



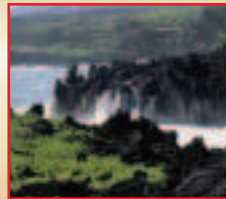
UNIT 5

Structure, Function, and Physical Principles in Living Systems

Huge Skeleton Your skeletal system supports your body much like the steel beams support the Golden Gate Bridge connecting the city of San Francisco and Marin County in California.



1867
The United States purchases Alaska from Russia.



1898
The United States, during the presidency of William McKinley, gains control of the Hawaiian Islands.

A.D. 1 1200 1300 1400 1500 1600 1700 1800 1900



1284
First known eyeglasses are invented.

1660
Marcello Malpighi proves previous blood circulation theories when he discovers capillaries connecting to arteries and veins in an eel.



1876
Alexander Graham Bell, at his laboratory in Boston, Massachusetts, invents the telephone, sending the sound of voices over electrical wires.

Concepts in Motion

Interactive Time Line To learn more about these events and others, visit ca7.msscience.com.

May 1937

The Golden Gate Bridge opens; its 1,260-m span—a world record that held for 27 years.



1984

Athletes from around the world meet at Los Angeles, California, to test their athletic skills at the Olympic Games.

June 2001

Scientists at the Lawrence Livermore Laboratory in California, announce they have discovered how organisms modify crystal shape and growth to form bone and shell structures.

1920

1940

1960

1980

2000

2020

1940s

Charles Richard Drew organizes a blood bank in NYC. It served as a model for the system run by the American Red Cross.

1950s

Ultrasound scans become useful tools for safely checking fetuses for size and growth patterns.

2001–2005

Paraplegic Matt Nagle uses a computer chip implanted in his brain to allow him to grasp objects with an artificial hand by thinking about moving his paralyzed hand.



CHAPTER 9

The Musculoskeletal System and Levers

The BIG Idea

Muscles, bones, and joints form simple machines in the body that produce movement and mechanical advantage.

LESSON 1 5.a, 5.c, 6.h, 7.a

The Musculoskeletal System

Main Idea Muscles, tendons, and bones work in a coordinated fashion to produce movement.

LESSON 2

6.h, 6.i, 7.a, 7.c, 7.d

The Body and Levers

Main Idea Muscles and bones are joined in a way that allows them to act as levers, providing force or speed advantages.



How does he *do that*?

This skateboarder is showing great control of his musculoskeletal system. His muscles and bones are working together to produce smooth, controlled movements that allow him to perform this trick.

Science Journal Write a paragraph about the activities you perform that you think require your muscles and bones to work together.

Start-Up Activities

Launch Lab

00:45
minutes

Is it easy to lift?

You might find it easier to carry your science book close to your chest rather than far away from it. Why?

Procedure



1. Read and complete a lab safety form.
2. Hold a **soup can** in one hand.
3. Lift the can using only your wrist.
4. Hold your elbow at your waist and lift the can by bending your arm at your elbow.
5. Hang your arm down and then without bending your elbow, raise the can in front of you to shoulder height and back.



Think About This

- **Report** Which of the actions moved the can the shortest distance? The longest?
- **Choose** Which movement felt easiest? Which felt hardest?
- **Differentiate** Did all the movements use the same parts of the arm? Which parts of your arm did you use?



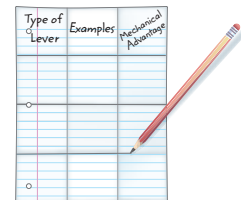
FOLDABLES™ Study Organizer

Levers in the Body Make the following Foldable to identify the levers found in the human body.

- ▶ **STEP 1** Fold a sheet of paper into thirds lengthwise.



- ▶ **STEP 2** Unfold and draw vertical lines along the folds. Draw three horizontal lines to divide the paper into four rows. Label as shown.



Reading Skill

Visualizing As you read this chapter, you will learn about parts of the body that act as levers. Identify each type of lever in the first column. Give examples in column 2. Explain the mechanical advantage to the body for each type of lever in column 3.

Science online

Visit ca7.msscience.com to:

- ▶ view **Concepts in Motion**
- ▶ explore Virtual Labs
- ▶ access content-related Web links
- ▶ take the Standards Check

Get Ready to Read

Make Connections

1 Learn It! Make connections between what you read and what you already know. Connections can be based on personal experiences (text-to-self), what you have read before (text-to-text), or events in other places (text-to-world).

As you read, ask connecting questions. Are you reminded of a personal experience? Have you read about the topic before? Did you think of a person, a place, or an event in another part of the world?

2 Practice It! Read the excerpt below and make connections to your own knowledge and experience.

Text-to-self:
When you exercise, how long does it take your muscles to get tired?

Text-to-text:
What did you read about mitochondria and cellular respiration in earlier chapters?

Text-to-world:
Think about Olympic athletes. How do you think the network of blood vessels going to their muscle cells would compare to nonathletes?

Movement of the muscle filaments during contraction requires energy. Muscle cells contain more mitochondria than other cells in order to produce the energy needed for contraction. A large network of blood vessels supplies muscles with the oxygen the mitochondria need for cellular respiration.

—from page 364

3 Apply It! As you read this chapter, choose five words or phrases that help you make a connection to something you already know.

Reading Tip

Make connections with memorable events, places, or people in your life. The better the connection, the more likely you will remember.

Target Your Reading

Use this to focus on the main ideas as you read the chapter.

1 Before you read the chapter, respond to the statements below on your worksheet or on a numbered sheet of paper.

- Write an **A** if you **agree** with the statement.
- Write a **D** if you **disagree** with the statement.

2 After you read the chapter, look back to this page to see if you've changed your mind about any of the statements.

- If any of your answers changed, explain why.
- Change any false statements into true statements.
- Use your revised statements as a study guide.

Before You Read A or D	Statement	After You Read A or D
	1 Your bones allow you flexibility in movement.	
	2 Your nose is not made from bone.	
	3 When a muscle relaxes, it causes the bone it moved to return to its original position.	
	4 Muscle fibers can actively lengthen.	
	5 A lever helps you complete a task with less work.	
	6 A shovel is a type of lever.	
	7 Some levers require you to use more force than you would need to complete the task without them.	
	8 Your body contains all three classes of levers.	
	9 Most of the levers in your body make the work you do require more effort.	
	10 Bones provide the effort force, while muscles are the levers.	



Print a worksheet of this page at ca7.msscience.com.



LESSON 1



Science Content Standards

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.

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

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).

Also covers: 7.a, 7.c

Reading Guide

What You'll Learn

- ▶ **Identify** the main characteristics of the skeletal system.
- ▶ **Examine** how muscles contract and relax.
- ▶ **Explain** how bones and muscles work together.

Why It's Important

Understanding the musculoskeletal systems helps you better appreciate how your body moves.

Vocabulary

skeletal system	contraction
bone	relaxation
joint	tendon
cartilage	flexion
muscle	extension

Review Vocabulary

mitochondrion: organelle that converts food molecules into usable energy (p. 61)

The Musculoskeletal System

Main Idea Muscles, tendons, and bones work in a coordinated fashion to produce movement.

Real-World Reading Connection What holds up the walls and the roof of a building and protects it from the outside elements? There are beams, braces, and insulation inside the walls and under the roof that you cannot see. What structures support and protect our bodies?

The Skeletal System

The hard structures within our bodies are part of the **skeletal system** (SKE luh tul • SIS tum), which provides support, protection, and movement. Press on your wrist, ankle, knee, or elbow. Do you feel something hard under your skin? You are feeling **bone**, a hard tissue made mostly of cells, collagen, and calcium. Collagen is a protein that forms strong fibers. Calcium is a mineral that adds strength to the collagen fibers. The human body has over 200 bones that make up the skeleton, shown in **Figure 1**.

Figure 1 The bones of the skeleton are a living support for the body.



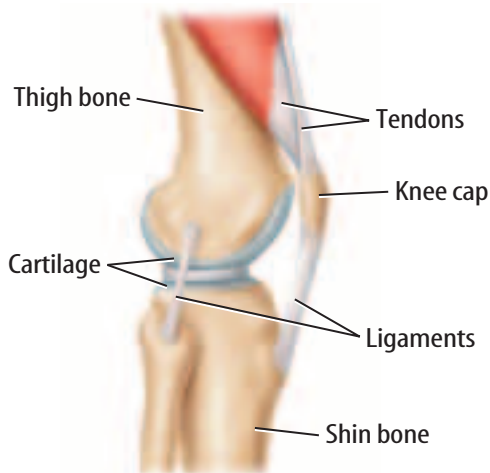


Figure 2 Ligaments and tendons hold bones and muscles together. There is very little space between the bones of many joints. Cartilage covers the ends of the bone and prevents the bones from rubbing against each other.

Infer why it would be important for bones to not rub directly against each other.

Functions of the Skeletal System

If you look at bones, you'll probably notice that they have different sizes and shapes. The surfaces of bones are not smooth. You'll see bumps, edges, round ends, rough spots, and many pits and holes where blood vessels and nerves enter and leave. Bones have many small, open spaces so they are not too heavy to move. These features allow the bones to perform all of their functions.

You might be wondering how your skeletal system can protect you from inside your body. The bones of your skull and vertebrae protect your brain and spinal cord. Ribs—the bones in your chest—protect the soft organs underneath, such as the heart and lungs. Without support from the skeletal system, you would be a soft mass without definite shape. The skeletal system also gives your muscles attachment points, which allow you to move. Your skeletal system stores calcium and phosphorus for later use. Both these minerals keep your bones hard. Finally, the middle of some bones, called marrow, is the place where blood cells are formed.



How does the skeletal system benefit the body?

Bones Connect at Joints

Because bones are hard, they cannot bend. However, our bodies are flexible and we can bend, twist, and rotate. This is possible because bones connect at **joints**. The softer tissues of the skeletal system, shown in **Figure 2**, help hold bones together at joints and add to our flexibility. Ligaments connect bones. Ligaments are similar to strong rubber bands that stretch when we move.

Cartilage is a strong, yet flexible and elastic tissue that reduces friction and increases flexibility. You can twist your lower arm without moving your upper arm. Can you do the same with your leg? The structure of a joint determines the movement.

WORD ORIGIN

joint

from Latin *junctus*; means *join*



Types of Joints

1 Hinge Joint The joints in your fingers, elbows, and knees are hinge joints. Hinge joints only allow bones to move back and forth, like the hinges of a door. **Table 1** shows the joints in the body, and simple machines that work similarly.

2 Saddle Joint Compare the movement of your thumb to the other fingers in your hand. The thumb has a wider range of motion. This is because the joint in the thumb is a saddle joint. In a saddle joint, both bones have ends shaped like saddles. The thumb is the only saddle joint in the body.

3 Ball-and-Socket Joint The shoulder joints and hip joints can rotate and move in nearly every direction. Hip and shoulder joints are ball-and-socket joints. Ball-and-socket joints are made of a bone that has a round end that fits into a cuplike depression of another bone. An ellipsoid joint is similar to a ball-and-socket joint, except the end of the bone is shaped like an ellipse instead of being round. The knuckles of our hands are examples of ellipsoid joints. An ellipsoid joint cannot move in as many directions as a ball-and-socket joint.



Where are your four ball-and-socket joints located?

4 Pivot Joint The cylindrical region of one bone fits into a ring-shaped structure of another bone in a pivot joint. Pivot joints only allow bones to rotate. The joint between the first two vertebrae in the neck is a pivot joint. This pivot joint allows you to turn your head from side to side. The pivot joint that connects the two bones in your forearm allows you to rotate your lower arm.


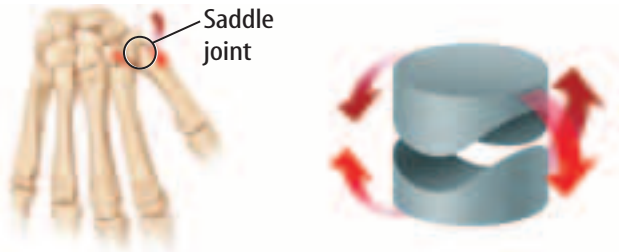
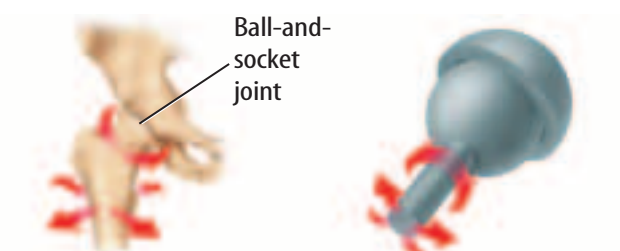
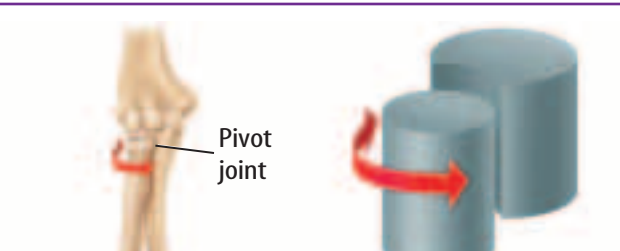
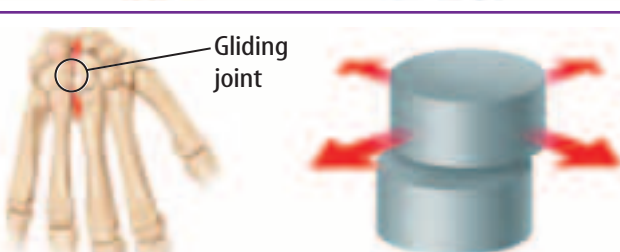
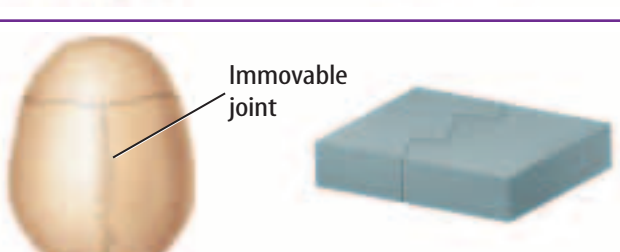
5 Gliding Joint Two bones that connect at flat surfaces are a gliding joint. The bones in a gliding joint can only move from side to side or front to back. Our ankles and wrists have gliding joints.

6 Immovable Joint Two bones held firmly together, allowing very little or no movement, form an immovable joint. You might be wondering why a joint would be immovable. Your skull contains immovable joints. When you were born, there was space between some of the bones of your skull. These spaces allowed your brain to increase in size. Eventually, the immovable joints fused the bones together. Your lower jaw is the only bone of the skull that moves after the immovable joints of the skull join.



Table 1 Which of these types of joints has the widest range of motion? The narrowest?

Table 1 Joints in the Human Body

Description of Joint	Mechanical Object and Joint
<p>1 Hinge Joints Allow bones to move back and forth Examples: fingers, elbows, and knees</p>	 <p>Hinge joint</p>
<p>2 Saddle Joints Allow bones to move back and forth and side to side, but have limited rotational ability Example: thumbs</p>	 <p>Saddle joint</p>
<p>3 Ball-and-Socket Joints Allow bones to move and rotate in nearly all directions Examples: hips and shoulders</p>	 <p>Ball-and-socket joint</p>
<p>4 Pivot Joint Allows bones to rotate Example: neck</p>	 <p>Pivot joint</p>
<p>5 Gliding Joint Allows bones to move side to side or front to back Examples: ankles and wrists</p>	 <p>Gliding joint</p>
<p>6 Immovable Joint Allows very little or no movement Example: skull</p>	 <p>Immovable joint</p>



ACADEMIC VOCABULARY

contract (kun TRAKT)

(*verb*) to make a smaller size by squeezing or forcing together *The word cannot can be contracted to can't.*

The Muscular System

When you think of the parts of your body that allow you to move, you probably think of muscles. **Muscle** (MUH sul) is tissue made of long cells that **contract**. There are more than 620 muscles in the human body. **Figure 3** shows that muscles are made of bundles of muscle cells called muscle fibers. Muscle fibers are not like most other cells. A single muscle fiber has hundreds of nuclei and many mitochondria. Some muscle fibers are as long as the muscle, which can be up to 30 cm. Muscle fibers contain bundles of small tubes that contain bundles of two different threadlike proteins, or muscle filaments. The arrangement of muscle filaments is lengthwise, with their ends partially overlapping. During muscle **contraction**, the muscle filaments move closer to each other. All the cells of a muscle contract at the same time and the muscle shortens. During muscle **relaxation**, all the muscle filaments move away from each other.



Figure 3 How do muscles get smaller when they contract?

Muscle Contractions

What makes our muscles contract? Muscles have nerve cells that receive signals from the nervous system. The nerve cells start a chemical reaction in the muscle cells that leads to contraction of the muscle. Movement of the muscle filaments during contraction requires energy. Muscle cells contain more mitochondria than other cells in order to produce the energy needed for contraction. A large network of blood vessels supplies muscles with the oxygen the mitochondria need for cellular respiration.

Types of Muscle

Your hand, arm, and leg muscles are voluntary muscles. A voluntary muscle is a muscle that you are able to control. Your heart and stomach are involuntary muscles. An involuntary muscle is one that you cannot control by thinking about it. These muscles work all day, every day, without your active involvement.

Recall from Chapter 2 that cells form tissues, tissues form organs, organs form organ systems, and organ systems form an organism. The same is true in the muscular system. Muscle cells form muscle tissue. There are three types of muscle tissue. Muscles that cause movement of your body are made up of skeletal muscle tissue. Cardiac muscle tissue is found only in your heart. Smooth muscle tissue is found in your internal organs, such as your stomach and blood vessels.

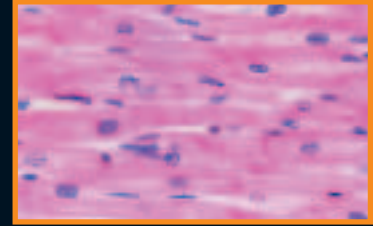
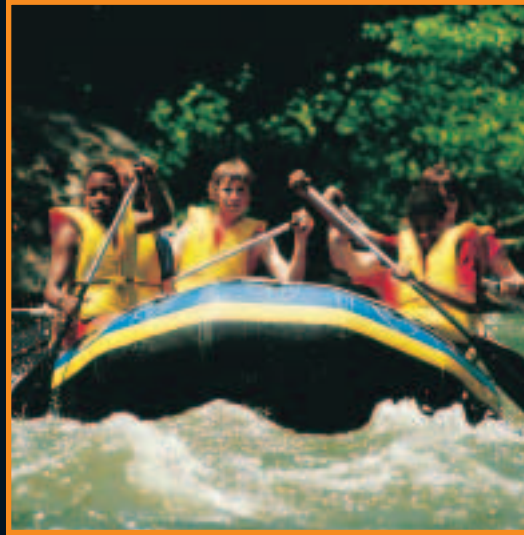


What are the three types of muscle tissue?

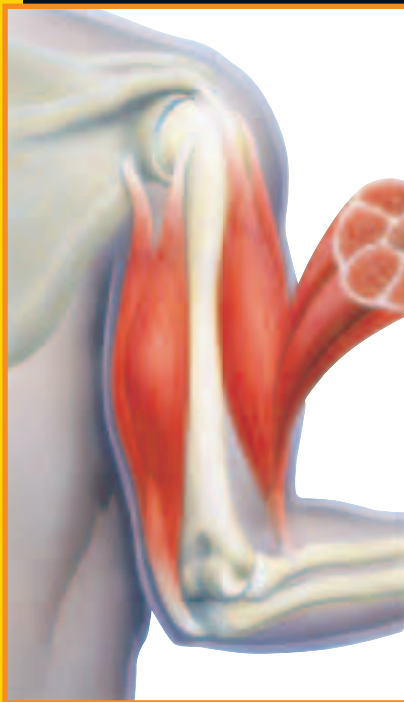
Visualizing Muscle Contractions

Figure 3

When a muscle contracts, the proteins in all the individual muscle fibers move closer together. This usually makes the muscle shorter and thicker.



▲ Muscle cells contain more mitochondria than other cells in order to have more energy available to perform their functions.



▲ Skeletal muscles are made up of bundles of muscle cells, or fibers. Each fiber is composed of many bundles of muscle filaments.



▲ A signal from a nerve fiber starts a chemical reaction in the muscle filament. This causes molecules in the muscle filament to gain energy and move. Many filaments moving together cause the muscle to contract.

Contributed by National Geographic



MiniLab

00:20
minutes

How do bones and muscles interact?

The interaction of your muscles and bones makes every movement of your body possible.

Procedure

1. Read and complete a lab safety form.
2. Feel your leg as you perform the following movements:
 - Flex your foot upward
 - Bend your knee
 - Pretend to kick a soccer ball
3. Feel your partner's arm as he or she performs the same movements you did earlier.

Analysis

1. **Compare and contrast** the location of the muscles with the location of the joint being moved.
2. **Describe** any differences you felt in the muscles of the arm versus the muscles of the leg. What can you infer from these differences?



5.c, 7.a



Try at Home

Interactions of the Musculoskeletal System

Our bones alone cannot move our bodies. Similarly, muscle contraction is only part of movement. In order for us to move, the muscular system must function with the skeletal system. Our skeleton provides support for our muscles.

How do you move?

Usually a muscle connects to at least two different bones. **Tendons** (TEN dunz) connect bones to muscles and do not stretch as much as ligaments. Tendons, ligaments, and cartilage are connective tissues. The rough spots on bones are places where the tendons and ligaments attach.

The biceps muscle causes your arm to bend. **Flexion** (FLEK shun) is the bending of a limb that decreases the angle between the bones of the limb. Flexion of your arm happens when the biceps muscle shortens during contraction. When the biceps muscle shortens, the lower arm moves closer to the upper arm, and the arm bends.

Opposing Muscle Groups

Muscles can contract and become shorter, but they cannot actively lengthen. **Extension** (eks TEN shun) is the straightening of a limb that increases the angle between the bones of the limb. How does your arm straighten during extension? Arrangement of muscles is often in opposing groups. Look at the muscles of the upper arm in **Figure 4**. Notice that there are muscles on each side of the arm. The triceps muscle is at the back of the arm, opposite from the biceps. Your arm bends when the biceps contract. The biceps relax and the triceps contract, resulting in an extension of the arm.

It is important to realize that opposing muscle groups, such as the biceps and triceps, may be contracting at the same time. At the same time the biceps muscle contracts, the triceps muscle is also slightly contracting. The triceps muscle contracts so the lifting motion is smooth and controlled.



How is it that when you flex your arm, you contract your tricep?

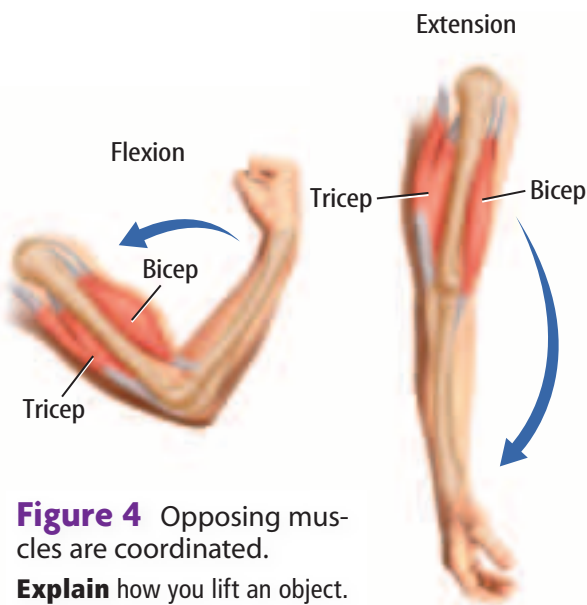


Figure 4 Opposing muscles are coordinated.

Explain how you lift an object.



What have you learned?

The musculoskeletal system works to move the body. The skeletal system—made of bones, ligaments, tendons, and cartilage—supports and protects the body. Muscles provide the contractions necessary to move bones when signaled by the nervous system. Joints maintain flexible connections between bones. The body has different types of joints that allow for motion in different directions. Opposing muscle groups function together to achieve controlled and smooth motion.

In the next lesson you will read that your bones and muscles work together as levers in the body. This important relationship in the body helps you gain speed and distance in doing even very routine activities, such as taking a step. It also helps to make work easier.

LESSON 1 Review

Summarize

Create your own lesson summary as you write a script for a **television news report**.

- Review** the text after the **red** main headings and write one sentence about each. These are the headlines of your broadcast.
- Review** the text and write 2–3 sentences about each **blue** subheading. These sentences should tell *who*, *what*, *when*, *where*, and *why* information about each **red** heading.
- Include** descriptive details in your report, such as names of reporters and local places and events.
- Present** your news report to other classmates alone or with a team.



ELA7: LS 2.2



Standards Check

Using Vocabulary

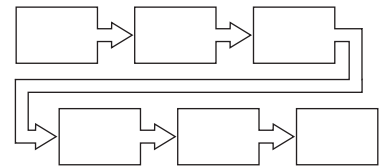
- Distinguish** between cartilage and tendons. **5.c**
- Use the words *bone* and *muscle* in a sentence. **5.c**
- Bones are connected at _____. **5.c**

Understanding Main Ideas

- Explain** why the skeletal and muscular systems cannot function without each other. **5.c**
- Give another example** of this joint that was not discussed in the text. **6.h**



- Construct** an events-chain map to illustrate the movement of a muscle. **5.a**



Applying Science

- Compare** your body, which has an internal skeleton, to the body of a slug, which has no internal skeleton. **5.c**
- Relate** everyday objects to the actions of your joints. How are they similar? What functions do the joints in machines serve? **6.h**



For more practice, visit **Standards Check** at ca7.msscience.com.



LESSON 2



Science Content Standards

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).

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

Also covers: 7.a, 7.c, 7.d

Reading Guide

What You'll Learn

- ▶ **Distinguish** the three classes of levers.
- ▶ **Identify** levers in the human body.
- ▶ **Describe** the advantage to having levers in the body.

Why It's Important

It's helpful to understand how levers work to understand your body.

Vocabulary

lever
fulcrum
first-class lever
second-class lever
third-class lever
mechanical advantage

Review Vocabulary

work: transfer of energy that occurs when a push or a pull causes movement (Grade 6)

The Body and Levers

Main Idea Muscles and bones are joined in a way that allows them to act as levers, providing force or speed advantages.

Real-World Reading Connection Can you imagine playing baseball without a bat or cutting paper without scissors? How long would it take you to dig a hole without a shovel? All of these tasks are easier when we use simple machines. However, you do not need to find any tools or common objects to see a lever in action. Your body is a living example of levers.

What is a lever?

“Give me a place to stand, and I will move the Earth” is a quote by the ancient Greek mathematician Archimedes (287–212 B.C.), usually credited with first describing the uses of simple machines called levers. A **lever** (LEE ver) is a simple machine made of anything rigid that pivots around a fixed point. The **fulcrum** (FUL krum) is the fixed point that a lever pivots around, also known as a pivot point. **Figure 5** is an example of a lever. Archimedes used the concept of levers to devise war machines used against the Roman Empire.

We use levers to make work easier. Sometimes levers allow the operator to perform a task using less force. Other times, the task can be completed in less time or by moving a shorter distance. By the end of this lesson, you'll be presented with clues to help you discover why Archimedes said he could move the world.

Figure 5 Children on a seesaw easily go up and down.

Describe an arrangement that would allow them to balance.



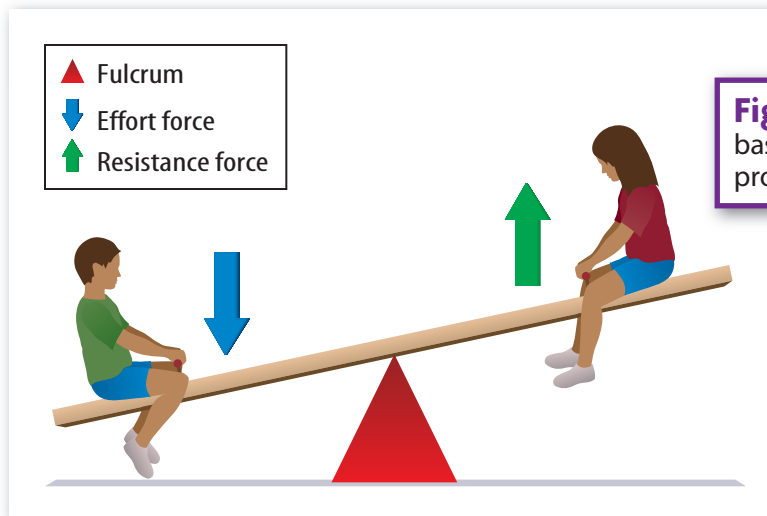


Figure 6 The board is the lever, the base is the fulcrum, and the children provide the effort and resistance forces.

The Three Classes of Levers

On a seesaw, the board the two people sit on is the lever. The base that the board rests upon is the fulcrum. Two forces act upon different parts of a lever. A force is a push or a pull on an object when it interacts with another object. The effort force moves an object over a distance. The resistance force opposes the effort force. In **Figure 6**, a child sitting on a seesaw provides the effort force needed to move the right side down. The child being pushed up on the opposite side exerts the resistance force. Note that while one child moves up when the other child moves down, they both move in the same direction around the fulcrum—either clockwise or counterclockwise.



What is the difference between the effort force and the resistance force?

The distance between the forces and the fulcrum determines how easy or how hard it will be to use the lever. If the effort force is very close to the fulcrum, it will take a lot of force to use the lever. The farther the effort force is from the fulcrum, the easier it will be to use. The situation is reversed for the resistance force: the closer to the fulcrum, the easier the resistance force will be to move. Likewise, the farther the resistance force is located from the fulcrum, the harder the lever will be to move.

In your body, if a bone is the lever and muscles supply the force, which part of your body is the fulcrum? The joints act as the fulcrum, the point around which the lever rotates. The connective tissues transfer the force to locations from bones to bones or from bones to muscles.

A seesaw is one of three different types of levers. Each type of lever is suited for different tasks. The location of the fulcrum, load, and applied force determines the type of lever. **Table 2** shows the three classes of levers.

WORD ORIGIN

lever

from Latin *levare*; means to raise

fulcrum

from Latin *fulcire*; means to support



ACADEMIC VOCABULARY...

stable (STAY buhl)

(*adjective*) resistant to change of position or condition

A chair or stool with three legs is more stable than one with four.

First-Class Levers

The resistance force and the effort force are on opposite sides of the fulcrum in a **first-class lever**. A seesaw, pliers, and scissors are examples of first-class levers. Scissors, shown in **Table 2**, are made of two first-class levers. When you open and close the scissors, the direction of the effort force changes.

The body has few first-class levers. Nodding your head uses a first-class lever. **Table 2** shows that the fulcrum is the joint connecting your skull to your backbone. The weight of your head is the resistance force. Your neck muscles provide the effort force.

Second-Class Levers

The resistance force is between the fulcrum and the effort force in a **second-class lever**, as shown in **Table 2**. Backpacks and luggage with wheels on the bottom are examples of second-class levers. The handle is where you exert the effort force. The weight of the backpack or luggage is the resistance force. The wheels act as a fulcrum. Another example of second-class levers is a wheelbarrow.

When you lift your heels off the ground and stand on your toes, as shown in **Table 2**, you are using a second-class lever. The fulcrum is at your toes. The resistance force is the weight of your body. The calf muscle in your lower leg supplies the effort force.



Table 2 Relative to the effort force provided by your calf muscle, what direction does the resistance force move?

Third-Class Levers

The effort force is between the resistance force and fulcrum in a **third-class lever**. This arrangement requires more effort force than the resistance force it produces. This means that using the lever to move the object is more difficult than moving the object without the lever. However, you are able to move the object farther or faster than you could without the lever. Most hand tools and sports equipment are third-class levers, such as baseball bats and rakes. **Table 2** shows a person gripping the end of a shovel. One hand grips the handle, **stabilizing** the shovel and acting as the fulcrum point. The other hand exerts the effort force. The effort force moves the resistance force, the weight of the dirt, at the end of the shovel.

The most common levers in the body are third-class levers. An example of a third-class lever is your upper arm and lower arm. **Table 2** shows that the fulcrum is the elbow joint. The lever is one of the bones of the lower arm. The resistance force is the weight of your lower arm and any object you may be lifting. The effort force is supplied by the biceps muscle.



Which class of levers is most common in your body?

Table 2 Levers in the Human Body


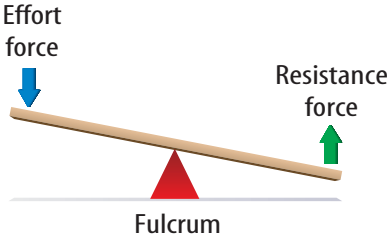
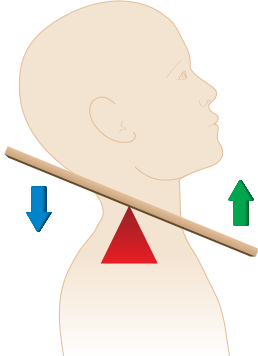

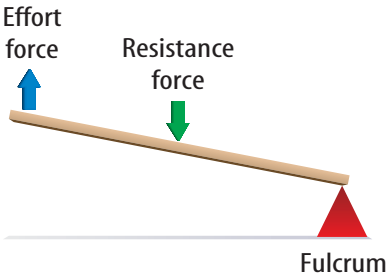
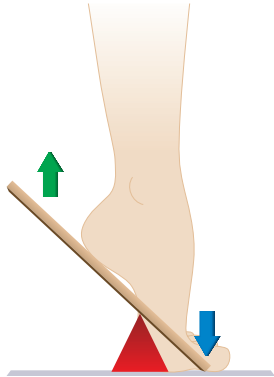

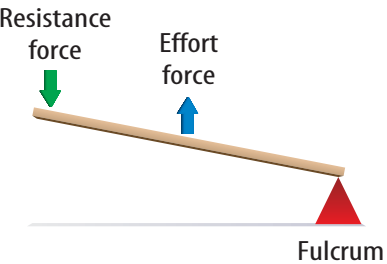
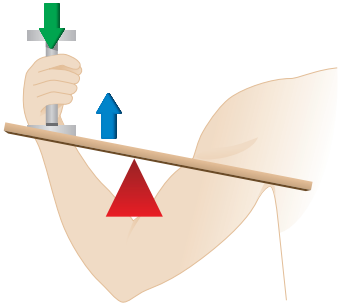
Common Object	Physics	In Human Body
<p>First class The fulcrum is between the resistance force and effort force in a first-class lever.</p> 		<p>This first-class lever reduces the strain on your neck muscles caused by the weight of your head.</p> 
<p>Second class The resistance force is between the fulcrum and effort force in a second-class lever.</p> 		<p>This second-class lever allows your calf muscles to easily lift nearly your entire body weight.</p> 
<p>Third class The effort force is between the resistance force and fulcrum in a third-class lever.</p> 		<p>This third-class lever allows you to quickly lift an object in your hand.</p> 



Figure 7 The position he is holding demonstrates his skill in balancing multiple forces using the multiple lever systems of his body.

Effort Forces and Resistance Forces in Levers

Levers in the human body can exert forces on objects, such as the gymnastic rings in **Figure 7**. When a lever is used, an effort force is applied to one end. This end moves as the effort force is applied. For example, if you push down on one end of a seesaw, that end moves. The distance this end moves is the effort distance.

When you push down, the other end of the seesaw moves up. This end of the seesaw exerts the resistance force. This distance this end of the seesaw moves is the resistance distance. The effort distance and resistance distance determine how the resistance force compares to the effort force.

Levers that Increase the Effort Force For first-class levers and second-class levers, the resistance distance is less than the effort distance. This means the point where the effort force is applied moves a greater distance than the point where the resistance force is applied. When the effort distance is greater than the resistance distance, the resistance force is greater than the effort force. As a result, for first-class and second-class levers the resistance force is greater than the effort force.

Levers that Decrease the Effort Force For third-class levers, the opposite is true—the resistance distance is greater than the effort distance. For example, when you use a broom, the distance your upper hand moves is shorter than the distance the bottom of the broom moves. However, when the effort distance is less than the resistance distance, the resistance force is less than the effort force. As a result, third-class levers decrease the effort force.



Figure 8 A jack is a lever commonly used to lift cars. Instead of lifting the car a short distance all at once, the girl will move it bit by bit over a longer distance.

Identify the class of levers to which the car jack belongs.

Why use levers?

Some levers make it easier to lift heavy objects, others make it easier to move objects faster and farther. How is this possible? The person in **Figure 8** is lifting a car with a jack. The jack makes it easier to do the work.

Mechanical Advantage

You just read that a lever could decrease the amount of force needed to do a task. **Mechanical advantage** (MA) is the ability of a machine to increase the amount of force put into the machine, a ratio of resistance force (F_R) to effort force (F_E).

$$\text{Mechanical advantage (MA)} = \frac{\text{Resistance force } (F_R)}{\text{Effort force } (F_E)}$$

What is the mechanical advantage of the lever in **Figure 9**?

$$\begin{aligned} \text{MA} &= \frac{60 \text{ N}}{20 \text{ N}} \\ \text{MA} &= 3 \end{aligned}$$

Therefore, the machine tripled the force applied to it. This is sometimes measured as the ratio of the distance the resistance force is from the fulcrum to the distance the effort force is from the fulcrum. This looks like this:

$$\text{MA} = \frac{\text{distance resistance force is from fulcrum } (D_R)}{\text{distance effort force is from fulcrum } (D_E)}$$

SCIENCE USE V. COMMON USE: work

Science Use the force needed to move the object multiplied by the distance the object moves. *The work needed to move an object cannot be decreased by using a lever, but the amount of force needed can be changed.*

Common Use the occupation for which you are paid. *In high school, many students decide what line of work they would like to pursue.*

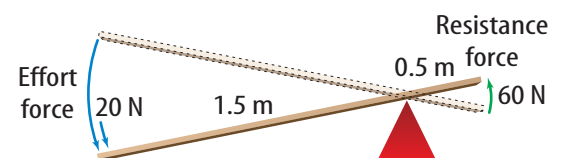


Figure 9 The effort force moves the lever 1.5 m. The lever moves only 0.5 m in the direction of the resistance force.



Figure 10 The end of the bat travels the greatest distance and therefore has the greatest velocity. A person playing baseball tries to hit the baseball with the end of the bat. This will result in the baseball traveling much faster and usually farther than if the ball were thrown.

Speed Advantage

Sometimes we need help moving objects quickly over long distances. Third-class levers can make it easier to move an object a long distance quickly. Recall that a baseball bat is an example of a third-class lever. **Figure 10** shows when you swing a bat, the handle moves a short distance. However, the end of the bat travels a longer distance and at a greater speed.



Figure 10 Compare the speeds of the parts of the bat where resistance force and effort force are exerted.

Having bones as levers helps us do work by giving us more efficient ways of using force. This usually allows us to move faster. The end of a swinging baseball bat moves farther and faster than the end grasped by the batter. The same is true for your limbs. Your limbs contain multiple joints and therefore multiple levers. As a result, your feet move much farther and faster than your upper leg when you walk. Therefore, levers allow you to have long, quick strides. Similar to your legs, levers increase the speed of your arms and hands as well.



How do levers allow parts of the body to move farther than others?

Levers in the Body

How can a length of a lever affect the way your body works? Consider arm wrestling. If you are facing an opponent whose arm is the same length as your own, who will win the match? Since the distance is the same, and work equals force times distance, the person who is able to produce more force will win. What if one person's arm is shorter? In this case, the person with the shorter arm will have to produce more force to win the match. However, it will be easier for the person with the shorter arm to produce more force because the effort and resistance force are closer together on a shorter arm. Less effort is required to match the resistance provided by the opponent. This is why shorter men and women have a natural advantage in sports such as gymnastics, diving, and figure skating.



What have you learned?

A lever is a simple machine that makes work easier. The force applied to a lever is changed in size or direction, but the work done by the lever cannot exceed the work put into it. There are three classes of levers. The location of the fulcrum, effort force, and resistance force determine the class of the lever. First- and second-class levers make work easier by multiplying the force you put into the machine. Third-class levers make work easier by increasing the range or speed of motion beyond what you are naturally capable of doing. In our bodies, bones act as levers, and muscles provide the force to move objects. The arrangement of multiple levers needed to perform even simple movements creates an advantage. You have each class of levers in your body, but most levers in the body are third-class levers. This is because of the necessary arrangement of muscles and bones.

LESSON 2 Review

Summarize

Create your own lesson summary as you design a **summary web**.

- Write** the lesson title, number, and page numbers at the top of a sheet of paper.
- Scan** the lesson to find the **red** main headings.
- Organize** these headings clockwise on branches around the lesson title.
- Review** the information under each **red** heading to design a branch for each **blue** subheading.
- List** 2–3 details, key terms, and definitions from each **blue** subheading on branches extending from the main heading branches.



ELA7: W 2.5



Standards Check

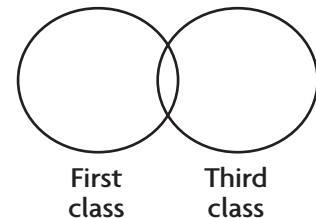
Using Vocabulary

- Define** lever. **6.i**
- Describe** a first-class lever, a second-class lever, and a third-class lever. **6.i**
- The ability of a machine to increase the amount of force put into a machine is _____. **6.i**

Understanding Main Ideas

- Calculate** If a lever has a resistance force of 40 N and an effort force of 10 N, what is the mechanical advantage of this lever? **6.i**
 - 0.25 N
 - 4 N
 - 40 N
 - 400 N

- Compare** the advantages of first-class levers and third-class levers in the body. **6.i**



Applying Science

- Suggest** a reason why it may be advantageous to have a shorter forearm when lifting a heavy weight. **6.i**
- Decide** which joint would be better for creating increased speed of a resistance force—the elbow joint or the ankle joint? Explain your answer. **6.i**



For more practice, visit **Standards Check** at ca7.msscience.com.



What is the mechanical advantage of a lever?

One important aspect of science is being able to base conclusions upon numeric data. Mechanical advantage can be used to compare levers.

Data

Comparing Levers			
	Lever 1	Lever 2	Lever 3
D_E (in cm)	10 cm	30 cm	50 cm
D_R (in cm)	50 cm	30 cm	10 cm
MA	?	?	?
Type of lever	?	?	?

Data Analysis

1. **Calculate** the mechanical advantage (MA) of a lever at each fulcrum point. Recall that $MA = \frac{D_E}{D_R}$.
2. **Identify** which type of lever the data are describing.
3. **Compare and contrast** the MA at each fulcrum point. Which D_E and D_R gave you the highest MA? The lowest?
4. **Diagram** each lever. Be sure to include the correct labels.



Science Content Standards

- 6.i** Students know how levers confer mechanical advantage and how the application of this principle applies to the musculoskeletal system.
- 7.d** Construct scale models, maps, and appropriately labeled diagrams to communicate scientific knowledge (e.g., motion of Earth's plates and cell structure).

Applying Math

Degree of Joint Rotation

Lumbar spine vertebrae have three-dimensional degrees of rotation to allow the spine to move. Similar to a three-dimensional coordinate graph, the lumbar spine has three axes of rotation shown in the diagram below.

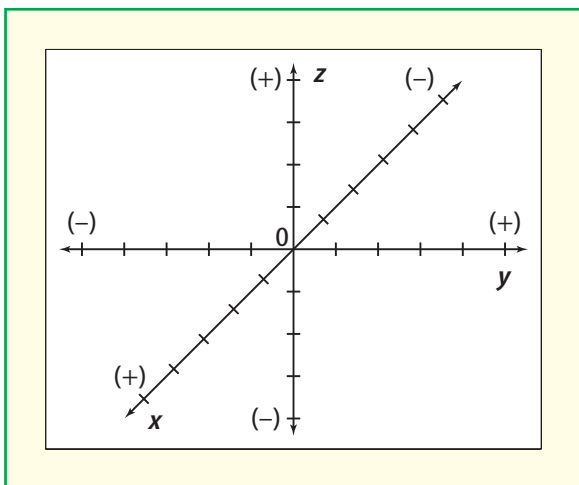


5.c, 6.h, 6.i



MA7: MR 1.2, MR 2.2

Three-Dimensional Graph



Lumbar Rotations

An extension is a bending of the torso in an angle along the y-axis. Lateral bending is a sideways rotation about the x-axis. Axial rotation is a twisting of the lumbar vertebrae around the z-axis.

Example

Which angle of rotation is associated with bending forward?

Answer: Bending forward is an extension rotation in the positive y-direction.

Practice Problems

1. Which angle of rotation is associated with bending backward?
2. Which angle of rotation is associated with twisting to the right?



For more math practice,
visit Math Practice at
ca7.msscience.com.

Model and Invent: Build Your Own Levers

Possible Materials

soup cans
weights
rulers
metersticks



Safety Precautions



Problem

You can calculate the mechanical advantage of the levers present in your body, but without very complicated equipment, you cannot measure the force exerted by your muscles.

Form a Hypothesis

By building a model of a lever, you can determine the input mass necessary to move the soup can the distance you recorded earlier. Predict the input that will move the soup can. How did you arrive at that prediction?

Collect Data and Make Observations

1. Read and complete a lab safety form.
2. Review your notes from the previous labs and recall how you have modeled levers in the past.
3. Choose a lever to model.
4. Measure, using centimeters, the D_E and D_R of your chosen lever.
5. Experiment to find an input that will move the load efficiently.
6. Model other classes of levers.
7. If materials are available, make scale models of levers in the body, with accurate weights and lengths.



Science Content Standards

- 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).
- 6.i** Students know how levers confer mechanical advantage and how the application of this principle applies to the musculoskeletal system.
- 7.a** Select and use appropriate tools and technology (including calculators, computers, balances, spring scales, microscopes, and binoculars) to perform tests, collect data, and display data.
- 7.c** Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.
- 7.d** Construct scale models, maps, and appropriately labeled diagrams to communicate scientific knowledge (e.g., motion of Earth's plates and cell structure).

Analyze and Conclude

1. **Explain** the process you used to come up with your model.
2. **Describe** your model by drawing and labeling it. What lever did you choose to model? What did you use for a fulcrum? What was the final input mass? Did you predict correctly?
3. **Calculate** the MA for the lever you modeled.
4. **Compare and contrast** the model you used for this lever with potential models for another lever.
5. **Calculate** the MA for the other levers you identified in Step 6. Which lever has the highest MA? Which has the lowest?
6. **Summarize** what you have learned about MA in the levers of your own body.



Communicate

Demonstrate your model to the class. **Share** your calculated mechanical advantage. What were other mechanical advantages? Were they all similar to yours or were they all different?

Real World Science

Science & Career

You can be an athletic trainer!



Athletic trainers help athletes get and stay in shape by designing training and nutrition programs. They work on injury prevention through training, education, and intervention techniques (tape, wraps, padding, braces, etc.). Working with a physician, they provide rehabilitation and therapy when an athlete is injured. The athletes pictured are performing leg exercises.

Visit **Careers** at ca7.msscience.com to find out more about what it takes to be an athletic trainer. Write a help wanted ad for a professional sports team's athletic trainer. List the education and certification required for this position. Give the salary range and any benefits.

Checking Out Your Knees

Many people will injure their knees in their lifetime, not just athletes. Most of these injuries involve tears in the cartilage within the joint. The traditional way to check for this is through arthroscopic surgery, where small incisions are made around the knee and a tiny camera is inserted to view the joint. Recently, a new type of magnetic resonance imaging (MRI) has become precise enough to look at the joint from the outside. It's called 3-Tesla MRI and is pictured here.

Visit **Technology** at ca7.msscience.com to find out more about options for finding problems in the knee. Create a table to compare and contrast arthroscopy versus MRI imaging for identifying knee joint problems. Make sure to consider the advantages and disadvantages of each method.

Science & Technology



Archimedes, Levers, and the Human Body

Archimedes is considered one of the greatest mathematicians of all time. He is called the “father of integral calculus” and also the “father of mathematical physics.” He provided the earliest writings that still exist about levers in the third century B.C. He has been quoted by Pappus of Alexandria as saying, “Give me the place to stand, and I shall move the earth.” Man has always been fascinated by levers and understanding them, as shown in this wall painting from around A.D. 1600.



Visit **History** at ca7.msscience.com to find out more about Archimedes and levers in the human body. If the foreman is 30 cm in length and the distance to the bicep is 6.5 cm, what is the force needed to create balance with barbells of 0.9, 2.3, 3.6, and 5.5 kg? Create a chart showing the equations and your answers.

Science & Society

Artificial People?



Recent studies have shown that people in the United States are living longer and remain healthier and more active as they age. But with this longevity, musculoskeletal conditions, such as arthritis, are increasing. Today, joint replacement is an option for some people. Joints of the ankle, hip, knee, shoulder, and finger can be replaced with synthetic ones, such as this artificial knee joint. These artificial joints allow better mobility and less pain for up to 15 years, sometimes longer.

Visit **Society** at ca7.msscience.com to find out more. Divide the students into groups to research and discuss the societal impacts of living longer with regard to musculoskeletal conditions. Create a list of at least four impacts to society. Discuss the findings within the class. Make sure to use correct spelling, capitalization, and grammar.



The BIG Idea

Muscles, bones, and joints form simple machines in the body that produce movement and mechanical advantage.

Lesson 1 The Musculoskeletal System



5.a, 5.c, 6.h, 7.a

Main Idea Muscles, tendons, and bones work in a coordinated fashion to produce movement.

- The musculoskeletal system works to move the body.
- The skeletal system—made of bones, ligaments, tendons, and cartilage—supports and protects the body.
- Muscles provide the contractions necessary to move bones when signaled by the nervous system.
- Joints maintain flexible connections between bones, different types of joints allow for motion in different directions.
- Opposing muscle groups function together to achieve controlled and smooth motion.

- bone (p. 360)
- cartilage (p. 361)
- contraction (p. 364)
- extension (p. 366)
- flexion (p. 366)
- joint (p. 361)
- muscle (p. 364)
- relaxation (p. 364)
- skeletal system (p. 360)
- tendon (p. 366)

Lesson 2 The Body and Levers



6.h, 6.i, 7.a, 7.c, 7.d

Main Idea Muscles and bones are joined in a way that allows them to act as levers, providing force or speed advantages.

- In our bodies, bones act as levers, and muscles provide the force to move objects.
- The arrangement of multiple levers needed to perform even simple movements creates lever advantage.
- You have each class of levers in your body, but most levers are third-class levers. This is because of the necessary arrangement of muscles and bones.

- first-class lever (p. 370)
- fulcrum (p. 368)
- lever (p. 368)
- mechanical advantage (p. 373)
- second-class lever (p. 370)
- third-class lever (p. 370)

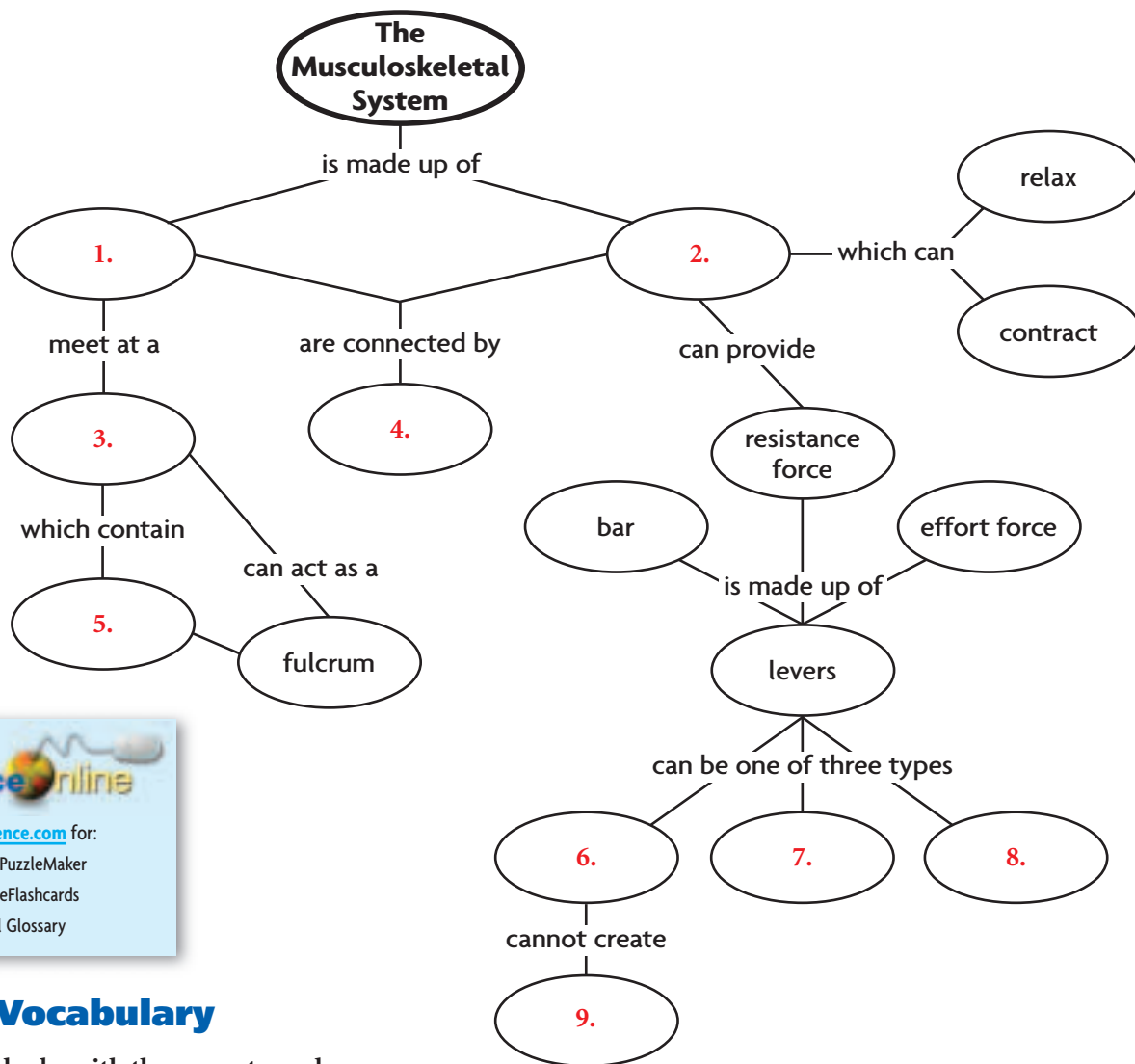


Download quizzes, key terms, and flash cards from ca7.msscience.com.



Linking Vocabulary and Main Ideas

Use the vocabulary terms on page 382 to complete the concept map.



Science  Online

Visit ca7.msscience.com for:

- ▶ Vocabulary PuzzleMaker
- ▶ Vocabulary eFlashcards
- ▶ Multilingual Glossary

Using Vocabulary

Fill in the blanks with the correct word or words.

10. _____ are a type of simple machine that makes tasks easier.
11. Levers can create _____, which can be increased by increasing the length of a lever in a first-class lever.
12. Bones connect at _____.
13. When muscles _____, they become shorter and bones move.
14. Muscles are coordinated. For example, the biceps cause flexion, while the triceps cause _____ of the arm.
15. Joints are the _____ of a lever.
16. Most of the bones in the body are _____, which allow us to make long, quick movements.
17. Your neck is a(n) _____ lever.



Understanding Main Ideas

Choose the word or phrase that best answers the question.

1. Scissors are an example of which class of lever?
 - A. first-class
 - B. second-class
 - C. third-class
 - D. fourth-class

6.i

2. What is the purpose of simple machines?
 - A. to make work harder
 - B. to make work easier
 - C. to create energy
 - D. to create work

6.i

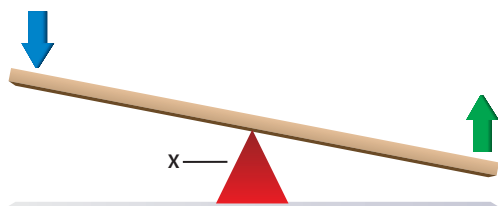
3. What is an example of a second-class lever?
 - A. the knee
 - B. the elbow
 - C. the ankle
 - D. the pelvis

6.i

4. Mechanical advantage is the ratio of the resistance force divided by what?
 - A. resistance distance
 - B. work
 - C. effort distance
 - D. effort force

6.i

5. Below is an image of a lever.



What does X point to?

- A. lever
- B. wheelbarrow
- C. resistance
- D. fulcrum

6.i

6. What connects bone to muscle?

- A. cartilage
- B. tendons
- C. ligaments
- D. collagen

5.c

7. What is another job of the skeletal system, besides support?

- A. to conduct nerve impulses
- B. to protect internal organs
- C. to clean blood
- D. to contract

5.c

8. What is the opposite of flexion?

- A. extension
- B. contraction
- C. hinge joint
- D. mechanical advantage

5.c

9. What types of joints are in the skull?

- A. ball-and-socket
- B. hinge
- C. saddle
- D. immovable

6.h

10. The figure to the right is a picture of which kind of joint?

- A. ball-and-socket
- B. hinge
- C. immovable
- D. pivot



6.h

11. The elbow joint is a fulcrum for which class of lever?

- A. first-class
- B. second-class
- C. third-class
- D. all classes

6.h

12. What does a mechanical advantage greater than one usually mean?

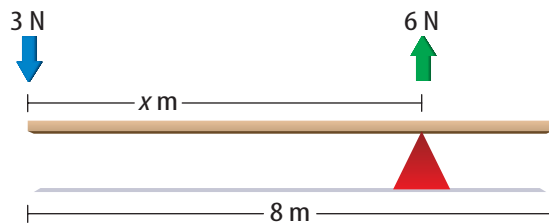
- A. Resistance is greater.
- B. Heavy objects can be lifted.
- C. Only light objects can be lifted.
- D. Input force is very high.

6.i



Applying Science

13. **Compare** second-class levers and third-class levers. **6.i**
14. **Explain** the interactions between the biceps muscles and the bones of the arms when drinking a glass of water. **5.c**
15. **Hypothesize** about what kind of joints are in your toes, based on what you learned about joints. **6.h**
16. **Draw** a diagram of the arm. Label the lever, the fulcrum, and where the force would be applied for movement if the bicep contracts. **6.h**
17. **Hypothesize** why bone is a lever, based on what you know about bone and muscle tissue. **6.h**



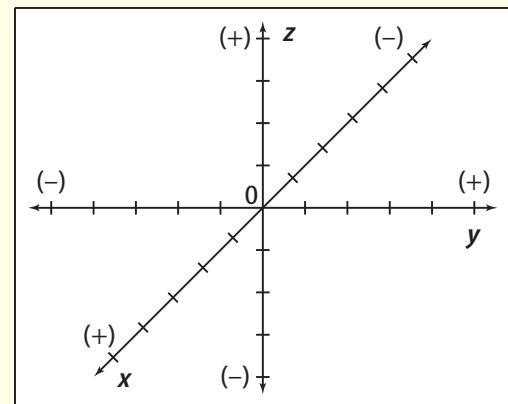
18. **Calculate** the resistance distance in the lever in the figure. **6.i**
19. **Determine** a way to use a shovel as either a first-class lever or a third-class lever without moving your hands. **6.i**
20. **Explain** how a muscle returns to the length it was before contraction, given that muscles can only contract. **5.c**
21. **Imagine** you could increase the length of your forearm. What would this do to the mechanical advantage you would experience? **6.i**
22. **Consider** how you would adjust the distance of the effort force from the fulcrum so that you could lift more weight, based on what you know about first-class levers. **6.i**
23. **Explain** how a third-class lever is different from the other level classes. **6.i**

WRITING in Science

24. Write a manual that explains how to open a screw-top jar. Be sure to note the muscles, joints, and levers needed to complete each action.

ELA7: 1.3

Applying Math



25. Which angle of rotation is associated with twisting to the left? **MA7: MR 1.2**
26. Which angle of rotation is associated with twisting the hips? **MA7: MR 1.2**
27. Which angle of rotation is associated with twisting the head? **MA7: MR 1.2**
28. An extension is a movement around which axis? **MA7: MR 1.2**
29. An axial rotation is a movement around which axis? **MA7: MR 1.2**

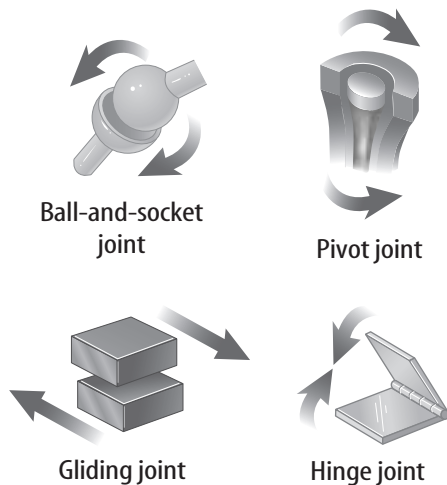


1 Which is true about voluntary and involuntary muscles?

- A Involuntary muscles can be consciously controlled; voluntary muscles are muscles that cannot be controlled consciously.
- B Involuntary muscles work randomly; voluntary muscles are always working.
- C Voluntary muscles can be consciously controlled; involuntary muscles cannot be controlled consciously.
- D Voluntary muscles are located in the heart and organs; involuntary muscles are located in the limbs.

5.c

Use the illustration below to answer to answer questions 2 and 3.



2 Which type of joint do your elbows have?

- A hinge
- B gliding
- C ball and socket
- D pivot

6.h

3 Which type of joint allows your legs and arms to swing in almost any direction?

- A hinge
- B gliding
- C ball and socket
- D pivot

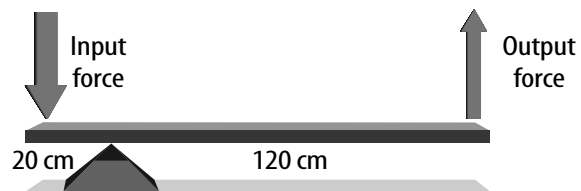
6.h

4 What is the most important difference between cardiac muscle and skeletal muscle?

- A Their cells contain different materials.
- B Their cells have different shapes.
- C They have different sizes of cells.
- D They have different functions.

5.a

Use the image below of a lever for questions 5 and 6.



5 What is the mechanical advantage of the lever shown above?

- A $\frac{1}{6}$
- B $\frac{1}{2}$
- C 2
- D 6

6.i

6 What is the mechanical advantage of the lever if the triangular block is moved 60 cm to the right.

- A $\frac{1}{4}$
- B $\frac{1}{2}$
- C 2
- D 4

6.i



7 Which statement is *always* true when you use a lever?

- A An object moves a shorter distance.
- B An object moves a longer distance.
- C Less force is needed.
- D More force is needed.

6.i

8 Explain the differences between the three classes of levers in terms of the location of the fulcrum, input force, and output force or load.

- A first-class lever: fulcrum is between input and output force; second-class lever: output force is between input force and fulcrum; third-class lever: input force is between fulcrum and output force
- B second-class lever: fulcrum is between input and output force; first-class lever: output force is between input force and fulcrum; third-class lever: input force is between fulcrum and output force
- C third-class lever: fulcrum is between input and output force; first-class lever: output force is between input force and fulcrum; second-class lever: input force is between fulcrum and output force
- D third-class lever: fulcrum is between input and output force; second-class lever: output force is between input force and fulcrum; first-class lever: input force is between fulcrum and output force

6.i

9 What is the name of the place about which a lever rotates?

- A center point
- B fulcrum
- C hinge
- D vertex

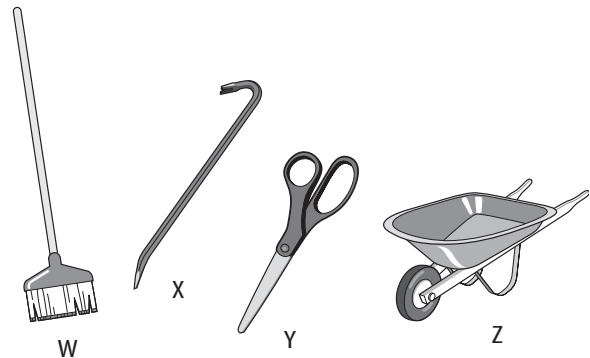
6.i

10 Hannah is using a shovel as a lever to lift rock in her garden. She is using a second rock as the fulcrum and pushing down on the handle of the shovel. She is not able to lift the rock. How can she increase the mechanical advantage of the lever?

- A She can place the fulcrum closer to the rock he is lifting.
- B She can move the fulcrum away from the rock she is lifting.
- C She can remove the fulcrum and lift on the end of the shovel instead.
- D She can push down on the shovel between the fulcrum and the rock.

6.i

11 The diagram below shows several levers.



Which is a second-class lever?

- A W
- B X
- C Y
- D Z

6.i