27.2 Respiration

THINK ABOUT IT All animal tissues require oxygen for respiration and produce carbon dioxide as a waste product. For that reason, all animals must obtain oxygen from their environment and release carbon dioxide. In other words, all animals need to "breathe." Humans can drown because our lungs can't extract the oxygen we need from water. Most fishes have the opposite problem; out of water, their gills don't work. How are these different respiratory systems adapted to their different functions?

Gas Exchange

What characteristics do the respiratory structures of all animals share?

Despite all the amazing things living cells can do, none can actively pump oxygen or carbon dioxide across membranes. Yet, in order to breathe, all animals must exchange oxygen and carbon dioxide with their surroundings. How do they do it? Animals have evolved respiratory structures that promote the movement of these gases in the required directions by passive diffusion.

Gas Diffusion and Membranes As you may recall, substances diffuse from an area of higher concentration to an area of lower concentration. Gases diffuse most efficiently across a thin, moist membrane that is permeable to those gases. The larger the surface area of that membrane, the more diffusion can take place, just as a bumpy paper towel absorbs more liquid than a smooth one does. These physical principles create a set of requirements that respiratory systems must meet, one way or another.

Requirements for Respiration Because of the behavior of gases, all respiratory systems share certain basic characteristics. **Respiratory structures provide a large surface area of moist, selectively permeable membrane. Respiratory structures maintain a difference in the relative concentrations of oxygen and carbon dioxide on either side of the respiratory membrane, promoting diffusion.**

Key Questions

What characteristics do the respiratory structures of all animals share?

How do aquatic animals breathe?

What respiratory structures enable land animals to breathe?

Vocabulary

gill • lung • alveolus

Taking Notes

Concept Map Draw a concept map showing the characteristics of the lung structures of vertebrates.

FIGURE 27–5 Requirements for Respiration Respiratory surfaces are moist, so exhaled air contains a lot of moisture. That exhaled moisture condenses into visible "fog" if outside air is cold.

Teach for Understanding

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

GUIDING QUESTION How do animals in different environments breathe?

EVIDENCE OF UNDERSTANDING *After completing the lesson, assign the following assessment to show students understand how animals in different environments breathe.* Have students work in small groups to create a series of labeled drawings or clippings, similar to a flowchart, that shows how one animal carries out the process of respiration. The drawings should show how and where gases are exchanged and the structures involved. Have groups share their completed graphics with the class.

Getting Started

Objectives

27.2.1 Describe the characteristics of respiratory structures that all animals share.

27.2.2 Explain how aquatic animals breathe.

27.2.3 Identify the respiratory structures that enable land animals to breathe.

Student Resources

Study Workbooks A and B, 27.2 Worksheets

Spanish Study Workbook, 27.2 Worksheets

BIOLOGY.com Lesson Overview • Lesson Notes • Activities: Art Review, Data Analysis • Assessment: Self-Test, Lesson Assessment

For corresponding lesson in the **Foundation Edition**, see pages 650–652.

Build Background

Explain that breathing involves taking needed gases from air or water into the body and expelling waste gases from the body. Ask students if they know what gas the body needs to take in and what gas it has to expel. *(The body needs oxygen and needs to expel carbon dioxide.)* Point out that to enter or leave a body, gases diffuse across a membrane. Ask students which way gas will move across a membrane if the gas is more concentrated on one side of a membrane than on the other. *(from the more concentrated side to the less concentrated side)*

NATIONAL SCIENCE EDUCATION STANDARDS

UNIFYING CONCEPTS AND PROCESSES

I, V

CONTENT

C.5.d

INQUIRY

A.1.b, A.2.a

Teach

Use Visuals

Refer to **Figure 27–6** to show how many aquatic animals breathe with gills. Explain that gill filaments are selectively permeable membranes. Point out that the gill filaments are shown in red, and make sure students understand that water is pumped *across* or *over* the gill filaments, not *through* them.

Ask What structures are inside the gill filaments that connect the gills with the rest of the body? *(capillaries)*

DIFFERENTIATED INSTRUCTION

L1 **Special Needs** Have students observe fishes. Tell them to look for the gills on either side of a fish's head and the movement of the operculum, or gill cover, as water that has moved across the gills is pumped out.

ELL Focus on ELL: Access Content

BEGINNING AND INTERMEDIATE SPEAKERS
Before students read, have them make a **KWL Chart.** Have them write what they know about respiration in the K column and what they want to learn about it in the W column. Students can write sentences, make lists, or make sketches. After reading each section of the lesson, they can fill in the L column.

Study Wkbks A/B, Appendix S27, KWL Chart.
Transparencies, GO11.

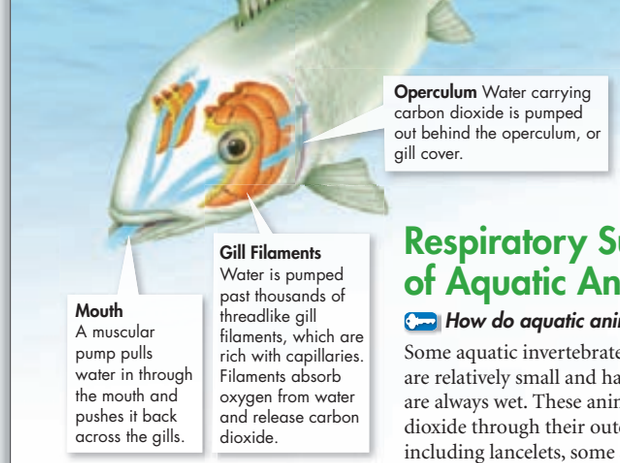


FIGURE 27–6 Respiration With Gills Many aquatic animals, such as fishes, respire with gills, which are thin, selectively permeable membranes. As water passes over the gills, gas exchange is completed within the gill capillaries.

Respiratory Surfaces of Aquatic Animals

How do aquatic animals breathe?

Some aquatic invertebrates, such as cnidarians and some flatworms, are relatively small and have thin-walled bodies whose outer surfaces are always wet. These animals rely on diffusion of oxygen and carbon dioxide through their outer body covering. A few aquatic chordates, including lancelets, some amphibians, and even some sea snakes, rely to varying extents on gas exchange by diffusion across body surfaces.

For large, active animals, however, skin respiration alone is insufficient. **Many aquatic invertebrates and most aquatic chordates other than reptiles and mammals exchange gases through gills.** As shown in **Figure 27–6, gills** are feathery structures that expose a large surface area of thin, selectively permeable membrane to water. Inside gill membranes is a network of tiny, thin-walled blood vessels called capillaries. Many animals, including aquatic mollusks and fishes, actively pump water over their gills as blood flows through inside. This helps maintain differences in oxygen and carbon dioxide concentration that promote diffusion. **Aquatic reptiles and aquatic mammals, such as whales, breathe with lungs and must hold their breath underwater. Lungs** are organs that exchange oxygen and carbon dioxide between blood and air. You will learn more about lungs shortly.

Quick Lab GUIDED INQUIRY

Breathing in Clams and Crayfishes

1. *Do not touch the clam or crayfish.* Put a drop of food coloring in the water near a clam's siphons. Observe what happens to the coloring.
2. Put a drop of food coloring in the water near the middle of a crayfish. **CAUTION:** *Keep your fingers away from the crayfish's pincers.* Observe what happens to the coloring.

Analyze and Conclude

1. **Observe** Describe what happened to the coloring in step 1. How does water move through a clam's gills?
2. **Infer** What is the clam's main defense? How is the location of the clam's siphons related to this defense?
3. **Compare and Contrast** What happened in step 2? Compare the flow of water through the gills of clams and crayfishes.
4. **Infer** Unlike many other arthropods, crayfishes have gills. Why do crayfishes need gills?

Quick Lab

PURPOSE Students will be able to relate differences in the mechanisms of gas exchange to the overall adaptations in a clam and a crayfish.

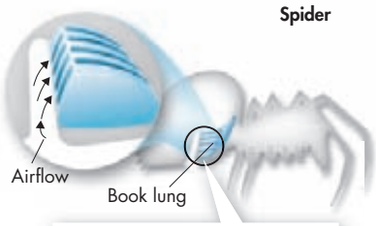
MATERIALS live clam, food coloring, dropper, live crayfish, 2 small containers of water

SAFETY Make sure students do not touch the organisms, and have them wash their hands in warm, soapy water when finished.

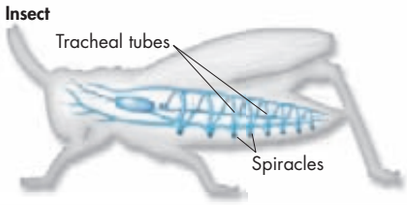
PLANNING You can keep marine clams alive for a few days in a 4% solution of sodium chloride.

ANALYZE AND CONCLUDE

1. The coloring entered one siphon and left through the other. Inside the clam, the coloring flowed over the gills.
2. Sample answer: Its main defense is its shell. The location of the siphons allows the clam to pump water over its gills without opening its shell very wide.
3. Sample answer: The coloring flowed into the crayfish's gills and then flowed back out. Both clams and crayfishes draw water into the body, pass it over the gills, and then release it. A clam must open its shell to do this, while a crayfish has openings through which water passes in and out.
4. Crayfishes need gills, because they are aquatic arthropods that use gills for the exchange of gases.



Spiders respire using organs called book lungs, which are made of parallel, sheetlike layers of thin tissues that contain blood vessels.



In most insects, a system of tracheal tubes extends throughout the body. Air enters and leaves the system through openings in the body surface called spiracles. In some insects, oxygen and carbon dioxide diffuse through the tracheal system, and in and out of body fluids. In other insects, body movements help pump air in and out of the tracheal system.

FIGURE 27–7 Respiratory Structures of Terrestrial Invertebrates Terrestrial invertebrates have a wide variety of respiratory structures, including skin, mantle cavities, book lungs, and tracheal tubes. These structures must stay moist even in the driest of conditions in order to function properly.

Respiratory Surfaces of Terrestrial Animals

What respiratory structures enable land animals to breathe?

Terrestrial animals, as you might have guessed, face a challenge that aquatic animals don't. Terrestrial animals must keep their respiratory membranes moist in dry environments.

Respiratory Surfaces in Land Invertebrates The wide range of body plans among terrestrial invertebrates reveals very different strategies for respiration. **Respiratory structures in terrestrial invertebrates include skin, mantle cavities, book lungs, and tracheal tubes.** Some land invertebrates, such as earthworms, that live in moist environments can respire across their skin, as long as it stays moist. In other invertebrates, such as land snails, respiration is accomplished by the mantle cavity, which is lined with moist tissue and blood vessels. Insects and spiders have more complex respiratory systems, as you can see in **Figure 27–7.**

Lung Structure in Vertebrates Terrestrial vertebrates display a wide range of breathing adaptations. **But all terrestrial vertebrates—reptiles, birds, mammals, and the land stages of most amphibians—breathe with lungs.** Although lung structure in these animals varies, the processes of inhaling and exhaling are similar. Inhaling brings oxygen-rich air through the trachea (TRAY kee uh), or airway, into the lungs. Inside the lungs, oxygen diffuses into the blood through lung capillaries. At the same time, carbon dioxide diffuses out of capillaries into the lungs. Oxygen-poor air is then exhaled.

In Your Notebook *Would you expect dolphins to breathe with gills or lungs? Explain your answer.*

BUILD Vocabulary

MULTIPLE MEANINGS The biological term *respiration* has different, though related, meanings. In animals, it can refer to gas exchange, the intake of oxygen and release of waste gases, or to *cellular respiration*, the cell process that releases energy by breaking down food molecules in the presence of oxygen. Because cellular respiration requires oxygen, the two processes are related.

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Check for Understanding

INDEX CARD SUMMARIES

Give each student an index card, and ask students to write one idea about respiration in animals that they understand on the front of the card. Then, have them write a question about respiration they have on the back of the card.

ADJUST INSTRUCTION

Read over the cards to get a sense of concepts students understand and concepts they are having trouble with. Read some of the questions aloud to the class, without identifying the students who wrote the questions, and call on volunteers to provide an answer. This will allow students to hear concepts expressed in various ways by their peers and give you a chance to address any misunderstandings.

Use Models

Have students examine the respiratory structures of a spider and an insect in **Figure 27–7,** and point out that both structures are adaptations that provide a large surface area in which gas exchange can occur. To drive home this concept, have students measure the front and back of a closed book. Then, have them divide the book into ten sections, holding the sections together with rubber bands. Ask students to calculate the total surface area of the divided book. They will determine that this surface area is more than ten times that of the closed book.

Ask What invertebrate respiratory structure is like a book with sections exposed to the air? *(a spider's book lungs)*

DIFFERENTIATED INSTRUCTION

L1 **Struggling Students** Show students a three-ring binder with several pieces of paper clipped inside. Trace the binder cover on the board near the top of the board. Below this, retrace the binder cover, and then take out each sheet of paper and tape them edge to edge to the side of the second tracing. Explain how the binder, with the sheets of paper inside, models the book lungs of a spider. Have them compare the surface area available for respiration of the binder "book lungs" to the set of lungs represented just by the cover tracing. Make sure they understand the advantage of the book lung structure.

Address Misconceptions

Respiration and Circulation Some students may have the misconception that air is inhaled into the lungs and then simply exhaled without any connection to the heart and the rest of the circulatory system. Emphasize that the gas exchange that occurs in the lungs is necessary because of the process of cellular respiration carried out by all cells. Have students re-examine the overall equation for cellular respiration in Chapter 9, with a special focus on oxygen as a reactant and carbon dioxide as a product. Then, discuss how the respiratory and circulatory systems work together.

BIOLOGY.com Students distinguish different types of respiratory systems in **Art Review: Respiratory Systems.** In **Data Analysis: Giant Insects of the Paleozoic,** students examine why insects were larger during the Paleozoic than they are today.

Answers

IN YOUR NOTEBOOK Dolphins breathe with lungs, because they are mammals.

Assess and Remediate

EVALUATE UNDERSTANDING

Call on students at random to explain or show how gas exchange occurs over gills, through spiracles and book lungs, or inside vertebrate lungs. Then, have students complete the 27.2 Assessment.

REMEDIATION SUGGESTION

L1 **Struggling Students** If your students have trouble answering **Question 3a,** have them review **Figures 27–7** and **27–8.** Have them write summaries of the information in the annotations and captions of the two figures.

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.**

Answers

FIGURE 27–8 The large surface area enables mammals to process the large amount of oxygen required by their high metabolic rates.

FIGURE 27–8 Lungs Terrestrial vertebrates breathe with lungs. Lungs with a larger surface area can take in more oxygen and release more carbon dioxide. Mammals have the greatest lung surface area among animals. **Infer** *Why do mammals require a large surface area with which to process oxygen?*

▶ ***Amphibian, Reptilian, and Mammalian Lungs*** The internal surface area of lungs increases from amphibians to reptiles to mammals, as shown in **Figure 27–8.** A typical amphibian lung is little more than a sac with ridges. Reptilian lungs are often divided into chambers that increase the surface area for gas exchange. Mammalian lungs branch extensively, and their entire volume is filled with bubblelike structures called **alveoli** (al VEE uh ly; singular: alveolus). Alveoli provide an enormous surface area for gas exchange. The structure of mammalian lungs enables mammals to take in the large amounts of oxygen required by their high metabolic rates. However, in the lungs of mammals and most other vertebrates, air moves in and out through the same tracheal passageway. For this reason, some stale, oxygen-poor air is trapped in the lungs. In humans, this stale air is typically equivalent to about one third of the air inhaled in a normal breath.

▶ ***Bird Lungs*** In birds, the lungs are structured so that air flows mostly in only one direction. No stale air gets trapped in the system. A unique system of tubes and air sacs in birds' respiratory systems enables this one-way airflow. Thus, gas exchange surfaces are continuously in contact with fresh air. This highly efficient gas exchange helps birds obtain the oxygen they need to power their flight muscles at high altitudes for long periods of time.

27.2 Assessment

Review Key Concepts

1. a. Review In what ways are the respiratory structures of all animals similar?

b. Apply Concepts Explain why it is important that respiratory surfaces are moist and selectively permeable.

2. a. Review Which groups of aquatic animals breathe with gills? With lungs?

b. Relate Cause and Effect Why do some animals actively pump water over their gills?

3. a. Review How do terrestrial invertebrates and terrestrial vertebrates breathe?

b. Interpret Visuals Contrast the structures of amphibian, reptilian, and mammalian lungs, as shown in **Figure 27–8.**

WRITE ABOUT SCIENCE

Description

4. Describe the events that occur when a mammal respires, including the path of air through its lungs.

BIOLOGY.com Search Lesson 27.2 GO • Self-Test • Lesson Assessment

Assessment Answers

1a. Animals all have respiratory structures that promote the movement of oxygen and carbon dioxide across moist, selectively permeable membranes by passive diffusion.

1b. Gases diffuse most efficiently across moist membranes. Surfaces must be selectively permeable so that not all substances can pass through.

2a. Many aquatic invertebrates and most aquatic chordates, other than reptiles and mammals, breathe with gills. Aquatic reptiles and aquatic mammals breathe with lungs.

2b. This helps maintain differences in oxygen and carbon dioxide concentration that promote diffusion.

3a. Some terrestrial invertebrates exchange gases through the skin. Other invertebrates breathe through respiratory structures, including mantle cavities, book lungs, and tracheal tubes. Terrestrial vertebrates breathe with lungs.

3b. All terrestrial vertebrates have lungs. The internal surface area of lungs increases from amphibians to reptiles to mammals. A typical amphibian lung is little more than a sac with ridges. A reptilian lung is often divided into chambers. A mammalian lung branches extensively and contains bubblelike structures called alveoli.

WRITE ABOUT SCIENCE

4. Sample answer: Air moves in through the tracheal passageway. On its way in, air moves through branches and into alveoli, where gas exchange takes place. Air moves out the same way it moved in.