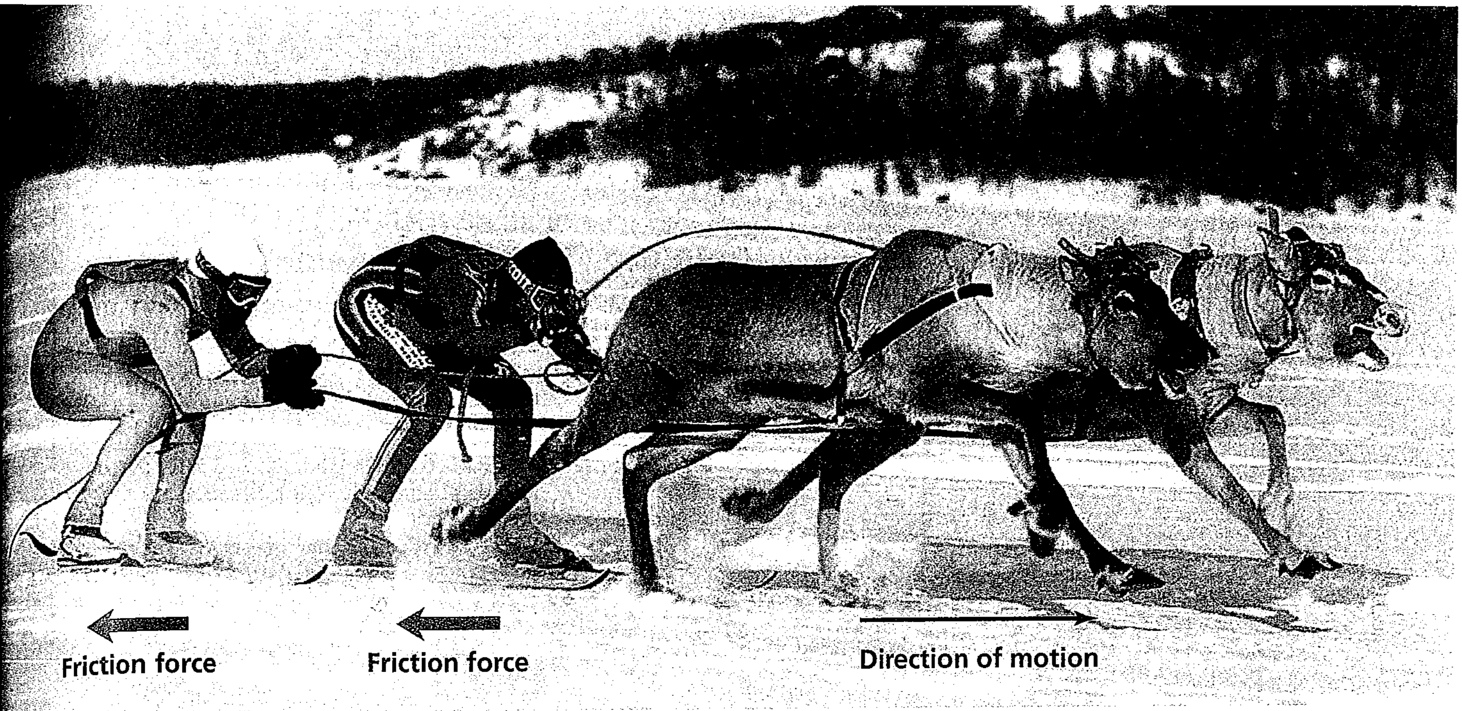

FIGURE 4
Friction and Smooth Surfaces The smooth surfaces of the skis make for a fast ride for these Finnish skiers.
Relating Diagrams and Photos *How does the direction of friction compare to the direction of motion?*

Friction

When a sled moves across snow, the bottom of the sled rubs against the surface of the snow. In the same way, the skin of a firefighter's hands rubs against the polished metal pole during the slide down the pole. The force that two surfaces exert on each other when they rub against each other is called **friction.**

The Causes of Friction In general, smooth surfaces produce less friction than rough surfaces. **The strength of the force of friction depends on two factors: how hard the surfaces push together and the types of surfaces involved.** The skiers in Figure 4 get a fast ride because there is very little friction between their skis and the snow. The reindeer would not be able to pull them easily over a rough surface such as sand. Friction also increases if surfaces push hard against each other. If you rub your hands together forcefully, there is more friction than if you rub your hands together lightly.

A snow-packed surface or a metal firehouse pole may seem quite smooth. But, as you can see in Figure 5, even the smoothest objects have irregular, bumpy surfaces. When the irregularities of one surface come into contact with those of another surface, friction occurs. Friction acts in a direction opposite to the direction of the object's motion. Without friction, a moving object might not stop until it strikes another object.

FIGURE 5
A Smooth Surface?
If you look at the polished surface of an aluminum alloy under a powerful microscope, you'll find that it is actually quite rough.

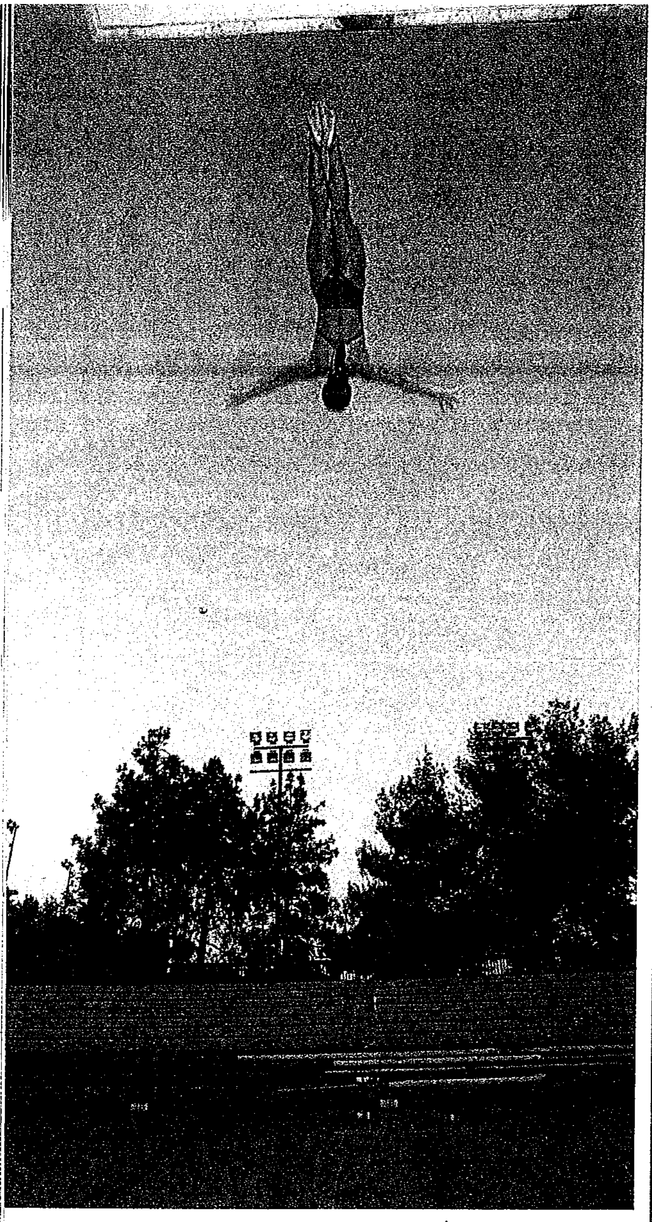

FIGURE 7
Gravity and Acceleration
Divers begin accelerating as soon as they leap from the platform.

Gravity

Would you be surprised if you let go of a pen you were holding and it did not fall? You are so used to objects falling that you may not have thought about why they fall. One person who thought about it was Isaac Newton. He concluded that a force acts to pull objects straight down toward the center of Earth. **Gravity** is a force that pulls objects toward each other.

Universal Gravitation Newton realized that gravity acts everywhere in the universe, not just on Earth. It is the force that makes an apple fall to the ground. It is the force that keeps the moon orbiting around Earth. It is the force that keeps all the planets in our solar system orbiting around the sun.

What Newton realized is now called the law of universal gravitation. The law of universal gravitation states that the force of gravity acts between all objects in the universe. This means that any two objects in the universe, without exception, attract each other. You are attracted not only to Earth but also to all the other objects around you. Earth and the objects around you are attracted to you as well. However, you do not notice the attraction among objects because these forces are small compared to the force of Earth's attraction.

Factors Affecting Gravity **Two factors affect the gravitational attraction between objects: mass and distance.** **Mass** is a measure of the amount of matter in an object. The SI unit of mass is the kilogram. One kilogram is the mass of about 400 modern pennies. Everything that has mass is made up of matter.

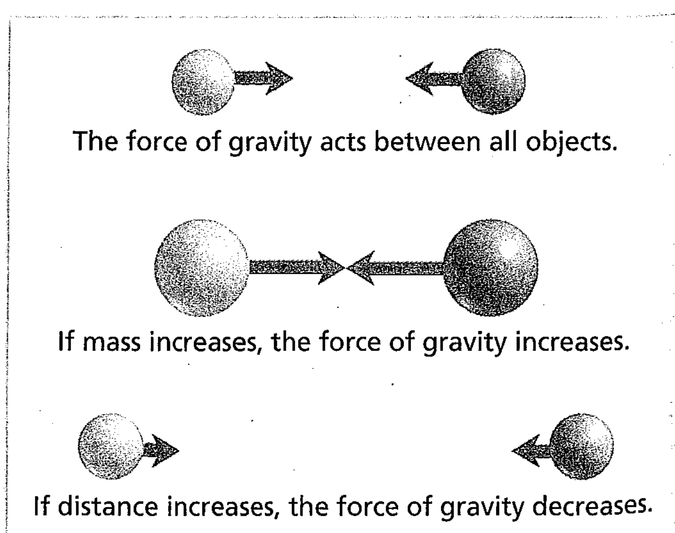

FIGURE 8
Gravitational Attraction
Gravity increases with mass and decreases with distance. **Inferring** *What happens to the force of gravity between two objects if the distance between them decreases?*

The more mass an object has, the greater its gravitational force. Because the sun's mass is so great, it exerts a large gravitational force on the planets. That's one reason why the planets orbit the sun.

In addition to mass, gravitational force depends on the distance between the objects. The farther apart two objects are, the lesser the gravitational force between them. For a spacecraft traveling toward Mars, Earth's gravitational pull decreases as the spacecraft's distance from Earth increases. Eventually the gravitational pull of Mars becomes greater than Earth's, and the spacecraft is more attracted toward Mars.

Weight and Mass Mass is sometimes confused with weight. Mass is a measure of the amount of matter in an object; weight is a measure of the gravitational force exerted on an object. The force of gravity on a person or object at the surface of a planet is known as **weight.** So, when you step on a bathroom scale, you are determining the gravitational force Earth is exerting on you.

Weight varies with the strength of the gravitational force but mass does not. Suppose you weighed yourself on Earth to be 450 newtons. Then you traveled to the moon and weighed yourself again. You might be surprised to find out that you weigh only about 75 newtons—the weight of about 8 kilograms on Earth! You weigh less on the moon because the moon's mass is only a fraction of Earth's.

Reading Checkpoint **What is the difference between weight and mass?**

Lab zone Skills Activity

Calculating

You can determine the weight of an object if you measure its mass.

1. Estimate the weight of four objects. (*Hint:* A small lemon weighs about 1 N.)
2. Use a balance to find the mass of each object. If the measurements are not in kilograms, convert them to kilograms.
3. Multiply each mass by 9.8 m/s^2 to find the weight in newtons.

How close to actual values were your estimates?

FIGURE 9
Mass and Weight This astronaut jumps easily on the moon. **Comparing and Contrasting** *How do his mass and weight on the moon compare to his mass and weight on Earth?*

Astronaut in Spacesuit		
Weight on Moon	=	270 N
Weight on Earth	=	1,617 N
Mass on Moon	=	165 kg
Mass on Earth	=	165 kg