CHAPTER

6

# Fluids and Living Things

## KEY IDEAS

- Fluids are important in natural and human-made systems.
- The human circulatory system is a hydraulic system.
- The human respiratory system is a pneumatic system.
- Human activities affect natural fluid systems.

### LEARNING TIP

Read the Key Ideas. This will give you specific information that you should pay attention to. Ask yourself, "What do I already know about the topic?"

Have you ever wondered what it would be like to live like a fish, completely surrounded by a fluid? Actually, you do live like that. You live in a fluid, only you cannot see it. This fluid is Earth's atmosphere. Like a water environment, it is all around you, providing you with a very essential fluid—oxygen. Earth's atmosphere also supplies plants with the carbon dioxide their cells need for photosynthesis. There is another fluid that both you and plants need for survival—water. Most living things cannot exist without these fluids. That is why the health of Earth's fluid systems is so important for the survival of all species.

Do fluids function in living things the same way they function in systems people create? How do changes in the properties of fluids and fluid systems affect living things? How do living things, particularly humans, affect natural fluid systems? In this chapter, you will explore the similarities between natural and human-made fluid systems. You will examine how humans and other organisms affect and are affected by natural fluid systems.

# From Bladders to Ballast: Altering Buoyancy

6.1

Fish and some aquatic plants have adaptations that alter their buoyancy in water (**Figure 1**). Similarly, design features of ships, submarines, hot-air balloons, and scuba equipment alter their buoyancy, allowing them to move vertically in water or air. Natural and engineered methods of altering buoyancy have many similarities.

**Figure 1**
Bladders filled with air enable seaweed to stay upright under water.

## Nature's Method

Fish control their depth in water by using swim bladders that contain air (**Figure 2**). They can get more gas into their swim bladders either by gulping air at the surface of the water or by releasing dissolved gases from their blood.


**Figure 2**
Swim bladder in a fish

## The Human Method

The human body has an overall density that is very close to that of water. A relaxed swimmer with filled lungs is positively buoyant when immersed in water. Wearing a wet suit further increases buoyancy. Scuba divers wear weight belts to give them more density and less buoyancy (**Figure 3**).

**Figure 3**
Without weight belts, the diver would find it hard to go below the surface of the water.

Scuba divers might also wear buoyancy compensator vests to alter their buoyancy in the water. If a diver wants to sink down, she releases air from the vest, thus making herself more dense. Buoyancy compensator vests also enable divers to stop descending and become neutrally buoyant. A diver can blow air into the vest to decrease her density and increase her buoyancy to swim back to the surface.

## Controlling Ballast

**Ballast** is any material carried on ships, submarines, hot-air balloons, or dirigibles (air ships or blimps) that acts as weight and alters buoyancy. Ballast helps a vessel to be stable and travel at the appropriate level in a fluid. Tanks of water often provide ballast for ships and submarines. In a hot-air balloon or dirigible, the ballast may be sand or water.

A fully loaded ship floats lower in the water and is more stable than an empty one. When a ship unloads its cargo, water is taken in as ballast to maintain stability in the water. When the ship takes on a new cargo, it pumps out the water it was using as ballast.

Hot-air balloons and dirigibles are immersed in air. They use ballast to control their buoyancy. The weight of the fuel and passengers is calculated before deciding how much ballast is needed. Once in flight, the crew can increase buoyancy in one of two ways. The crew can increase the volume of gas in the balloon by heating the air or adding more helium. Alternatively, the crew can release some of the ballast. To

decrease buoyancy, the crew has to reduce the volume of the gas (by letting it cool or releasing some of it) or pick up more ballast (perhaps by scooping water from a lake using a bucket on a long rope).

Similarly, a submarine descends if its ballast tanks are filled with water (**Figure 4**). When the submarine reaches the desired level, some of the water in the ballast tanks is pumped out, to be replaced with air. This continues until the submarine stops sinking and becomes neutrally buoyant. To make the submarine surface, or float at a higher level, some of the water in the ballast tanks is replaced with air.

**Figure 4**
Changing the amount of water in its ballast tanks makes a submarine sink or rise.

## 6.1 CHECK YOUR UNDERSTANDING

**1.** (a) By expanding and contracting their swim bladders, fish can change their level in the water. How does this enable fish to become more or less buoyant?

(b) Speculate why fish need to descend or rise to different water levels.

(c) How would an adaptation such as air bladders benefit seaweed?

**2.** In what ways are fish bladders and buoyancy compensator vests similar?

**3.** Where might the air come from to replace the water that is pumped out of a submarine's ballast tanks?

**4.** If the force of gravity (weight) on a scuba diver is 600 N, what should the buoyant force be if the diver wants to

(a) descend?

(b) rise to the surface?

**5.** You are asked to add ballast to a helium-filled balloon until it will float in the centre of a room.

(a) What could you use as ballast?

(b) How would you describe the balloon when it is floating in the centre of the room?

(c) What happens if you add or remove some ballast?

### LEARNING TIP

Writing helps you think back on your reading. In your notebook, summarize in your own words what you have read in Section 6.1.

### PERFORMANCE TASK

If you want a device to move up or down in water or air, the buoyant force needs to be altered. How might this information help you with the Performance Task?

# 6.2 Explore an Issue

DECISION-MAKING SKILLS

- Defining the Issue
- Researching
- Identifying Alternatives
- Analyzing the Issue
- Defending a Decision
- Communicating
- Evaluating

## The Human Impact on Natural Fluid Systems

Earth is surrounded by fluids. These fluids are the water we drink and the air we breathe. Healthy fluid systems are necessary for the survival of natural ecosystems and for human health. As well, many economic activities such as fishing, shipping, and tourism depend on these fluid systems. We must manage Earth's fluid systems in a way that benefits the environment, the economy, and society. Despite their importance, these fluid systems have been abused and neglected.

### The Issue: Ballast Water Management

Each year, ships from around the world arrive in Canadian harbours. These ships carry everything from raw materials, such as grain and oil, to electronic products and automobiles. In each port where they unload cargo, these ships take in water for ballast. When they load cargo in the next port, they pump out the water (**Figure 1**).

**Figure 1**
Ballast water that is discharged from ships can contain plant and animal species.

**Figure 2**
Eurasian water milfoil was introduced to North America around 1940. It is an aggressive invader that quickly clogs waterways and competes with native aquatic plants.

The problem is that the dumped ballast can contain more than just water. It can contain living things from other parts of the world, which are not normally found in Canadian waters. These are referred to as **exotic species**. They are also sometimes called invasive, non-native, or alien species. Exotic species include species of plants (especially algae), fish, and microscopic organisms (**Figure 2**).

When conditions are favourable, exotic species can multiply rapidly in their new environment. Usually they have no natural predators, so

their growth can go unchecked for years—until a predator develops or a method of control is found.

Exotic species that may have been brought to British Columbia in ballast water include the European green crab, the mitten crab, and Japanese eel grass. They may prey on native species or compete with native populations for food and shelter, upsetting the balance of the ecosystem. This is a concern because fish are an important source of food, recreation, and income for British Columbians.

## Statement

Action should be taken to stop the introduction of exotic species into Canadian water by contaminated ballast water.

## Background to the Issue

It is thought that the European green crab (**Figure 3**) was introduced by ship's ballast to the San Francisco estuary around 1989. It has now spread north up the coast and has been found in Barkley Sound and Esquimalt Harbour in British Columbia. The green crab is very adaptable and easily establishes populations in new areas. It is also a very good predator and feeds on clams, oysters, mussels, and small crustaceans. The green crab is likely to impact any ecosystem that it is introduced to. It can out-compete and possibly eliminate other species of crab from an area. Because of its sources of food, the green crab is in direct competition with commercial fishers who harvest these food sources for a living.

**Figure 3**
The European green crab is a threat to native oysters and clams because it eats large numbers of their young.

## Make a Decision

1. Read the sample stakeholder opinions and evaluate each one.
2. Record the main ideas under appropriate headings in a table. Add your own ideas under these headings, as well.
3. In your group, decide on a position on the issue, and prepare arguments to defend your position.

**LEARNING TIP**

For help with the Explore an Issue, see "Making a Decision" and "Communicating Your Decision" in the Skills Handbook section **Exploring an Issue**.

## Sample Stakeholder Opinions

### Fisher

The introduction of the green crab and other exotic species can seriously affect the marine ecosystem along the West Coast. The green crab feeds on the species that we depend on for our livelihood—clams, oysters, and mussels. Something must be done to prevent the introduction of these species and to prevent the spread of the populations to new areas.

### Port Official

Ships are designed to float at a certain depth, so they have to carry ballast when they have no cargo and empty the ballast when they load cargo. If Canadian ports make too great a demand on shipping companies, these companies will go to other ports. Thousands of Canadian jobs will be lost, and the cost of shipping to and from Canada will increase. Canadian consumers will have to pay more.

### An Ecologist

In most cases, exotic species cannot compete with native species so we do not need to take any measures to prevent their introduction. If exotic species become established, the natural environment will eventually find a balance. Human activity caused the problem so humans should put up with the consequences.

### First Nations Community Leader

The introduction of an exotic species that feeds on shellfish is another threat to the shellfish industry in coastal British Columbia. The livelihood of First Nations groups who depend on the shell fishery is threatened. In many communities, the shell fishery is the main source of employment. First Nations people have detailed knowledge about their local ecosystems and can help to ensure that resources are managed properly. We also need to consider alternatives to the traditional wild fishery, such as the controlled farming of shellfish.

## Communicate Your Decision

4. Prepare a presentation for your class that summarizes your position on the issue. You may include a solution and explain how it addresses the concerns of the stakeholders and could reduce the impact of exotic species on the environment.

### 6.2 CHECK YOUR UNDERSTANDING

1. Do you think that the introduction of exotic species is harmful to the environment? Give reasons for your opinion.
2. What other stakeholders might be concerned about this issue? Briefly describe their opinions.
3. Think about how you arrived at the decision in your group.
   (a) What aspects of the decision-making process worked well?
   (b) What problems did you experience in reaching a decision?
   (c) What could you have done differently to make the decision-making process easier?

**PERFORMANCE TASK**

Are there any environmental concerns that you should keep in mind as you complete the Performance Task?

# Pressurized Fluid Systems: Hydraulics

6.3

Hydraulic systems use liquids under pressure to move many things. For example, huge amounts of soil at a construction site can be moved with hydraulic machinery, such as backhoes and excavators (**Figure 1**).

**Figure 1**
Hydraulics enable us to do work that could not be done easily with muscle power alone.

## What Makes Up a Hydraulic System?

The liquid in a hydraulic system is called the **hydraulic fluid**. The hydraulic fluid in the system in **Figure 2** is oil. Oil from the tank is sent along a conductor (a hose, tube, or pipe) to a pump, where it is pushed into a **cylinder**. The cylinder resembles a giant syringe. The oil pushes up the **piston** in the cylinder like a plunger moving inside a syringe. This upward movement of the piston can be used to do the work by moving something else.

**LEARNING TIP**

Diagrams play an important role in reader comprehension. As you study **Figure 2**, ask yourself, "What does this show?" Look at each part of the diagram to see how it relates to the other parts.

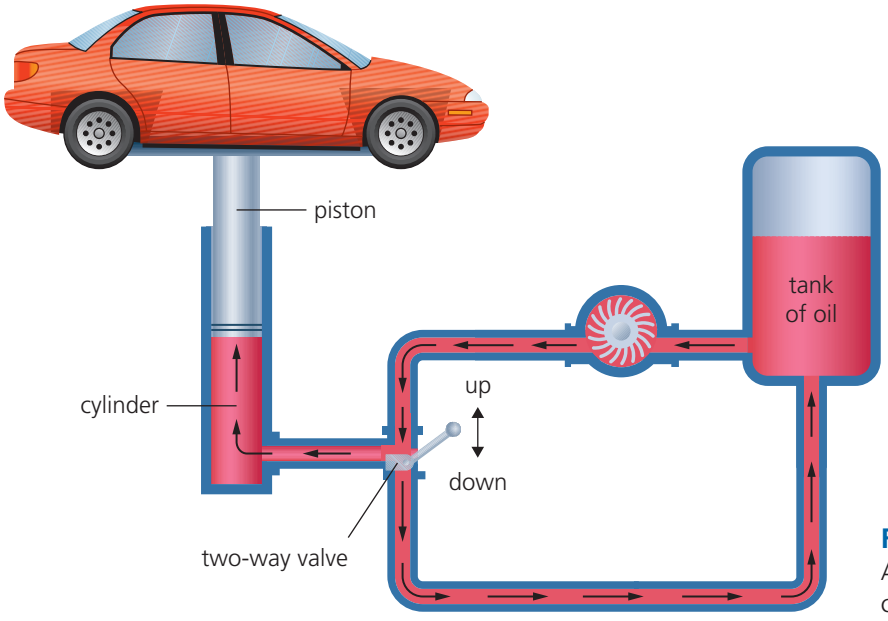
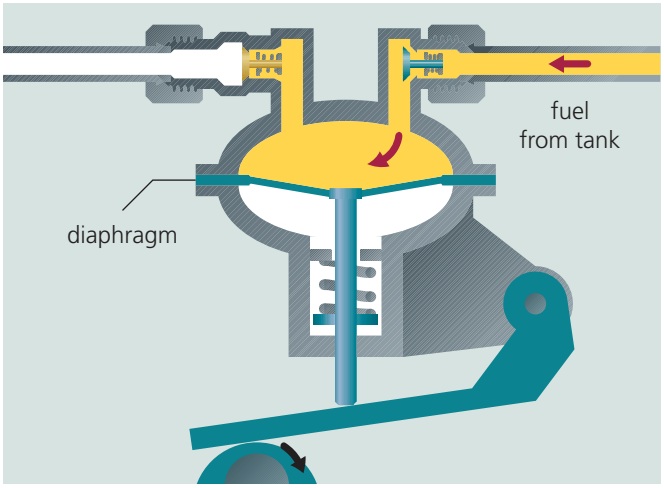



**Figure 2**
A hydraulic system, such as this car hoist, can be used to lift heavy weights.

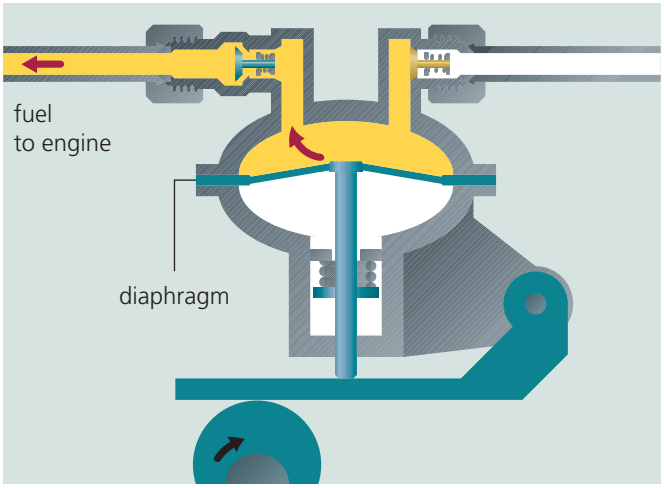
A two-way valve placed between the pump and the cylinder controls the flow of oil. In the "up" position, this valve allows the pump to force the fluid into the cylinder. This causes the piston to be moved a little or a lot. In the "down" position, the valve allows the oil to flow back into the storage tank, pushed by the weight of the piston and the vehicle. The fluid is circulated through the system and is not used up.

## Pumps and Valves

A pump is used to create a flow of fluid. A pump often makes fluids flow against gravity. Pumps are found in car engines, gasoline pumps at gas stations, dishwashers, and many other machines (**Figure 3**).




**(a)** In a car fuel pump, the diaphragm pulls down, allowing fuel to enter the pump chamber. Notice that the valve on the right is open and the valve on the left is closed.




**(b)** Fuel is pushed into the engine when the diaphragm pushes up. Now the valve on the right is closed and the valve on the left is open.

**Figure 3**

Valves control the flow of fluid. There are many different types of valves, but they all have a similar function: to keep a fluid flowing in the desired direction. When you turn on a water tap, you are opening up a valve. There are numerous places where valves are found, such as tires, soccer balls, and the human heart. Can you think of any other places?

## The Heart: A Hydraulic System

Your heart is also a pump (**Figure 4**). It beats over 100 000 times a day to push blood through the veins and arteries that make up your circulatory system. There are four chambers in the heart: right atrium, right ventricle, left atrium, and left ventricle (recall Section 3.2). The chambers in the upper part of the heart are separated from the chambers below by valves. The valves allow blood to flow in only one direction. Knowledge of how a fluid flows through valves was used to design artificial heart valves.

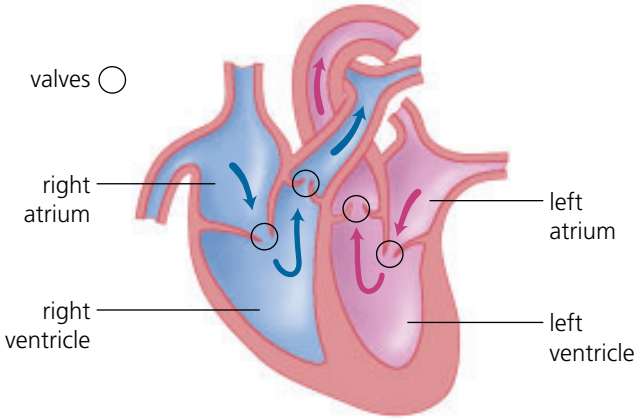



**Figure 4**
The heart is essentially a pump that pushes blood around the body. The valves prevent the blood from flowing backward in the system.

Blood pressure ensures that all of your organs receive blood. Blood pressure is measured with an instrument called a **sphygmomanometer** (**Figure 5**).

**Figure 5**
A sphygmomanometer is used to measure blood pressure.

### 6.3 CHECK YOUR UNDERSTANDING

1. List two industries that use hydraulic power.
2. What makes the fluid flow in a pressurized system? What controls this flow?
3. (a) What conductors can be used in a hydraulic system?
   (b) What conductors serve this function in the human circulatory system?
   (c) What conductors are found in a tree? What is the fluid that is being moved?
4. Use a Venn diagram to compare and contrast a car fuel pump with a human heart.

**PERFORMANCE TASK**

What conductors will you use to move the fluid in the Performance Task?

# 6.4 Pressurized Fluid Systems: Pneumatics

Like hydraulic systems, pneumatic systems possess a great deal of power that can be used to move objects or do other types of work.

## What Makes Up a Pneumatic System?

A pneumatic system is very similar to a hydraulic system (**Figure 1**). An air compressor provides the supply of air in a pneumatic system. Thus, the purpose of the air compressor is similar to that of the pump in a hydraulic system.

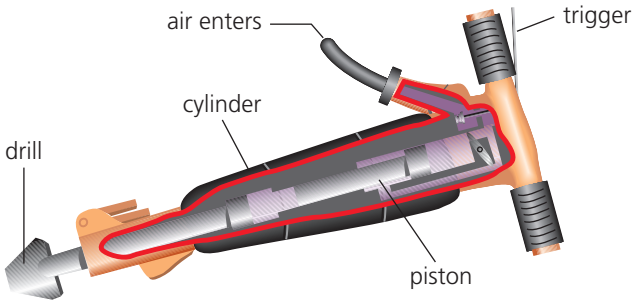



**Figure 1**
A jackhammer is a pneumatic drill. Compressed air moves a piston up and down, which moves the drill. This portable machine is used to break apart rocks and concrete.

Pneumatic systems are used in machinery such as air conditioning systems in aircraft and ejection seats in fighter planes. Pneumatic wrenches are used to remove or tighten nuts during a tire change. **Figure 2** shows a pneumatic drill in operation.

**Figure 2**
A pneumatic drill hammers away at concrete to break it up, ready for removal.

## The Lungs: A Pneumatic System

Your lungs operate like a pump (**Figure 3**). They draw in air with oxygen and push out air and extra carbon dioxide. They could not function without the diaphragm (recall Section 3.1). The diaphragm works in a similar way to the plunger in a syringe. When the diaphragm contracts, it becomes shorter and pulls away from the lungs. The volume of the lungs increases, and the pressure inside lowers. The air outside your body is then at a higher pressure than the air in your lungs. This causes air to rush in. To expel gas, the diaphragm pushes up, the pressure inside the lungs increases, and you exhale. About 1 L of air always remains in your lungs to prevent them from collapsing.

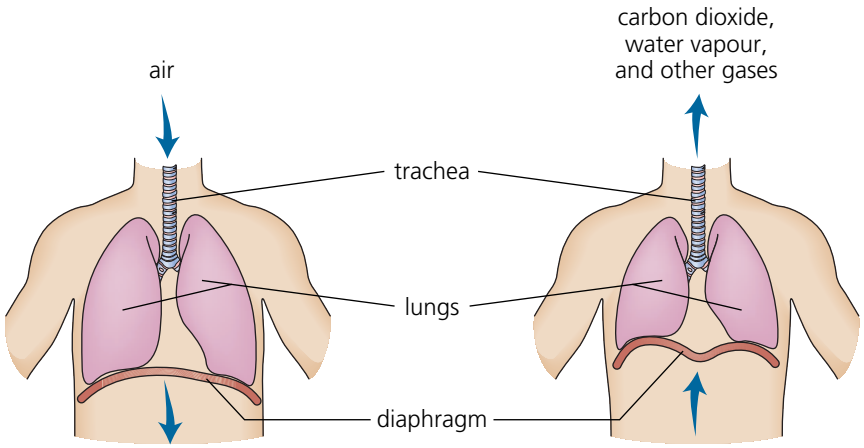



**Figure 3**
The diaphragm contracts when you breathe in and relaxes when you breathe out.

**LEARNING TIP**

Check your understanding as you read. Ask yourself, "What do I need to understand and remember about pneumatic systems?"

### 6.4 CHECK YOUR UNDERSTANDING

1. List machines other than a jack hammer that use pneumatic systems.
2. (a) How does the gas on top of the liquid in an aerosol can cause the liquid to come out of the spray nozzle?
   (b) Why are you asked to *shake* before spraying?
3. Use a Venn diagram to compare and contrast a car fuel pump with a human lung.
4. What is the purpose of a compressor in a pneumatic system?
5. Use the diagrams in **Figure 3** to explain the role of the diaphragm in breathing.

**LEARNING TIP**

For help with Venn diagrams, see **Using Graphic Organizers** in the Skills Handbook.

CHAPTER 6

# *Review* Fluids and Living Things

## Key Ideas

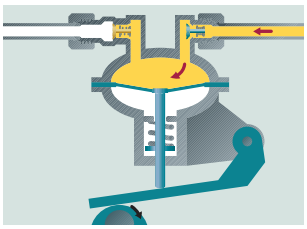
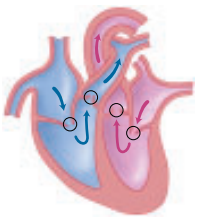
**Fluids are important in natural and human-made systems.**

- Water and air are two essential fluids that all living things depend on.
- Species that live in water control buoyancy to survive in their habitat.
- Human-made machines and devices such as submarines and hot-air balloons require buoyancy to function properly.
- The design of the buoyancy control system of a submarine is based on the buoyancy system in fish.



**The human circulatory system is a hydraulic system.**

- The liquid in a hydraulic system is called the hydraulic fluid.
- A piston in a cylinder of a hydraulic system transmits force that can do the work of moving an object.
- The heart in the human circulatory system acts like the pump in a hydraulic system, forcing the blood through a system of blood vessels.
- Valves in the heart keep blood flowing in one direction.
- Investigating fluid flow through valves helped scientists design artificial heart valves.

## Vocabulary

**ballast**, p. 170

**exotic species**, p. 172

**hydraulic fluid**, p. 175

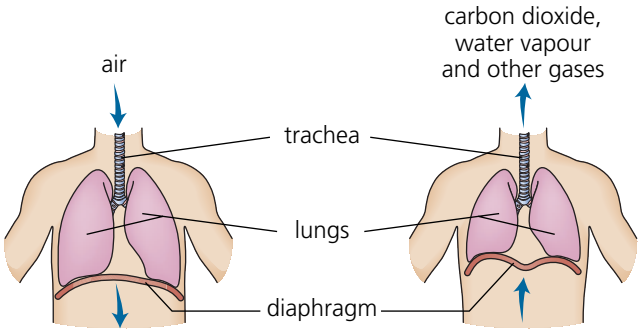
**cylinder**, p. 175

**piston**, p. 175

**sphygmomanometer**, p. 177

**The human respiratory system is a pneumatic system.**

- Pneumatic systems use air or another gas to transmit forces to move objects or do other work.
- A compressor increases the pressure on the gas in a pneumatic system.
- The diaphragm of the human respiratory system acts like a compressor, increasing and decreasing the pressure of air in the lungs.
- When the diaphragm contracts, air pressure in the lungs decreases and you inhale. When the diaphragm relaxes, air pressure in the lungs increases and you exhale.




**Human activities affect natural fluid systems.**

- Human activities may have a negative effect on fluid systems in the natural environment.
- Aboriginal groups can provide detailed knowledge of the negative effects of human activity on natural fluid systems. Aboriginal groups are an important source of ideas and recommendations for improving our natural fluid systems.
- Living things that have been introduced into an ecosystem are called exotic species. Species that normally live in an ecosystem are called native species.
- Exotic species can multiply rapidly, competing with and forcing out or killing native species.

## Review Key Ideas and Vocabulary

1. For each statement write "T" if it is true. If the statement is false, rewrite it to make it true.
   (a) Ballast acts as a weight and decreases buoyancy.
   (b) Tanks of water help to provide ballast for ships and submarines.
   (c) A fully loaded ship floats higher in the water than an empty one.
   (d) Ballast tanks in submarines are filled with water when the submarine needs to ascend.
   (e) The advantage of a hydraulic system is that one piston/cylinder can be connected to two or more other pistons/cylinders to apply force in more than one direction.
   (f) In a pneumatic system, a force applied to one piston travels through the liquid to move a load on the other end.
2. Species that are introduced to, or establish themselves in, an ecosystem where they are not normally found are referred to as
   (a) tropical species
   (b) native species
   (c) ballast species
   (d) exotic species
   (e) predator species
3. What structure in a fluid system controls the flow of fluid?
   (a) conductor
   (b) valve
   (c) hydraulic fluid
   (d) piston
   (e) cylinder
4. Compressor is to pneumatic system as _____?_____ is to respiratory system.
   (a) lung
   (b) trachea
   (c) valve
   (d) heart
   (e) diaphragm
5. Air may not be the most appropriate fluid to use in a system because
   (a) air is virtually incompressible
   (b) air is very compressible
   (c) only a fraction of the applied force is transferred
   (d) air will leak more easily than a liquid
   (e) air is very combustible
6. Name two things that the crew of a hot-air balloon could do to make the balloon rise over some trees.
7. List 10 machines or devices that use fluid-power systems.
8. Compare how a submarine, fish, and scuba diver control their depth in the water.

## Use What You've Learned

9. What factors can determine how much water is carried in a submarine's ballast tanks?
10. You and your family are building a pier at your cottage on the lake. Explain how buoyant force makes work a little easier when you are moving rocks underwater to make the base of the pier in the shallow water.
11. Use the following pairs of terms to compare a hydraulic system with the human circulatory system:
    pump, heart
    hydraulic fluid, blood
    conductor, blood vessels
    hydraulic fluid pressure, blood pressure
12. A bicycle pump pushes air into the bicycle inner tube. What is the purpose of the valve at the entrance to the tube (**Figure 1**)?

Figure 1

13. Look at the picture of a car jack raising a car (**Figure 2**).
    (a) Sketch the hydraulic cylinder inside the car jack.
    (b) Explain how you are able to lift a car using a small hydraulic car jack.

Figure 2

## Think Critically

14. Human activities often have negative impacts on natural fluid systems such as rivers, lakes, oceans, and the atmosphere. Do you think it is reasonable that we can stop such activities and engage only in activities that do not affect natural systems? Explain your answer.

15. Aboriginal groups have traditionally had a different, more caring, relationship with natural fluid systems than Western cultures. If possible, contact the elders of an Aboriginal group to discuss how the group views the place of humans in the natural world. If access to an Aboriginal group is not possible, use the Internet and other resources to research Aboriginal groups' views of natural fluid systems. Prepare a one-page report that compares current practices regarding fluid systems with the traditional Aboriginal groups' views of how humans should interact with air and water.

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16. Hydraulic jacks are used in industries such as mining, forestry, and manufacturing. Research one example of how a hydraulic jack is used. Include a diagram and explain how the forces are multiplied in the jack.

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## Reflect on Your Learning

17. Write a short essay that describes your feelings about how your life depends on a small pump, some valves, and a certain volume of fluid.
18. How has knowledge of hydraulics helped your understanding of the human circulatory system?
19. What have you found difficult to understand in this chapter? Why? What have you done that has helped you understand and remember a concept?

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