chapter 5

# Energy

## section ● The Nature of Energy

**What You'll Learn**
- the different forms of energy
- how energy can be stored

## Before You Read

Energy comes in many forms. List as many types of energy as you can think of on the lines below.

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Study Coach

**State the Main Ideas** As you read this section, stop after each paragraph and write the main idea of what you read in your own words.

## Read to Learn

### What is energy?

Changes are taking place all around you all the time. For example, lightbulbs are heating the air around them, and the wind may be blowing leaves in the trees. Even you are changing as you breathe, blink, or move around at your desk.

All changes involve energy. Imagine a baseball flying through the air. It hits a window and breaks the glass into small pieces. The moving baseball causes the solid pane of glass to change into the small pieces. The moving baseball has energy.

### How are energy and work related?

**Energy** is the ability to do work. Work is done when a force causes something to move. A moving baseball does work on a window. The ball exerts a force on the glass and causes it to break. Energy is also the ability to cause change. When work is done, energy moves from one place to another or changes from one form to another.

Reading Check

1. **Define** What is energy?

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### What are some different forms of energy?

Turn on an electric light, and a dark room becomes brighter. Turn on your CD player, and sound comes through the headphones. In both of these cases, energy moves from one place to another. These changes are different from each other. They are also different from the change caused by the baseball hitting the window. Energy has many different forms. Some forms are electrical, chemical, radiant, and thermal.


The figure shows some forms of energy and some objects associated with these forms of energy. The lightbulb uses electric energy to light a room. Chemical energy is stored in the food you eat and in the fuel in a car. Radiant energy from the Sun travels to Earth and warms the planet. Energy plays a role in every activity.

### How is energy like money?

Suppose you have $100. You could have one hundred-dollar bill, two fifty-dollar bills, 100 one-dollar bills, or 10,000 pennies. You could start with the $100 in one form and change it into another form. But, no matter what form it is in, it is still $100. This is also true of energy. It is the same no matter what form it is in. Energy from the Sun that warms you and energy from the food you eat are just different forms of the same thing—energy.

## Kinetic Energy

When you think of energy, you might think of moving objects. An object in motion, like the baseball, does have energy. **Kinetic energy** is the energy a moving object has because of its motion. The kinetic energy of a moving object depends on the object's mass and speed. You can find the kinetic energy of an object using the following equation.

$$\textbf{kinetic energy}\ \text{(joules)} = \frac{1}{2}\textbf{mass}\ \text{(kg)} \times [\textbf{speed}\ \text{(m/s)}]^2$$

$$KE = \frac{1}{2}mv^2$$

Energy is measured using the SI unit called the **joule**. The letter $J$ stands for joule. If you drop a baseball from about 0.5 m, it will have a kinetic energy of about one joule, or 1 J.

## Picture This

**2. Illustrate** In the space below, draw another representation of one of the types of energy shown in the figure.

**FOLDABLES**™

● **Find Main Ideas** Fold a piece of paper into 12 sections and label. Fill in the main ideas about kinetic and potential energy.

| The Nature of Energy | Define | Examples of. . . | Calculate |
|---|---|---|---|
| Kinetic Energy | | | |
| Potential Energy | | | |

**Using the Equation** A jogger whose mass is 60 kg is moving at a speed of 3 m/s. Use the equation to find the jogger's kinetic energy.

$$
\begin{aligned}
KE &= \frac{1}{2}mv^2 \\
&= \frac{1}{2}(60\ \text{kg})(3\ \text{m/s})^2 \\
&= \frac{1}{2}(60\ \text{kg})(9\ \text{m}^2/\text{s}^2) \\
&= \frac{1}{2}(540\ \text{kg} \cdot \text{m}^2/\text{s}^2) \\
&= 270\ \text{kg} \cdot \text{m}^2/\text{s}^2
\end{aligned}
$$

The kinetic energy of the jogger is 270 J.

**Applying Math**

**3. Explain** Look at the problem about the jogger. Why does $(3\ \text{m/s})^2$ become $(9\ \text{m}^2/\text{s}^2)$?

## Potential Energy

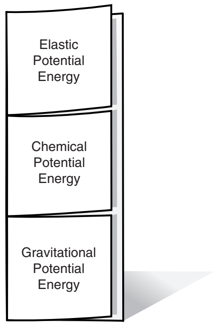
An object with energy does not have to be moving. Objects that are at rest have stored energy. For example, an apple that is hanging from a tree has stored energy. If the apple stays in the tree, it will keep its stored energy because of its position above the ground. If the apple falls to the ground, a change happens. Because the apple can cause change, it has energy. Stored energy due to position is called **potential energy**. The stored energy of position, potential energy, will change to energy of motion, kinetic energy, when the apple falls.

### What is elastic potential energy?

Energy can be stored in other ways, too. Suppose you stretch a rubber band. If you let the rubber band go, it will fly through the air. Where did this kinetic energy come from? The stretched rubber band had something called elastic potential energy. **Elastic potential energy** is energy stored by an object that can stretch or shrink, like a rubber band or a spring. When you let the rubber band fly through the air, its elastic potential energy becomes kinetic energy.

**FOLDABLES™**

**Compare and Contrast** Make the following Foldable to compare and contrast the properties of different types of potential energy.




### What is chemical potential energy?

Where does your body get the energy to make it move? The food that you eat each day has stored energy. To be more exact, food's energy is stored in chemical bonds between atoms. Natural gas stores energy in the same way. Energy stored in chemical bonds is called **chemical potential energy**. In natural gas, energy is stored in the bonds that hold the carbon and hydrogen atoms together. This energy is released when the gas is burned.

## What is gravitational potential energy?

Anything that can fall has stored energy called gravitational potential energy. **Gravitational potential energy** (GPE) is energy that is stored by objects that are above Earth's surface. The apple in the tree has GPE. The GPE of an object depends on two things—the object's mass and its height above the ground. Gravitational potential energy can be found using the following equation.

**gravitational potential energy** (J) =
**mass** (kg) × **acceleration due to gravity** (m/s²) × **height** (m)

$$GPE = mgh$$

On Earth, the acceleration due to gravity is 9.8 $m/s^2$ and has the symbol *g*. Like all forms of energy, gravitational potential energy is measured in joules.

Suppose a ceiling fan has a mass of 7 kg and is 4 m above the floor. What is the gravitational potential energy of the ceiling fan?

$$\begin{aligned} GPE &= mgh \\ &= (7\ \text{kg})(9.8\ \text{m/s}^2)(4\ \text{m}) \\ &= 274\ \text{kg m}^2/\text{s}^2 \end{aligned}$$

The ceiling fan has a GPE of 274 kg $m^2/s^2$, or 274 J.

## How is potential energy stored?

So far, you have studied three types of potential energy. The table below lists how each is stored.

| Potential Energy | Way It Is Stored |
|---|---|
| Elastic | stored by an object that can stretch or shrink |
| Chemical | stored in chemical bonds |
| Gravitational | stored by objects that are above Earth's surface |

## How does GPE change?

By looking at the equation for gravitational potential energy, you can see that two things can change an object's gravitational potential energy. The acceleration of gravity, *g*, is always 9.8 $m/s^2$. It is the constant. So, the two factors in the equation that can change are mass, *m*, and height, *h*. They are the variables.

So if you change the mass or height of an object, its gravitational potential energy will also change.

**Reading Check**

4. **List** two things that determine an object's GPE.

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**Applying Math**

5. **Interpret** In the formula *GPE* = *mgh*, which symbols represent the constants and which symbols represent the variables?

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**Changing GPE** Look at the vase near the bottom of the bookcase. If you fill the vase with water, you increase its GPE by increasing its mass. If you move the vase to a higher shelf, you also increase its GPE by increasing its height. The gravitational potential energy of an object can increase if you change its mass or move the object higher above the ground.

If two objects are at the same height, then the object with the greater mass will have more GPE. If two objects have the same mass, the one that is higher above the ground will have the greater GPE.

## Picture This

6. **Reasoning** Which would have a greater GPE, a feather on a high shelf or a large book on the next shelf down? Explain your reasoning.

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## What does GPE change into?

What would happen if the vase on the top shelf fell? As the vase falls, it starts moving. It now has both GPE and kinetic energy. As the vase gets closer to the ground, its GPE decreases. At the same time, its kinetic energy increases. The GPE changes into kinetic energy.

Look at the two vases in the figure. If the vase on the top shelf falls, it will start with more GPE and end with more kinetic energy when it hits the ground. This is why a vase that falls from a high shelf is more likely to break than a vase that falls from a lower shelf.

**Reading Check**

7. **Determine** As an object falls, what does its gravitational potential energy change to? (Circle your choice.)

   a. chemical energy
   b. kinetic energy
   c. thermal energy
   d. radiant energy

## After You Read

### Mini Glossary

**chemical potential energy:** energy stored in chemical bonds

**elastic potential energy:** energy stored by things that stretch or shrink

**energy:** the ability to do work

**gravitational potential energy:** energy stored by things that are above Earth

**joule:** the standard unit for measuring energy

**kinetic energy:** energy in the form of motion

**potential energy:** energy stored in a motionless object

**1.** Review the terms and their definitions in the Mini Glossary. Explain the difference between kinetic energy and potential energy on the lines below.

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**2.** Complete the chart below. Fill in the first column with the three kinds of potential energy. Fill in the second column with an example of something that stores each type of potential energy.

| Kinds of Potential Energy | Examples |
|---|---|
| → | |
| → | |
| → | |

**3.** Think about what you have learned. How did you decide what was the main idea of each paragraph?

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End of Section

# Energy

chapter 5

## section ● Conservation of Energy

**What You'll Learn**

- how energy can be changed from one form to another
- how energy is conserved

## Before You Read

The motion of objects appears to change all the time. Imagine a person swinging on a swing. Explain the person's motion while swinging.

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Mark the Text

**Identify the Main Point** Highlight the main point in each paragraph. Highlight in a different color a detail or example that helps explain the main point.

## Read to Learn

### Changing Forms of Energy

When a vase on a shelf falls to the ground, its potential energy changes into kinetic energy. Many situations involve changing energy from one form to another. Some examples of energy changing form are race cars using fuel for energy, your body digesting food for energy, and the Sun warming your skin.

#### How can electric energy change?

Every day, you use many items that change energy from one form to another. You are probably reading this page in a room that is lit by lightbulbs. The lightbulbs transform the electric energy that they receive into light energy.

**Picture This**

1. **Relate** Name other items that change electric energy into heat.

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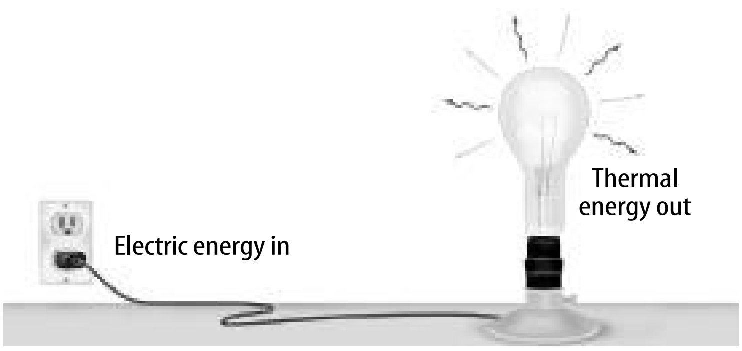
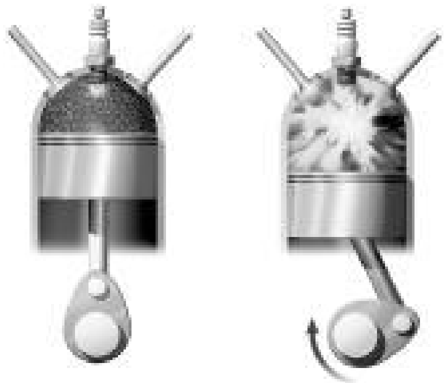


The heat you can feel around the bulb lets you know that some of the electric energy also is changed to thermal energy, as shown in the figure on the previous page.

## How can chemical energy change?

Chemical energy can be changed into kinetic energy. A fuel, such as gasoline, stores energy in the form of chemical potential energy. Cars and buses usually run on gasoline. As shown in the figure, an electric spark causes a small amount of fuel in the engine to burn. This transforms the chemical potential energy stored in the gasoline molecules into thermal energy. The thermal energy heats up gases and they expand. The expanding gases cause parts of the car to move. The moving parts have kinetic energy. Chemical energy has been changed into thermal energy and then into kinetic energy.



Spark plug fires　　Gases expand

## Picture This

**2. Identify** Circle the moving parts in the figure. What type of energy is this?

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## Do all energy changes result in motion?

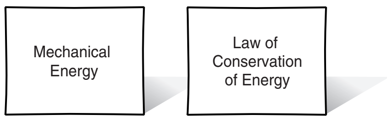
Not all changes in energy result in motion that can be seen. Nor do they result in sound, heat, or light. For example, every green plant changes light energy from the Sun into chemical energy that is stored in the plant. When you eat an ear of corn, the chemical potential energy in the corn is transformed to other forms of energy by your body.

# Conversions Between Kinetic and Potential Energy

Recall that a rubber band has elastic potential energy. When a stretched rubber band is let go, the potential energy is changed into kinetic energy. **Mechanical energy** is the total amount of potential and kinetic energy in a system. The mechanical energy of the rubber band is the total of its potential energy and its kinetic energy at any one time. Mechanical energy is the result of the position of an object and its motion.

FOLDABLES™

**Collect Information** Make note cards from two half-sheets of paper as shown. Write on each note card what you learn about mechanical energy and the law of conservation of energy.



## Think it Over

3. **Explain** Does the mechanical energy of an object falling from a shelf change? Explain.

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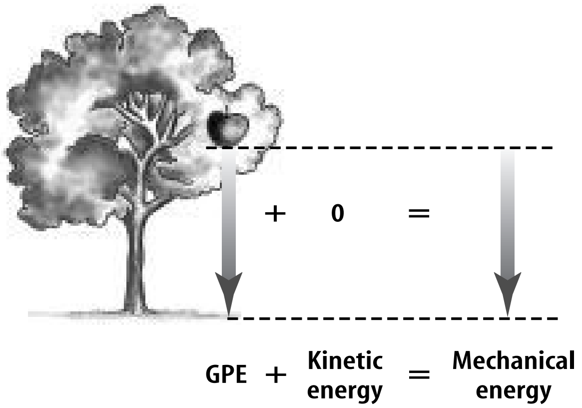
## Does mechanical energy of an object change?

What happens to the mechanical energy of an object as its potential energy is transformed into kinetic energy? Look at the apple in the tree below. It has gravitational potential energy because Earth is pulling down on it. The apple does not have kinetic energy while it hangs in the tree. The apple's gravitational potential energy and its mechanical energy are the same.




Look at the apple in the second figure. As it falls, the apple loses height, so its gravitational potential energy becomes less. As the velocity of the apple increases, its kinetic energy increases. The potential energy of the apple is being changed to kinetic energy. However, the mechanical energy will not change. The potential energy that the apple loses is being gained back as kinetic energy. The form of the energy changes, but the total amount of the energy remains the same.

## Picture This

4. **Interpret** What do the arrows in the figures mean?

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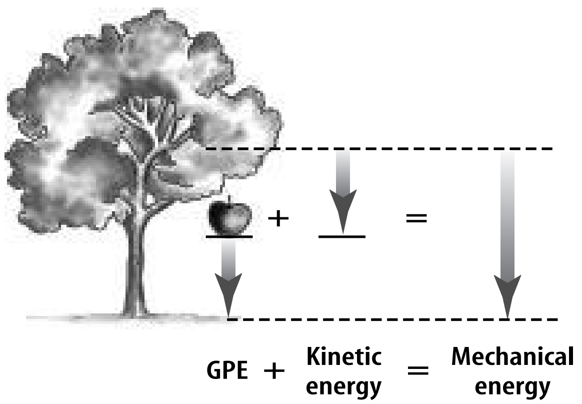
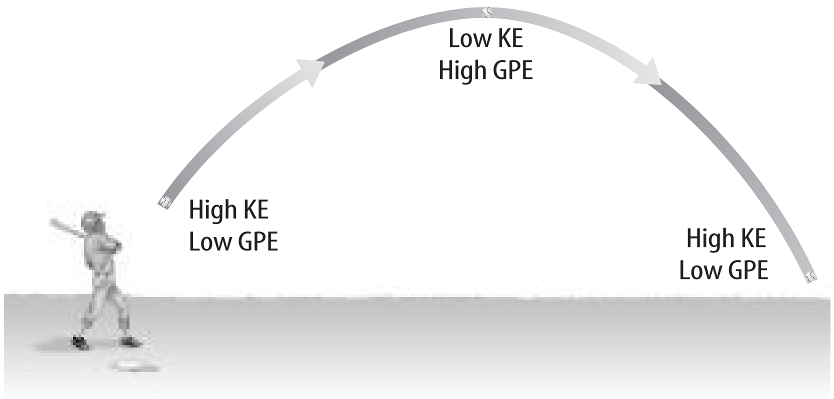



This can be explained using the mechanical energy equation. As one value of the mechanical energy equation decreases, the other value increases by the same amount. The sum of the two stays the same. Therefore, the mechanical energy of an object stays the same.

## How does energy change in projectile motion?

Energy transformations also occur during projectile motion. During projectile motion, an object moves through the air in a curved path. Look at the figure below. As the ball leaves the bat, it has mostly kinetic energy. As the ball rises, its gravitational potential energy becomes greater, but its kinetic energy becomes less due to decreasing velocity. As the ball falls, its gravitational potential energy becomes less, but its kinetic energy becomes greater due to increasing velocity. However, the total mechanical energy of the ball does not change as the ball moves through the air.




## What happens to energy while swinging?

When you ride on a swing, part of the fun is the way you feel just as you drop from the highest part of the swing's path. Energy is constantly changing during your ride on a swing. The push that gets you moving is kinetic energy. As the swing rises, you lose speed. This means the kinetic energy is changing into gravitational potential energy. At the top of the path, the GPE is at its greatest and the kinetic energy is at its lowest. As the swing starts its downward path and its speed increases, the GPE changes into kinetic energy. At the bottom of the swing's path, the kinetic energy is at its greatest and the GPE is at its lowest. As you swing back and forth, kinetic and potential energy are constantly changing.

# The Law of Conservation of Energy

As a batted ball speeds up or slows down, its kinetic and potential energy are always changing. But the amount of mechanical energy always stays the same. The kinetic and potential energy continually change form back and forth, and no energy is destroyed.

### Picture This

5. **Observe** What does the symbol *KE* represent in the figure?

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### Think it Over

6. **Analyze** Why is kinetic energy at its lowest at the top of the swing's path?

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**All Forms Change** Energy can change from one form to another, but the total amount of energy never changes. Another way to say this is that energy is conserved. The **law of conservation of energy** states that energy cannot be created or destroyed. This means that the total amount of energy in the universe is always the same. It just changes from one form to another.

You might have heard the phrase *energy conservation* before. Conserving energy means reducing the need for energy so we use fewer energy resources such as coal and oil. This is not the same as the law of conservation of energy. The law of conservation of energy describes what happens to energy as it is changed, or transferred, from one object to another.

Reading Check

7. **Explain** What does the law of conservation of energy state?

## Is energy always conserved?

There are times when it seems that energy is not conserved. For example, when you are coasting along a flat road on a bicycle, you eventually stop if you don't pedal. If energy is conserved, why wouldn't your kinetic energy stay the same so you could keep coasting forever? It might appear that energy is destroyed when you slow down and come to a stop. Sometimes is it hard to see the law of conservation of energy at work.

## How does friction affect energy?

Suppose you are swinging on a swing. If you stop pumping and no one is pushing you, you will soon stop swinging. It would seem that the mechanical (kinetic and potential) energy of the swing is lost. Wouldn't this go against the law of conservation of energy?

If the energy of the swing decreases, then the energy of some other object must increase by the same amount. What object has an energy increase? With every motion, the swing's ropes or chains rub on their hooks, and air pushes on the rider. Friction and air resistance cause the temperature of the hooks and air to increase a little. The mechanical energy is not destroyed. It is changed into thermal energy. So, the total amount of energy stays the same—it just changes form.

Think it Over

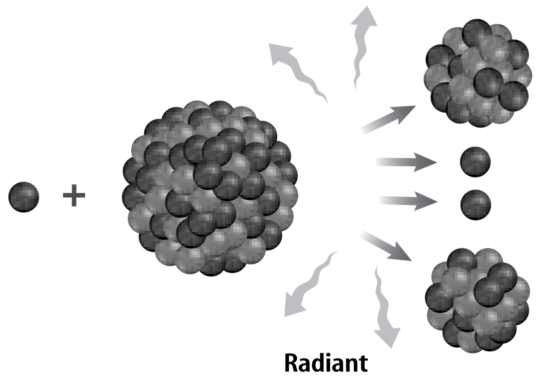
8. **Describe** how energy is conserved when a bicycle coasts to a stop.

## Where does the Sun get its energy?

Have you ever wondered how the Sun gives off enough energy to light and warm Earth? The Sun and other stars have a special way of changing their energy. It is called nuclear fusion. Nuclear fusion is the reaction that takes place when nuclei join together. Nuclear fusion uses the law of conservation of energy when it changes the potential energy of a small amount of mass into a huge amount of energy.

## What is nuclear fission?

Another way to change a small amount of mass into a huge amount of energy is through nuclear fission. Both nuclear fusion and nuclear fission involve the nuclei of matter. In nuclear fusion, the nuclei are fused, or joined. The nuclei are not fused in nuclear fission. They are broken apart. In either process, fusion or fission, mass is changed into energy. In both processes, the total amount of energy is conserved if the energy content of the masses used are included. Nuclear fission is how nuclear power plants produce energy. The figure below shows nuclear fission. In both nuclear fusion and nuclear fission, mass is changed into energy. In nuclear fission, the mass of the large nucleus on the left is greater than the combined mass of the other two nuclei and the neutrons. But once again, the total amount of mass and energy does not change during these reactions. ☑




**Reading Check**

**9. Compare and contrast** nuclear fusion and nuclear fission.

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**Picture This**

**10. Determine** How can you determine that this figure models fission, not fusion?

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## The Human Body—Balancing the Energy Equation

With your right hand, reach up and feel your left shoulder. With that simple move, stored potential energy in your body is changed to kinetic energy when you move your arm. Does your shoulder feel warm? Some of the stored chemical potential energy also is being used to keep your body at about the same temperature. Do you feel warmer if someone wraps their arms around you? Some of the body's potential energy is changed into heat that the body gives off to its surroundings.

### How does your body store and use energy?

The law of conservation of energy applies to the chemical and physical changes that are going on in your body. Your body stores potential energy in the form of fat and other chemical compounds. This chemical potential energy is the fuel for processes such as the beating of your heart, digesting of food, and moving muscles.

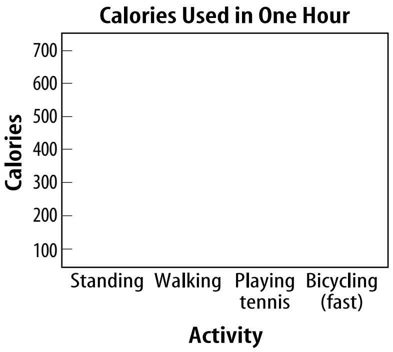
## What are food Calories?

The potential energy stored in your body comes from the food you eat. Your body breaks down the food you eat into molecules that can be used as fuel. The chemical potential energy in these molecules supplies the cells of your body with the energy they need to function. Your body also can use the chemical potential energy stored in fat for its energy needs.

The food Calorie (C) is a unit nutritionists use to measure how much energy you get from different foods. One Calorie is equal to about 4,184 J. These Calories produce the energy needed by your body. Look at the labels on food packages. They provide information about the Calories contained in a serving, as well as the amount of protein, fat, and carbohydrates. To maintain a healthy weight, you must have a proper balance between the food you eat and the energy your body uses. The table below shows the amount of energy used in doing various activities.

**Applying Math**

**11. Displaying Data** On the graph below, make a bar graph comparing the number of calories used by a medium-framed person for the following activities: standing, walking, playing tennis, and bicycling.




**Calories Used in One Hour**

| Type of Activity | Body Frames | | |
|---|---|---|---|
| | Small | Medium | Large |
| Sleeping | 48 | 56 | 64 |
| Sitting | 72 | 84 | 96 |
| Eating | 84 | 98 | 112 |
| Standing | 96 | 112 | 123 |
| Walking | 180 | 210 | 240 |
| Playing tennis | 380 | 420 | 460 |
| Bicycling (fast) | 500 | 600 | 700 |
| Running | 700 | 850 | 1,000 |

# After You Read

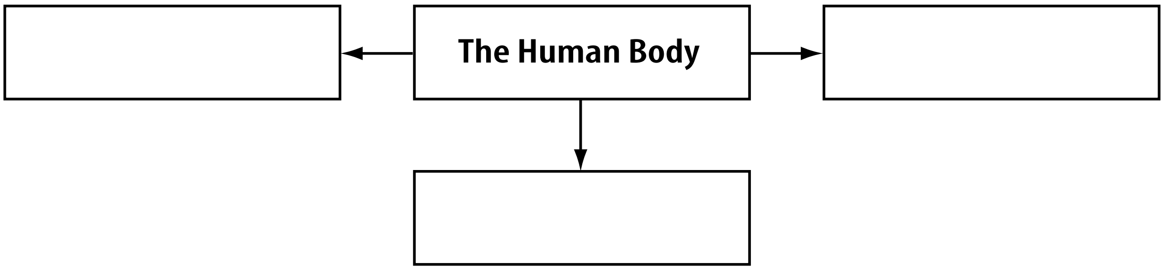
## Mini Glossary

**law of conservation of energy:** energy may change from one form to another, but the total amount of energy never changes

**mechanical energy:** the total amount of potential and kinetic energy in a system

1. Review the terms and their definitions in the Mini Glossary. Describe a real-world example in which the amount of potential and kinetic energy change, but the total amount of mechanical energy stays the same.

2. In this section, you learned that chemical potential energy can be changed in the human body. Complete the chart below by naming three processes in the body that are fueled by chemical potential energy.




3. Think about what you have learned. How did highlighting the main points and details or examples help you learn the new material?



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End of Section