Section 1
Fluids and Pressure

Key Concept Fluid is a nonsolid state of matter. All fluids can flow and exert pressure evenly in all directions.

What You Will Learn
- Pressure is the amount of force exerted on a given area.
- Fluid pressure increases as depth increases.
- Density is mass per unit volume. Because water is denser than air, water exerts more pressure than air does.
- Fluids flow from areas of high pressure to areas of low pressure.

Why It Matters
Differences in pressure are important in explaining how you breathe.

You have something in common with a dog, a sea gull, and a dolphin. You and all of these other living things spend a lifetime moving through fluids. A **fluid** is any material that can flow and that takes the shape of its container. Liquids and gases are fluids. For example, you could fill a fishbowl with water or with air. Each would take the shape of the bowl. Fluids can flow because the particles in fluids move past one another easily.

Fluids and Pressure
You have probably heard the terms *air pressure* and *water pressure.* Air and water are both fluids. All fluids exert pressure. So, what is pressure? When you pump up a bicycle tire, you push air into the tire. And like all matter, air is made of tiny particles that are constantly moving. Look at **Figure 1.** Inside the tire, the air particles bump against one another and against the walls of the tire. The bumping of particles creates a force on the tire. The amount of force exerted on a given area is **pressure.** So, any force, such as the weight of an object, acting on an area creates pressure.

Figure 1 The force of the air particles hitting the inner surface of the tire creates pressure, which keeps the tire inflated.

Calculating Pressure

Pressure can be calculated by using the following equation:

$$pressure = \frac{force}{area}$$

The SI unit for pressure is the **pascal**. One pascal (1 Pa) is the force of one newton exerted over an area of one square meter (1 N/m^2).

[redacted]

Pressure and Bubbles

When you pour a carbonated liquid into a glass, you can see gas bubbles in the liquid. Why are the bubbles round? The shape of the bubbles depends partly on an important property of fluids: Fluids exert pressure evenly in all directions. The gas in the bubble exerts pressure evenly in all directions. So, the bubble expands in all directions to make a round shape.

Atmospheric Pressure

The *atmosphere* is the layer of nitrogen, oxygen, and other gases that surrounds Earth. Earth's atmosphere is held in place by gravity, which pulls the gases toward Earth. The pressure caused by the weight of the atmosphere is called **atmospheric pressure.**

Atmospheric pressure is exerted on everything on Earth, including you. At sea level, the atmosphere exerts a pressure of about 101,300 N on every square meter, or 101,300 Pa. So, there is a weight of about 10 N (about 2 lb) on every square centimeter of your body. Why don't you feel this crushing pressure? Like the air inside a balloon, the fluids inside your body exert pressure. This pressure inside your body acts against the atmospheric pressure. **Figure 2** can help you understand why you don't feel the pressure.

Figure 2 The air inside a balloon exerts pressure that keeps the balloon inflated against atmospheric pressure. Similarly, fluid inside your body exerts pressure that acts against atmospheric pressure.

[redacted]

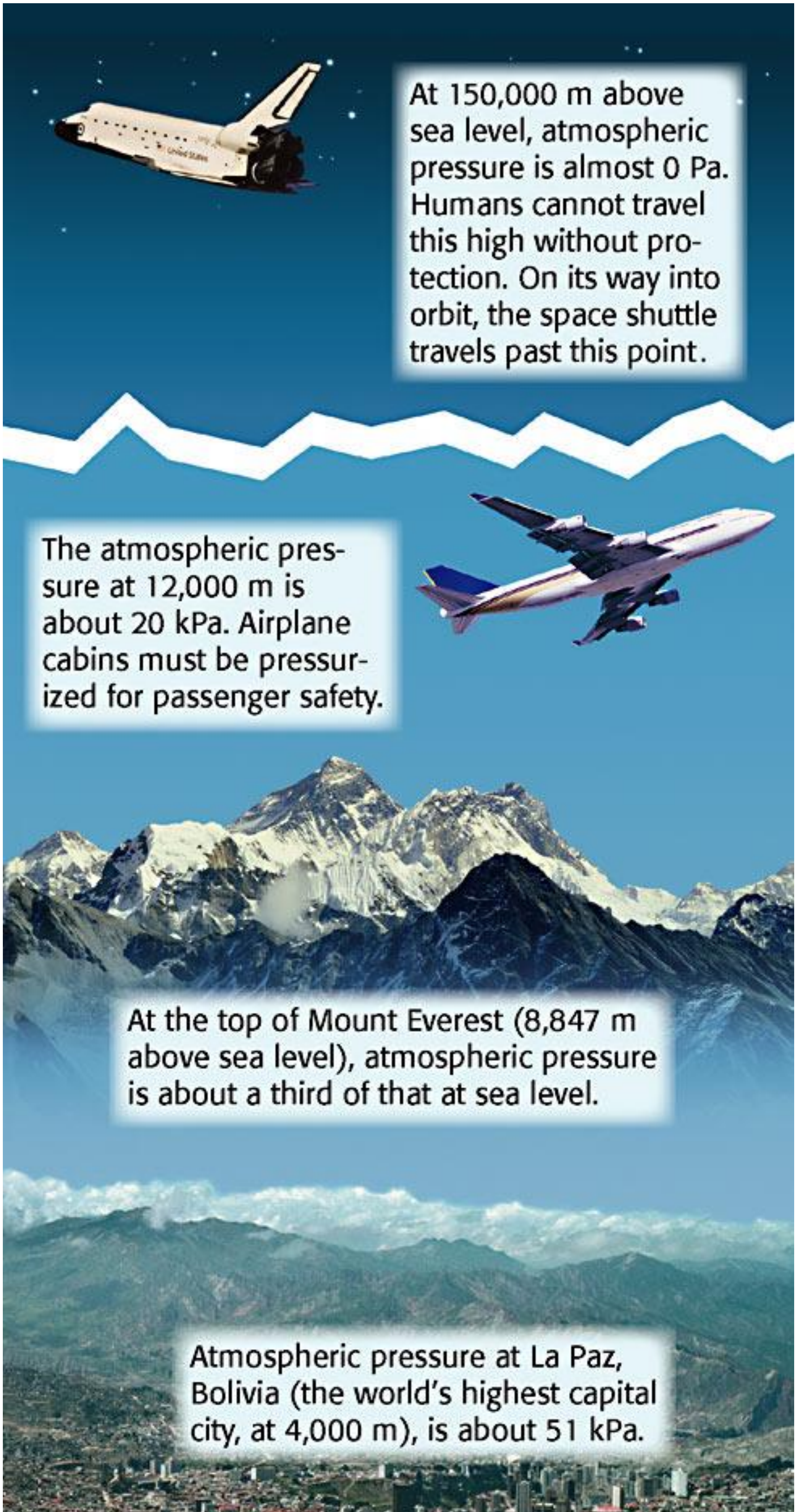
Variation of Atmospheric Pressure

The atmosphere stretches about 150 km above Earth’s surface. However, about 80% of the atmosphere’s gases are found within 10 km of Earth’s surface. At the top of the atmosphere, pressure is almost non existent. The pressure is close to 0 Pa because there are fewer gas particles and they rarely collide. The small number of gas particles is one of the reasons it is harder to breathe at high altitudes. There isn’t as much air! Mount Everest in south- central Asia is the highest point on Earth. At the top of Mount Everest, atmospheric pressure is about 33,000 Pa, or 33 kilo pascals (33 kPa). People who climb Mount Everest bring oxygen tanks to help them breathe at that altitude. At sea level, atmospheric pressure is about 101 kPa.

Atmospheric Pressure and Depth

Take a look at **Figure 3.** Notice how atmospheric pressure changes as you travel through the atmosphere. As you travel farther down into Earth's atmosphere, pressure increases. In other words, the pressure increases as the atmosphere gets "deeper." An important point to remember about fluids is that pressure varies depending on depth. At lower levels of the atmosphere, more fluid from above is being pulled by Earth's gravitational force. So, there is more pressure at lower levels of the atmosphere.

Figure 3 Differences in Atmospheric Pressure


At 150,000 m above sea level, atmospheric pressure is almost 0 Pa. Humans cannot travel this high without protection. On its way into orbit, the space shuttle travels past this point.
The atmospheric pressure at 12,000 m is about 20 kPa. Airplane cabins must be pressurized for passenger safety.
At the top of Mount Everest (8,847 m above sea level), atmospheric pressure is about a third of that at sea level.
Atmospheric pressure at La Paz, Bolivia (the world's highest capital city, at 4,000 m), is about 51 kPa.

Water Pressure

Water is a fluid. So, like the atmosphere, water exerts pressure. Also, water pressure increases as depth increases, as shown in **Figure 4.** As a diver goes deeper into the water, pressure increases. The pressure increases because more water above the diver is being pulled by Earth's gravitational force. Also, the atmosphere presses down on the water. So the total pressure on the diver includes water pressure and atmospheric pressure.

Figure 4 Differences in Water Pressure

Pressure exerted on a diver 10 m below the water's surface is twice the pressure at the surface.

At 500 m below the surface, pressure is about 5,000 kPa. Divers at or below this level must wear special suits to survive the pressure.

The wreck of the *Titanic* is 3,660 m below the surface. The water pressure at this depth is 36,600 kPa.

The viper fish lives 8,000 m below the ocean's surface. No fish are found below this level. Water pressure at this depth is 80,000 kPa.

In 1960, the *Trieste* descended to the deepest part of the ocean (11,000 m), where the pressure is 110,000 kPa.

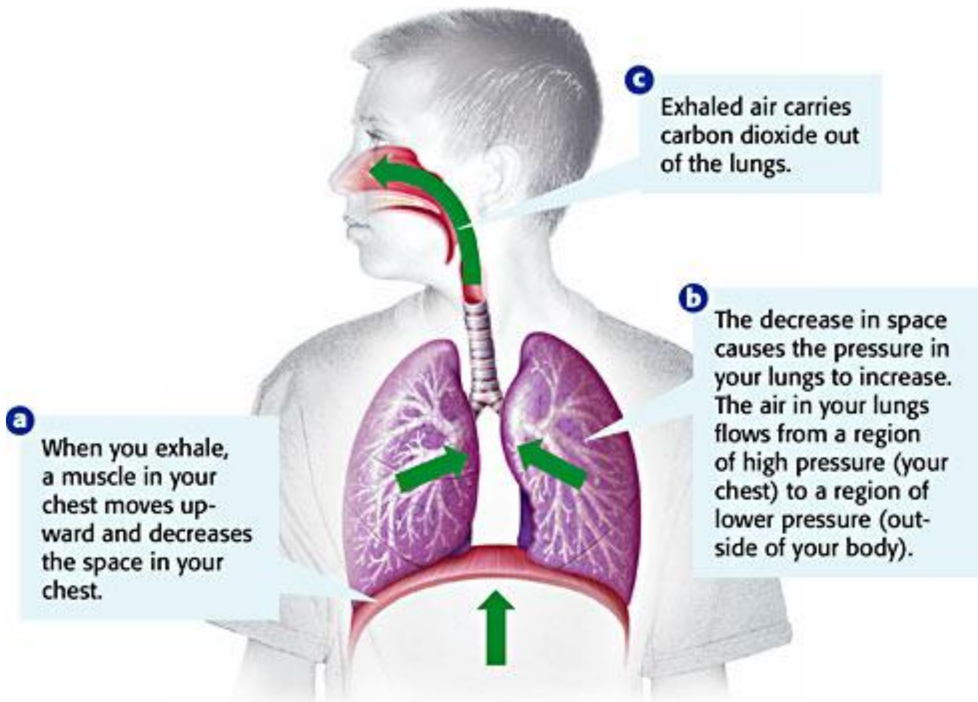
Pressure Differences and Fluid Flow

When you drink through a straw, you remove some of the air in the straw. Because there is less air inside the straw, the pressure in the straw is reduced. But the atmospheric pressure on the surface of the liquid remains the same. Thus, there is a difference between the pressure inside the straw and the pressure outside the straw. The outside pressure forces the liquid up the straw and into your mouth. So, just by drinking through a straw, you can observe an important property of fluids: Fluids flow from areas of high pressure to areas of low pressure.

Pressure Differences and Breathing

Take a deep breath—fluid is flowing from high to low pressure! When you inhale, a muscle moves down in your chest. This movement makes the space in your chest bigger. So your lungs have room to expand. This expansion lowers the pressure in your lungs. The pressure in your lungs becomes lower than the air pressure outside your lungs. Then air flows into your lungs—from high to low pressure. **Figure 5** shows the reverse process when you exhale. Exhaling also causes fluids to flow from high to low pressure. When you exhale, the air in your lungs flows out from a region of high pressure (inside your chest) to a region of lower pressure (outside your body).

Figure 5 Exhaling, Pressure, and Fluid Flow



[redacted]

Pressure Differences and Tornadoes

Look at the tornado in **Figure 6.** Some of the damaging winds caused by tornadoes are the result of pressure differences. The air pressure inside a tornado is very low. Because the air pressure outside the tornado is higher than the pressure inside, air rushes into the tornado. The rushing air causes objects to be pushed into the tornado as though the tornado were a giant vacuum cleaner. The winds are usually very strong and affect the area around the tornado. So sometimes, the winds damage trees and buildings that are not even in the direct path of the tornado.

Figure 6 Pressure differences in tornadoes make tornadoes like giant vacuum cleaners.

Section Summary

- A fluid is any material that flows and that takes the shape of its container.
- Pressure is the amount of force exerted on a given area.
- Moving particles of matter create pressure by colliding with one another and with the walls of their container.
- Atmospheric pressure is the pressure caused by the weight of the atmosphere.
- Fluid pressure increases as depth increases.
- Because water is denser than air, water exerts more pressure than air does.
- Fluids flow from areas of high pressure to areas of low pressure.