeteria. The unmistakable aroma of hot pizza makes your mouth water. At last, you balance your tray of pizza and salad while you pay the cashier. You look around the cafeteria for your friends. Then, you walk to the table, sit down, and begin to eat.

Think about how many parts of your body were involved in the simple act of getting and eating your lunch. Every minute of the day, whether you are eating, studying, walking, or even sleeping, your body is busy. Each part of the body has a specific function, or job. And all the different parts of your body usually work together so smoothly that you don't even notice them.

This smooth functioning is due partly to the way in which the body is organized. **The levels of organization in the human body consist of cells, tissues, organs, and organ systems.** The smallest unit of organization is the cell. The next largest unit is tissue; then, organs. Finally, the organ system is the largest unit of organization.

Cells

From the cell theory, you know that a cell is the basic unit of structure and function in a living thing. Complex organisms are composed of many cells in the same way a brick building is composed of many bricks. The human body contains about 100 trillion cells.

Structures of Cells Most animal cells, including those in the human body, have a structure similar to the cell in Figure 1. You may recall that the cell forms the outside boundary of the cell. Inside the cell is a large structure called the nucleus, which directs the cell's activities. The nucleus also contains DNA—the information that determines the cell's form and function. When the cell divides, or reproduces, this information is passed along to the newly formed cells. The material within a cell apart from the nucleus is the cytoplasm. The cytoplasm is made of a clear, jellylike substance containing many cell structures called organelles.

Functions of Cells Cells carry on processes that keep organisms alive. Inside cells, for example, molecules from digested food undergo cellular respiration that releases energy for the body's activities. Cells also grow and reproduce. And they get rid of waste products that result from these activities.

Reading Checkpoint What is the function of the nucleus?

Lab zone Try This Activity

How Is a Book Organized?

In this activity, you will analyze the levels of organization in a book.

1. Examine this textbook to see how it is subdivided—into chapters, sections, and so on.
2. Make a concept map that shows this pattern of organization. Place the largest subdivision at the top of the map and the smallest at the bottom.
3. Compare the levels of organization in this textbook to those in the human body.

Making Models Which level of organization in the textbook represents cells? Which represents tissues? Organs? Organ systems?

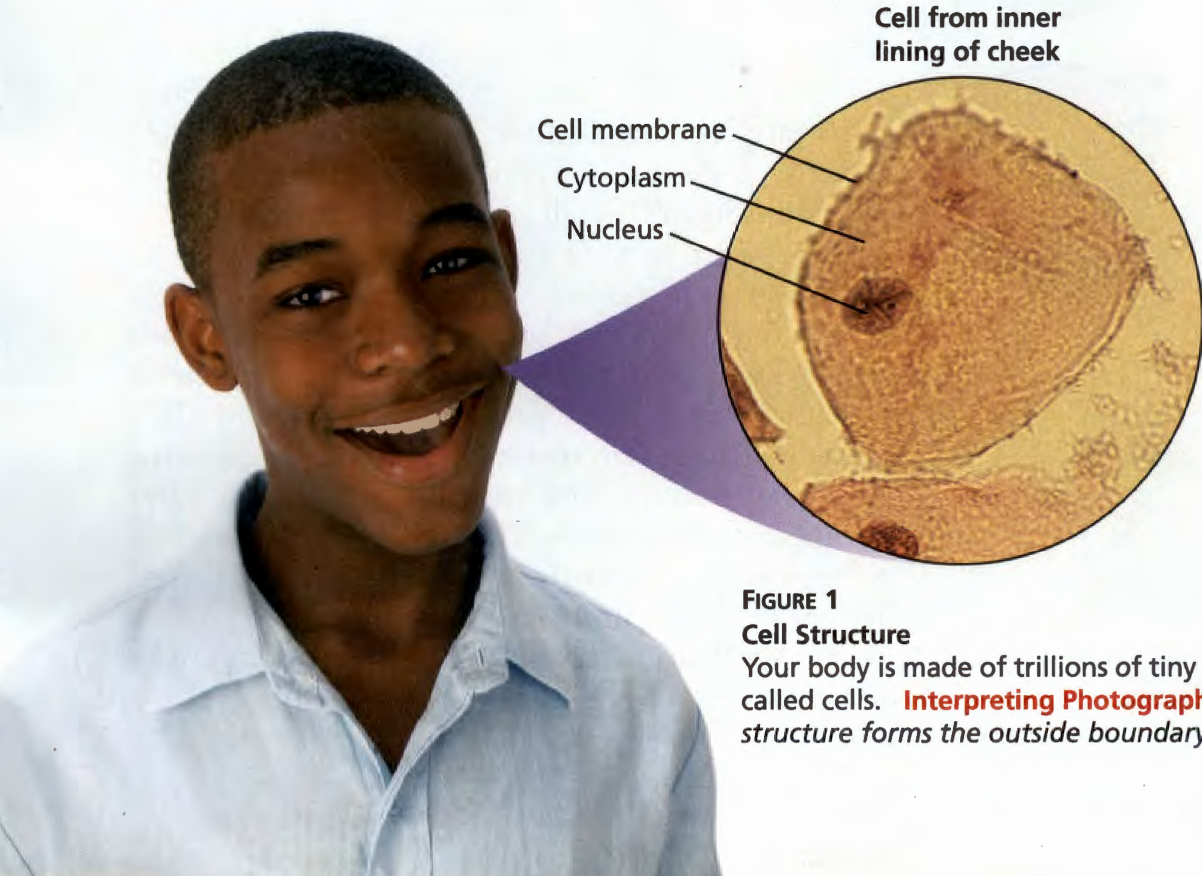
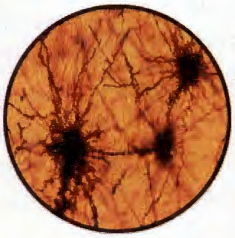


FIGURE 1
Cell Structure
Your body is made of trillions of tiny structures called cells. **Interpreting Photographs** *What structure forms the outside boundary of the cell?*

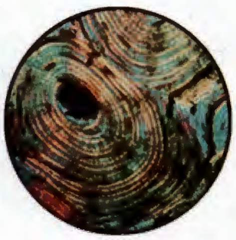
FIGURE 2
Types of Tissues
Your body contains four kinds of tissues: muscle, nervous, connective, and epithelial.
Comparing and Contrasting *How is the function of nervous tissue different from that of epithelial tissue?*

Muscle Tissue
Every movement you make depends on muscle tissue. The muscle tissue shown here allows your body to move.

Nervous Tissue
Nervous tissue, such as the brain cells shown here, enables you to see, hear, and think.



Connective Tissue
Connective tissue, such as the bone shown here, connects and supports parts of your body.



Epithelial Tissue
Epithelial tissue, such as the skin cells shown here, covers the surfaces of your body and lines your internal organs.

Tissues
The next largest unit of organization in your body is a tissue—a group of specialized cells that perform the same function. The human body contains four basic types of tissue. Look at Figure 2 as you read about each type.

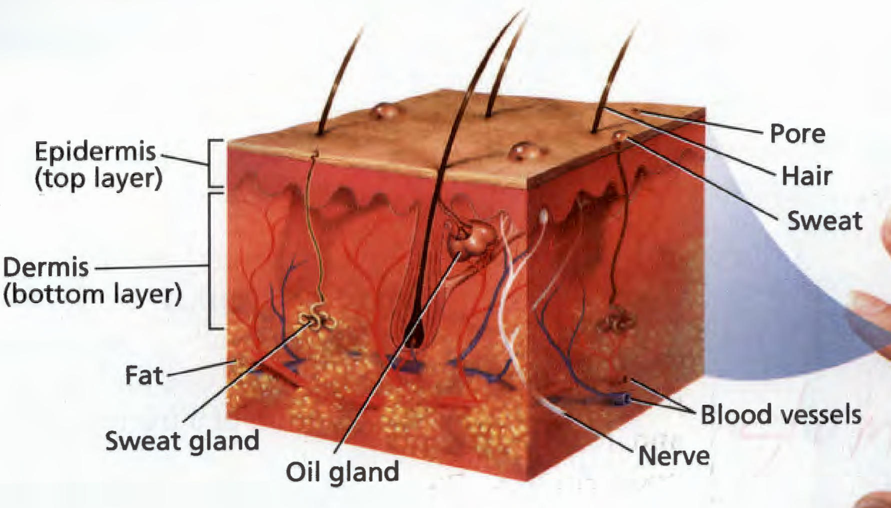
Like the muscle cells that form it, **muscle tissue** can contract, or shorten. By doing this, muscle tissue makes parts of your body move. While muscle tissue carries out movement, **nervous tissue** directs and controls the process. Nervous tissue carries electrical messages back and forth between the brain and other parts of the body. Another type of tissue, **connective tissue**, provides support for your body and connects all its parts. Bone tissue and fat are connective tissues.

The surfaces of your body, inside and out, are covered by **epithelial tissue** (ep uh THEE lee ul). Some epithelial tissue, such as your skin, protects the delicate structures that lie beneath it. The lining of your digestive system consists of epithelial tissue that allows you to digest and absorb the nutrients in your food.

Reading Checkpoint **What is the job of muscle tissue?**

Organs and Organ Systems
The stomach, heart, brain, and lungs are all organs. Recall that an organ is a structure that is composed of different kinds of tissue and does specific jobs. For example, your heart pumps blood through your body. The heart contains all four kinds of tissue—muscle, nervous, connective, and epithelial. Each tissue contributes to the organ's overall job of pumping blood.

Each organ in your body is part of a system. An **organ system** is a group of organs that work together to perform a major function. **The human body has 11 organ systems. The integumentary, skeletal, and muscular systems provide structure and allow movement. The circulatory, respiratory, digestive, excretory, immune, and reproductive systems carry out the processes of life. The nervous and endocrine systems provide control over body processes.** The next five pages describe the major functions of these systems. Remember that for each system to function, its organs and tissues must work together. And so must its cells.

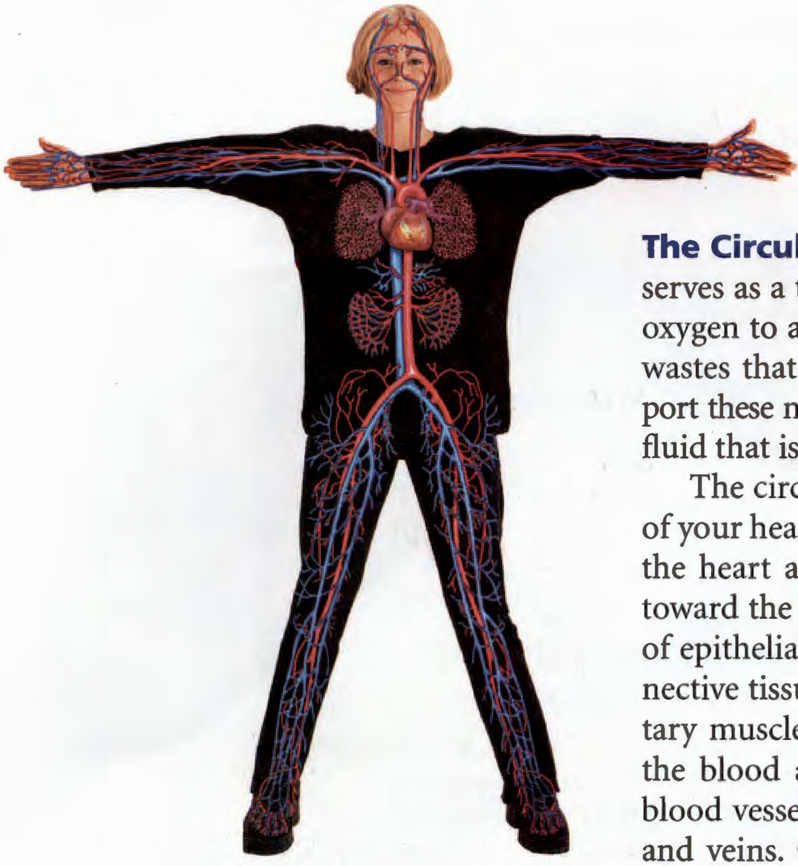


The Integumentary System Your skin, hair, and nails make up your body's covering, or integumentary system. Figure 3 shows the structure of human skin. The cells and tissues of your skin work together to create a barrier that protects your body from injury and disease-causing bacteria and viruses. Skin also helps regulate your body temperature and keeps your cells from drying out. Your skin works with other systems, too. As part of your excretory system, skin helps remove waste when you perspire. Skin works with your nervous system to give you information about your environment.

FIGURE 3
The Skin
In some ways, the skin is the body's largest organ. It accounts for about 15 percent of body weight, heavier than any internal organ. In an adult of average size, the skin covers a surface area of about 1.5 or 2 square meters.

The Skeletal System Your skeletal system is made up of all the bones in your body and other connective tissues. The skeletal system supports the body and gives it structure. It also protects your body's organs. For example, hard rib bones shield your heart and lungs from damage. Your bones consist of hard, compact layers of tissue. Different kinds of specialized tissue provide structure, produce blood cells, and store important minerals, such as calcium. Connective tissue attaches one bone to another and forms joints that allow movement.

The Muscular System Most of your muscles work to move your body by pulling on your skeleton. These muscles, called skeletal muscles, usually work only when you want them to. Other muscles work involuntarily—that is, when you don't think about them. Together, your muscles and bones are sometimes called the musculoskeletal system. Each muscle cell contains mitochondria, which release energy for muscles to work. These muscle cells are combined into bundles of fibers, which work together during movement. Fiber bundles are then combined into muscle groups that move your bones. For example, the biceps is a muscle group that helps move your arm.



▲ Circulatory System

The Circulatory System Your circulatory system serves as a transportation network. It carries food and oxygen to all the cells of your body. It also collects the wastes that must be removed. Tube-like vessels transport these materials in the form of a mixture of cells and fluid that is called blood.

The circulatory system is powered by the pumping of your heart. Blood vessels that carry blood away from the heart are called arteries. Vessels that carry blood toward the heart are called veins. These vessels consist of epithelial tissue that lines their inner walls and connective tissue that covers their outer surfaces. Involuntary muscle tissue within the vessel walls helps move the blood as it circulates. The smallest and thinnest blood vessels—called capillaries—connect the arteries and veins. Capillaries reach every cell, delivering and collecting the materials transported by the blood.

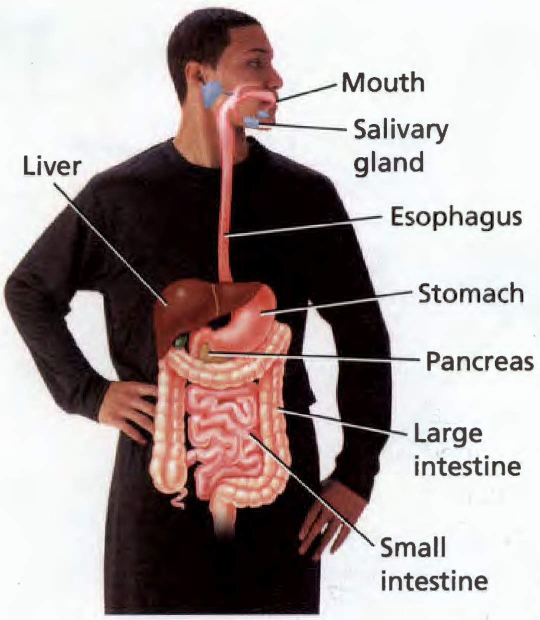
FIGURE 4
Blowing Bubbles
The respiratory system moves air in and out of the lungs.

The Respiratory System Take a deep breath. You can feel your lungs fill with air. The lungs are the main organs of your respiratory system, which takes in oxygen and disposes of carbon dioxide. (Recall that your cells use oxygen for cellular respiration. Carbon dioxide is a waste product in this process.)

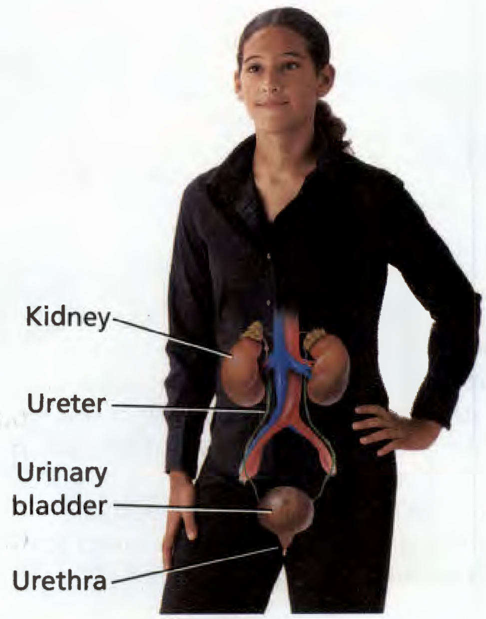
When you breathe, air moves into your lungs through a set of branching passageways. These passageways end in clusters of tissue that are surrounded by capillaries. There, oxygen crosses into the blood and is then distributed through the body by the circulatory system.

Air moves in and out of your body as a result of the actions of muscles in your chest. You can sometimes control the action of these muscles. But not for long. Soon your respiratory system starts working on its own again.

The Digestive System Have you had anything to eat today? Food provides your body with materials for growing and for repairing tissues. Food also provides energy for everything you do. **Digestion** is the breakdown of food into small molecules the body can use. The digestive system does this job.



▲ Digestive System



▲ Excretory System

FIGURE 5
Materials in the Body
The digestive system breaks down materials needed by the body. The excretory system removes wastes.
Interpreting Diagrams *What structure carries food from the mouth to the stomach?*

Figure 5 shows most of the organs of the digestive system. Food enters the body through your mouth and gradually moves through the system. Epithelial tissues in the stomach and small intestine produce chemicals called enzymes that help digest the food. Involuntary muscle tissue churns the food and keeps it moving.

Meanwhile, bile produced by the liver and enzymes from the pancreas help break down the food in the small intestine even more. Specialized cells in the lining of the small intestine then absorb the nutrients into the bloodstream. When the left-over material moves into the large intestine, water is removed and the solid waste material passes out of the body.

The Excretory System Your body produces excess water and waste from the activities in cells and from the breakdown of some materials in the digestive system. The excretory system, shown in Figure 5, removes these wastes from your bloodstream.

Your two **kidneys** are the major organs of the excretory system. Each kidney contains about 1 million specialized structures called **nephrons** that act as tiny filtering factories. These structures remove both wastes and needed materials from the blood. Then, the needed materials are returned to the bloodstream, and the wastes are combined with water to create urine. Urine flows from the kidneys to the **urinary bladder**, where it is stored until it leaves the body through the urethra.

Reading Checkpoint **What is the function of the kidneys?**

Lab zone Try This Activity

Break Up!

Model the breakup of fats in the small intestine.

1. Fill two plastic jars half full of water. Add a few drops of oil to each jar.
2. Add about $\frac{1}{4}$ spoonful of baking soda to one jar.
3. Stir the contents of both jars. Record your observations.

Observing In which jar did the oil begin to break up? What type of substance does the baking soda represent?

FIGURE 6
Protection Against Disease
Caught! The white blood cell in this colorized photo specializes in trapping and destroying bacteria.
Predicting *How would the body be affected if white blood cells failed to attack an invading pathogen?*

Lab zone Try This **Activity**

Which Pieces Fit Together?

What does this activity tell you about how cells defend your body against pathogens?

1. Your teacher will give you a piece of paper with a jagged edge.
2. One student in the class has a piece of paper with a jagged edge that matches yours, like two pieces of a jigsaw puzzle. Find that student and fit the two edges together.

Inferring Suppose one piece of paper is a pathogen, and the other is a cell in your body that fights invading pathogens. How many kinds of pathogens can each defender cell recognize?

The Immune System Your immune system protects your body from disease-causing bacteria and viruses, or **pathogens.** Specialized white blood cells target and destroy these pathogens. An example of one kind of white blood cell is shown in Figure 6. Its captures and destroys bacteria that could cause infection. Other white blood cells specialize in identifying specific types of viruses. These white blood cells recognize different marker molecules on the surface of the viruses. In some cases, the white blood cells attack and destroy these viruses. In other cases, white blood cells activate different cells that make **antibodies**—proteins that help destroy pathogens. The antibodies bind to the marker molecules on the pathogens, causing them to clump together. These clumps are then destroyed by white blood cells like the one in the figure.

After an infection, your immune system "remembers" the pathogen and can produce antibodies more quickly if you are exposed again. This ability to destroy pathogens before they can cause disease is called **immunity**.

The Reproductive System The reproductive systems of males and females contain organs that produce sex cells. Recall that sex cells carry information in the form of DNA. When these cells combine, the DNA can direct the development of a new individual. The organs of the reproductive system also produce chemicals that regulate the physical development of maturing bodies. In mature females, for example, these chemicals make pregnancy and the delivery of a baby possible.

Reading Checkpoint **What is the function of the immune system?**

FIGURE 7
Senses of Your Nervous System
Your eyes, ears, skin, mouth, and nose contain nerve cells that transmit information to your brain about the world around you.

The Nervous System You can think, move, hear music, and do much more because of your nervous system. The nervous system takes in information from your environment and from within your body. It processes this information and commands the body to respond. For example, you might sense that it is too warm and decide to take off your coat. In this case, you actually think about what to do. But in many other ways, your nervous system functions automatically.

The nervous system includes the brain and spinal cord. Specialized nerve cells make up these two organs. These nerve cells also reach from the spinal cord to all parts of your body. Nerve cells transmit information between the parts of your body and the spinal cord and brain.

The Endocrine System The systems in your body constantly make adjustments to maintain the internal conditions you need to live and function. Your endocrine system helps regulate the activities of the organs and organ systems by releasing hormones. Hormones are chemicals that change the activity in your body's cells. Each hormone affects a specific group of cells or an organ in a particular way.

The endocrine system consists of a collection of glands—specialized tissues that produce and release hormones. Your endocrine glands are located in different places throughout your body. These glands release their hormones into your bloodstream, where the circulatory system carries them to the targeted tissues. Complex processes regulate the amount of every hormone in your body. The levels can go up or down, depending on signals from other glands or from your brain.

FIGURE 8
Some Glands of the Endocrine System
The endocrine glands produce hormones, which are then released into the bloodstream.
Interpreting Diagrams *Which glands are located in the throat?*

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Homeostasis

The different organ systems work together and depend on one another. When you ride a bike, you use your muscular and skeletal systems to steer and push the pedals. But you also need your nervous system to direct your arms and legs to move. Your respiratory, digestive, and circulatory systems work together to fuel your muscles with the energy they need. And your circulatory, respiratory, and excretory systems remove the wastes produced while your muscles are hard at work.

All the systems of the body work together to maintain **homeostasis** (hoh mee oh STAY sis), the body's tendency to keep an internal balance. **Homeostasis is the process by which an organism's internal environment is kept stable in spite of changes in the external environment.**

Homeostasis in Action To see homeostasis in action, all you have to do is take your temperature when the air is cold. Then, take it again in an overheated room. No matter what the temperature of the air around you, your internal body temperature will be close to 37°C. Of course, if you become sick, your body temperature may rise. But when you are well again, it returns to 37°C.

Maintaining Homeostasis Your body has various ways of maintaining homeostasis. For example, when you are too warm, you sweat. Sweating helps to cool your body. On the other hand, when you are cold, you shiver. Shivering occurs when your muscles rapidly contract and relax. This action produces heat that helps keep you warm. Both of these processes help your body regulate your temperature and maintain homeostasis.

FIGURE 9
Maintaining Homeostasis
Regardless of the surrounding temperature, your body temperature remains fairly constant at about 37°C. Sweating (left) and shivering (right) help regulate your body temperature.
Applying Concepts *What is the term for the body's tendency to maintain a stable internal environment?*

Stress and Homeostasis Sometimes, things can happen to disrupt homeostasis. As a result, your heart may beat more rapidly or your breathing may increase. These reactions of your circulatory and respiratory systems are signs of stress. **Stress** is the reaction of your body to potentially threatening, challenging, or disturbing events.

Think about what happens when you leave the starting line in a bike race. As you pedal, your heart beats faster and your breathing increases. What is happening in your body? First, your endocrine system releases a chemical called adrenaline into your bloodstream. Adrenaline gives you a burst of energy and prepares your body to take action.

As you pedal, your muscles work harder and require more oxygen. Oxygen is carried by the circulatory system, so your heart beats even faster to move more blood to your muscles. Your breath comes faster and faster, too, so that more oxygen can get into your body. Your body is experiencing stress.

If stress is over quickly, your body soon returns to its normal state. Think about the bike race again. After you cross the finish line, you continue to breathe hard for the next few minutes. Soon, however, your breathing and heart rate return to normal. The level of adrenaline in your blood returns to normal. Thus, homeostasis is restored after just a few minutes of rest.

Reading Checkpoint What is stress?

FIGURE 10
Stress
Your body reacts to stress, such as the start of a bike race, by releasing adrenaline and carrying more oxygen to body cells.

Section 1 Assessment

S 7.5.a, E-LA: Reading 7.2.0, Writing 7.2.5

Target Reading Skill Take Notes Review your notes for this section. What are two important ideas that you noted under Organs and Organ Systems?

Reviewing Key Concepts

1. a. **Identifying** List the four levels of organization in the human body from smallest to largest. Give an example of each level.
   b. **Comparing and Contrasting** What is the difference between tissues and organs?
2. a. **Listing** List the 11 main systems of the human body.
   b. **Describing** Next to the name of each system, write a phrase that describes its function.
3. a. **Defining** What is homeostasis?
   b. **Explaining** How does stress affect homeostasis?
   c. **Relating Cause and Effect** Describe what happens inside your body as you give an oral report in front of your class.

Writing in Science

Summary Write a paragraph that explains what body systems are involved when you prepare a sandwich and then eat it. Be sure to begin your paragraph with a topic sentence and include supporting details.

Section 2

The Skeletal System

CALIFORNIA Standards Focus

S 7.5.c Students know how bones and muscles work together to provide a structural framework for movement.

S 7.6.h Students know how to compare joints in the body (wrist, shoulder, thigh) with structures used in machines and simple devices (hinge, ball-and-socket, and sliding joints).

- What are the functions of the skeleton?
- What role do joints play in the body?
- What are the characteristics of bone, and how can you keep your bones strong and healthy?

Key Terms

- skeleton
- vertebrae
- joint
- ligament
- cartilage
- compact bone
- spongy bone
- marrow
- osteoporosis

Lab zone [redacted]p

Hard as a Rock?

1. Your teacher will give you a rock and a leg bone from a cooked turkey or chicken.
2. Use a hand lens to examine both the rock and the bone.
3. Gently tap both the rock and the bone on a hard surface.
4. Pick up each object to feel how heavy it is.
5. Wash your hands. Then make notes of your observations.

Think It Over

Observing Based on your observations, why do you think bones are sometimes compared to rocks? List some ways in which bones and rocks are similar and different.

A high rise construction site is a busy place. After workers have prepared the building's foundation, they begin to assemble thousands of steel pieces into a frame for the building. People watch as the steel pieces are joined to create a rigid frame that climbs toward the sky. By the time the building is finished, however, the building's framework will no longer be visible.

Like a building, you also have an inner framework, but it isn't made up of steel. Your framework, or **skeleton,** is made up of all the bones in your body. The number of bones in your skeleton, or skeletal system, depends on your age. A newborn has about 275 bones. An adult, however, has about 206 bones. As a baby grows, some of the bones in the body fuse together. For example, as you grew, some of the bones in your skull fused together.

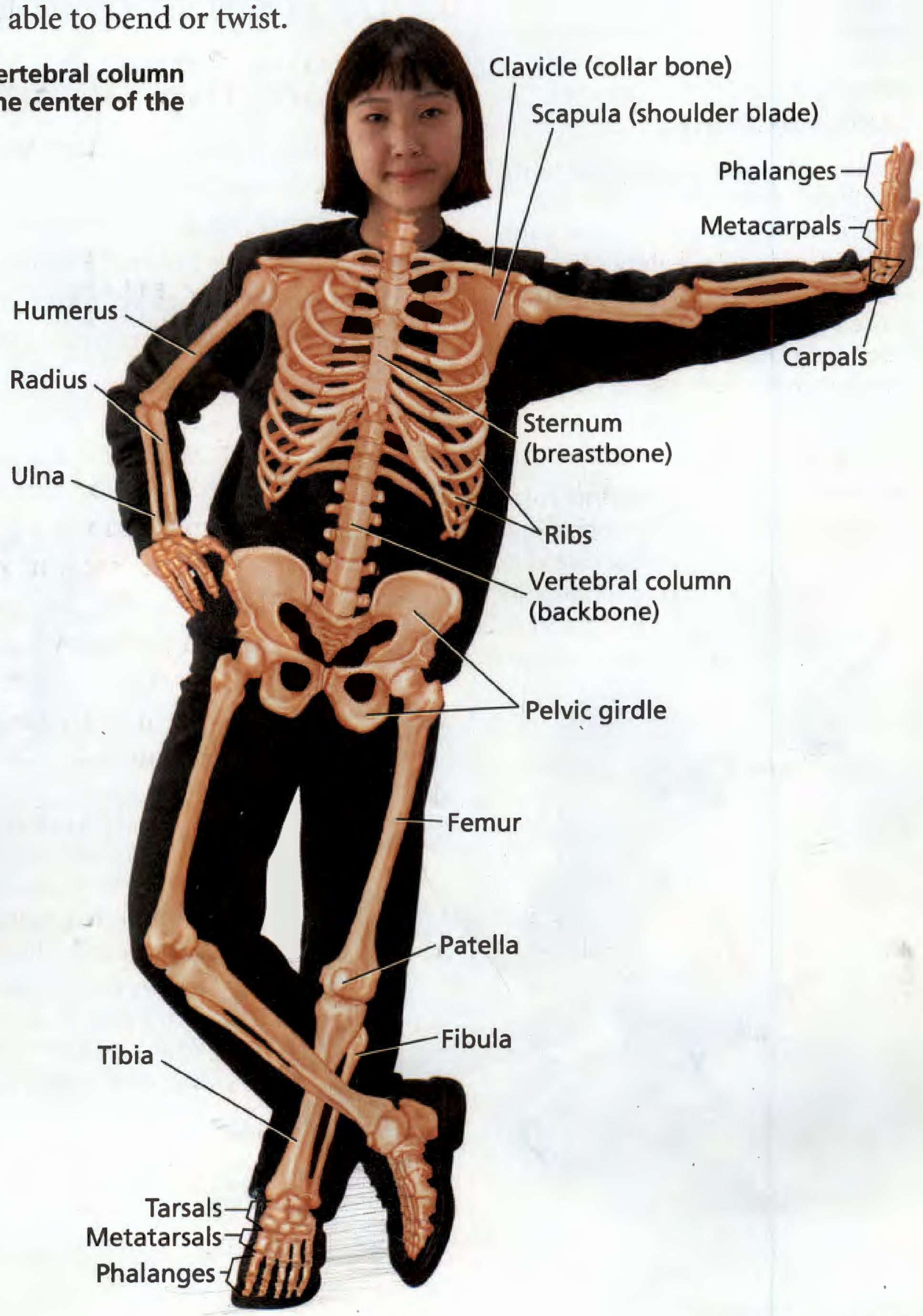
Functions of the Skeletal System

Just as a building could not stand without its frame, you would collapse without your skeleton. **Your skeleton has five major functions. It provides shape and support, enables you to move, protects your organs, produces blood cells, and stores minerals and other materials until your body needs them.**

Shape and Support Your skeleton determines the shape of your body, much as a steel frame determines the shape of a building. The backbone, also called the vertebral or spinal column, is the center of the skeleton. Locate the backbone in Figure 11. Notice that the bones in the skeleton are in some way connected to this column. If you move your fingers down the center of your back, you can feel the 26 small bones, or **vertebrae** (VUR tuh bray) (singular: *vertebra*), that make up your backbone. Bend forward at the waist and feel the bones adjust as you move. Each individual vertebra is like a bead on a string. Just as a beaded necklace is flexible and able to bend, so too is your vertebral column. If your backbone were just one bone, you would not be able to bend or twist.

Reading Checkpoint **Why is the vertebral column considered the center of the skeleton?**

FIGURE 11
The Skeleton
The skeleton provides a framework that supports and protects many other body parts. **Comparing and Contrasting** *In what ways is the skeleton like the steel framework of a building? In what ways is it different?*



Skull

Movement and Protection Your skeleton allows you to move. Most of the body's bones are associated with muscles. The muscles pull on the bones to make the body move. Bones also protect many of the organs in your body. For example, your skull protects your brain, and your breastbone and ribs form a protective cage around your heart and lungs.

Production and Storage of Substances Some of your bones produce substances that your body needs. You can think of the long bones of your arms and legs as factories that make certain blood cells. Bones also store minerals such as calcium and phosphorus. When the body needs these minerals, the bones release small amounts of them into the blood.

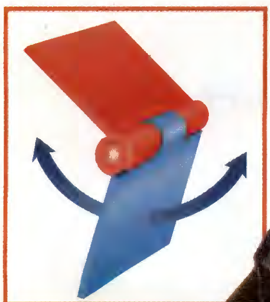
Go Online
active art

For: Movable Joints activity
Visit: PHSchool.com
Web Code: cep-4012

Joints of the Skeleton

Suppose that a single long bone ran the length of your leg. How would you get out of bed or run for a bus? Luckily, your body contains many small bones rather than fewer large ones. A **joint** is a place in the body where two bones come together. **Joints allow bones to move in different ways.** There are two kinds of joints—immovable joints and movable joints.

FIGURE 12
Movable Joints
Without movable joints, your body would be as stiff as a board. The different kinds of joints allow your body to move in a variety of ways.
Comparing and Contrasting *How is the movement of a hinge joint different from that of a ball-and-socket joint?*



Hinge Joint
A hinge joint allows forward or backward motion. Your knee is a hinge joint that allows you to bend and straighten your leg. Your elbow is also a hinge joint.

Ball-and-Socket Joint
Ball-and-socket joints allow the greatest range of motion. The ball-and-socket joint in your shoulder allows you to swing your arm freely in a circle. Your hips also have ball-and-socket joints.

Immovable Joints Some joints in the body connect bones in a way that allows little or no movement. These joints are called immovable joints. The bones of the skull are held together by immovable joints.

Movable Joints Most joints in the body are movable joints. Movable joints allow the body to make a wide range of movements. Look at Figure 12 to see the variety of movements that these joints make possible. Notice how some joints move much like a simple machine. For example, your knee makes the same motion as a door hinge.

The bones in movable joints are held together by strong connective tissues called **ligaments.** Most joints have a second type of connective tissue, called **cartilage** (KAHR tuh lij), which is more flexible than bone. Cartilage covers the ends of the bones and keeps them from rubbing against each other. For example, in the knee, cartilage acts as a cushion that keeps your femur (thighbone) from rubbing against the bones of your lower leg. In addition, a fluid lubricates the ends of the bones, allowing them to move smoothly over each other.

Reading Checkpoint How are movable joints held together?

Lab zone Skills Activity

Classifying

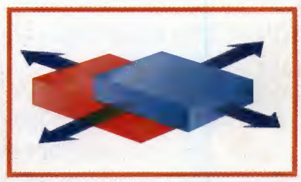
Perform these activities.

- Move your arm in a circle.
- Push open a door.
- Lift a book from a desk.
- Kneel down.
- Wave your hand.
- Twist your head from side to side.

Determine which type of movable joint or joints is involved in performing each activity. Give a reason to support your classifications.

Pivot Joint
A pivot joint allows one bone to rotate around another. The pivot joint in your neck allows you to turn your head from side to side.

Sliding Joint
A sliding joint allows one bone to slide over another. The sliding joint in your wrist or ankle enables you to bend and flex as well as make limited side-to-side motions.



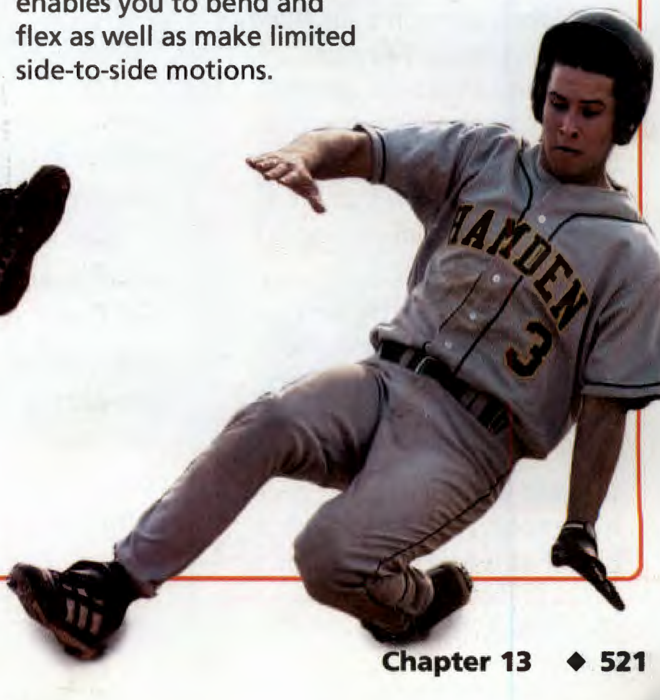


FIGURE 13
Bone Structure
The most obvious feature of a long bone, such as the femur, is its long shaft. Running through the compact bone tissue within the shaft is a system of canals. The canals bring materials to the living bone cells.
Interpreting Diagrams *What different tissues make up the femur?*

Bones—Strong and Living

When you think of a skeleton, you may think of the paper cutouts that are used as decorations at Halloween. Many people connect skeletons with death. The ancient Greeks did, too. The word *skeleton* actually comes from a Greek word meaning "a dried body." The bones of your skeleton, however, are not dead at all. **Bones are complex living structures that undergo growth and development.**

Bone Structure Figure 13 shows the structure of the femur, or thighbone. The femur, which is the body's longest bone, connects the pelvic bones to the lower leg bones. Notice that a thin, tough membrane covers all of the bone except the ends. Blood vessels and nerves enter and leave the bone through the membrane. Beneath the bone's outer membrane is a layer of **compact bone**, which is hard and dense, but not solid. As you can see in Figure 13, small canals run through the compact bone. These canals carry blood vessels and nerves from the bone's surface to the living cells within the bone.

Just inside the femur's compact bone is a layer of spongy bone. Like a sponge, **spongy bone** has many small spaces within it. This structure makes spongy bone tissue lightweight but strong. Spongy bone is also found at the ends of the bone.

The spaces in many bones contain a soft, connective tissue called **marrow**. There are two types of marrow—red and yellow. Red bone marrow produces most of the body's blood cells. As a child, most of your bones contained red bone marrow. As a teenager, only the ends of your femurs, skull, hip bones, and sternum (breastbone) contain red marrow. Your other bones contain yellow marrow. This marrow stores fat that can serve as an energy reserve.

Reading Checkpoint **What are the two types of bone marrow?**

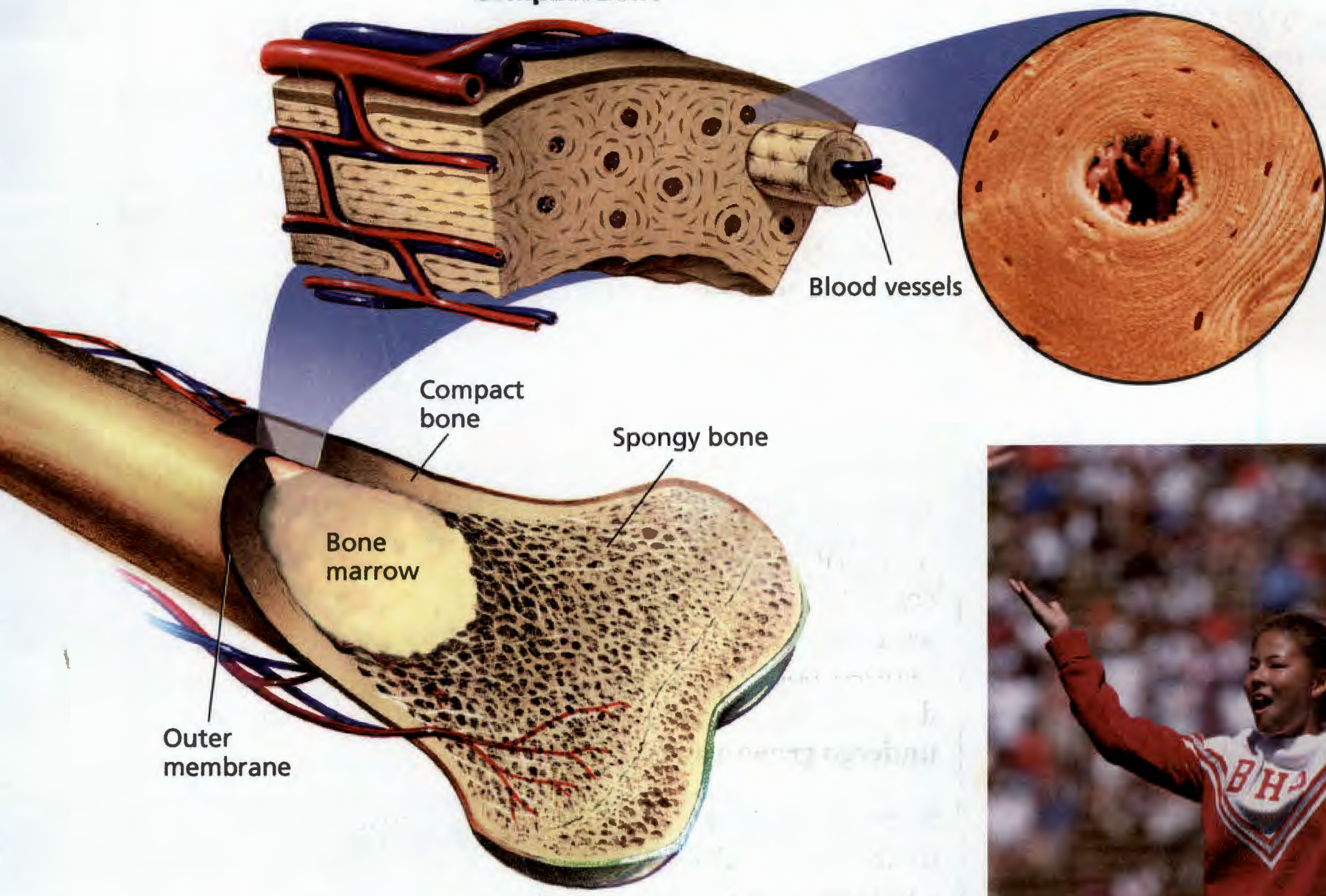
Lab zone Try This Activity

Soft Bones?

In this activity, you will explore the role that calcium plays in bones.

1. Put on protective gloves. Soak one clean chicken bone in a jar filled with water. Soak a second clean chicken bone in a jar filled with vinegar. (Vinegar causes calcium to dissolve out of bone.)
2. After one week, put on protective gloves and remove the bones from the jars.
3. Compare how the two bones look and feel. Note any differences between the two bones.

Drawing Conclusions Based on your results, explain why it is important to consume a diet that is high in calcium.



Bone Strength The structure of bone makes it both strong and lightweight. Bones are so strong that they can absorb more force without breaking than can concrete or granite rock. Yet, bones are much lighter than these materials. In fact, only about 20 percent of an average adult's body weight is bone.

Have you ever heard the phrase "as hard as a rock"? Most rock is hard because it is made up of minerals that are packed tightly together. In a similar way, bones are hard because they contain minerals—primarily phosphorus and calcium.

Bone Growth Bones are alive—they contain cells and tissues, such as blood and nerves. Because they are alive, bones also form new bone tissue as you grow. Even after you are grown, bone tissue continues to form within your bones. For example, every time you play soccer or basketball, some of your bones absorb the force of your weight. They respond by making new bone tissue.

Sometimes, new bone tissue forms after an accident. If you break a bone, for example, new bone tissue forms to fill the gap between the broken ends of the bone. In fact, the healed region of new bone may be stronger than the original bone!

▲ You can jump up and down or turn cartwheels without breaking bones.

Video Field Trip
Discovery Channel School
Bones, Muscle, and Skin

Bone Development Try this activity: Move the tip of your nose from side to side with your fingers. Notice that the tip of your nose is not stiff. That is because it contains cartilage. As an infant, much of your skeleton was cartilage. Over time, most of the cartilage was replaced with hard bone tissue.

The replacement of cartilage by bone tissue usually is complete by the time you stop growing. You've seen, however, that not all of your body's cartilage is replaced by bone. Even in adults, many joints contain cartilage that protects the ends of the bones.

Taking Care of Your Bones

Because your skeleton performs so many necessary functions, it is important to keep it healthy. **A combination of a balanced diet and regular exercise are important for a lifetime of healthy bones.**

Diet One way to help ensure healthy bones is to eat a well-balanced diet. A well-balanced diet includes enough calcium and phosphorus to keep your bones strong while they are growing. Meats, whole grains, and leafy green vegetables are all good sources of both calcium and phosphorus. Dairy products, including yogurt, are good sources of calcium.

Exercise Another way to build and maintain strong bones is to get plenty of exercise. During activities such as running, skating, or dancing, your bones support the weight of your entire body. These weight-bearing activities help your bones grow stronger and denser. To prevent injuries while exercising, be sure to wear appropriate safety equipment, such as a helmet and pads.

Reading Checkpoint **What are two ways to keep your bones healthy?**

FIGURE 14
Caring for Your Bones
Exercising regularly and eating a balanced diet help to keep your bones strong and healthy.

Healthy Spine

Spine With Osteoporosis

FIGURE 15
Osteoporosis
Without enough calcium in the diet, a person's bones weaken. These photos show how the shape and structure of vertebrae in a healthy spine compare with those in a person with osteoporosis.
Relating Cause and Effect *What can you do to prevent osteoporosis?*

Osteoporosis As people become older, their bones begin to lose some of the minerals they contain. Mineral loss can lead to **osteoporosis** (ahs tee oh puh ROH sis), a condition in which the body's bones become weak and break easily. You can see the effect of osteoporosis in Figure 15. Evidence indicates that regular exercise throughout life and a diet with enough calcium can help prevent osteoporosis. If you eat enough calcium-rich foods now, you may help prevent osteoporosis later in life.

Section 2 Assessment

S 7.5.c, 7.6.h,
E-LA: Reading 7.1.2

Vocabulary Skill **Latin Word Origins** The Greek word *osteon* means "bone." What does the Latin word *porus* mean? How do these two word parts combine to produce the meaning of *osteoporosis*?

Reviewing Key Concepts

1. a. **Listing** What are five functions of the skeleton?
   b. **Explaining** How does the skeleton protect the body?
   c. **Predicting** How would your life be different if your backbone were just one long bone?
2. a. **Naming** What are four types of movable joints?
   b. **Comparing and Contrasting** Compare immovable joints with movable joints.
   c. **Classifying** Which of your movable joints are ball-and-socket joints?
3. a. **Identifying** What are three layers within the femur?
   b. **Relating Cause and Effect** How does the structure of bones make them both strong and lightweight?
   c. **Applying Concepts** How do a well-balanced diet and weight-bearing exercise help keep bones strong?

Lab zone At-Home Activity

Model Joints Choose two examples of movable joints from Figure 12. Ask a family member to perform separate movements that involve one joint and then the other. Make drawings to represent the joints and bones involved in each movement. Use the drawings to explain to your family how the motions of the two joints differ.

Section 3

The Muscular System

CALIFORNIA Standards Focus

S 7.5.c Students know how bones and muscles work together to provide a structural framework for movement.

- What types of muscles are found in the body?
- Why do skeletal muscles work in pairs?

Key Terms

- involuntary muscle
- voluntary muscle
- skeletal muscle
- tendon
- striated muscle
- smooth muscle
- cardiac muscle

Lab zone Standards Warm-Up

How Do Muscles Work?

1. Grip a spring-type clothespin with the thumb and index finger of your writing hand. Squeeze the clothespin open and shut as quickly as possible for two minutes. Count how many times you can squeeze the clothespin before your muscles tire.
2. Rest for one minute. Then, repeat Step 1.

Think It Over

Predicting What do you think would happen if you repeated Steps 1 and 2 with your other hand? Give a reason for your prediction. Then, test your prediction.

A rabbit becomes still when it senses danger. The rabbit sits so still that it doesn't seem to move a muscle. Could you sit without moving any muscles? Saliva builds up in your mouth. You swallow. You need to breathe. Your chest expands to let air in. All of these actions involve muscles. It is impossible to sit absolutely still without muscle movement.

There are about 600 muscles in your body. Muscles have many functions. For example, they keep your heart beating, pull your mouth into a smile, and move the bones of your skeleton. The girl doing karate on the next page uses many of her muscles to move her arms, legs, hands, feet, and head. Other muscles expand and contract her chest and allow her to breathe.

Types of Muscle

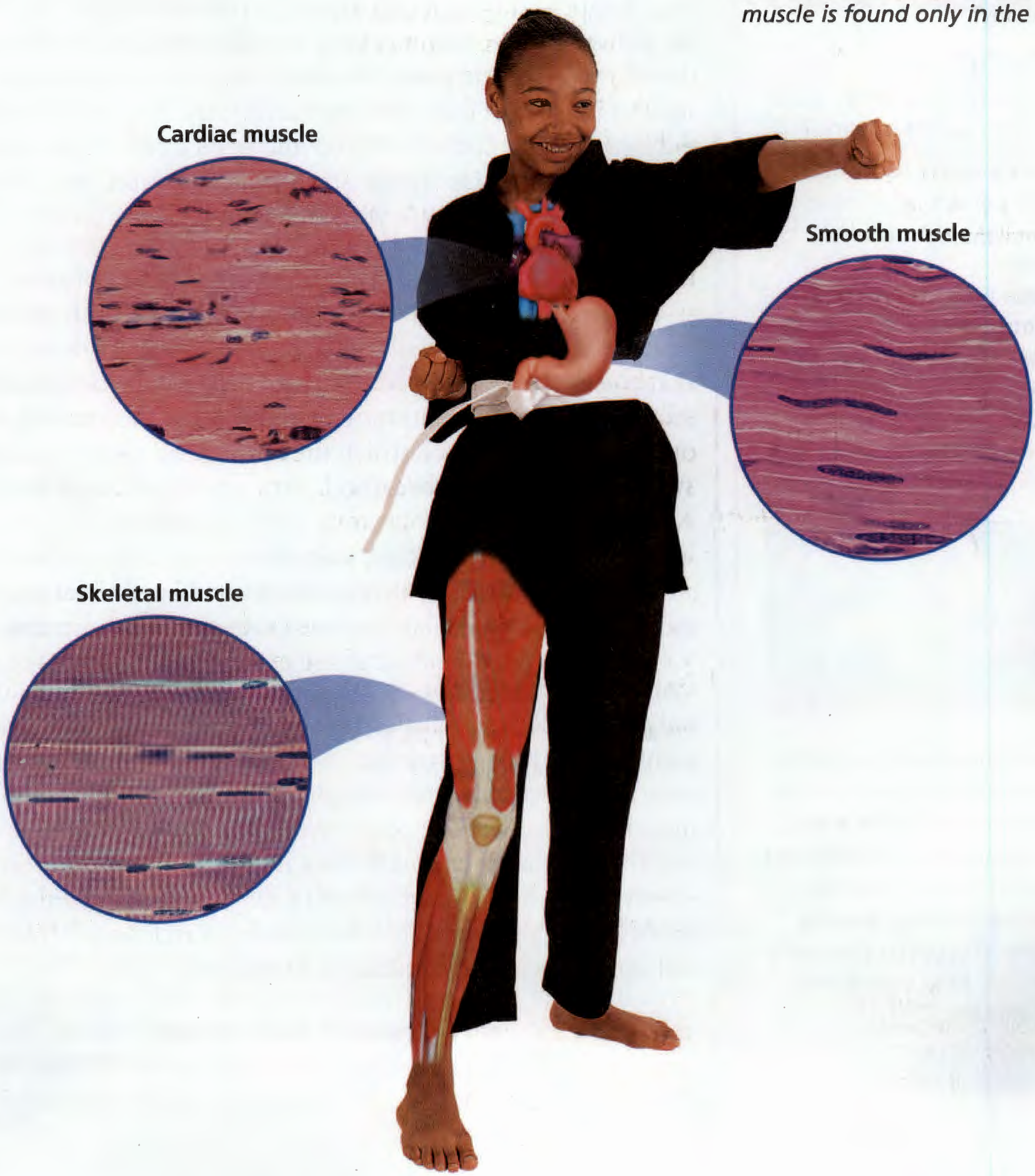
Some of your body's movements, such as smiling, are easy to control. Other movements, such as the beating of your heart, are impossible to control completely. That is because some of your muscles are not under your conscious control. Those muscles are called **involuntary muscles**. Involuntary muscles are responsible for such essential activities as moving food along the digestive tract and controlling the size of an eye's pupil.

Go Online
PHSchool.com
For: More on muscle types
Visit: PHSchool.com
Web Code: ced-4014

The muscles that are under your conscious control are called **voluntary muscles.** Smiling, turning a page in a book, and getting out of your chair when the bell rings are all actions controlled by voluntary muscles.

Your body has three types of muscle tissue—skeletal muscle, smooth muscle, and cardiac muscle. Only skeletal muscle is voluntary. Smooth muscle and cardiac muscle are involuntary. In Figure 16, you see a magnified view of each type of muscle in the body. Both skeletal and smooth muscles are found in many places in the body. Cardiac muscle is found only in the heart. Each muscle type performs specific functions in the body.

FIGURE 16
Types of Muscle
Your body has three types of muscle tissue: skeletal muscle, smooth muscle, and cardiac muscle. **Classifying** *Which type of muscle is found only in the heart?*



Skeletal Muscle Every time you type on a computer keyboard, shoot a basketball, or walk across a room, you are using skeletal muscles. As their name suggests, **skeletal muscles** are attached to the bones of your skeleton. These muscles provide the force that moves your bones. At each end of a skeletal muscle is a tendon. A **tendon** is a strong connective tissue that attaches muscle to bone. Skeletal muscle cells appear banded, or striated. For this reason, skeletal muscle tissue is sometimes called **striated** (STRY ay tid) **muscle**.

Because you have conscious control of skeletal muscles, they are classified as voluntary muscles. One characteristic of skeletal muscles is that they react very quickly. Think about what happens during a swim meet. Immediately after the starting gun sounds, a swimmer's leg muscles push the swimmer off the block into the pool. However, another characteristic of skeletal muscles is that they tire quickly. By the end of the race, the swimmer's muscles are tired and need a rest. If you did the Standards Warm-Up at the start of this section, you felt the effects of tired muscles in your fingers.

Smooth Muscle The inside of many internal organs, such as the stomach and blood vessels, contain **smooth muscles.** Smooth muscles are involuntary muscles. They work automatically to control certain movements inside your body, such as those involved in digestion. For example, as the smooth muscles of your stomach contract, they produce a churning action. The churning mixes the food with chemicals, and helps to digest the food.

Unlike skeletal muscles, smooth muscle cells are not striated. Smooth muscles behave differently than skeletal muscles, too. Smooth muscles react more slowly and tire more slowly.

Cardiac Muscle The tissue called **cardiac muscle** is found only in your heart. Cardiac muscle has some characteristics in common with both smooth muscle and skeletal muscle. Like smooth muscle, cardiac muscle is involuntary. Like skeletal muscle, cardiac muscle cells are striated. However, unlike skeletal muscle, cardiac muscle does not get tired. It can contract repeatedly. A specialized group of nerve cells within the heart sends out signals that cause the cardiac muscle to contract. You call those repeated contractions heartbeats.

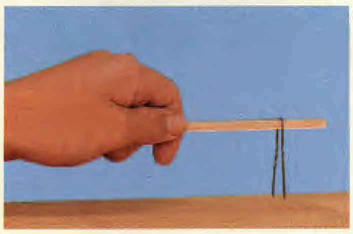
Reading Checkpoint Where is smooth muscle found?

Lab zone Try This Activity

Get a Grip

Are skeletal muscles at work when you're not moving?

1. Hold a stirrer in front of you, parallel to a table top. Do not touch the table.
2. Have a partner place a hairpin on the stirrer.
3. Raise the stirrer until the "legs" of the hairpin just touch the table. The "head" of the hairpin should rest on the stirrer.



4. Hold the stirrer steady for 20 seconds. Observe what happens to the hairpin.
5. Grip the stirrer tighter and repeat Step 4. Observe.

Inferring Are the skeletal muscles in your hand at work when you hold your hand still? Explain.

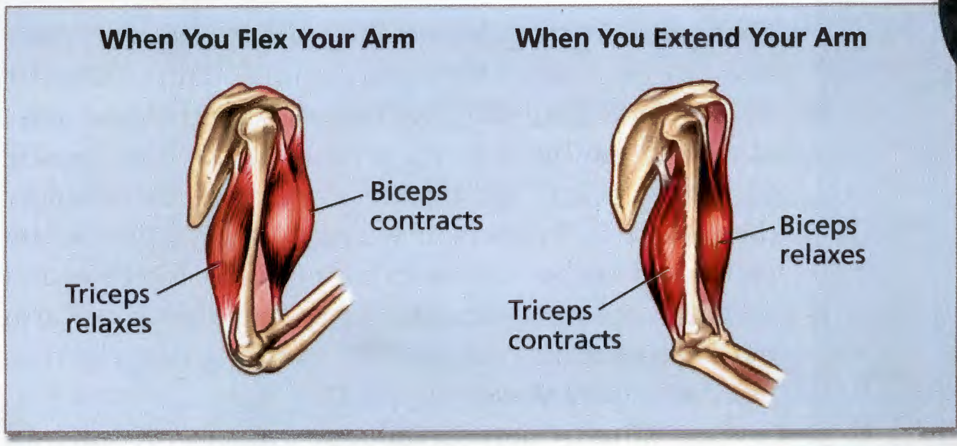


FIGURE 17
Muscle Pairs
Because muscles can only contract, or shorten, they must work in pairs. To bend the arm at the elbow, the biceps contracts while the triceps returns to its original length. **Interpreting Diagrams** *What happens to each muscle to straighten the arm?*

Muscles at Work

Has anyone ever asked you to "make a muscle"? If so, you probably tightened your fist, bent your arm at the elbow, and made the muscles in your upper arm bulge. Like other skeletal muscles, the muscles in your arm do their work by contracting, becoming shorter and thicker. Muscles work in coordination with the skeletal system and the nervous system. First, messages from the nervous system cause a muscle to contract. Then the shortened muscle pulls on the attached bone, causing it to move. **Because muscle cells can only move bones by contracting, skeletal muscles must work in pairs. While one muscle contracts, the other muscle in the pair relaxes to its original length.**

Muscles Work in Pairs The coordinated contraction and relaxation of different muscles allows you, for instance, to bend your arm. Figure 17 shows this action. The biceps muscle on the upper arm contracts. This motion bends, or flexes, your arm at the elbow. The angle between the bones in your forearm (the radius and ulna) and the bone in your upper arm (the humerus) then decreases. Your biceps muscle bulges as it shortens. You "make a muscle." As the biceps contracts, the triceps on the back of the upper arm relaxes and extends.

To move the weight down, the biceps and triceps also work together. This time, the triceps muscle contracts. The action causes the angle between your upper arm bone and lower arm bone to increase. In other words, our arm straightens. At the same time, the biceps relaxes and extends to its original length.

When you lift a weight, the biceps moves your arm. But the triceps is important, too. It helps keep the motion smooth and controlled, protecting the elbow joint from a sudden, strong contraction. When you extend your arm, the biceps smoothes the motion. The flexing and extending of your arm is a good example of how muscles work in coordinated pairs.

FIGURE 18
Preventing Muscle Injuries
When you warm up before exercising, you increase the flexibility of your muscles.

Muscular Strength and Flexibility Regular exercise is important for maintaining both muscular strength and flexibility. Exercise makes individual muscle cells grow in size. As a result, the whole muscle becomes thicker. The thicker a muscle is, the stronger the muscle is. When you warm up thoroughly before exercising, the blood flow to your muscles increases and they become more flexible. Stretching after you warm up helps prepare your muscles for the more vigorous exercise or play ahead.

Sometimes, despite taking proper precautions, muscles can become injured. A muscle strain, or pulled muscle, can occur when muscles are overworked or overstretched. Tendons can also be overstretched or partially torn. After a long period of exercise, a skeletal muscle can cramp. When a muscle cramps, the entire muscle contracts strongly and stays contracted. If you injure a muscle or tendon, it is important to follow medical instructions and to rest the injured area so it can heal.

Reading Checkpoint **What are two ways to prepare the muscles for exercise?**

Section 3 Assessment

S 7.5.c, E-LA: Reading 7.2.0, Writing 7.2.0

Target Reading Skill **Take Notes** Review your notes for this section. What are two important ideas that you noted under Muscles at Work?

Reviewing Key Concepts

1. a. **Identifying** What are the three types of muscle tissue?
   b. **Comparing and Contrasting** How do voluntary and involuntary muscles differ? Give an example of each type of muscle.
   c. **Predicting** The muscles that move your fingers are attached to the bones in your fingers by tendons. Suppose one of the tendons in a person's index finger were cut. How would it affect movement in the finger?
2. a. **Identifying** Where might you find muscle pairs?
   b. **Describing** Describe how the muscles in your upper arm work together to bend and straighten your arm.
   c. **Applying Concepts** When exercising to build muscular strength, why is it important to exercise both muscles in a muscle pair equally?

Writing in Science

Comparison Paragraph Write a paragraph comparing smooth muscle tissue and skeletal muscle tissue. Include whether these muscle tissues are voluntary or involuntary, where they are found and what their functions are. In addition, describe what you might expect to see if you looked at these muscle tissues under a microscope.

A Look Beneath the Skin

S 7.5.c, 7.7.d

Problem

What are some characteristics of skeletal muscles? How do skeletal muscles work?

Skills Focus

observing, inferring, classifying

Materials

- water
- paper towels
- scissors
- dissecting tray
- uncooked chicken wing, treated with bleach

Procedure

1. Put on goggles, an apron, and protective gloves. **CAUTION:** *Wear gloves whenever you handle the chicken.*
2. Your teacher will give you a chicken wing. Rinse it well with water, dry it with paper towels, and place it in a dissecting tray.
3. Carefully extend the wing to find out how many major parts it has. Draw a diagram of the external structure. Label the upper arm, elbow, lower arm, and hand (wing tip).
4. Use scissors to remove the skin. Cut only through the skin. **CAUTION:** *Cut away from your body and your classmates.*
5. Examine the muscles, which are the bundles of pink tissue around the bones. Find the two groups of muscles in the upper arm. Hold the arm down at the shoulder, and alternately pull on each muscle group. Observe what happens.
6. Find the two groups of muscles in the lower arm. Hold down the arm at the elbow, and alternately pull on each muscle group. Then, make a diagram of the wing's muscles.
7. Find the tendons—shiny white tissue at the ends of the muscles. Notice what parts the tendons connect. Add the tendons to your diagram.

8. Remove the muscles and tendons. Find the ligaments, which are the whitish ribbon-shaped structures between bones. Add them to your diagram.
9. Dispose of the chicken parts according to your teacher's instructions. Wash your hands.

Analyze and Conclude

1. **Observing** How does a chicken wing move at the elbow? How does the motion compare to how your elbow moves? What type of joint is involved?
2. **Inferring** What happened when you pulled on one of the arm muscles? What muscle action does the pulling represent?
3. **Classifying** Categorize the muscles you observed as smooth, cardiac, or skeletal.
4. **Communicating** Why is it valuable to record your observations with accurate diagrams? Write a paragraph in which you describe what your diagrams show.

More to Explore

Use the procedures from this lab to examine an uncooked chicken thigh and leg. Compare how the chicken leg and a human leg move. *Obtain your teacher's permission before carrying out your investigation.*

Section 4

Machines and the Body

CALIFORNIA Standards Focus

S 7.6.h. Students know how to compare joints in the body (wrist, shoulder, thigh) with structures used in machines and simple devices (hinge, ball-and-socket, and sliding joints).

S 7.6.i. Students know how levers confer mechanical advantage and how the application of this principle applies to the musculoskeletal system.

- How are force and work related?
- How does a lever make work easier?
- How do bones and muscles function as levers in the body?

Key Terms

- force
- work
- machine
- lever
- fulcrum
- effort force
- effort distance
- resistance force
- resistance distance
- mechanical advantage
- effort arm
- resistance arm

Lab zone Standards Warm-Up

Are You an Eating Machine?

1. Using your front teeth, bite off a piece of a cracker.
2. Now chew the cracker. Pay attention to how your lower jaw moves. Touch your jaw just in front of your ear, as shown in the photo. As you chew, push in slightly on your jaw so that you can feel how it moves. If the movement is still not clear, try opening your mouth wide while you feel the back of the jaw.

Think It Over

Inferring When you bite and chew, the back of your jaw moves less than your teeth. Why is that?

A fresh load of soil for your school's garden has been dumped too far from the garden. To move the soil, you might use simple machines such as a lever, shovel, or wheelbarrow to make the job easier. As you work in the garden, you may also lift handfuls of soil by bending your arm and using your hand just like a shovel. Many bones and muscles of the human body act like the simple machine known as a lever.

FIGURE 19
Using Machines
Shovels and rakes make the work of these students easier.

Force and Work

To understand how parts of your body act like machines, you first need to know about two concepts: force and work.

Force A **force** is a push or a pull on an object. A force is described by its strength, or magnitude, and the direction in which it acts. If you push on a door, you exert a force in a different direction than if you pull on the door.

The standard unit for the magnitude of a force is the newton (N). An arrow can represent the direction and strength of a force. The arrow points in the direction of the force. The longer the arrow is drawn, the greater the force's strength.

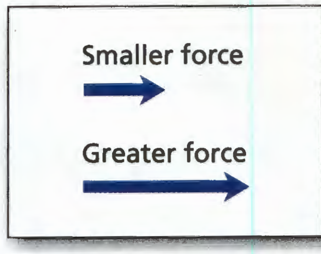


FIGURE 20
Representing Forces
Arrows tell you how the strengths of different forces compare. A force arrow points in the direction of a force.

Work You do **work** when you exert a force on an object that causes the object to move some distance in the same direction as the force. **You can calculate the amount of work done on an object by multiplying force times distance.**

$$\text{Work} = \text{Force} \times \text{Distance}$$

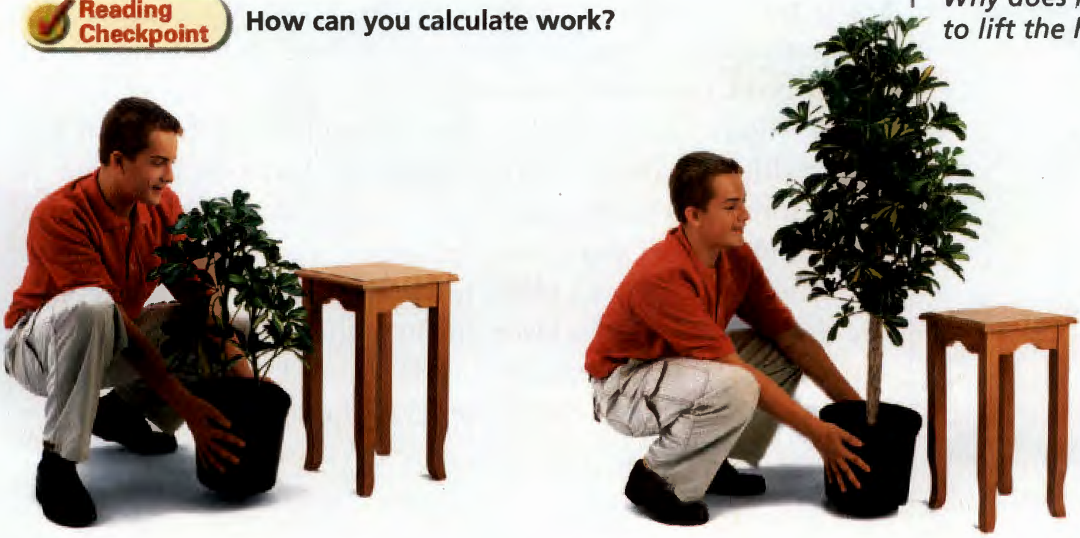
You can use this formula to calculate the amount of work you do to lift a plant. When you lift an object, the upward force must be at least equal to the object's weight. So, to lift a plant that weighs 50 newtons by a distance of 0.5 meter requires 25 newton-meters (N•m) of work. The • symbol means that the units are multiplied.

$$\text{Work} = 50\ \text{N} \times 0.5\ \text{m} = 25\ \text{N}\cdot\text{m}$$

But what can you do if an object weighs more than the amount of force you can exert? For example, what if you wanted to lift a piano up a flight of stairs? You would need to use a machine. A **machine** is a device that allows you to do work in a way that is easier or more effective.

Reading Checkpoint How can you calculate work?

FIGURE 21
Amount of Work
When you lift a plant, you do work. You do more work when you lift a heavier plant the same distance.
Relating Cause and Effect
Why does it take more work to lift the heavier plant?



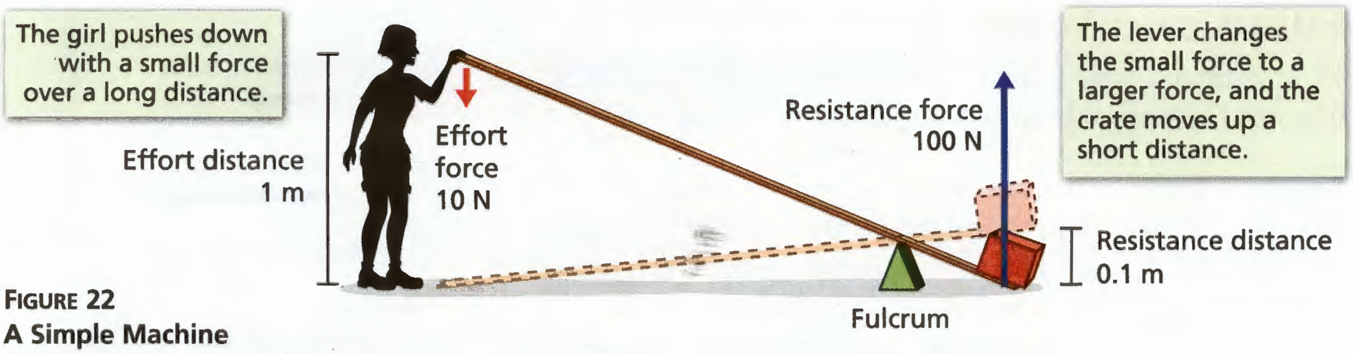


FIGURE 22
A Simple Machine
A lever is a simple machine that makes lifting heavy objects easier. **Applying Concepts** *Why does the girl place the fulcrum close to the crate?*

Levers

Have you ever played pick-up sticks? If so, you are already familiar with a simple machine called a lever. A **lever** is a rigid rod that is free to rotate around a fixed pivot point. The fixed point that a lever rotates around is called the **fulcrum.** You can use a lever to turn a small force into a large force so you can lift a piano.

Levers were probably used in prehistoric times. But the first person to explain how levers work was Archimedes, a mathematician of ancient Greece.

Force and Work in Levers To understand levers, look at Figure 22. The girl is using a lever to lift a crate that weighs 100 newtons. She places the fulcrum close to the crate and stands far away from the fulcrum, on the other side. She applies a force on the lever of 10 newtons over a distance of 1 meter. In this way, she can lift the 100-N crate 0.1 meter. The work done on each side of the lever is equal, but the girl has to apply less force than she would need without a lever. **A lever makes work easier by changing the amount of force exerted, the distance over which the force is exerted, or the direction of the force.**

The force that you exert on a lever is called the **effort force.** The distance you push down is the **effort distance.** In contrast, the force that a lever exerts on an object is called the **resistance force,** and the distance the lever pushes up on an object is the **resistance distance.**

In Figure 22, the girl applies a small effort force on the lever, which becomes a larger resistance force on the crate. A small force that is applied over a long distance can create a larger force over a short distance.

When you apply an effort force over an effort distance, you are doing work on the lever. In turn, the lever applies a resistance force over a resistance distance and does work on an object. The work you do on the lever equals the work the lever does on the object.

FIGURE 23
Pulling Out a Nail
A hammer acts as a lever when you use it to pull a nail from a board. The hammer changes the direction and amount of force you exert, so the nail is easier to remove.

The relationship between the work done on a lever and the work that the lever does on an object can be written as this formula.

$$\text{Effort force} \times \text{Effort distance} = \text{Resistance force} \times \text{Resistance distance}$$

If you know any three values in the formula, you can calculate the fourth value, as shown in the Sample Problem below.

Math: Measurement and Geometry 7.1.3

Math Sample Problem

Calculating Effort Distance

Suppose you need to move a boulder. Using a wooden plank as a lever and a log for the fulcrum, you plan to lift the boulder 0.05 m and then let it roll away. The boulder weighs 240 N and you can exert 80 N of force. How far will you have to push down on your end of the lever to lift the boulder?

1 Read and Understand

What information are you given?

Resistance force = 240 N

Resistance distance = 0.05 m

Effort force = 80 N

2 Plan and Solve

What quantity are you trying to calculate?

Effort distance = ■

What formula contains the given quantities and the unknown quantity?

$$\text{Effort force} \times \text{Effort distance} = \text{Resistance force} \times \text{Resistance distance}$$

Perform the calculation.

$$80\ \text{N} \times \text{Effort distance} = 240\ \text{N} \times 0.05\ \text{m}$$

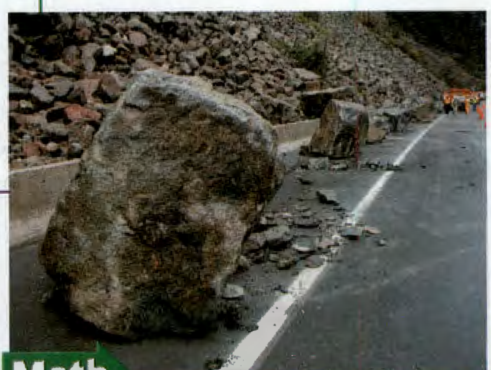
$$80\ \text{N} \times \text{Effort distance} = 12\ \text{N}\cdot\text{m}$$

$$\text{Effort distance} = \frac{12\ \text{N}\cdot\text{m}}{80\ \text{N}} = 0.15\ \text{m}$$

3 Look Back and Check

Does your answer make sense?

An effort distance of 0.15 m is more than the resistance distance of 0.05 m. This answer makes sense because, your effort force is less than the resistance force.



Math Practice

1. **Calculating Effort Force** A friend who weighs 400 N is sitting on the end of a seesaw. You push down a distance of 0.5 m on the opposite end, which lifts your friend a distance of 0.1 m. How much effort force did you apply?
2. **Calculating Resistance Force** In order to lift a box, you push down 0.75 m on a lever with an effort force of 100 N. If the box moves up 0.25 m, how much does the box weigh?

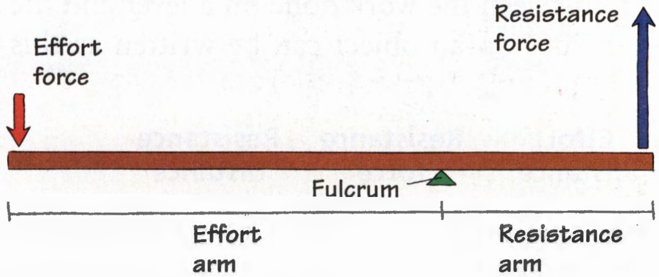


FIGURE 24
The Law of the Lever
A lever's effort arm is the distance from the fulcrum to the effort force. A lever's resistance arm is the distance from the fulcrum to the resistance force.

Mechanical Advantage If you compare the effort force to the resistance force, you can find the advantage of using a lever. A lever's **mechanical advantage** is the number of times a lever increases a force exerted on it. The mechanical advantage of a lever is equal to the ratio of resistance force to the effort force.

$$\text{Mechanical advantage} = \frac{\text{Resistance force}}{\text{Effort force}}$$

In the sample problem on the previous page, an effort force of 80 newtons was exerted to move a 240-newton boulder. The lever's mechanical advantage is 240 newtons divided by 80 newtons, or 3. The lever tripled the effort force.

The Law of the Lever Have you ever balanced a metal spoon on your finger? If so, you have experience with the law of the lever. The spoon is a lever, and your finger acts as the fulcrum. To make the spoon balance, your finger has to be closer to the heavier, bowl end of the spoon than to the other end.

Figure 24 shows how a lever may be balanced when the effort force and resistance force are different. Notice that the fulcrum is not in the middle. The distance from the fulcrum to the effort force is called the **effort arm.** The distance from the fulcrum to the resistance force is the **resistance arm.** The law of the lever states, that for a lever to be balanced, the effort force times the effort arm must be equal to the resistance force times the resistance arm.

Different Classes of Levers There are three classes of levers. These are defined by the location of the fulcrum relative to the effort force and the resistance force. In a first-class lever, the fulcrum is between the effort force and the resistance force. In a second-class lever, the resistance force is between the effort force and the fulcrum. In a third-class lever, the effort force is between the resistance force and the fulcrum. Figure 25 shows examples of all three classes of levers.

Reading Checkpoint How many different classes of levers are there?

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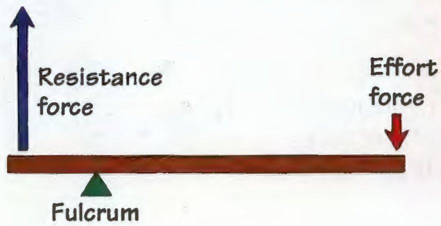
FIGURE 25

Three Classes of Levers

The three classes of levers differ in the positions of the fulcrum, effort force, and resistance force. **Applying Concepts** *Which type of lever always has a mechanical advantage less than 1?*

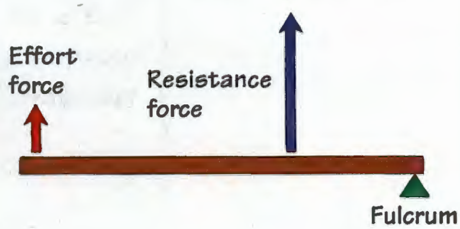
First-Class Levers

First-class levers always change the direction of the effort force. If the fulcrum is closer to the resistance force, these levers also increase force. If the fulcrum is closer to the effort force, these levers also increase distance. Other examples include scissors, pliers, and seesaws.



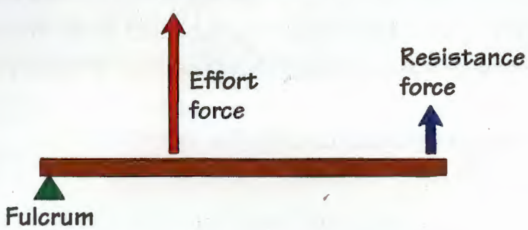
Second-Class Levers

These levers increase force, but do not change the direction of the effort force. Other examples include doors, nutcrackers, and bottle openers.



Third-Class Levers

These levers increase distance, but do not change the direction of the effort force. Other examples include fishing poles, shovels, and baseball bats.



Math: Algebra and Functions 7.3.3

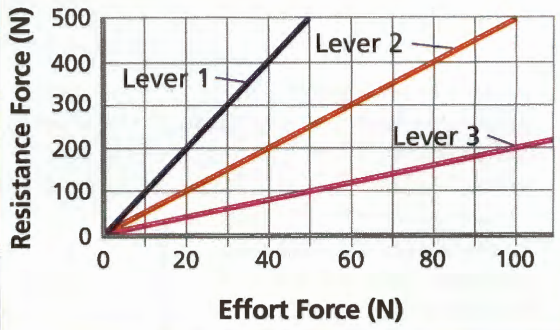
Math Analyzing Data

Mechanical Advantage

The effort force and resistance force for three different levers are shown in the graph.

1. **Reading Graphs** What variable is plotted on the horizontal axis?
2. **Interpreting Data** If an 80-N effort force is exerted on Lever 2, what is the resistance force?
3. **Calculating** Calculate the mechanical advantage of Lever 2.
4. **Drawing Conclusions** Which lever produces the greatest resistance force when an effort force of 20 N is exerted? Of 40 N? Which lever has the greatest mechanical advantage?

Mechanical Advantages of Levers



Machines in the Body

Now that you know how levers work, you can see how parts of your body act like levers. When you move your legs, hips, hands, or head, you are using a lever system to perform the movement. Most of the machines in your body are levers that consist of bones and muscles.

Joints as Machine Structures In Section 2, you learned about the joints of the human skeleton. **Many of the body's movable joints are actually fulcrums. The joints in the body act as pivot points for the bones. The bones act as levers, and muscles provide the force.** The thigh joint, the wrist joint, the shoulder joint, the knee joint, and the elbow joint are examples of fulcrums for third-class levers in the body.

The thigh joint, also known as the hip joint, is an example of a ball-and-socket joint. Your thigh bone, or femur, has a rounded end that fits into a hole of the bone that is your pelvic girdle. Another example of a ball-and-socket joint is your shoulder.

Your wrist is an example of a sliding joint, where one bone slides over another bone. Your elbow and your knee are examples of hinge joints. These joints function like the hinges on a door.

Reading Checkpoint What kind of joint is the wrist?

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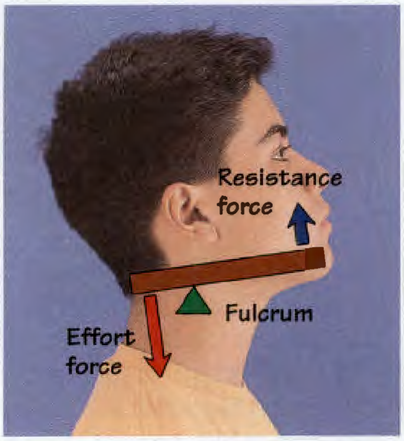
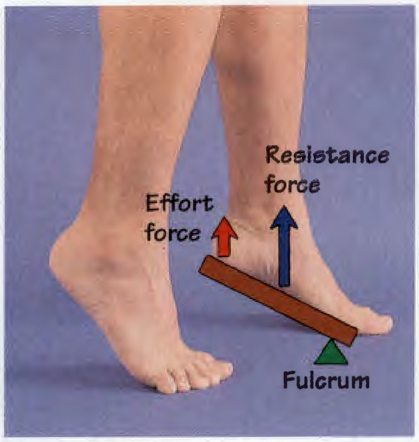
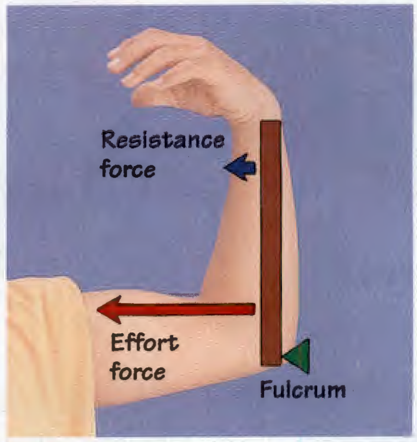


First-Class Lever The joint at the top of your neck is the fulcrum of a first-class lever. The muscles in the back of your neck provide the effort force. The resistance force is used to tilt your head back.



Second-Class Lever The ball of your foot is the fulcrum of a second-class lever. The muscle in the calf of your leg provides the effort force. The resistance force is used to raise your body.



Third-Class Lever Your elbow is the fulcrum of a third-class lever. Your biceps muscle provides the effort force. The resistance force is used to lift your arm.

FIGURE 26
Levers in the Body
You don't need to look further than your own body to find machines. Three different types of levers are responsible for many of your movements.

Bones and Muscles as Lever Systems The most common type of lever in your body is the third-class lever. But your body also has first-class and second-class levers. You can see examples of all three classes of levers in Figure 26. In each case, the effort force is applied at the point where a muscle attaches to a bone. The bone serves as the lever, and the resistance force is the force exerted by the bone. This force may be used for many things, such as chewing, running, or lifting a glass of water.

Section 4 Assessment

S 7.6.h, 7.6.i
E-LA: Reading 7.1.2

Vocabulary Skill **Latin Word Origins** Remember that the Latin word *resistere* means "to place against." How does this meaning help you understand the key term *resistance force*?

Reviewing Key Concepts

1. a. **Defining** What is a force?
   b. **Comparing and Contrasting** How is work different from force?
   c. **Measuring** How is the value for a distance measurement important in calculating work done on an object?
2. a. **Reviewing** What is a lever, and how is a lever useful?
   b. **Explaining** What is the mechanical advantage of a lever?
   c. **Comparing and Contrasting** How does a first-class lever differ from a second-class lever?
3. a. **Listing** Name three joints that act as fulcrums for levers in the body.
   b. **Applying Concepts** For one of the joints you listed above, explain how the joint functions as a fulcrum when you move.

Math Practice

4. **Calculating** With an effort force of 50 N, Archimedes pushes a lever down. On the other side of the fulcrum, a statue that weighs 5,000 N rises 0.01 m. How far down did Archimedes push the lever?
5. **Calculating** A lever has an effort force of 40 N and a resistance force of 80 N. What is its mechanical advantage?

Lab zone **Skills Lab**

Using Your Leverage

S 7.6.h, 7.6.i, 7.7.a

Problem

Is the law of the lever accurate?

Skills Focus

calculating, predicting, interpreting data

Materials

- meter stick
- set of hooked weights
- set of weight holders
- 3 spring scales (5-N, 10-N, 20-N)
- plastic fulcrum or other pivoted support

Procedure

PART 1 First-Class Lever

1. Copy the data table onto a separate piece of paper. Label the data table *First-Class Lever*.
2. Place the meter stick with its center resting on the fulcrum so that it is balanced evenly. Make sure the left end is above the table and the right end hangs over the edge.
3. Choose a position on the meter stick to the left of the fulcrum. Record the distance from the fulcrum to that position as the resistance arm. Hang the lightest hooked weight at that position. The meter stick should tilt until that side is resting on the table. Record the value of the hooked weight in newtons as the resistance force.
   (*Hint*: A mass of 1 gram weighs 0.01 newtons, so you can convert grams to newtons by multiplying the mass by 0.01.)
4. Choose a position on the meter stick to the right of the fulcrum. Record the distance from the fulcrum to that position as the effort arm. Using the 5-N spring scale at that position, pull down on the meter stick until it is horizontal with the table. Record the reading on the spring scale in newtons as the effort force.
5. Repeat the experiment four more times with four different hooked weights. Record your data in the table. If necessary, use a larger spring scale for heavier weights.

PART 2 Second-Class Lever

6. Draw a new data table on a separate piece of paper. Label the table *Second-Class Lever*.
7. Balance the meter stick from its center by hanging it on the 5-N spring scale. Record the weight of the meter stick in newtons. You will need this value because the weight of the meter stick adds to the resistance force.
8. Place the meter stick with one end resting on the fulcrum and the other end resting on the table.
9. Choose the 50-cm mark as the resistance arm. Hang the lightest hooked weight at that position. Record the resistance force in newtons as the sum of the weights of the meter stick (from Step 7) and the hooked weight. (Recall that you can convert grams to newtons by multiplying the mass by 0.01.)

▼ Part 1

▼ Part 2

Data Table							
Trial #	Resistance Arm (cm)	Resistance Force (N)	Effort Arm (cm)	Effort Force (N)	RA x RF (N·cm)	EA x EF (N·cm)	Mechanical Advantage
1							
2							
3							
4							
5							

10. Choose the 100-cm mark at the free end of the meter stick as the effort arm. Using the 5-N spring scale at that position, lift the meter stick until it is horizontal with the table. Record the reading on the spring scale in newtons as the effort force.
11. Repeat the experiment four more times with four different hooked weights. Record all your data. If necessary, use a larger spring scale for heavier weights.

Analyze and Conclude

1. **Calculating** In each data table, calculate the value of the resistance arm times the resistance force and the value of the effort arm times the effort force. Record the results in the appropriate place on each data table.
2. **Interpreting Data** How do your calculations in Question 1 compare to the law of the lever as it is stated on page 536?
3. **Calculating** Calculate and record the mechanical advantage of the lever for each trial.
4. **Interpreting Data** Did the two classes of levers have the same mechanical advantage? If so, why? If not, which type of lever had the greater mechanical advantage? Why?
5. **Predicting** How can you balance a first-class lever using a 100-gram hooked weight and a 200-gram hooked weight? Explain. With your teacher's permission, test your prediction.
6. **Communicating** Many sports such as tennis and baseball use equipment that extends the arm. The racquet or bat is made of material that is strong, but lightweight. Suppose you work for a company that produces racquets or bats. Write an advertisement describing your product. In the advertisement, explain how the racquet or bat acts as a lever to make the work of hitting the ball easier.

More to Explore

Repeat the experiment with a third-class lever. Hang the weight at the end of the meter stick, and pull up with the spring scale at the center of the meter stick. Remember to take into account the weight of the meter stick as you did for the second-class lever. This time, however, the weight of the stick opposes your effort force and must be subtracted from the value on the spring scale. Does the third-class lever give you the same results as the second-class lever? Explain.

Chapter 13 Study Guide

The BIG Idea When muscles contract, they exert a force that pulls on a bone and makes it move. Many bones act as levers by rotating around a joint that acts as a fulcrum.

1 Organ Systems and Homeostasis

Key Concepts S 7.5.a

- The levels of organization in the body consist of cells, tissues, organs, and organ systems.
- The human body has 11 organ systems. The integumentary, skeletal, and muscular systems provide structure and allow movement. The circulatory, respiratory, digestive, excretory, immune, and reproductive systems carry out the processes of life. The nervous and endocrine systems provide control over body processes.
- Homeostasis is the process by which an organism's internal environment is kept stable in spite of changes in the external environment.

Key Terms

muscle tissue
nervous tissue
connective tissue
epithelial tissue
organ system
digestion
kidney
nephron
urinary bladder
pathogen
antibody
immunity
homeostasis
stress

2 The Skeletal System

Key Concepts S 7.5.c, 7.6.h

- Your skeleton provides shape and support, enables you to move, protects your organs, produces blood cells, and stores minerals and other materials until your body needs them.
- Joints allow bones to move in different ways.
- Bones are complex living structures that undergo growth and development.
- A balanced diet and regular exercise are important for a lifetime of healthy bones.

Key Terms

skeleton
vertebrae
joint
ligament
cartilage
compact bone
spongy bone
marrow
osteoporosis

3 The Muscular System

Key Concepts S 7.5.c

- Your body has three types of muscle tissue—skeletal, smooth, and cardiac.
- Skeletal muscles work in pairs. While one muscle contracts, the other muscle in the pair relaxes to its original length.

Key Terms

involuntary muscle
voluntary muscle
skeletal muscle
tendon
striated muscle
smooth muscle
cardiac muscle

4 Machines and the Body

Key Concepts S 7.6.h, 7.6.i

- How are force and work related?
- How does a lever make work easier?
- How do bones and muscles function as levers in the body?

Key Terms

force
work
machine
lever
fulcrum
effort force
effort distance
resistance force
resistance distance
mechanical advantage
effort arm
resistance arm

Review and Assessment

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Target Reading Skill

Take Notes To help you review part of Section 2, take notes on the text following the heading Joints of the Skeleton (pages 520-521). The notes have been started for you at the right.

Questions	Notes: Joints of the Skeleton
What is a joint?	A place in the body where two bones come together
What is the function of joints?	

Reviewing Key Terms

Choose the letter of the best answer.

1. Which type of body tissue covers the surfaces of the body?
   a. muscle tissue
   b. nervous tissue
   c. connective tissue
   d. epithelial tissue
2. A soft, connective tissue found inside some bones is
   a. cytoplasm.
   b. marrow.
   c. cartilage.
   d. osteoporosis.
3. Muscles that help the bones move are
   a. cardiac muscles.
   b. smooth muscles.
   c. skeletal muscles.
   d. involuntary muscles.
4. The force you apply to a lever is called the
   a. effort force.
   b. resistance force.
   c. effort distance.
   d. resistance distance.
5. The distance from the fulcrum to the resistance force in a lever is called the
   a. effort distance.
   b. resistance distance.
   c. effort arm.
   d. resistance arm.

Complete the following sentences so that your answers clearly explain the Key Terms.

6. The mouth, stomach, and small intestine are organs that function in **digestion,** which involves ________.
7. Strong connective tissue found at the ends of bones is called **cartilage,** which is important because ________.
8. Smooth muscles are also called **involuntary muscles** because ________.
9. A **lever** is a type of machine, which is useful because ________.
10. A lever can increase **mechanical advantage,** which is ________.

Writing in Science

Descriptive Paragraph Pretend you are a writer for a science magazine for children. Write a few paragraphs that compare the characteristics of cartilage with the characteristics of bones. Be sure to explain the advantages of both types of materials.

Video Assessment
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Bones, Muscles, and Skin

Review and Assessment

Checking Concepts

11. Explain the relationship among cells, tissues, organs, and organ systems.
12. List the four kinds of movable joints. Describe the type of movement each joint allows.
13. How does eating a well-balanced diet and exercising regularly contribute to healthy bones?
14. Explain how skeletal muscles work in pairs.
15. What three things can a lever do to make work easier?
16. Describe a third-class lever in your body. Locate the effort force, the resistance force, and the fulcrum.

Thinking Critically

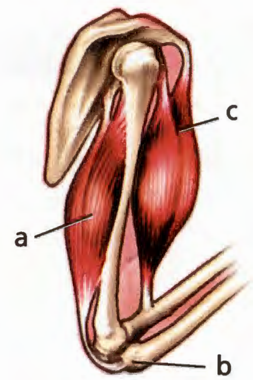
17. **Inferring** In addition to bone, cartilage, and fat, scientists classify blood as a connective tissue. Explain why.
18. **Making Generalizations** How is homeostasis important to survival?
19. **Comparing and Contrasting** Explain how the structure of compact bone and spongy bone relate to the function of a bone, such as your femur.
20. **Predicting** If smooth muscle had to be controlled consciously, what problems could you foresee in day-to-day living?
21. **Making Judgments** Suppose a member of your running team suggests eliminating "warm-up time" because it takes too much time away from practice. Do you think this suggestion is a good idea? Why or why not?
22. **Applying Concepts** How does the law of the lever explain why the seesaw pictured below stays balanced?

Math Practice

23. **Calculating** You use a lever to lift a 100-N box onto a shelf. If you push down an effort distance of 1.5 m using an effort force of 60 N, how high will the box rise? (*Hint*: In this problem, the box's weight is equal to the resistance force.)

Applying Skills

Use the diagram to answer Questions 24–26.



24. **Classifying** Which structure in the diagram is the triceps? Which is the biceps?
25. **Predicting** How will the shape of each muscle change if the arm in the diagram is extended?
26. **Interpreting Diagrams** Which structure in the diagram serves as the fulcrum for extending the arm?

Lab zone Standards Investigation

Performance Assessment Before testing your prosthetic hand, explain to your classmates how and why you designed the hand the way you did. When you test the hand, observe how it picks up objects. How does it compare with a real human hand? How could you improve the function of your prosthetic hand?

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Choose the letter of the best answer.

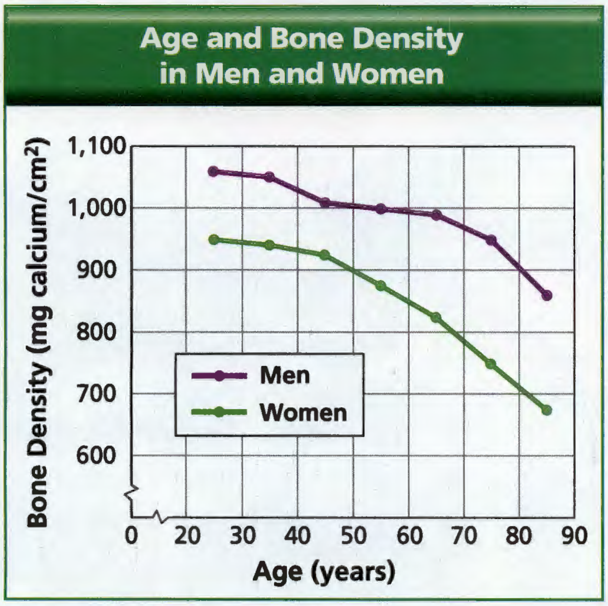
1. Which of the following represents the smallest level of organization in the body?
   - **A** cardiac muscle tissue
   - **B** the heart
   - **C** a muscle cell
   - **D** the circulatory system

   S 7.5.a

2. The muscles that you use to lift a book are
   - **A** cardiac muscles.
   - **B** smooth muscles.
   - **C** involuntary muscles.
   - **D** skeletal muscles.

   S 7.5.c

Use the graph to answer Question 3.



3. Which of the following statements is true according to the graph shown above?
   - **A** The bones of women are more dense than the bones of men.
   - **B** The bones of men contain less calcium than do the bones of women.
   - **C** The bone density of both men and women decreases as they age.
   - **D** An average 55-year-old woman has stronger bones than an average 55-year-old man.

   S 7.5.a

4. Which skeletal joint functions most like the machine shown below?

   - **A** neck
   - **B** knee
   - **C** wrist
   - **D** shoulder

   S 7.6.h

5. Which statement describes what happens when you bend your arm at the elbow?
   - **A** The biceps contracts and the triceps relaxes.
   - **B** The triceps contracts and the biceps relaxes.
   - **C** Both the biceps and the triceps contract.
   - **D** Only the triceps functions.

   S 7.5.c

6. To open a door, you push on the part of the door that is farthest from the hinges. Why would it be harder to open the door if you pushed on its center?
   - **A** You would have to apply a larger effort force.
   - **B** You would have to apply a larger resistance force.
   - **C** The door is a first-class lever.
   - **D** You would be increasing the effort arm.

   S 7.6.i

Apply the BIG Idea

7. A shovel is a type of lever that has a greater effort force than resistance force. Explain why a shovel is still useful. What class of lever is the shovel? Identify an example of how this class of lever is used in the body. **S 7.6.h, 7.6.i**