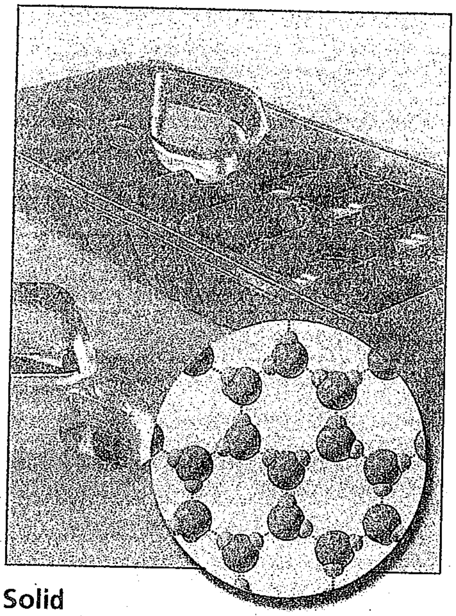
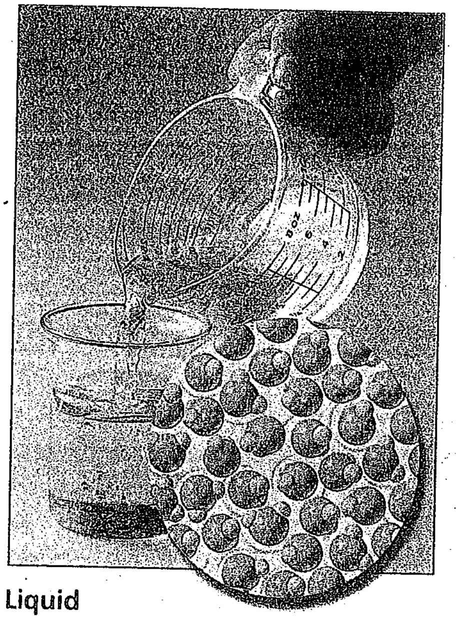
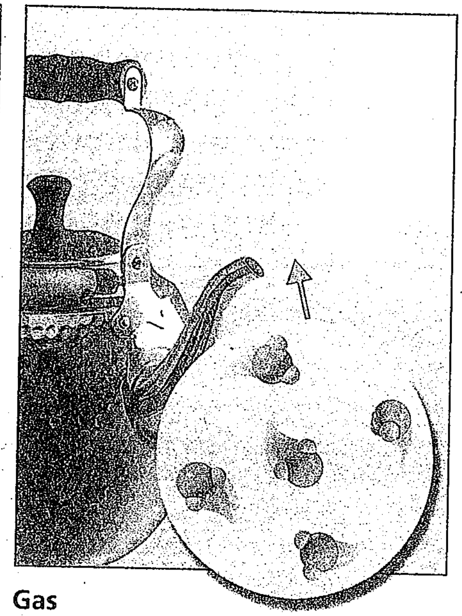


Solid
The molecules in solid ice are close together and form a rigid structure.



Liquid
The molecules move more freely, and the water takes the shape of its container.



Gas
The molecules in water vapor move very freely and spread out to fill a space.

FIGURE 4
The Three States of Water
Water commonly exists as a solid, a liquid, and a gas.
Comparing and Contrasting
In which state do the molecules move the slowest? The fastest?

Changing State

It's a hot, humid summer day. To cool down, you put some ice cubes in a glass and add cold water. You are interacting with water in three different states, or forms: solid, liquid, and gas. **The ice is solid water, the familiar form of water is a liquid, and the water vapor in the air is a gas.** Water is the only substance on Earth that commonly exists in all of these different states. Figure 4 shows how the arrangement of the water molecules differs in each state.

Boiling and Evaporation If you've ever poured water into a pot, you've seen how the liquid takes the shape of the container. This is true because the molecules in liquid water move freely, bouncing off one another.

What happens if you place the pot of water on a stove and heat it? As more energy is added to the liquid water, the speed of the molecules increases and the temperature rises. At 100°C, the water boils and a change of state occurs. The molecules have enough energy to escape the liquid and become invisible water vapor. The molecules in a gas move even more freely than those in a liquid.

Another way that liquid water can become a gas is through evaporation. **Evaporation** is the process by which molecules at the surface of a liquid absorb enough energy to change to the gaseous state. If you let your hair air-dry after going swimming, you are taking advantage of evaporation.

Condensation As water vapor cools down, it releases some of its energy to the surroundings. The molecules slow down and the temperature decreases. As the temperature of the gas reaches 100°C, the water vapor begins to change back to the liquid state. The process by which a gas changes to a liquid is called **condensation.** When you fog up a window by breathing on it, you are seeing the effects of condensation. The invisible water vapor in your breath is cooled by the window and forms drops of liquid water.

Freezing If those drops of liquid water cooled, the molecules would lose energy. They would start to move more and more slowly. At 0°C, the liquid water freezes, changing into solid ice. If you have ever observed an icicle forming from water dripping off a roof, you have seen this change of state in progress.

Melting Suppose that you put an ice cube in a pot and place it on the stove. As you heated it, the molecules in the ice would start moving faster. The temperature would rise. When the temperature reached 0°C, the solid ice would melt and become liquid water.

Reading Checkpoint **What is condensation?**

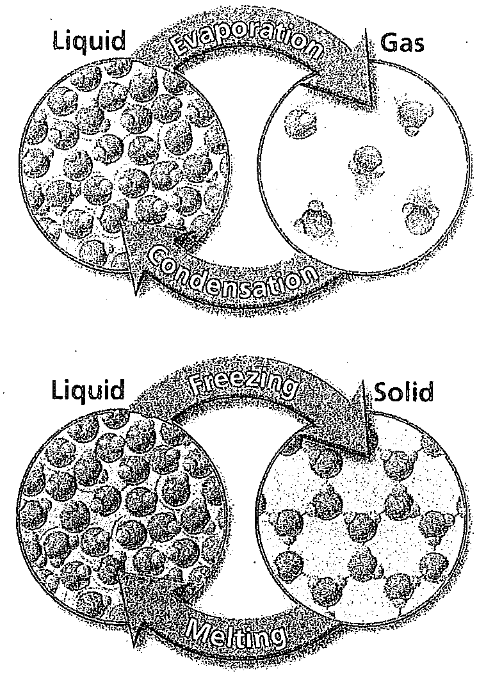


FIGURE 5
Changing State
Water moves between the liquid and gaseous states by evaporation and condensation. Water moves between the liquid and solid states by freezing and melting.

Section 1 Assessment

Target Reading Skill **Building Vocabulary** Use your definitions to help answer the questions below.

Reviewing Key Concepts

1. a. **Reviewing** What atoms make up a water molecule?
   b. **Describing** Describe the electric charge on each end of a water molecule.
   c. **Relating Cause and Effect** What causes water molecules to be attracted to one another?
2. a. **Listing** Name four unusual properties that water exhibits.
   b. **Explaining** Briefly explain why water exhibits each property.
   c. **Predicting** Oil is a nonpolar molecule. Would it dissolve in water? Why or why not?
3. a. **Identifying** What are the three states in which water exists on Earth?
   b. **Sequencing** Describe how water changes state as a patch of ice is heated by the sun.

Lab zone At-Home Activity

Observing Water's Properties Put a penny on a piece of paper. With a plastic dropper or a toothpick, have a family member place a single drop of water on the penny. Ask the person to predict how many more drops he or she can add before the water spills off the penny. Have the person add drops one at a time until the water overflows. How does the result differ from the prediction? Explain what property of water accounts for the results.

Section 2

Floating and Sinking

Reading Preview

Key Concepts

- What is the effect of the buoyant force?
- How can you use density to determine whether an object will float or sink in a fluid?

Key Terms

- buoyant force
- Archimedes' principle
- density

Target Reading Skill

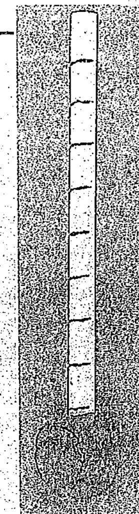
Relating Cause and Effect
As you read, identify the reasons why an object sinks. Write the information in a graphic organizer like the one below.

Causes
- Weight is greater than buoyant force
-
-

Effect
- Object sinks

Lab zone Discover Activity

What Can You Measure With a Straw?



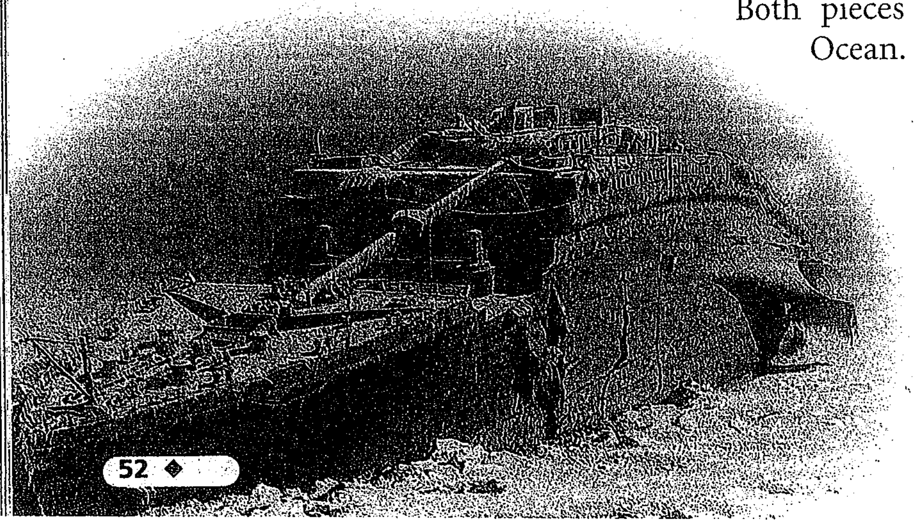
1. Cut a plastic straw to a 10-cm length.
2. Use a waterproof marker to make marks on the straw that are 1 cm apart.
3. Roll some modeling clay into a ball about 1.5 cm in diameter. Stick one end of the straw in the clay. You have built a device known as a hydrometer.
4. Place the hydrometer in a glass of water. About half of the straw should remain above water. If it sinks, remove some of the clay. Make sure no water gets into the straw.
5. Dissolve 10 spoonfuls of sugar in a glass of water. Try out your hydrometer in this liquid.

Think It Over

Predicting Compare your observations in Steps 4 and 5. Then predict what will happen if you use 20 spoonfuls of sugar in a glass of water. Test your prediction.

In April 1912, the *Titanic* departed from England on its first and only voyage. At the time, it was the largest ship afloat—nearly three football fields long. The *Titanic* was also the most technologically advanced ship in existence. Its hull was divided into compartments, and it was considered to be unsinkable.

Yet a few days into the voyage, the *Titanic* struck an iceberg. One compartment after another filled with water. Less than three hours later, the bow of the great ship slipped under the waves. As the stern rose high into the air, the ship broke in two. Both pieces sank to the bottom of the Atlantic Ocean. More than a thousand people died.



◁ **The bow section of the *Titanic* resting on the ocean floor**

Buoyancy

Ships are designed to have buoyancy—the ability to float. How is it possible that a huge ship can float easily in water under certain conditions, and then in a few hours become a sunken wreck? To answer this question, you need to understand the buoyant force.

Gravity and the Buoyant Force You have probably experienced the buoyant force. If you have ever picked up an object under water, you know that it seems much lighter in water than in air. Water and other fluids exert an upward force called the **buoyant force** that acts on a submerged object. **The buoyant force acts in the direction opposite to the force of gravity, so it makes an object feel lighter.**

As you can see in Figure 6, a fluid exerts pressure on all surfaces of a submerged object. Since the pressure in a fluid increases with depth, the upward pressure on the bottom of the object is greater than the downward pressure on the top. The result is a net force acting upward on the submerged object. This is the buoyant force.

Remember that the weight of a submerged object is a downward force. An object sinks if its weight is greater than the buoyant force because a net force acts downward on the object. If the weight of a submerged object is equal to the buoyant force, no net force acts on the object. The object floats while either partly submerged or totally submerged, depending on its weight. For example, both the jellyfish and the turtle shown in Figure 7 have balanced forces acting on them.

FIGURE 6
Buoyant Force
The pressure on the bottom of a submerged object is greater than the pressure on the top. The result is a net force in the upward direction.

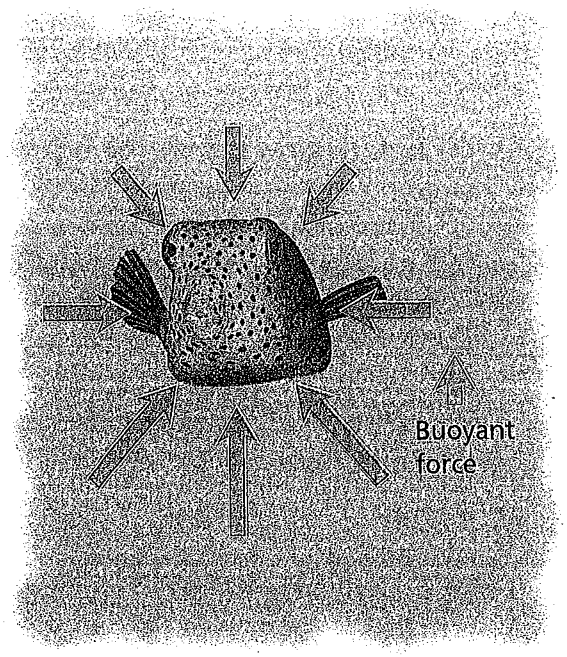


FIGURE 7
Buoyant Force and Weight
The weight of an object is a force that works opposite the buoyant force on the object. **Comparing and Contrasting** *Why don't all three creatures float?*

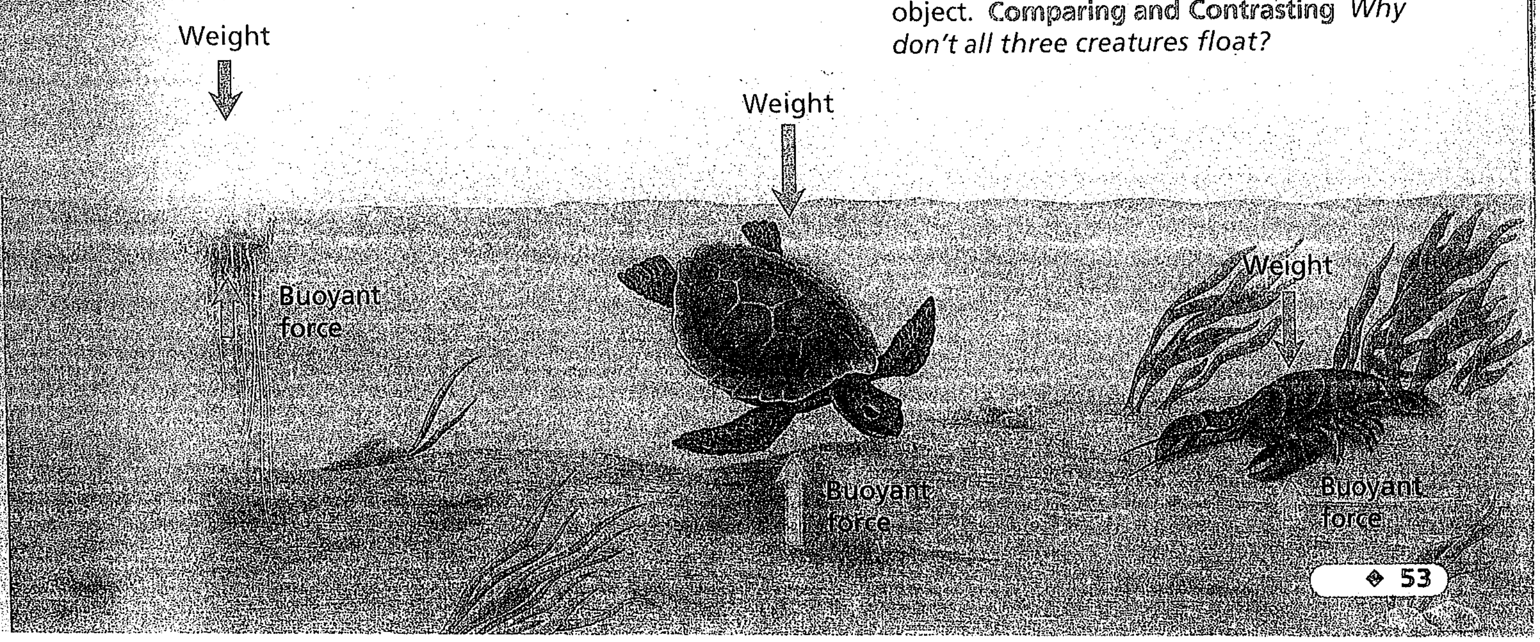
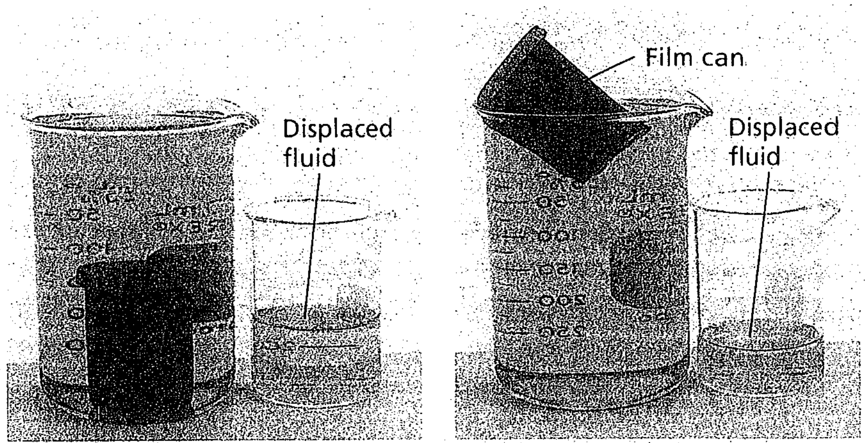


FIGURE 8
Archimedes' Principle
Archimedes' principle applies to both sinking and floating objects.
Predicting *If you press down on the floating film can, what will happen to the volume of the displaced fluid in the small beaker?*



Sinking
When the film can has film in it, it sinks. The volume of fluid displaced by the can is equal to the volume of the can.

Floating
When the film can is empty, it floats. The volume of displaced fluid is equal to the volume of the submerged portion of the can.

Archimedes' Principle You know that all objects take up space. A submerged object displaces, or takes the place of, a volume of fluid equal to its own volume. A partly submerged object, however, displaces a volume of fluid equal to the volume of its submerged portion only. You can see this in Figure 8.

Archimedes, a mathematician of ancient Greece, discovered a connection between the weight of a fluid displaced by an object and the buoyant force acting on it. This connection is known as Archimedes' principle. **Archimedes' principle** states that the buoyant force acting on a submerged object is equal to the weight of the fluid the object displaces. To understand what this means, think about swimming in a pool. Suppose your body displaces 50 liters of water. The buoyant force exerted on you will be equal to the weight of 50 liters of water, or about 500 N.

You can use Archimedes' principle to explain why a ship floats. Since the buoyant force equals the weight of the displaced fluid, the buoyant force will increase if more fluid is displaced. A large object displaces more fluid than a small object. Therefore, a greater buoyant force acts on the larger object—even if the large object has the same weight as the small object.

Look at Figure 9. The shape of a ship's hull causes the ship to displace a greater volume of water than a solid piece of steel with the same mass. A ship displaces a volume of water equal in weight to the submerged portion of the ship. According to Archimedes' principle, the weight of the displaced water is equal to the buoyant force. Since a ship displaces more water than a block of steel, a greater buoyant force acts on the ship. A ship floats as long as the buoyant force acting on it is equal to its weight.

Discovery Channel School

Forces in Fluids

Video Preview
▷ Video Field Trip
Video Assessment

Reading Checkpoint **Does a greater buoyant force act on a large object or a small object?**

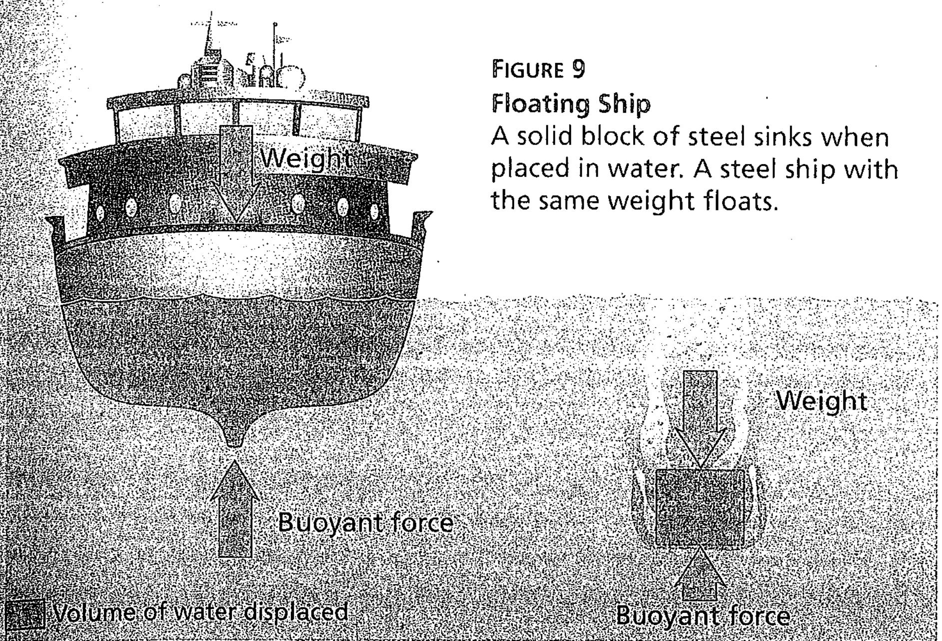


FIGURE 9
Floating Ship
A solid block of steel sinks when placed in water. A steel ship with the same weight floats.

Density

Exactly why do some objects float and others sink? To find the answer, you must relate an object's mass to its volume. In other words, you need to know the object's density.

What Is Density? The **density** of a substance is its mass per unit volume.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

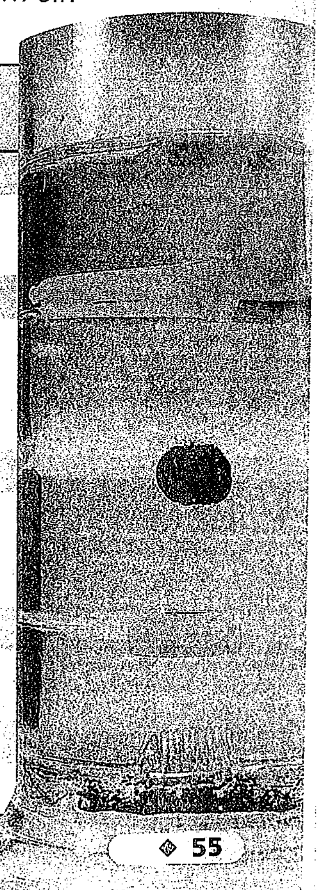
For example, one cubic centimeter (cm^3) of lead has a mass of 11.3 grams, so its density is 11.3 g/cm^3. In contrast, one cubic centimeter of cork has a mass of only about 0.25 gram. So the density of cork is about 0.25 g/cm^3. Lead is more dense than cork. The density of water is 1.0 g/cm^3. So water is less dense than lead but more dense than cork.

Comparing Densities of Substances In Figure 10, several liquids and other materials are shown along with their densities. Notice that liquids can float on top of other liquids. (You may have seen salad oil floating on top of vinegar.) The liquids and materials with the greatest densities are near the bottom of the cylinder.

By comparing densities, you can predict whether an object will float or sink in a fluid. An object that is more dense than the fluid in which it is immersed sinks. An object that is less dense than the fluid in which it is immersed floats to the surface. And if the density of an object is equal to the density of the fluid in which it is immersed, the object neither rises nor sinks in the fluid. Instead, it floats at a constant depth.

FIGURE 10
Densities of Substances
You can use density to predict whether an object will sink or float when placed in a liquid. **Interpreting Data** *Will a rubber washer sink or float in corn oil?*

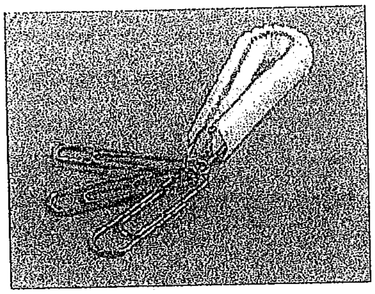
Substance	Density (g/cm^3)
Wood	0.7
Corn oil	0.925
Plastic	0.93
Water	1.00
Tar ball	1.02
Glycerin	1.26
Rubber washer	1.34
Corn syrup	1.38
Copper wire	8.8
Mercury	13.6



Lab zone **Try This Activity**

Cartesian Diver

1. Fill a plastic jar or bottle almost completely with water.



2. Bend a plastic straw into a U shape and cut the ends so that each side is 4 cm long. Attach the ends with a paper clip. Drop the straw in the jar, paper clip first.
3. Attach more paper clips to the first one until the straw floats with its top about 0.5 cm above the surface. This is the diver.
4. Put the lid on the jar. Observe what happens when you slowly squeeze and release the jar several times.

Drawing Conclusions Explain the behavior of the Cartesian diver.

Changing Density Changing density can explain why an object floats or sinks. For example, you can change the density of water by freezing it into ice. Since water expands when it freezes, ice occupies more space than water. That's why ice is less dense than water. But it's just a little less dense! So most of a floating ice cube is below the water's surface. An iceberg like the one shown in Figure 11 is really a very large ice cube. The part that you see above water is only a small fraction of the entire iceberg.

You can make an object sink or float in a fluid by changing its density. Look at Figure 12 to see how this happens to a submarine. The density of a submarine is increased when water fills its flotation tanks. The overall mass of the submarine increases. Since its volume remains the same, its density increases when its mass increases. So the submarine will dive. To make the submarine float, water is pumped out of it, decreasing its mass. In this way, its density decreases, and it rises toward the surface.

You can also explain why a submarine dives and floats by means of the buoyant force. Since the buoyant force is equal to the weight of the displaced fluid, the buoyant force on the submerged submarine stays the same. Changing the water level in the flotation tanks changes the weight of the submarine. The submarine dives when its weight is greater than the buoyant force. It rises to the surface when its weight is less than the buoyant force.

Don't forget that air is also a fluid. If you decrease the density of an object, such as a balloon, the object will float and not sink in air. Instead of air, you can fill a balloon with helium gas. A helium balloon rises because helium is less dense than air. A balloon filled with air, however, is denser than the surrounding air because the air inside it is under pressure. The denser air inside, along with the weight of the balloon, make it fall to the ground.

Reading Checkpoint **Why does a helium balloon float in air?**

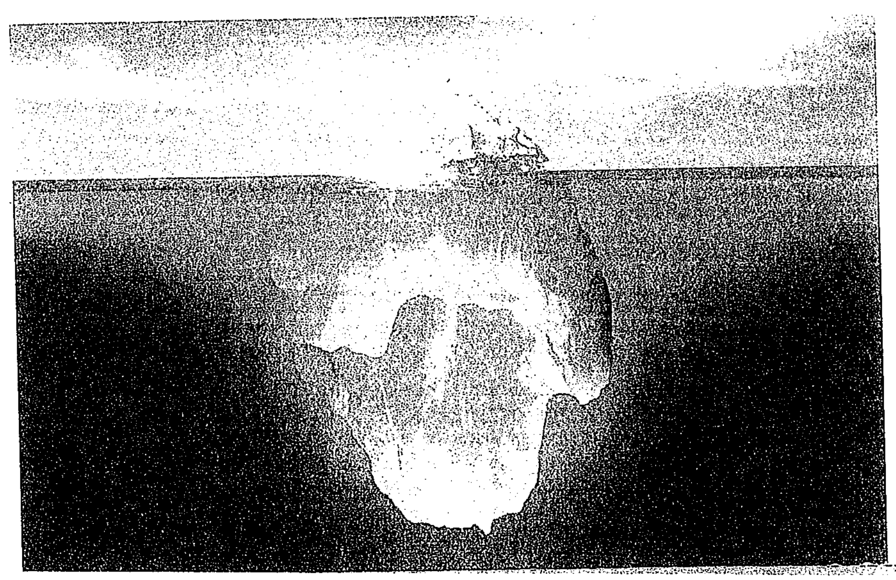


FIGURE 11
Iceberg
An iceberg is dangerous to ships because most of it is under water.

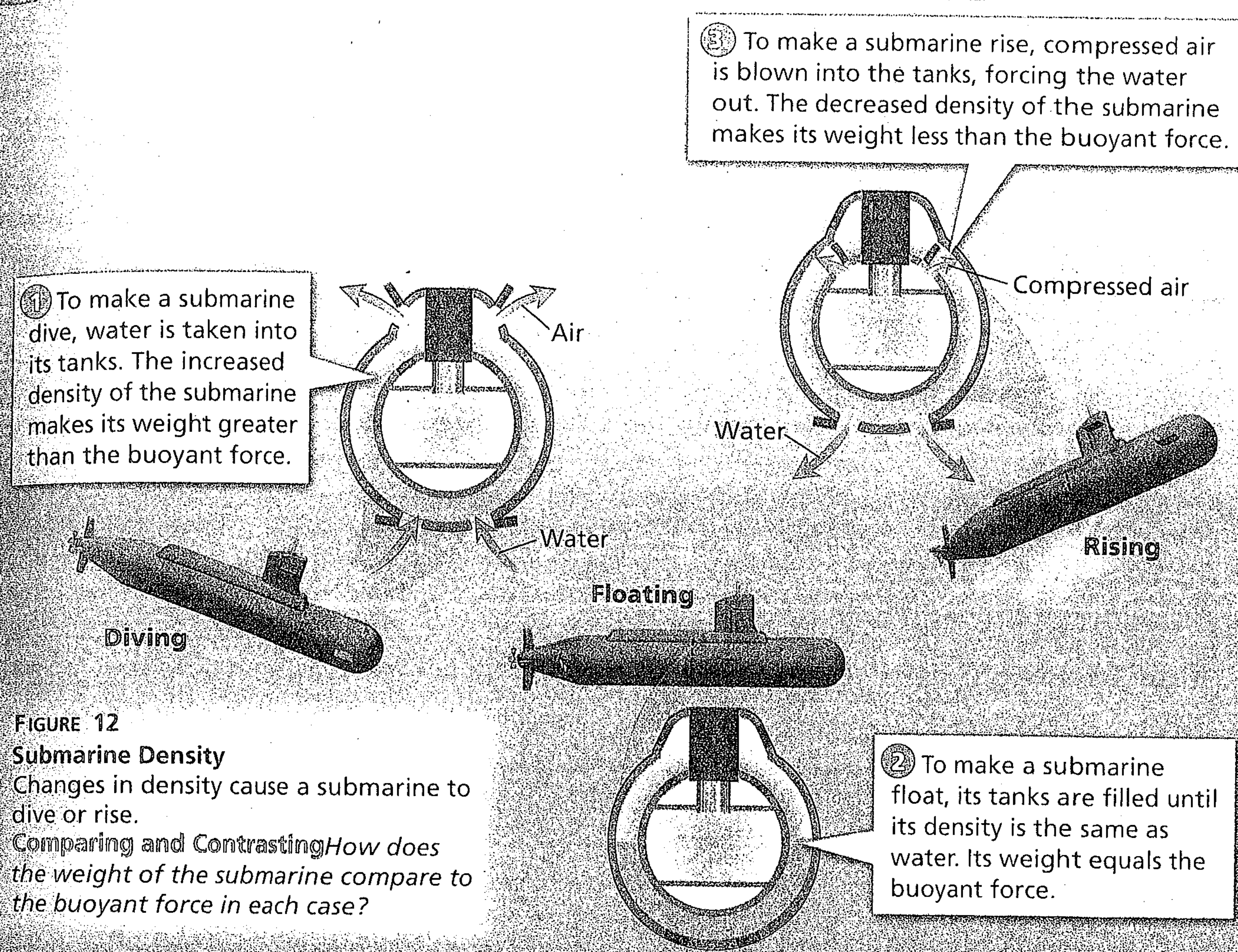


FIGURE 12
Submarine Density
Changes in density cause a submarine to dive or rise.
Comparing and Contrasting *How does the weight of the submarine compare to the buoyant force in each case?*

Section 2 Assessment

Target Reading Skill

Relating Cause and Effect Refer to your graphic organizer to help you answer the questions below.

Reviewing Key Concepts

1. a. **Explaining** How does the buoyant force affect a submerged object?
   b. **Summarizing** How does Archimedes' principle relate the buoyant force acting on an object to the fluid displaced by the object?
   c. **Calculating** An object that weighs 340 N floats on a lake. What is the weight of the displaced water? What is the buoyant force?
2. a. **Defining** What is density?
   b. **Explaining** How can you use the density of an object to predict whether it will float or sink in water?
   c. **Applying Concepts** Some canoes have compartments on either end that are hollow and watertight. These canoes won't sink, even when they capsize. Explain why.

Lab zone At-Home Activity

Changing Balloon Density Attach paper clips to the string of a helium balloon. Ask a family member to predict how many paper clips you will need to attach to make the balloon sink to the floor. How many paper clips can you attach and still keep the helium balloon suspended in the air? Explain how adding paper clips changes the overall density of the balloon.