27.3 Circulation

THINK ABOUT IT Your mouth takes food into your body, and your digestive tract breaks it down. But how do the energy and nutrients get to your body cells? How does oxygen from your lungs get to your brain and the rest of your body? How do carbon dioxide and wastes generated within your body get eliminated? While some aquatic animals with bodies only a few cells thick rely solely on diffusion to transport materials, most animals rely on a circulatory system.

Key Questions

How do open and closed circulatory systems compare?

How do the patterns of circulation in vertebrates compare?

Vocabulary

heart
open circulatory system
closed circulatory system
atrium
ventricle

Taking Notes

Cycle Diagram As you read, draw a cycle diagram showing a five-step sequence in which blood pumps through a closed, two-loop circulatory system.

Open and Closed Circulatory Systems

How do open and closed circulatory systems compare?

Many animals move blood through their bodies using one or more hearts. A **heart** is a hollow, muscular organ that pumps blood around the body. A heart can be part of either an open or a closed circulatory system.

Open Circulatory Systems Arthropods and most mollusks have **open circulatory systems,** such as the one in **Figure 27–9.** **In an open circulatory system, blood is only partially contained within a system of blood vessels as it travels through the body.** One or more hearts or heartlike organs pump blood through vessels that empty into a system of sinuses, or spongy cavities. There, blood comes into direct contact with body tissues. Blood then collects in another set of sinuses and eventually makes its way back to the heart.

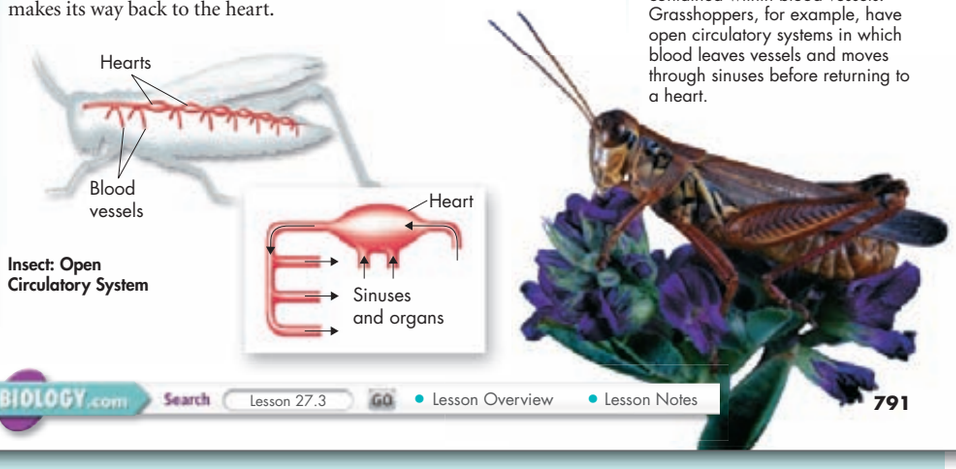


FIGURE 27–9 Open Circulatory System In an open circulatory system, blood is not entirely contained within blood vessels. Grasshoppers, for example, have open circulatory systems in which blood leaves vessels and moves through sinuses before returning to a heart.

Teach for Understanding

ENDURING UNDERSTANDING Animals have evolved diverse ways to carry out basic life processes and maintain homeostasis.

GUIDING QUESTION How have animals evolved complex, efficient ways to move materials through their bodies?

EVIDENCE OF UNDERSTANDING *After completing the lesson, assign the following assessment to show students understand the two types of circulatory systems found in animals.* Divide the class in half, and assign one half to be advocates of an open circulatory system and the other half to be advocates of a closed circulatory system. Have students meet in small groups to discuss how to advocate for one system or the other. Then, have all groups advocating the same system meet to agree on arguments for that system. Finally, stage a debate about the two systems.

Getting Started

Objectives

27.3.1 Compare open and closed circulatory systems.

27.3.2 Compare patterns of circulation in vertebrates.

Student Resources

Study Workbooks A and B, 27.3 Worksheets

Spanish Study Workbook, 27.3 Worksheets

BIOLOGY.com Lesson Overview • Lesson Notes • Activity: InterActive Art • Assessment: Self-Test, Lesson Assessment

For corresponding lesson in the **Foundation Edition**, see pages 653–655.

Build Background

Explain that many animals, including insects, have an open circulatory system instead of the closed system of blood vessels that humans have. Have students observe an open system in **Figure 27–9.** Point out that, in an open circulatory system, the blood comes in direct contact with tissues and cells. As students read through the lesson, suggest they think about why an open circulatory system might work well for a grasshopper, but perhaps not as well for a human.

NATIONAL SCIENCE EDUCATION STANDARDS

UNIFYING CONCEPTS AND PROCESSES

I, IV, V

CONTENT

C.3.a, C.5.d

INQUIRY

A.2.a

Teach

Use Visuals

Have small groups of students compare and contrast single- and double-loop circulation by discussing the two systems shown in **Figure 27–11.** After groups have had time for an exchange of ideas, discuss the two patterns of circulation as a class. Call on groups to report important differences they observed in the two systems. Encourage students from other groups to build on what earlier groups have reported.

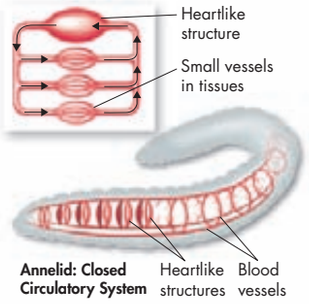
DIFFERENTIATED INSTRUCTION

L1 Struggling Students For students who don't seem to grasp the main differences in the two systems shown in **Figure 27–11,** have them trace each system with a finger, following the arrows, and then identify how the two systems are different.

L3 Advanced Students If school policy permits, have students dissect a mammalian heart to gain a better understanding of a four-chambered heart. Obtain cow, pig, or sheep hearts from a local butcher, and provide students with dissecting tools and a dissecting tray. Remind students to handle the sharp dissecting tools with care, and make sure they wear goggles, a lab apron, and disposable plastic gloves during the dissection. Ask students to diagram what they observe and add labels for parts they can identify. Be sure students wash their hands thoroughly in warm, soapy water afterward.

BIOLOGY.com Students compare single- and double-loop circulation in **InterActive Art: Vertebrate Circulatory Systems.**

FIGURE 27–10 Closed Circulatory System Annelids, such as earthworms, and many more-complex animals have closed circulatory systems. Blood stays within the vessels of a closed circulatory system.



Closed Circulatory Systems Many larger, more active invertebrates, including annelids and some mollusks, and all vertebrates have **closed circulatory systems,** such as the one shown in **Figure 27–10.** **In a closed circulatory system, blood circulates entirely within blood vessels that extend throughout the body.** A heart or heartlike organ forces blood through these vessels. Nutrients and oxygen reach body tissues by diffusing across thin walls of capillaries, the smallest blood vessels. Blood that is completely contained within blood vessels can be pumped under higher pressure, and thus can be circulated more efficiently, than can blood in an open system.

Single- and Double-Loop Circulation

How do the patterns of circulation in vertebrates compare?

As chordates evolved, they developed more-complex organ systems and more-efficient channels for internal transport. You can see two main types of circulatory systems of vertebrates in **Figure 27–11.**

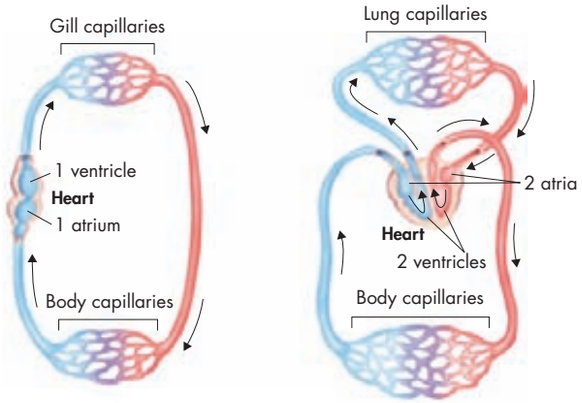
Single-Loop Circulation **Most vertebrates with gills have a single-loop circulatory system with a single pump that forces blood around the body in one direction.** In fishes, for example, the heart consists of two chambers: an atrium and a ventricle. The **atrium** (plural: atria) receives blood from the body. The **ventricle** then pumps blood out of the heart and to the gills. Oxygen-rich blood then travels from the gills to the rest of the body and returns, oxygen-poor, to the atrium.

BUILD Vocabulary

MULTIPLE MEANINGS The word **atrium** has different but parallel meanings in everyday usage and in biology. In everyday usage, it means a large entrance hall. In biology, it means a heart chamber through which blood from the body enters the heart.

Double-Loop Circulation As terrestrial vertebrates evolved into larger and more active forms, their capillary networks became larger. Using a single pump to force blood through the entire system would have been increasingly difficult. This issue was avoided as the lineage of vertebrates that led to reptiles, birds, and mammals evolved. **Most vertebrates that use lungs for respiration have a double-loop, two-pump circulatory system.**

FIGURE 27–11 Single- and Double-Loop Circulation Most vertebrates that use gills for respiration have a single-loop circulatory system that forces blood around the body in one direction (left). Vertebrates that use lungs have a double-loop system (right). (Note that in diagrams of animals' circulatory systems, blood vessels carrying oxygen-rich blood are red, while blood vessels carrying oxygen-poor blood are blue.)



UbD Check for Understanding

ONE-MINUTE RESPONSE

Give students one minute to write a response to the following:

- In double-loop circulation, how does the heart work like two pumps operating together? *(Responses should mention that one side of the heart pumps blood from the heart to the lungs. When oxygen-rich blood returns from the lungs, the other side of the heart pumps it to the rest of the body.)*

ADJUST INSTRUCTION

If responses show that students do not understand the role of the heart in double-loop circulation, provide pairs of students with an unlabeled drawing of double-loop circulation similar to **Figure 27–11.** Ask partners to label the drawing and add arrows showing the path of blood through the heart as well as the rest of the system.

The first loop, powered by one side of the heart, forces oxygen-poor blood from the heart to the lungs. After the blood picks up oxygen (and drops off carbon dioxide) in the lungs, it returns to the heart. Then, the other side of the heart pumps this oxygen-rich blood through the second circulatory loop to the rest of the body. Oxygen-poor blood from the body returns to the heart, and the cycle begins again.

Mammalian Heart-Chamber Evolution Four-chambered hearts like those in modern mammals are actually two separate pumps working next to one another. But where did the second pump come from? During chordate evolution, partitions evolved that divided the original two chambers into four. Those partitions transformed one pump into two parallel pumps. The partitions also separated oxygen-rich blood from oxygen-poor blood. We can get an idea of how the partitions evolved by looking at other modern vertebrates.

Amphibian hearts usually have three chambers: two atria and one ventricle. The left atrium receives oxygen-rich blood from the lungs. The right atrium receives oxygen-poor blood from the body. Both atria empty into the ventricle. Some mixing of oxygen-rich and oxygen-poor blood in the ventricle occurs. However, the internal structure of the ventricle directs blood flow so that most oxygen-poor blood goes to the lungs, and most oxygen-rich blood goes to the rest of the body.

Reptilian hearts typically have three chambers. However, most reptiles have a partial partition in their ventricle. Because of this partition, there is even less mixing of oxygen-rich and oxygen-poor blood than there is in amphibian hearts.

MYSTERY CLUE

Human blood is only about a third as salty as seawater. It needs to circulate through very small capillaries. What might happen if the water content of a person's blood were to drop too low?

FIGURE 27–12 Reptilian Heart
Under the armor-like hide of this crocodile lies a heart with two atria and one ventricle.

27.3 Assessment

Review Key Concepts

1. a. Review Describe an open circulatory system. Describe a closed circulatory system.

b. Explain Which groups of animals tend to have each type of circulatory system?

c. Relate Cause and Effect How does having a closed circulatory system benefit a large, active animal?

2. a. Review What are two different patterns of circulation found in vertebrates?

b. Compare and Contrast What is the major structural difference between vertebrates that have single-loop circulatory systems and those that have double-loop systems?

Apply the Big idea

Structure and Function

3. Do you think large, active vertebrates would have been likely to succeed if closed circulatory systems had not evolved? Explain your reasoning.

BIOLOGY.com Search Lesson 27.3 GO • Self-Test • Lesson Assessment

MYSTERY CLUE Point out to students that blood is made up of many different molecules and cells suspended in fluid. Have them speculate on what might happen to blood if there were less fluid but the same amount of materials suspended in it. Lead them to conclude that the blood might get thicker. Then, have students infer what could happen inside vessels and a four-chambered heart if the water content of blood dropped below normal. Students can go online to Biology.com to gather their evidence.

Assess and Remediate

EVALUATE UNDERSTANDING

List the lesson's five vocabulary terms on the board. Then, call on a student at random to explain what one of the terms means. After the student gives a definition, call on other students to contribute details related to circulation in animals that the term brings to mind. Continue until all terms have been defined and discussed. Then, have students complete the 27.3 Assessment.

REMEDIATION SUGGESTION

L1 **Struggling Students** If students have trouble answering **Question 2b,** have them re-examine **Figure 27–11.**

BIOLOGY.com Students can check their understanding of lesson concepts with the **Self-Test** assessment. They can then take an online version of the **Lesson Assessment.**

Assessment Answers

1a. In an open circulatory system, one or more hearts or heartlike organs pump blood through vessels that empty into a system of sinuses, or spongy cavities. There, blood comes into contact with tissues. Blood then collects in another set of sinuses and eventually makes its way back to the heart. In a closed circulatory system, blood circulates entirely within blood vessels. A heart or heartlike organ forces blood through the vessels. Nutrients and oxygen reach body tissues by diffusing across thin walls of capillaries.

1b. Arthropods and most mollusks have open circulatory systems. Many larger, more active invertebrates and all vertebrates have closed circulatory systems.

1c. Blood is pumped under higher pressure, and thus, can be circulated more efficiently, thereby providing the oxygen needed for a higher metabolism.

2a. single-loop circulation and double-loop circulation

2b. The heart in a single-loop system has one atrium and one ventricle; the heart in a double-loop system has two atria and one or two ventricles.

3. Big idea Answers will vary. Students should back up their opinions with reasoning that shows an understanding of the structures and functions of both open and closed circulatory systems.