CK-12 Foundation

Monadnock Life Science Flexbook

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Printed: March 17, 2012

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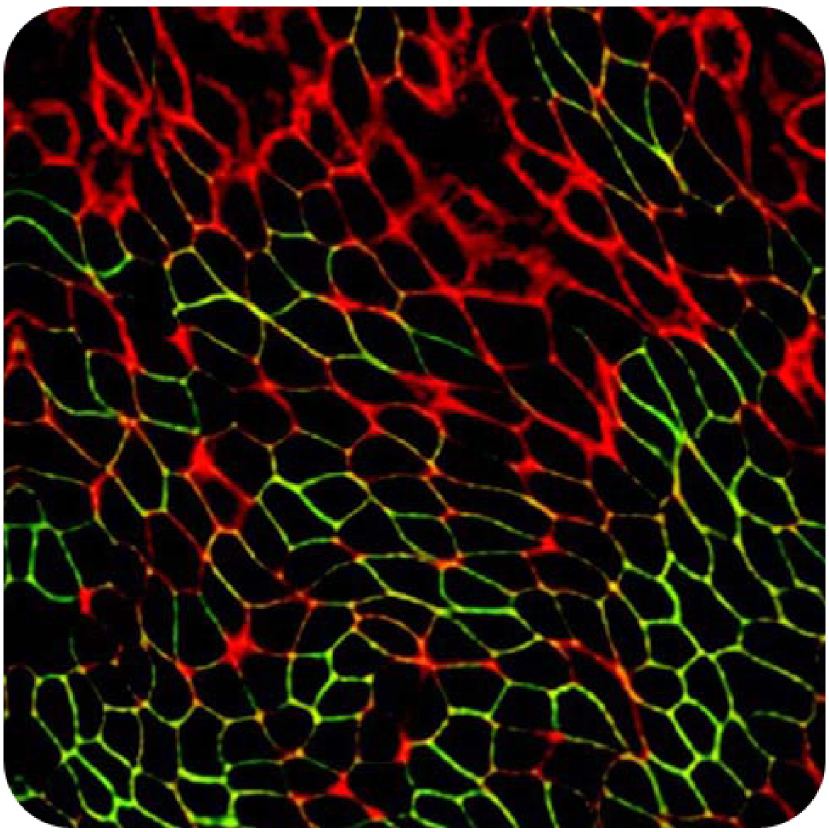
MS Cells and Their Structures



Look carefully at the above image. What do you see? What colors? What shapes? Can you guess what it is?

These are actually cells from a dog's kidney. Cells are the smallest units of living things. You are made of cells. Plants are made of cells. So are dogs, chickens, bees and mushrooms. Our cells even look very similar to the above dog cells.

But the cells of a kidney are not actually bright green and red. Scientists remove cells from organisms, dye them with different colors, and look at them under strong microscopes. The above image is an example of what scientists see under these microscopes. Now, we will explore what different types of cells look like and what they do.

1.1 Introduction to Cells

Lesson Objectives

- Explain how cells are observed.
- Define the three main parts of the cell theory.
- Explain the levels of organization in an organism.

Check Your Understanding

- What are the five main characteristics of living things?
- Name the four main classes of organic molecules that are building blocks of life.

Vocabulary

- organ
- organ system
- tissue

What are cells?

In the chapter *What is a Living Organism?*, you learned that living things are made of big molecules called proteins, lipids, carbohydrates, and nucleic acids. When these big molecules come together, they form a cell. A **cell** is the smallest unit of an organism that is still considered living (see the onion cells in **Figure** 1.1). Some organisms, like bacteria, consist of only one cell. Big organisms, like humans, consist of trillions of cells. Compare a human to a banana. On the outside, they look very different, but if you look close enough you'll see that their cells are actually very similar.

The Inner Life of the Cell can be viewed at `http://www.youtube.com/watch?v=Mszlckmc4Hw` (5:28).

Observing Cells

Most cells are so tiny that you cannot see them without the help of a microscope. It was not until 1665 that English scientist Robert Hooke invented a basic light microscope and observed cells for the first time. You may use light microscopes in the classroom. You can use a light microscope to see cells. But many structures in the cell are too small to see with a light microscope. So, what do you do if you want to see the tiny structures inside of cells?

In the 1950s, scientists developed more powerful microscopes. A light microscope sends a beam of light through a **specimen**, or the object you are studying. A more powerful microscope, called an **electron microscope**, passes a beam of electrons through the specimen. Sending electrons through a cell allows us to see its tiniest parts (**Figure** 1.3).

Without electron microscopes, we would not know what the inside of a cell looked like. The only problem with using an electron microscope is that it only works with dead cells. Scientists and students still use light microscopes to study living cells.

How to Correctly Use a Microscope can be viewed at `http://www.youtube.com/watch?v=jP9HtcAvGDk&feature=related` (1:43).

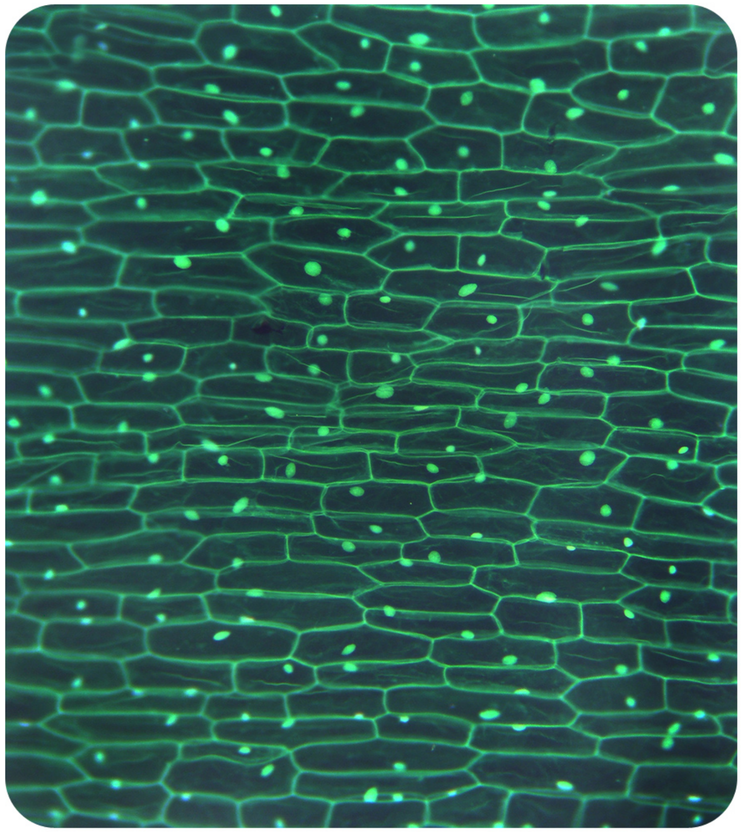


Figure 1.1: The outline of onion cells are visible under a light microscope.

Figure 1.2: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/588

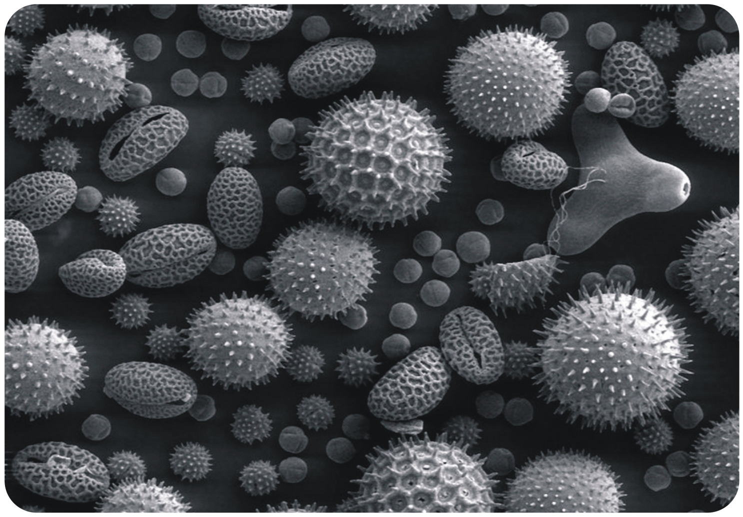


Figure 1.3: An electron microscope allows scientists to see much more detail than a light microscope, as with this sample of pollen. But a light microscope allows scientists to study living cells.

Figure 1.4: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/591

Cell Theory

In 1858, after using microscopes much better than Hooke's first microscope, Rudolf Virchow developed the hypothesis that cells only come from other cells. For example, bacteria are composed of only one cell (**Figure** 1.5) and divide in half to make new bacteria. In the same way, your body makes new cells by dividing the cells you already have. In all cases, cells only come from cells that have existed before. This idea led to the development of one of the most important theories in biology, cell theory.

Cell theory states that:

1. All organisms are composed of cells.
2. Cells are alive and the basic living units of organization in all organisms.
3. All cells come from other cells.

As with other scientific theories, many hundreds, if not thousands, of experiments support the cell theory. Since Virchow created the theory, no evidence has ever contradicted it.

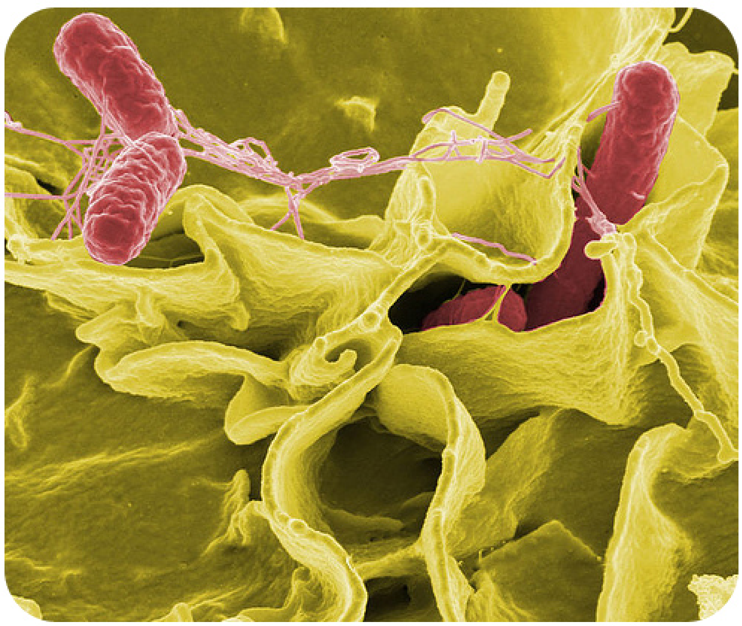


Figure 1.5: Bacteria (pink) are an example of an organism consisting of only one cell.

Levels of Organization

Although cells share many of the same features and structures, they also can be very different. Each cell in your body is designed for a specific task.

For example:

- Red blood cells (**Figure** 1.6) are shaped with a pocket that traps oxygen and brings it to other body cells.
- Nerve cells, which can quickly send the feeling of touching a hot stove to your brain, are long and stringy in order to form a line of communication with other nerve cells, like a wire (**Figure** 1.7).
- Skin cells (**Figure** 1.8) are flat and fit tightly together to protect your body.

An animation comparing the size of red blood cells and skin cells to other structures can be found at http://learn.genetics.utah.edu/content/begin/cells/scale/.

As you can see, cells are shaped in ways that help them do their jobs. Multicellular (many-celled) organisms have many types of specialized cells in their bodies.

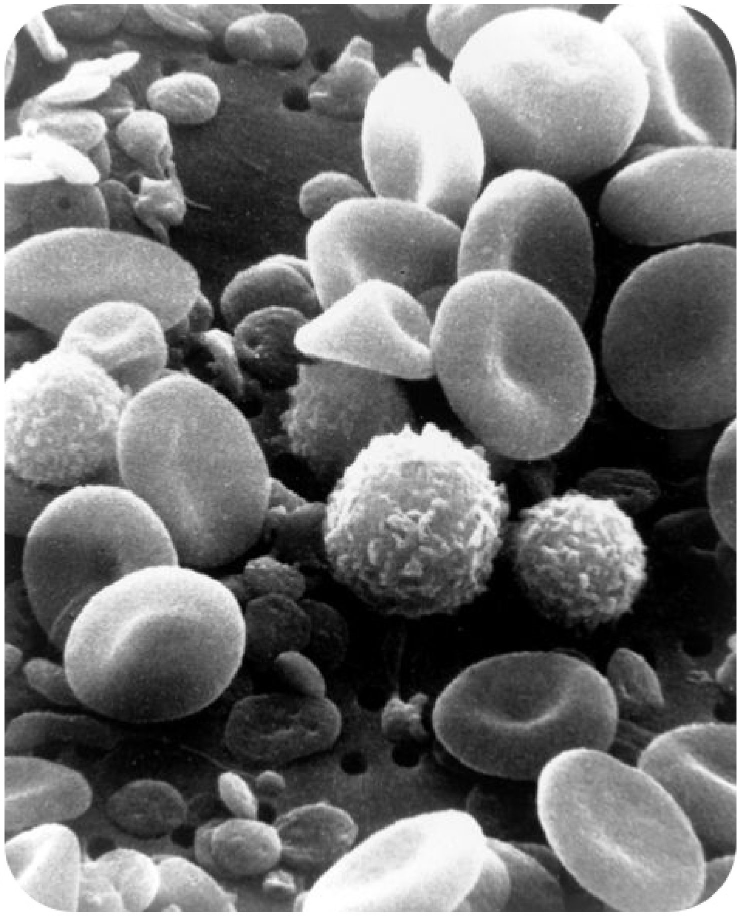


Figure 1.6: Red blood cells are specialized to carry oxygen in the blood.

While cells are the basic units of an organism, groups of cells can be specialized, or perform a specific job. Specialized cells can be organized into tissues. For example, your liver cells are organized into liver tissue, which is organized into an organ, your liver. Organs are formed from two or more specialized tissues working together to perform a job that helps your body work. All organs, from your heart to your liver, are made up of an organized group of tissues.

These organs are part of a larger system, the organ systems. For example, your brain works together with your spinal cord and other nerves to form the nervous system. This organ system must be organized with other organ systems, such as the circulatory system and the digestive system, for your body to work. Organ systems work together to form the entire organism. As you can see (**Figure** 1.9), there are many levels of organization in living things.

Lesson Summary

- Cells were first observed under a light microscope, but today's electron microscopes allow scientists to take a closer look at the inside of cells.

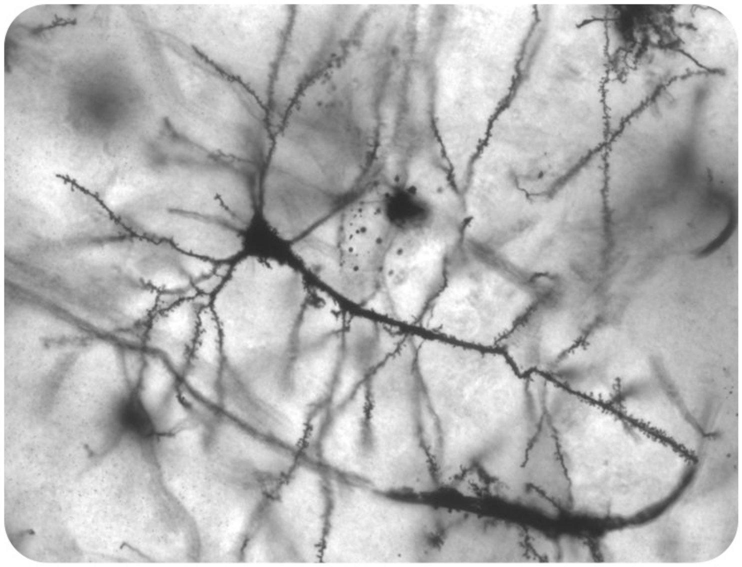


Figure 1.7: Neurons are shaped to conduct electrical impulses to many other nerve cells.

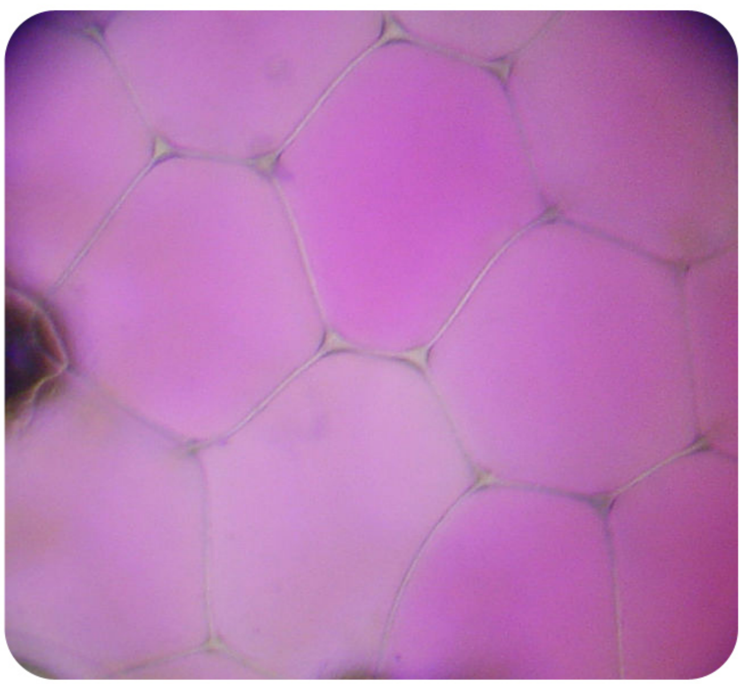


Figure 1.8: These epidermal cells make up the "skin" of plants. Note how the cells fit tightly together.

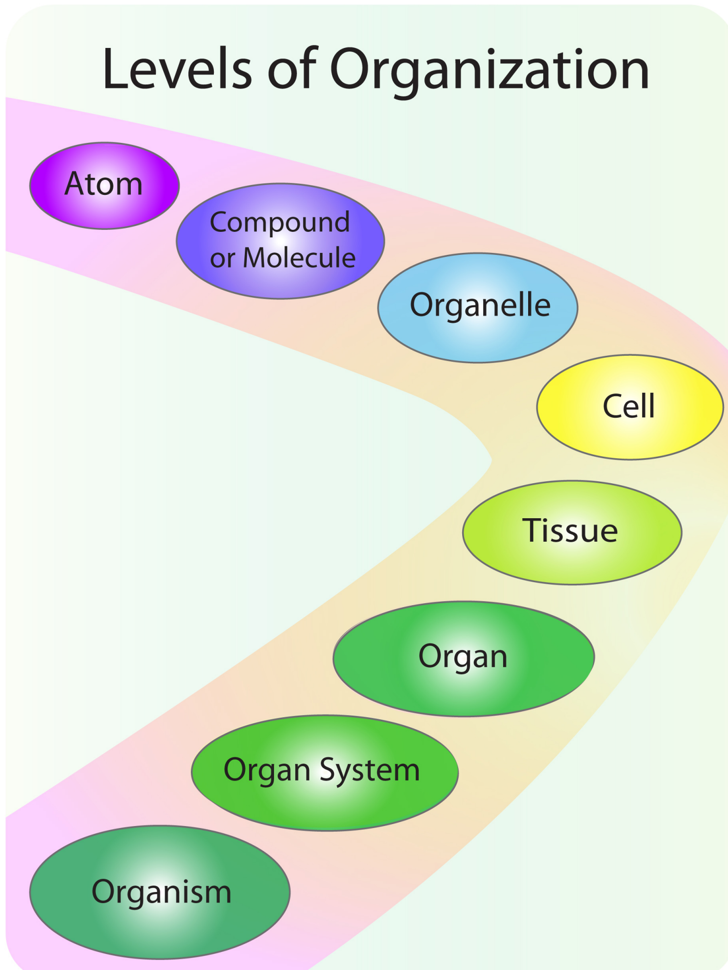


Figure 1.9: Levels of Organization, from the atom to the organism.

- Cell theory says that:
  - All organisms are composed of cells;
  - Cells are alive and the basic living units of organization in all organisms; and
  - All cells come from other cells.
- Cells are organized into tissues, which are organized into organs, which are organized into organ systems, which are organized to create the whole organism.

Review Questions

Recall

1. What scientific tool was used to first observe cells?
2. What are the three main parts of the cell theory?

Apply Concepts

3. Put the following in the correct order from simplest to most complex: organ, cell, tissue, organ system.
4. What type of microscope would be best for studying the structures found inside of cells?

Think Critically

5. According to the cell theory, can we create a new cell in laboratory by putting different molecules together? Why or why not?

Further Reading / Supplemental Links

- Baeuerle, Patrick A. and Landa, Norbert. *The Cell Works: Microexplorers.* Barron's; 1997, Hauppauge, New York.
- Sneddon, Robert. *The World of the Cell: Life on a Small Scale.* Heinemann Library; 2003, Chicago.
- Wallace, Holly. *Cells and Systems.* Heinemann Library; 2001, Chicago.

Points to Consider

- Do you think there would be a significant difference between bacterial cells and your brain cells? What might they be?
- Do you think a bacterial cell and a brain cell have some things in common? What might they be?
- Do you think cells have organs like we do? How would that benefit cells?

1.2 Cell Structures

Lesson Objectives

- Compare prokaryotic and eukaryotic cells.
- List the organelles of the cell and their functions.
- Discuss the structure and function of the cell membrane and cytosol.
- Describe the structure and function of the nucleus.
- Distinguish between plant and animal cells.

Check Your Understanding

- What is a cell?
- How do we visualize cells?

Vocabulary

- cell wall
- central vacuole
- chloroplast
- chromosome
- cytoplasm
- cytoskeleton
- cytosol
- endoplasmic reticulum (ER)
- eukaryote
- Golgi apparatus
- lysosome
- mitochondria
- nuclear envelope
- nucleus
- organelle
- plasma membrane
- prokaryote
- ribosome
- rough endoplasmic reticulum
- semipermeable
- smooth endoplasmic reticulum
- vesicle

Prokaryotic and Eukaryotic Cells

There are two basic types of cells, prokaryotic cells (**Figure** 1.10), found in organisms called **prokaryotes**, and eukaryotic cells (**Figure** 1.11), found in organisms called **eukaryotes**.

The main difference between eukaryotic and prokaryotic cells is that eukaryotic cells have a **nucleus**, where they store their DNA, or genetic material. The nucleus is membrane-bound, which means it is surrounded by a phospholipid membrane. Prokaryotic cells do not have a "membrane-bound" nucleus. Instead, their

DNA floats around inside the cell.

Here are some other key features of eukaryotic cells:

1. They have membrane-bound structures called **organelles**. A list of the main eukaryotic organelles is located in **Table** 1.2.
2. Eukaryotic cells include the cells of fungi, animals, protists, and plants.
3. These cells are more specialized than prokaryotic cells.

Key features of prokaryotic cells include:

1. The cells are usually smaller and simpler than eukaryotic cells.
2. Prokaryotic cells do not have membrane-bound structures.
3. The DNA, or genetic material, forms a single large circle that coils up on itself.
4. Prokaryotic cells belong to the domains Bacteria or Archaea. These two domains were discussed in the *What is a Living Organism?* chapter.

From the above information, are the cells found in your body prokaryotic cells or eukaryotic cells? **Table** 1.1 compares prokaryotic and eukaryotic cells.

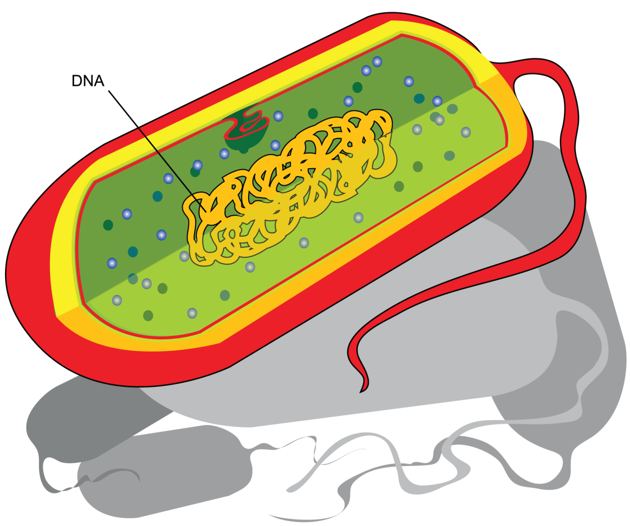


Figure 1.10: Prokaryotes do not have a nucleus. Instead, their genetic material is a simple loop of DNA.

Table 1.1: **Comparison of Prokaryotic and Eukaryotic Cells**

Feature	Prokaryotic cells	Eukaryotic cells
DNA	Single "naked" circle; plasmids	In membrane-enclosed nucleus
Membrane-enclosed organelles	No	Yes
Examples	Bacteria	Plants, animals, fungi

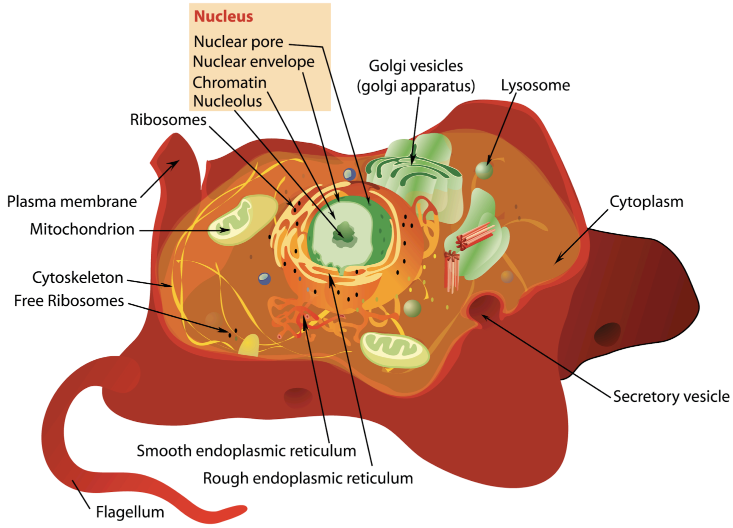


Figure 1.11: Eukaryotic cells contain a nucleus (where the DNA lives, and surrounded by a membrane) and various other special compartments surrounded by membranes, called organelles. For example, notice in this image the mitochondria, lysosomes, and peroxisomes.

The Plasma Membrane and Cytosol

Both eukaryotic and prokaryotic cells have walls around them that separate them from other cells and make sure the parts of the cell do not just float away. This wall is called a plasma membrane. The **plasma membrane** is made of a double layer of lipids, known as phospholipids. The function of the plasma membrane, also known as the cell membrane, is to control what goes in and out of the cell.

Some molecules can go through the cell membrane and enter and leave the cell, but some cannot. "Permeable" means that anything can cross a barrier. An open door is completely permeable to anything that wants to enter or exit through the door. The plasma membrane is **semipermeable,** meaning that some things can enter the cell and some things cannot.

The inside of eukaryotic and prokaryotic cells also both contain a jelly-like substance called **cytosol**. Cytosol is composed of water and other molecules, including enzymes that speed up the cell's chemical reactions. Everything in the cell - the nucleus and the organelles - sit in the cytosol, like fruit in a Jell-o mold. The term **cytoplasm** refers to the cytosol and all of the organelles, but not the nucleus.

Table 1.2: **Some Eukaryotic Organelles**

Organelle	Function
Ribosomes	Involved in making proteins
Golgi apparatus	Packages proteins and some polysaccharides
Mitochondria	Where ATP is made
Smooth Endoplasmic Reticulum	Makes lipids
Chloroplast	Makes sugar (photosynthesis)
Lysosomes	Digests macromolecules

The Nucleus

The nucleus is only found in eukaryotic cells. It is a membrane-bound structure that contains most of the genetic material of the cell (**Figure** 1.12). The nucleus contains important information that helps the cell create important molecules for life. The **nuclear envelope**, a double membrane that surrounds the nucleus, controls which molecules go in and out of the nucleus.

Inside of the nucleus, you will find the chromosomes. **Chromosomes** are strands of DNA wrapped around proteins. They contain genes, or small units of genetic material that create proteins.

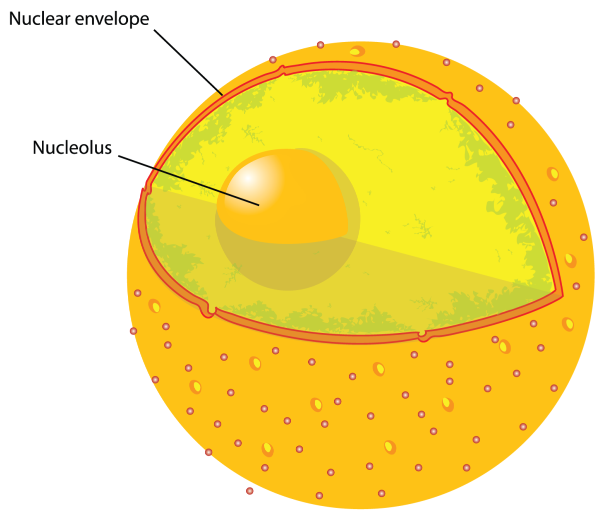


Figure 1.12: In eukaryotic cells, the DNA is kept in a nucleus. The nucleus is surrounded by a double plasma membrane called the nuclear envelope. Within the nucleus is the (smaller yellow ball).

photosynthesis (**Figure** 1.13). (The cells of animals and fungi do not photosynthesize and do not have chloroplasts.)

3. The **vacuoles** are like storage centers. Plant cells have larger ones than animal cells because they need to store water and other nutrients.
4. The **lysosomes** are like the recycling trucks that carry waste away from the factory. Inside lysosomes are enzymes that break down old molecules into parts that can be recycled into new ones.
5. Eukaryotic cells also contain a skeleton-like structure called the **cytoskeleton**. Like our bony skeleton, a cell's cytoskeleton gives the cell its shape and helps the cell to move. What part of a factory would act like a cytoskeleton?
6. In both eukaryotes and prokaryotes, **ribosomes** are where proteins are made. Ribosomes are like the machines in the factory that produce the factory's main product. Proteins are the main product of the cell.
7. Some ribosomes can be found on folded membranes called the endoplasmic reticulum (ER). If the ER is covered with ribosomes, it looks bumpy and is called **rough endoplasmic reticulum**. If the ER does not contain ribosomes, it is smooth and called the **smooth endoplasmic reticulum**. Proteins are made on the rough ER. Lipids are made on the smooth ER.
8. The **Golgi apparatus**, works like a mail room. The Golgi apparatus receives the proteins from the rough ER, puts "shipping addresses" on the proteins, packages them up in vesicles, and then sends them to the right place in the cell.

Differences between Plant and Animal Cells

Even though plants and animals are both eukaryotes, plant cells differ in some ways from animal cells. First, plant cells have a large central vacuole that holds a mixture of water, nutrients, and wastes. A plant cell's vacuole can make up 90% of the cell's volume. In animal cells, vacuoles are much smaller.

Second, plant cells have a cell wall, while animal cells do not. A **cell wall** gives the plant cell strength and protection.

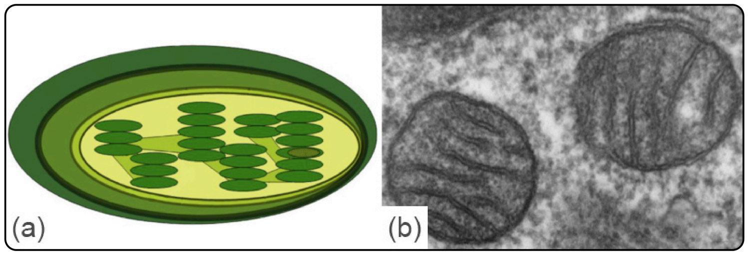


Figure 1.13: Diagram of chloroplast (a) and electron microscope image of two mitochondria (b). Chloroplasts and mitochondria provide energy to cells. If the bar at the bottom of the electron micrograph image is 200 nanometers, what is the diameter of one of the mitochondria?

A third difference between plant and animal cells is that plants have several kinds of organelles called **plastids**. There are several kinds of plastids, including chloroplasts, needed for photosynthesis; **leucoplasts**, which store starch and oil; and brightly colored **chromoplasts**, which give some flowers and fruits their yellow, orange, or red color. You will learn more about chloroplasts and photosynthesis in the chapter titled *Cell Functions*. Under a microscope one can see plant cells more clearly (**Figure** 1.14 and **Figure** 1.15).

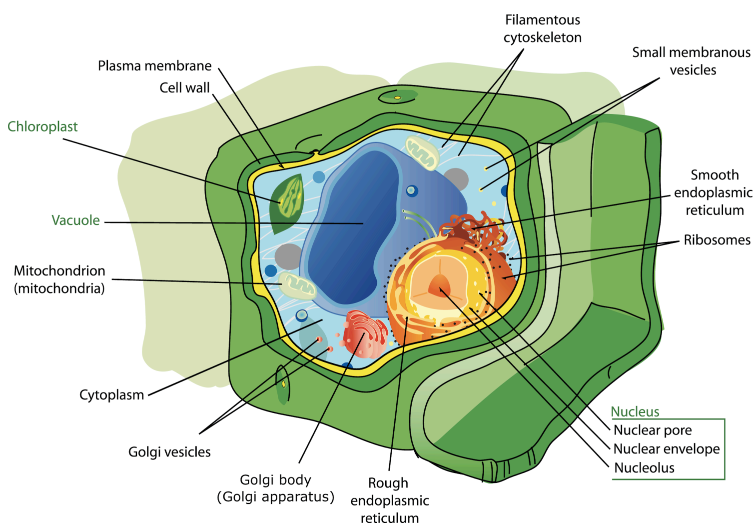


Figure 1.14: A plant cell has several features that make it different from an animal cell, including a cell wall, huge vacuoles, and several kinds of plastids, including chloroplasts (which photosynthesize).

Lesson Summary

- Prokaryotic cells lack a nucleus; eukaryotic cells have a nucleus.
- Each component of a cell has a specific function.
- Plant cells are different from animal cells. For example, plant cells contain plastids, cell walls, and large vacuoles.

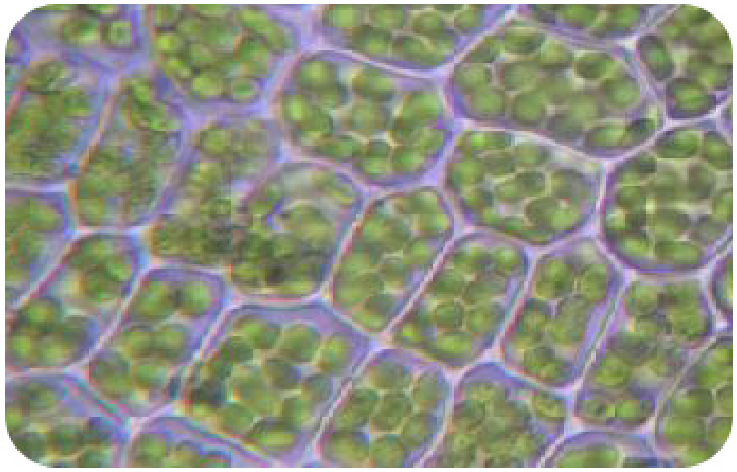


Figure 1.15: In this photo of plant cells taken with a light microscope, you can see a cell wall (purple) around each cell and green chloroplasts.

Review Questions

Recall

1. What are the two basic types of cells?
2. What are organelles?
3. Discuss the main differences between prokaryotic cells and eukaryotic cells.

Apply Concepts

4. What is the plasma membrane and what is its role?
5. Why is the mitochondria known as the powerhouse of the cell?

Think Critically

6. Why does photosynthesis not occur in animal cells?

Further Reading / Supplemental Links

- Baeuerle, Patrick A. and Landa, Norbert. *The Cell Works: Microexplorers.* Barron's; 1997, Hauppauge, New York.
- Sneddon, Robert. *The World of the Cell: Life on a Small Scale.* Heinemann Library; 2003, Chicago.
- Wallace, Holly. *Cells and Systems.* Heinemann Library; 2001, Chicago.

Points to Consider

- Think about what molecules would need to be transported into cells.
- Discuss why you think it would be important for some molecules to be kept out of a cell.

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Chapter 2

MS Cell Functions

Multi-celled organisms, like dolphins, are made up of trillions of cells. How do you think they work together to move an organism? How do the cells of a tree allow it to absorb water and produce leaves? How are the cells interacting with the world inside of the body and outside of the body? Do small one-celled organisms function the same way as the cells in big organisms like dolphins? We need to know how cells function, so we can understand how entire organisms, both large and small, function.

2.1 Transport

Lesson Objectives

- Describe methods of transporting molecules into and out of the cell.
- Distinguish between active and passive transport.
- Explain how diffusion and osmosis work.

Check Your Understanding

- What structure surrounds the cell?
- What is the primary part of the cell membrane?
- What does homeostasis mean?

Vocabulary

- active transport
- concentration
- diffusion
- hypertonic solution
- hypotonic solution
- isotonic solution
- osmosis
- passive transport
- phospholipid
- selectively permeable

Introduction

Cells are found in all different types of environments, and these environments are constantly changing. One-celled organisms, like bacteria, can be found on your skin, or in the ground, or in all different types of water. The cells of your body interact with the food you eat, and also with other cells in your body. All cells need a way to protect themselves. This job is done by the cell membrane.

The cell membrane is semipermeable, or **selectively permeable**, which means that only some molecules can get through the membrane. If the cell membrane were completely permeable, the inside of the cell would be the same as the outside of the cell. It would be impossible for the cell to maintain homeostasis. Homeostasis means maintaining a stable internal environment. For example, if your body cells have a temperature of 98.6 degrees F, and it is freezing outside, your cells will maintain homeostasis if the temperature of the cells stays the same and does not drop.

How does the cell ensure it is semipermeable? How does the cell control what molecules enter and leave the cell? The ways that cells control what passes through the cell membrane will be the focus of this lesson.

What is Transport?

Molecules in the cell membrane allow it to be semipermeable. The membrane is made of a double layer of phospholipids (a ”bilayer”) and proteins (**Figure** 2.1). A single phospholipid molecule has two parts:

1. A head that is **hydrophilic**, or water-loving.
2. A tail that is **hydrophobic**, or water-fearing.

There is water found on both the inside and the outside of cells. Since hydrophilic means water-loving and they want to be near water, the heads face the inside and outside of the cell where water is found. The water-fearing, hydrophobic tails face each other in the middle of the cell membrane because water is not found in this space. An interesting quality of the plasma membrane is that it is constantly moving, like a soap bubble. Water and small molecules such as oxygen and carbon dioxide can pass freely through the membrane, but larger molecules cannot easily pass through the plasma membrane. Some molecules need a special way to get across the membrane.

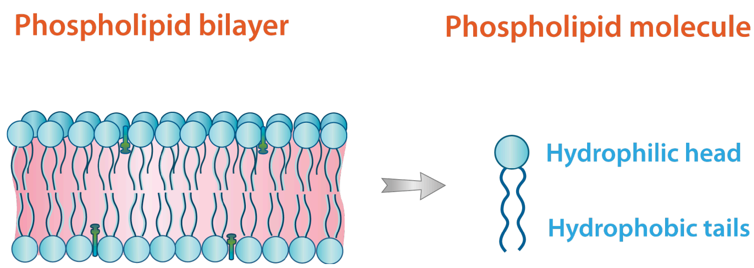

Figure 2.1: The cell membrane is made up of a phospholipid bilayer, two layers of phospholipid molecules.

Diffusion

Small molecules can pass through the plasma membrane through a process called diffusion. **Diffusion** is the movement of molecules from an area where there is a higher concentration (larger amount) of the substance to an area where there is a lower concentration (lower amount) of the substance (**Figure** 2.2). The amount of a substance in relation to the total volume is the **concentration**.

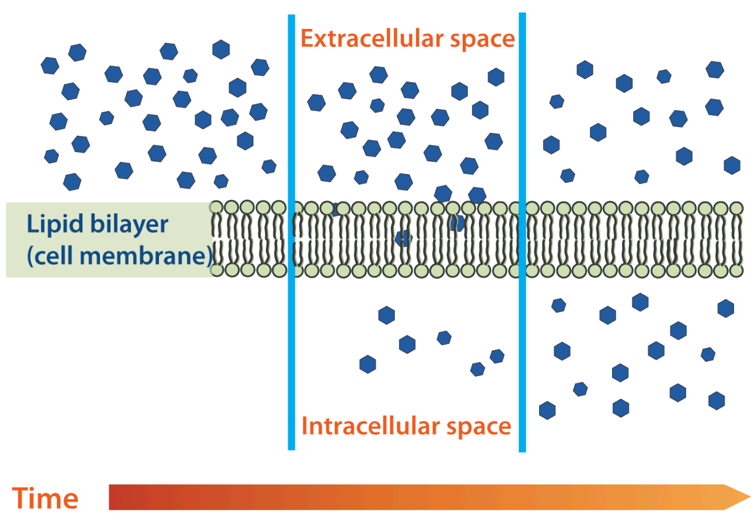

Figure 2.2: Diffusion is the movement of a substance from an area of a higher amount towards an area of lower amount. Equilibrium is reached when there is an equal amount on both sides of the membrane.

The diffusion of water across a membrane because of a difference in concentration is called **osmosis**. Let's explore three different situations and analyze the flow of water.

1. A **hypotonic solution** means the environment outside of the cell has a lower concentration of dissolved material than the inside of the cell. If a cell is placed in a hypotonic solution, water will move into the cell. This causes the cell to swell, and it may even burst.
2. A **hypertonic solution** means the environment outside of the cell has more dissolved material than inside of the cell. If a cell is placed in a hypertonic solution, water will leave the cell. This can cause a cell to shrink and shrivel.
3. An **isotonic solution** is a solution in which the amount of dissolved material is equal both inside and outside of the cell. Water still flows in both directions, but an equal amount enters and leaves the cell.

How do marine animals keep their cells from shrinking? How do blood cells keep from bursting? Both have to do with the cell membrane and transport of materials. Marine animals live in salt water, which is a hypertonic environment; there is more salt in the water than in their cells. To prevent losing too much water from their bodies, these animals intake large quantities of salt water and secrete salt by active transport, which will be discussed later in this lesson. Red blood cells can be kept from bursting or shriveling if put in a solution that is isotonic to the blood cells. If the blood cells were put in pure water, the solution would be hypotonic to the blood cells, so water would enter the blood cells and they would swell and burst. This is represented in **Figure** 2.3.

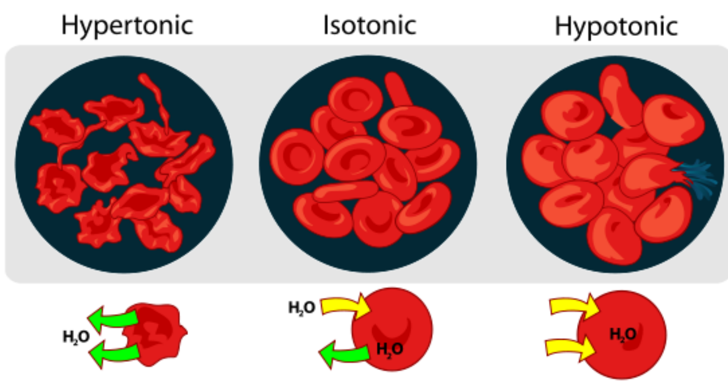

Figure 2.3: Osmosis causes these red blood cells to change shape by losing or gaining water.

Passive Transport

Diffusion is called **passive transport**. This means it does not require energy to move molecules. For example, oxygen diffuses out of the air sacs in your lungs into your bloodstream because oxygen is more concentrated in your lungs than in your blood. Oxygen moves from the high concentration of oxygen in your lungs to the low concentration of oxygen in your bloodstream. Sometimes, special proteins are needed to help molecules move across the membrane. These are called channel proteins or carrier proteins (**Figure** 2.4).

Diffusion Across Cell Membranes: Passive Transport can be viewed at `http://www.youtube.com/watch?v=JShwXBWGMyY` (4:41).

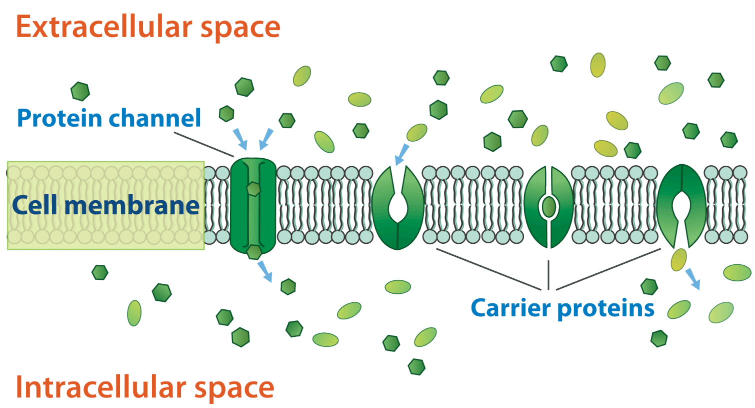

Figure 2.4: Protein channels and carrier proteins are involved in passive transport.

Figure 2.5: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/593

Active Transport

During **active transport,** molecules move from an area of low concentration to high concentration. This is the opposite of diffusion. Active transport is called "active" because this type of transport requires energy to move molecules. A protein in the membrane carries the molecules across the membrane. These proteins are often called "pumps", because like other pumps they use energy to move molecules. There are many cells in your body that use pumps to move molecules. For example, your nerve cells would not send messages to your brain unless you had protein pumps moving molecules by active transport. The sodium-potassium pump (**Figure** 2.7) is an example of an active transport pump.

An overviewof active transport can be viewed at `http://www.youtube.com/watch?v=yz7EHJFDEJs&feature=related` (1:26).

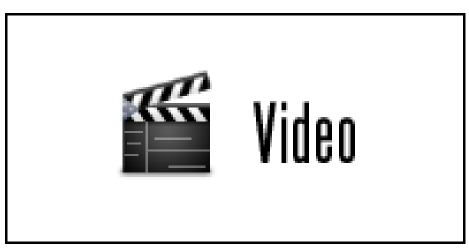

Figure 2.6: (Watch Youtube Video)
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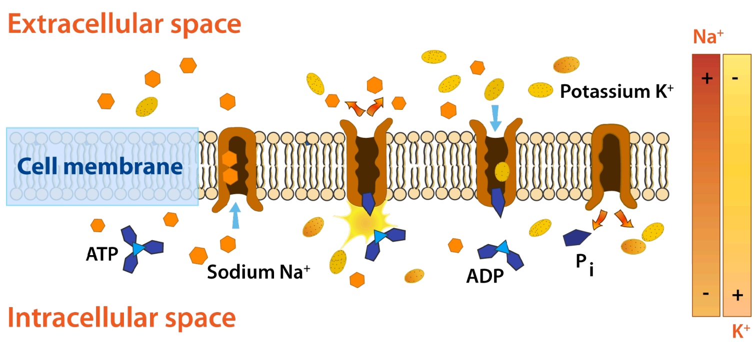

Figure 2.7: The sodium-potassium pump moves sodium ions to the outside of the cell and potassium ions to the inside of the cell. ATP is required for the protein to change shape. As ATP adds a phosphate group to the protein, it leaves behind adenosine diphosphate (ADP).

Lesson Summary

- The plasma membrane is semipermeable, meaning that some molecules can move through the membrane easily, while others cannot.
- Passive transport, such as diffusion and osmosis, does not require energy.
- Active transport moves molecules in the direction of the higher concentration and requires energy and a carrier protein.

Review Questions

Recall

1. What's the main difference between active and passive transport?

2. List the two types of passive transport.

3. Why is the plasma membrane considered semipermeable?

4. What is diffusion?

Apply Concepts

5. What happens when a cell is placed in a hypotonic solution?

6. What happens when a cell is placed in a hypertonic solution?

Critical Thinking

7. If a plant cell is placed in a solution and the cell shrivels up, what type of solution was it placed in? How do you know?

8. If a there are 100 X molecules on the outside of a cell and 10 X molecules inside of the cell, will X molecules flow into or out of the cell? Explain why.

Points to Consider

The next lesson discusses photosynthesis.

- It is often said that plants make their own food. What do you think this means?
- What substances do you think would need to move into a leaf cell for the cell to make its own food?
- What substances would need to move out of a leaf cell?

2.2 Photosynthesis

Lesson Objectives

- Explain the importance of photosynthesis.
- Write and interpret the chemical equation for photosynthesis.
- Describe what happens during the light reactions and the Calvin Cycle.

Check Your Understanding

- How are plant cells different from animal cells?
- In what organelle does photosynthesis take place?

Vocabulary

- chlorophyll
- photosynthesis
- stomata
- stroma
- thylakoid

What is Photosynthesis?

If a plant gets hungry, it cannot walk to a local restaurant and buy a slice of pizza. So how does a plant get the food it needs to survive? **Photosynthesis** is the process plants use to make their own "food" from the sun's energy, carbon dioxide and water.

Actually, almost all organisms obtain their energy from photosynthetic organisms. For example, if a bird eats a caterpillar, then the bird gets the energy that the caterpillar gets from the plants it eats. So the bird is indirectly getting energy that began with the "food" formed through photosynthesis. Therefore, the process of photosynthesis is central to sustaining life on Earth.

During photosynthesis, carbon dioxide and water combine with solar energy to create glucose and oxygen. Glucose is a sugar that acts as the "food" source for plants. Oxygen, which is necessary for animal life, is the waste of photosynthesis.

The Photosynthesis Song can be heard at http://www.youtube.com/watch?v=C1_uez5WX1o (1:52).

Figure 2.8: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/476

The Process of Photosynthesis

Photosynthesis takes place in chloroplasts. Chloroplasts are one of the main differences between plant and animal cells. There are two separate parts of a chloroplast (**Figure** 2.9).

- The inner compartments formed by the flattened sacs, or **thylakoids,** are called the thylakoid space. Energy from sunlight is absorbed by the pigment chlorophyll in the thylakoid membrane.
- The interior space that surrounds the thylakoids is filled with a fluid called **stroma.** This is where carbon dioxide is used to produce glucose.

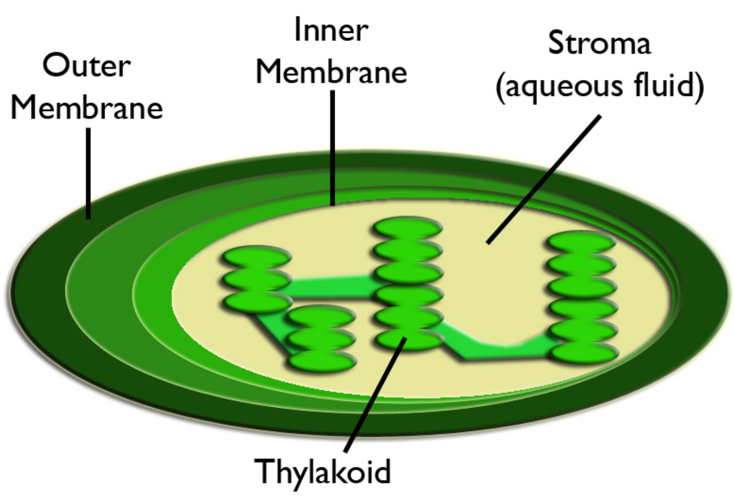

Figure 2.9: The chloroplast is the photosynthesis factory of the plant.

The Reactants

What goes into the plant cell? The reactants of photosynthesis are carbon dioxide and water, and the energy from sunlight. This means that carbon dioxide, water, and the sun's energy are necessary for the chemical reactions of photosynthesis.

- **Chlorophyll** is the green pigment in leaves that captures energy from the sun.
- The *veins* in a plant carry water from the roots to the leaves.
- Carbon dioxide enters the leaf from the air through special openings called **stomata** (**Figure** 2.10).

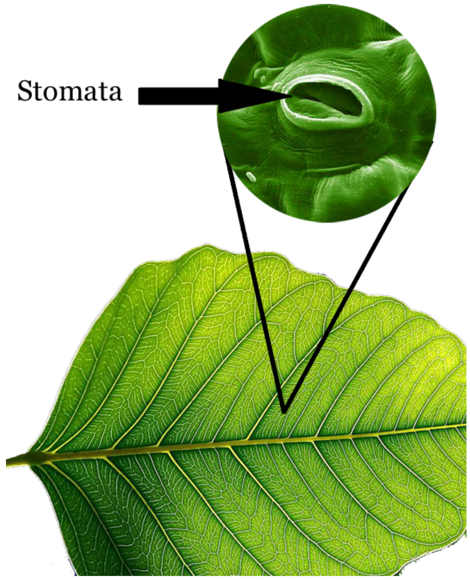

Figure 2.10: Stomata are special pores that allow gasses to enter and exit the leaf.

The Products

What is produced by the plant cell? The products of photosynthesis are glucose and oxygen. This means they are produced at the end of photosynthesis.

- Glucose, the food of plants, can be used to store energy for later in the form of carbohydrate molecules.
- Oxygen is a plant waste product. It is released into the atmosphere through the stomata. As you know, animals need oxygen to live. Without photosynthetic organisms like plants, there would not be enough oxygen in the atmosphere for animals to survive.

The Chemical Reaction

The overall chemical reaction for photosynthesis is 6 molecules of carbon dioxide (CO_2) and 6 molecules of water (H_20), with the addition of solar energy. This produces 1 molecule of glucose ($C_6H_{12}O_6$) and 6 molecules of oxygen (O_2) (**Figure** 2.11). Using chemical symbols the equation is represented as follows:

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$.

Lesson Summary

- The net reaction for photosynthesis is that carbon dioxide and water, together with energy from the sun, produce glucose and oxygen.

A review of photosynthesis can be viewed at http://www.youtube.com/watch?v=mpPwmvtDjWw (2:41).

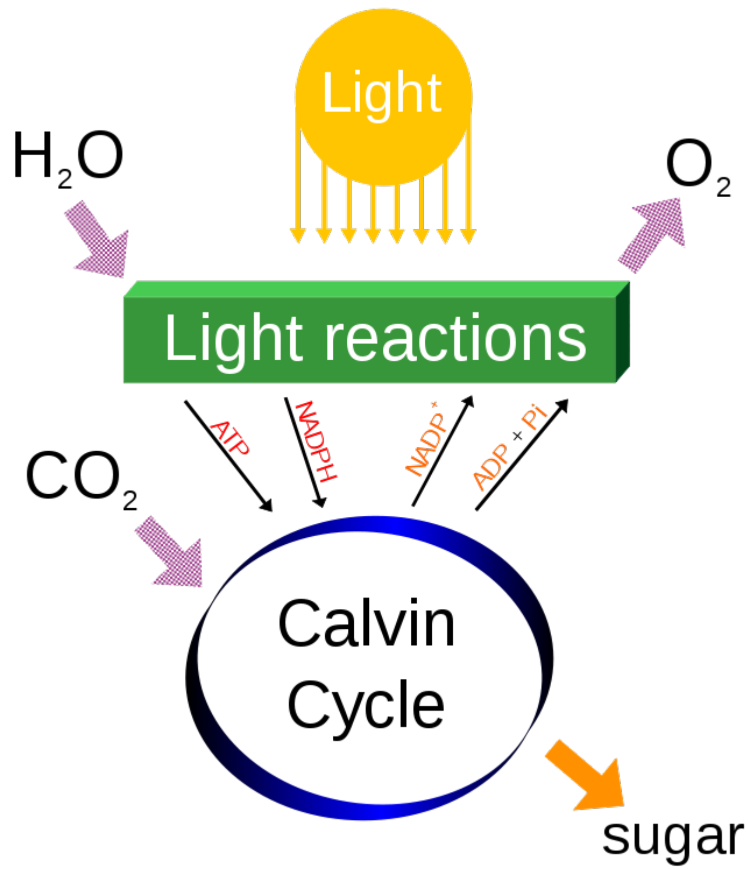

Figure 2.11: As is depicted here, the energy from sunlight is needed to start photosynthesis. The initial steps are called the light reactions as they occur only in the presence of light. During these initial reactions, water is used and oxygen is released. The energy from sunlight is converted into a small amount of ATP and an energy carrier called NADPH. Together with carbon dioxide, these are used to make glucose (sugar) through a process called the Calvin Cycle. NADP+ and ADP (and Pi, inorganic phosphate) are regenerated to complete the process.

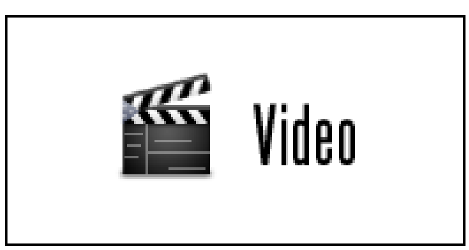

Figure 2.12: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/595

Review Questions

Recall

1. What are the reactants required for photosynthesis?
2. What are the products of photosynthesis?

Apply Concepts

3. What happens to the glucose produced from photosynthesis?
4. Why is it important to animals that oxygen is released during photosynthesis?
5. Describe the structures of the chloroplast where photosynthesis takes place.

Critical Thinking

6. What would happen if the stomata of a plant leaf were glued shut? Would that plant be able to perform photosynthesis? Why or why not?

Points to Consider

The next lesson is about Cellular Respiration.

- How do you gain energy from the food you eat?
- Which do you think provides more energy- a bowl of pasta or a small piece of candy?
- What "waste" gas do you exhale?

2.3 Cellular Respiration

Lesson Objectives

- Write and explain the chemical formula for cellular respiration.
- Explain the two states of cellular respiration.
- Compare photosynthesis with cellular respiration.

Check Your Understanding

- Where does the energy captured at the beginning of photosynthesis originate from?
- What is the form of chemical energy produced by photosynthesis?
- What occurs in oxidation and reduction reactions?

Vocabulary

- aerobic respiration
- alcoholic fermentation
- anaerobic respiration

- ATP
- cellular respiration
- fermentation
- lactic acid fermentation

What is Cellular Respiration?

How does the food you eat provide energy? When you need a quick boost of energy, you might reach for an apple or a candy bar. But cells do not "eat" apples or candy bars, these foods need to be broken down so that cells can use them. Through the process of **cellular respiration,** the energy in food is changed into energy that can be used by the body's cells. In other words, glucose and oxygen are converted into ATP, carbon dioxide, and water. **ATP**, or adenosine triphosphate, is chemical energy the cell can use. It is the molecule that provides energy for your cells to perform work, such as moving your muscles as you walk down the street.

A video of cellular respiration can be seen at `http://www.youtube.com/watch?v=nkRcdfmHqqI` (7:58).

Figure 2.13: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/596

The Process of Cellular Respiration

What happens inside of the cell? Glucose is broken down in the cytoplasm of the cells and then transported to the mitochondria, the organelles known as the energy "powerhouses" of the cells (**Figure** 2.14). Inside the mitochondria, the "broken-down" glucose is broken down again to release ATP. Oxygen is needed to help the process of turning glucose into ATP. The initial step releases just two molecules of ATP for each glucose. The later steps release much more ATP.

The Reactants

What goes into the cell? Oxygen and glucose are both reactants in the process of cellular respiration. Oxygen enters the body when an organism breathes. Glucose enters the body when an organism eats.

The Products

What does the cell produce? The main product of cellular respiration is ATP. Waste products include carbon dioxide and water. Carbon dioxide is transported from your mitochondria out of your cell, to your red blood cells, and back to your lungs to be exhaled.

When one molecule of glucose is broken down, it can be converted to a net total of 36 or 38 molecules of ATP. This only occurs in the presence of oxygen.

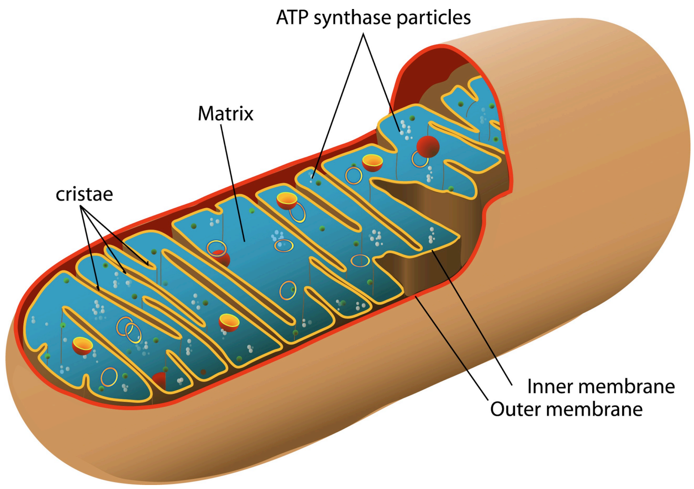

Figure 2.14: Most of the reactions of cellular respiration are carried out in the mitochondria.

The Chemical Reaction

The overall chemical reaction for cellular respiration is 1 molecule of glucose ($C_6H_{12}O_6$) and 6 molecules of oxygen (O_2) yields 6 molecules of carbon dioxide (CO_2) and 6 molecules of water (H_20). Using chemical symbols the equation is represented as follows:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

Connecting Cellular Respiration and Photosynthesis

Notice that the equation for cellular respiration is the direct opposite of photosynthesis (**Figure** 2.15). While water was broken down to form oxygen during photosynthesis, in cellular respiration oxygen is combined with hydrogen to form water. While photosynthesis requires carbon dioxide and releases oxygen, cellular respiration requires oxygen and releases carbon dioxide. This exchange of carbon dioxide and oxygen in all the organisms that use photosynthesis or cellular respiration worldwide helps to keep atmospheric oxygen and carbon dioxide at stable levels.

Fermentation

Sometimes cellular respiration is **anaerobic**, occurring in the absence of oxygen. In this process, called **fermentation**, no additional ATP is produced, so the organism only obtains the two ATP molecules per glucose molecule from the initial step of this process (compare that to 36-38 ATP produced with oxygen!).

Yeasts (single-celled eukaryotic organisms) perform **alcoholic fermentation** in the absence of oxygen, making ethyl alcohol (drinking alcohol) and carbon dioxide. This process is used to make common food and drinks. For example, alcoholic fermentation is used to bake bread. The carbon dioxide bubbles allow the bread to rise, and the alcohol evaporates. In wine making, the sugars of grapes are fermented to produce the wine.

Animals and some bacteria and fungi carry out **lactic acid fermentation.** Lactic acid is a waste product of this process. Our muscles perform lactic acid fermentation during strenuous exercise, when oxygen cannot be delivered to the muscles quickly enough. The buildup of lactic acid is what makes your muscles sore after exercise.

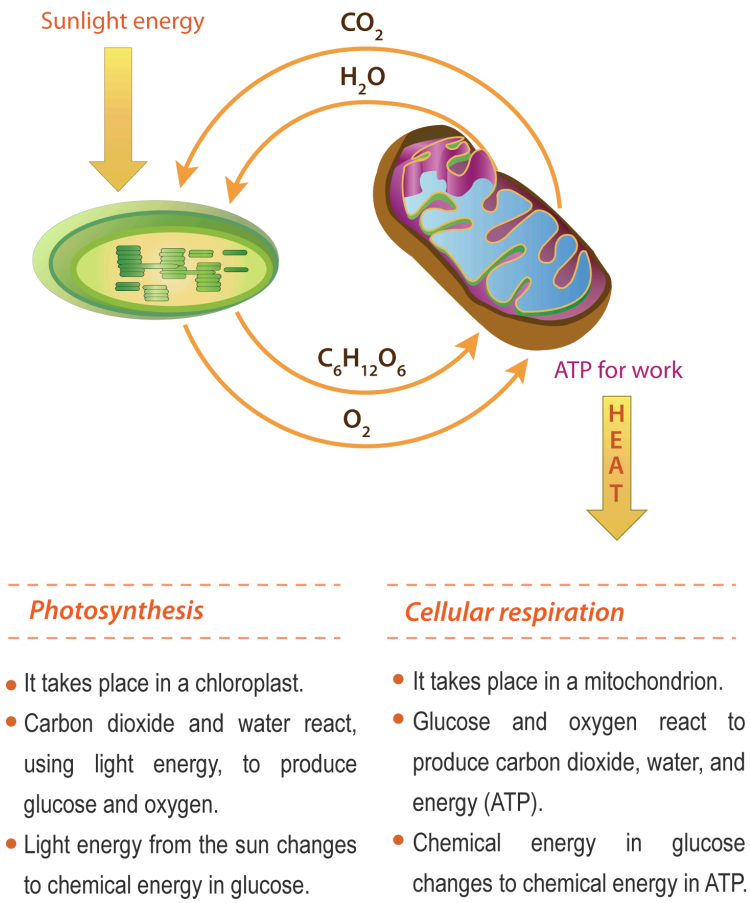

Figure 2.15: Cellular respiration and photosynthesis are direct opposite reactions. Some of the ATP made in the mitochondria is used as energy for work, and some is lost to the environment as heat. Can you explain what is depicted in this diagram?

Bacteria that produce lactic acid are used to make cheese and yogurt (**Figure** 2.16). Tooth decay is also increased by lactic acid from the bacteria that use the sugars in your mouth for energy.

Figure 2.16: Products of fermentation include cheese (lactic acid fermentation) and wine (alcoholic fermentation).

Lesson Summary

- Cellular respiration is the breakdown of glucose to release energy in the form of ATP.
- If oxygen is not available, the process of fermentation can break down glucose without the presence of oxygen.

A summary of cellular respiration can be viewed at http://www.youtube.com/watch?v=wqqYIgY40OE (8:50).

Figure 2.17: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/597

Review Questions

Recall

1. What is the purpose of cellular respiration?

2. Where is glucose broken down to form ATP?

Apply Concepts

3. What are the products of alcoholic fermentation?

4. Write the chemical reaction for the overall process of cellular respiration.

5. What produces more ATP, aerobic or anaerobic cellular respiration? What is the purpose of fermentation?

Critical Thinking

6. Why do your muscles get sore after vigorous exercise?

7. Why is the cellular respiration equation the opposite of the photosynthesis equation?

Supplemental Links

- http://en.wikipedia.org/wiki/Cellular_respiration
- http://biology.clc.uc.edu/Courses/bio104/cellresp.htm
- http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookGlyc.html
- http://biology.clc.uc.edu/Courses/bio104/cellresp.htm
- http://www.science.smith.edu/departments/Biology/Bio231/glycolysis.html

Points to Consider

- What do you think could happen if your cells divide uncontrollably?
- When new life is formed, do you think it receives all the DNA of the mother and the father?
- Why do you think you might need new cells throughout your life?

Image Sources

(1) Garrett and Kitty Wilkin. http://www.flickr.com/photos/gareandkitty/244555951/. CC BY-NC-SA 2.0.

(2) Mariana Ruiz Villarreal. http://commons.wikimedia.org/wiki/File:Scheme_facilitated_diffusion_in_cell_membrane-en.svg. Public Domain.

(3) CK-12 Foundation. . CC-BY-NC-SA 3.0.

(4) Daniel Mayer. http://commons.wikimedia.org/wiki/File:Simple_photosynthesis_overview.svg. CC-BY-SA 3.0.

(5) CK-12 Foundation. http://commons.wikimedia.org/wiki/File:Animal_mitochondrion_diagram_en.svg. Public Domain.

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(9) Stomata: Photohound; Leaf: Jon Sullivan/pdphoto.org. *[Stomata: http://en.wikipedia.org/wiki/File:Tomato_leaf_stomate_1-color.jpg; Leaf: http://en.wikipedia.org/wiki/File:Leaf_1_web.jpg]*. Both images are in the public domain.

(10) Mariana Ruiz Villarreal. http://commons.wikimedia.org/wiki/File:Scheme_sodium-potassium_pump-en.svg. Public Domain.

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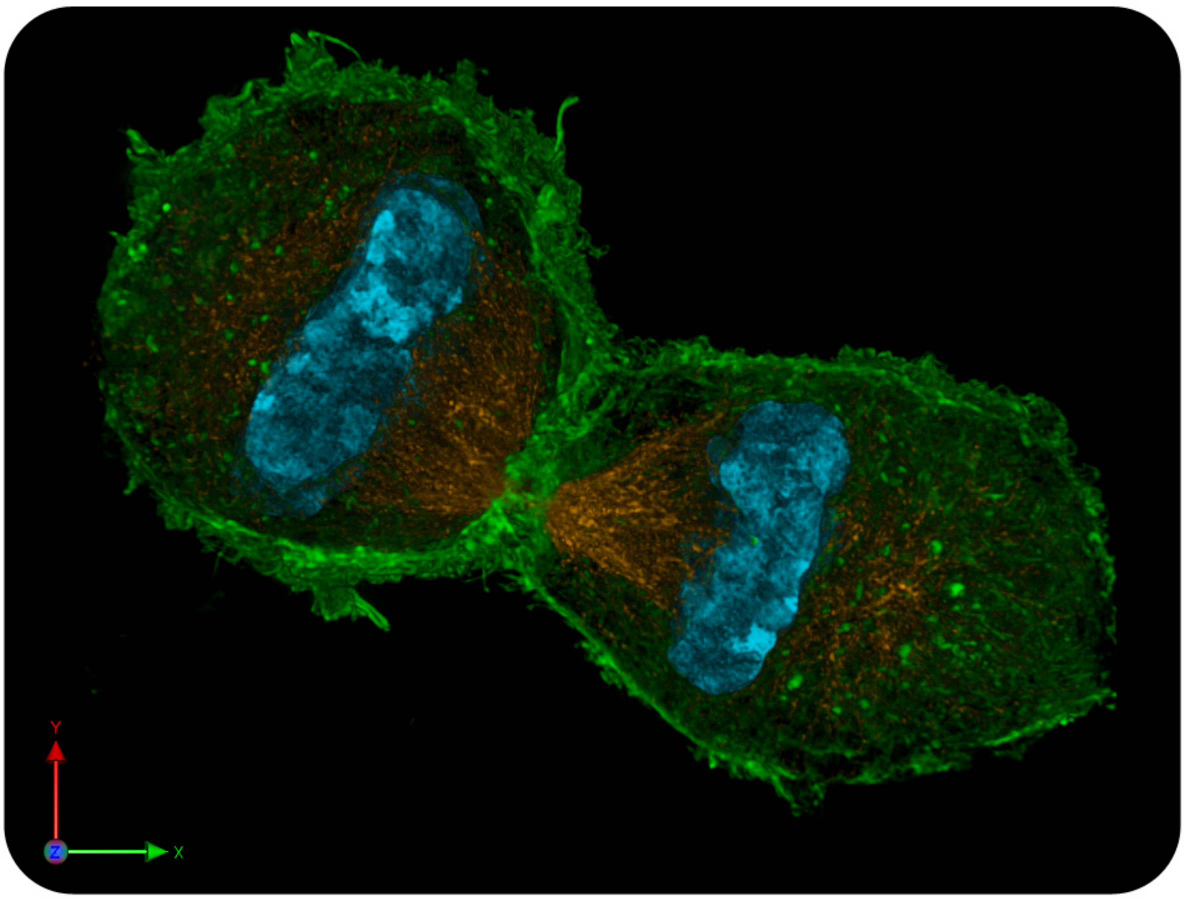
Chapter 3

MS Cell Division, Reproduction, and DNA



What has to happen for a cell to divide? Plenty. The above image shows the mitotic spindle in a sand dollar embryo. The mitotic spindle separates DNA in cells that are dividing. But that is just one step in the process. Why do you think cells need to divide? Do all cells divide the same way? How do cells help us reproduce? What would happen to living things if their cells failed to divide? What happens if cells divide uncontrollably? Think about these questions as you begin to understand why and how cells divide and how cell division helps the reproduction of all living things.

3.1 Cell Division

Lesson Objectives

- Explain why cells need to divide.
- List the stages of the cell cycle and explain what happens at each stage.
- List the stages of mitosis and explain what happens at each stage.

Check Your Understanding

- What is the cell theory?
- In what part of your cells is the genetic information located?

Vocabulary

- anaphase
- cancer
- cell cycle
- chromosome
- cytokinesis
- daughter cell
- interphase
- metaphase
- mitosis
- parent cell
- prophase
- sister chromatids
- spindle
- telophase

Why Cells Divide

Imagine the first stages of life. In humans, a sperm fertilizes an egg, forming the first cell. But humans are made up of trillions of cells, so where do the new cells come from? Remember that according to cell theory, all cells must come from existing cells. From that one cell, an entire baby will develop.

How does a new life go from one cell to so many? The cell divides in half, creating two cells. Then those two cells divide, for a total of four cells. The new cells continue to divide and divide. One cell becomes two, then four, then eight, and so on (**Figure** 3.1).

Besides the development of a baby, there are many other reasons that cell division is necessary for life:

1. To grow and develop, you must form new cells. Imagine how often your cells must divide during a growth spurt. Growing just an inch requires countless cell divisions.
2. Cell division is also necessary to repair damaged cells. Imagine you cut your finger. After the scab forms, it will eventually disappear and new skin cells will grow to repair the wound. Where do these cells come from? Some of your existing skin cells divide and produce new cells.
3. Your cells can also simply wear out. Over time you must replace old and worn-out cells. Cell division is essential to this process.

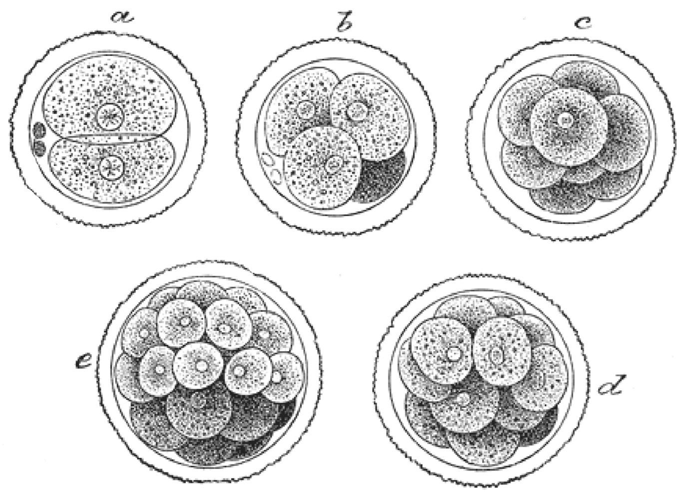


Figure 3.1: Cells divide repeatedly to produce an embryo. Previously the one-celled zygote (the first cell of a new organism) divided to make two cells (a). Each of the two cells divides to yield four cells (b), then the four cells divide to make eight cells (c), and so on. Through cell division, an entire embryo forms from one initial cell.

The Cell Cycle

The process of cell division in eukaryotic cells is carefully controlled. The **cell cycle** is the lifecycle of a cell, with cell division at the end of the cycle. Like a human lifecycle that is made up of different phases, like childhood, adolescence, and adulthood, there are a series of steps that lead to cell division (**Figure** 3.2).

These steps can be divided into two main components, interphase and mitosis.

1. Interphase: The stage when the cell mostly performs its "everyday" functions. For example, it is when a kidney cell does what a kidney cell is supposed to do.
2. Mitosis: The stage when the cell prepares to become two cells.

Most of the cell cycle consists of **interphase,** the time between cell divisions. Interphase can be divided into three stages:

1. The first growth phase (G1): During the G1 stage, the cell doubles in size and doubles the number of organelles.
2. The synthesis phase (S): The DNA is replicated during this phase. In other words, an identical copy of all the cell's DNA is made. This ensures that each new cell has a set of genetic material identical to that of the parental cell. DNA replication will be further discussed in lesson 5.3.
3. The second growth phase (G2): Proteins are synthesized that will help the cell divide. At the end of interphase, the cell is ready to enter mitosis.

During **mitosis**, the nucleus divides. Mitosis is followed by **cytokinesis**, when the cytoplasm divides, resulting in two cells. After cytokinesis, cell division is complete. Scientists say that one **parent cell**, or the dividing cell, forms two genetically identical **daughter cells,** or the cells that divide from the parent cell. The term "genetically identical" means that each cell has an identical set of DNA, and this DNA is

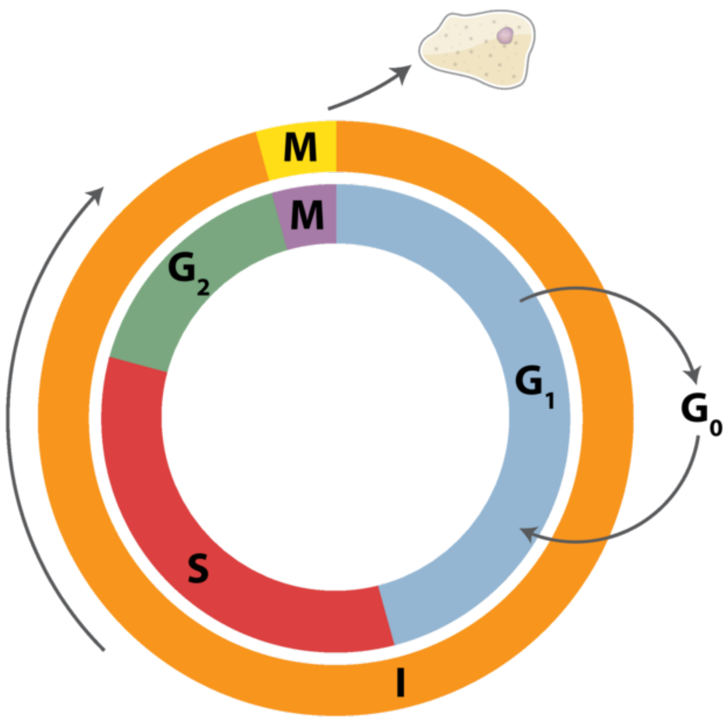


Figure 3.2: The cell cycle is the repeated process of growth and division. Notice that most of the cell cycle is spent in interphase (G1, S, and G2) (I). G0 is a resting state of the cell cycle.

also identical to that of the parent cell. If the cell cycle is not carefully controlled, it can cause a disease called **cancer**, which causes cell division to happen too fast. A tumor can result from this kind of growth.

Cancer is discussed in the video at http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/11/RZhL7LDPk8w. (12:36).

Figure 3.3: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/126

Two animations of the cell cycle are available at the following links. See if you can explain what is happening in these animations.

- http://www.wisc-online.com/objects/index_tj.asp?objID=AP13604
- http://www.cellsalive.com/cell_cycle.htm

Mitosis and Chromosomes

The genetic information of the cell, or DNA, is stored in the nucleus. During mitosis, two nuclei (plural for nucleus) must form, so that one nucleus can be in each of the new cells. The DNA inside of the nucleus is also copied. The copied DNA needs to be moved into the nucleus, so each cell can have a correct set of genetic instructions.

To begin mitosis, the DNA in the nucleus wraps around proteins to form **chromosomes**. Each organism has a unique number of chromosomes. In human cells, our DNA is divided up into 23 pairs of chromosomes. After the DNA is replicated during the S stage of interphase, each chromosome has two identical molecules of DNA, called **sister chromatids**, forming the "X" shaped molecule depicted in **Figure** 3.4.

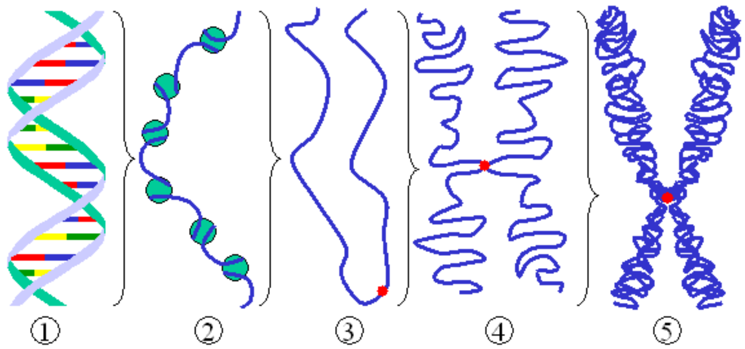


Figure 3.4: The DNA double helix wraps around proteins (2) and tightly coils a number of times to form a chromosome (5). This figure shows the complexity of the coiling process. The red dot shows the location of the centromere, where the microtubules attach during mitosis and meiosis.

The Four Phases of Mitosis

During mitosis, the two sister chromatids must be split apart. Each resulting chromosome is made of *1/2* of the "X". Through this process, each daughter cell receives one copy of each chromosome. Mitosis is divided into four phases (**Figure** 3.5):

1. **Prophase**: The chromosomes "condense," or become so tightly wound that you can see them under a microscope. The wall around the nucleus, called the nuclear envelope, disappears. **Spindles** also form and attach to chromosomes to help them move.
2. **Metaphase**: The chromosomes line up in the center of the cell. The chromosomes line up in a row, one on top of the next.
3. **Anaphase**: The two sister chromatids of each chromosome separate, resulting in two sets of identical chromosomes.
4. **Telophase**: The spindle dissolves and nuclear envelopes form around the chromosomes in both cells.

Each new nucleus contains the exact same number and type of chromosomes as the original cell. The cell is now ready for cytokinesis, which literally means "cell movement." The cells separate, producing two genetically identical cells, each with its own nucleus. **Figure** 3.7 is a representation of dividing plant cells.

The phases of mitosis are discussed in the video: http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/8/LLKX_4DHE3I (20:42).

Additional animations of mitosis can be viewed at the following links:

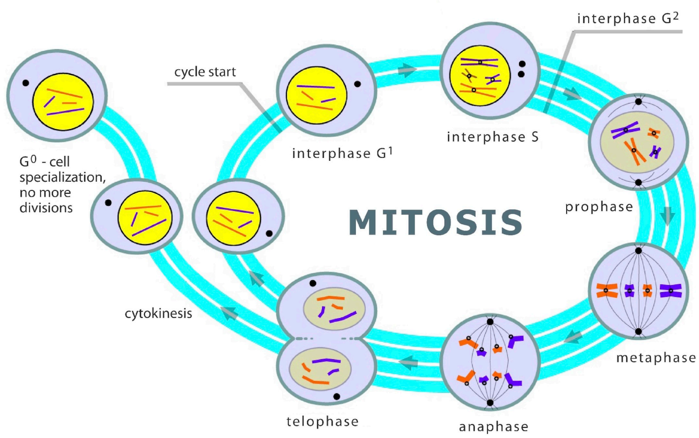


Figure 3.5: An overview of the cell cycle and mitosis: during prophase the chromosomes condense, during metaphase the chromosomes line up, during anaphase the sister chromatids are pulled to opposite sides of the cell, and during telophase the nuclear envelope forms.

Figure 3.6: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/128

- http://www.cellsalive.com/mitosis.htm
- http://www.youtube.com/watch?v=7hQ5xXJSmK4&feature=related

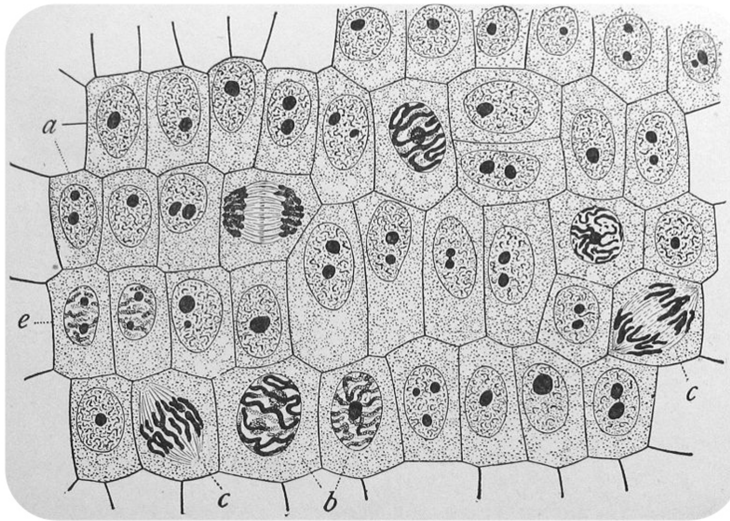


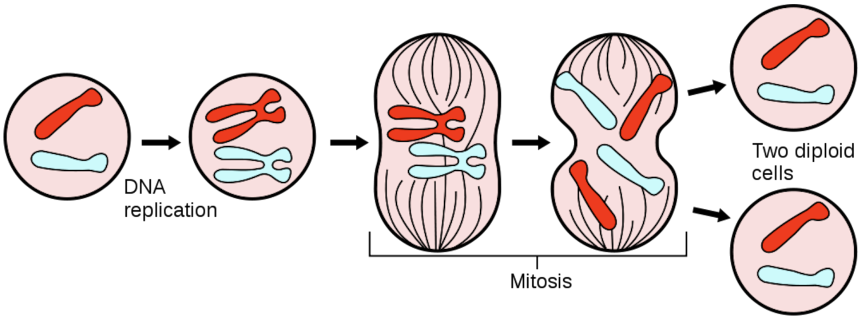
Figure 3.7: This is a representation of dividing plant cells. Cell division in plant cells differs slightly from animal cells as a cell wall must form. Note that most of the cells are in interphase. Can you find examples of the different stages of mitosis?

Mitosis in Real Time can be viewed at http://www.youtube.com/watch?v=m73i1Zk8EA0&feature=related (0:19).

Figure 3.8: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/598

Lesson Summary

- Cells divide for growth, development, reproduction and replacement of injured or worn-out cells.
- The cell cycle is a series of controlled steps by which a cell divides.
- During mitosis, the newly duplicated chromosomes are divided into two daughter nuclei.
- This summary diagram depicts one cell dividing into two genetically identical cells. Mitosis occurs after DNA replication. A diploid cell has two sets of chromosomes, as is shown here.



Review Questions

Recall

1. In what phase of mitosis are chromosomes moving toward opposite sides of the cell?
2. In what phase of mitosis do the duplicated chromosomes condense?
3. What step of the cell cycle is the longest?
4. What is the term for the division of the cytoplasm?
5. What happens during the S stage of interphase?

Apply Concepts

6. Interphase used to be considered the "resting" stage of the cell cycle. Why is this not correct?
7. What are some reasons that cells divide?
8. During what stage of the cell cycle does the cell double in size?
9. Why must cell division be tightly regulated?

Critical Thinking

10. What would happen if the cells in your liver stopped going through the process of mitosis?
11. What do you think might happen if mitosis could NOT stop happening to the cells in your brain?

Further Reading / Supplemental Links

- http://en.wikipedia.org/wiki/Mitosis
- http://www.biology.arizona.edu/Cell_bio/tutorials/cell_cycle/cells3.html
- http://biology.clc.uc.edu/courses/bio104/mitosis.htm
- http://en.wikipedia.org/wiki/Cell_cycle

Points to Consider

- How might a cell without a nucleus divide?
- How are new cells made that include the DNA of two parents?

3.2 Reproduction

Lesson Objectives

- Name the types of asexual reproduction.
- Explain the advantage of sexual reproduction.
- List the stages of meiosis and explain what happens in each stage.

Check Your Understanding

- Can something that does not reproduce still be considered living?
- What stores the genetic information that is passed on to offspring?
- How many chromosomes are in the human nucleus?

Vocabulary

- allele
- asexual reproduction
- binary fission
- crossing-over
- cross-pollination
- diploid
- external fertilization
- gamete
- gonad
- haploid
- internal fertilization
- meiosis
- ovaries
- parthenogenesis
- sexual reproduction
- testes
- zygote

What is reproduction?

What does reproduction mean? Can an organism be considered alive if it cannot make the next generation? Since individuals cannot live forever, they must reproduce for the species to survive. Reproduction is the ability to make the next generation.

Two methods of reproduction are:

1. **Asexual reproduction**, or the process of forming a new individual from a single parent.
2. **Sexual reproduction**, or the process of forming a new individual from two parents.

There are advantages and disadvantages to each method, but the result is always the same: a new life begins.

Asexual Reproduction

For humans to reproduce, DNA must be passed from the mother and father to the child. Humans cannot reproduce with just one parent, but it is possible in other organisms, like bacteria, some insects and some fish. These organisms can reproduce asexually, meaning that the offspring (children) have a single parent and share the exact same genetic material as the parent. This is very different from humans.

The advantage of asexual reproduction is that it can be very quick and does not require the meeting of a male and female organism. The disadvantage of asexual reproduction is that organisms cannot mix beneficial traits from both parents. An organism that is born through asexual reproduction only has the DNA from the one parent, and it is the exact copy of that parent. This can cause problems for the individual. For example, if the parent organism has a gene that causes cancer, the offspring will also have the gene that causes cancer. Organisms produced sexually may or may not inherit the cancerous gene because there are two parents mixing up their genes.

Types of organisms that reproduce asexually include:

1. Prokaryotic organisms, like bacteria. Bacteria reproduce through **binary fission,** where they grow and divide in half (**Figure** 3.9). First, their chromosome replicates (bacteria only have one chromosome) and the cell enlarges. After cell division, the two new cells each have one identical chromosome (mitosis is not necessary because bacteria do not have nuclei). Then, new membranes form to separate the two cells. This simple process allows bacteria to reproduce very rapidly.
2. Flatworms, an animal species. Flatworms divide in two, then each half regenerates into a new flatworm identical to the original.
3. Different types of insects, fish, and lizards. These organisms can reproduce asexually through a process called parthenogenesis (**Figure** 3.10). **Parthenogenesis** happens when an unfertilized egg cell grows into a new organism. The resulting organism has half the amount of genetic material of the parent. Parthenogenesis is common in honeybees. In a hive, the sexually produced eggs become workers, while the asexually produced eggs become drones.

Sexual Reproduction

During sexual reproduction, two parents are involved. Most animals are dioecious, meaning there is a separate male and female sex, with the male producing sperm and the female producing eggs. When a sperm and egg meet, a **zygote,** the first cell of a new organism, is formed (**Figure** 3.11). The zygote will divide and grow into the embryo.

Let's explore how animals, plants, and fungi reproduce sexually:

- Animals often have **gonads,** organs that produce eggs or sperm. The male gonads are the **testes,** which produce the sperm, and the female gonads are the **ovaries,** which produce the eggs. Sperm and egg, the two sex cells, are known as **gametes**, and can combine two different ways:

1. Fish and other aquatic animals release their gametes in the water, which is called **external fertilization.** These gametes will combine by chance. (**Figure** 3.12).
2. Animals that live on land reproduce by **internal fertilization**. Typically males have a penis that deposits sperm into the vagina of the female. Birds do not have penises, but they do have a chamber called the cloaca that they place close to another bird's cloaca to deposit sperm.

- Plants can also reproduce sexually, but their reproductive organs are different from animals' gonads. Plants that have flowers have their reproductive parts in the flower. The sperm is contained in the

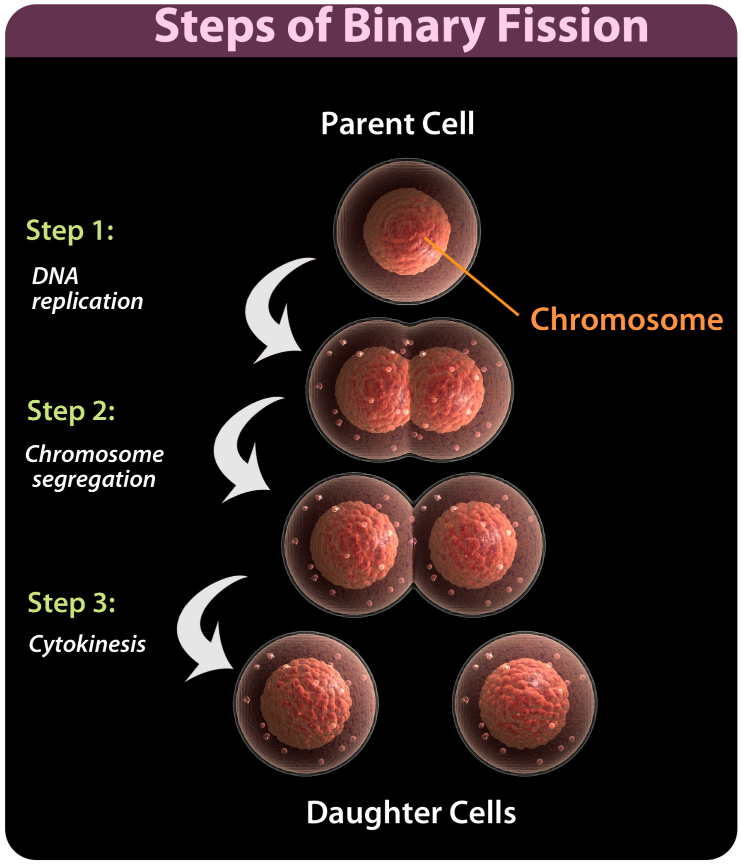


Figure 3.9: Bacteria reproduce by binary fission. Shown is one bacterium reproducing and becoming two bacteria.

Figure 3.10: This Komodo dragon was born by parthenogenesis.

Figure 3.11: During sexual reproduction, a sperm fertilizes an egg.

Figure 3.12: This fish guards her eggs, which will be fertilized externally.

pollen, while the egg is contained in the ovary, deep within the flower. The sperm can reach the egg two different ways:

1. In self-pollination, the egg is fertilized by the pollen of the same flower.
2. In **cross-pollination**, sperm from the pollen of one flower fertilizes the egg of another flower. Like other types of sexual reproduction, cross-pollination allows new combinations of traits. Cross-pollination occurs when pollen is carried by the wind to another flower. It can also occur when animal pollinators, like honeybees, or butterflies (**Figure** 3.13) carry the pollen from flower to flower.

- Fungi can also reproduce sexually, but instead of female and male sexes, they have (+) and (-) strains. When the filaments of a (+) and (-) fungi meet, the zygote is formed. Just like in plants and animals, each zygote receives DNA from two parent strains.

Figure 3.13: Butterflies receive nectar when they deposit pollen into flowers, resulting in cross-pollination.

Meiosis and Gametes

Meiosis is a process of cell division that produces sex cells, or gametes. Gametes are reproductive cells, such as sperm and egg. As gametes are produced, the number of chromosomes must be reduced by half. Why? The zygote must contain information from the mother and from the father, so the gametes must contain half of the chromosomes found in normal body cells.

In humans, our cells have 23 pairs of chromosomes, and each chromosome within a pair is called a **homologous chromosome.** For each of the 23 chromosome pairs, you received one chromosome from your father and one chromosome from your mother. The homologous chromosomes are separated when gametes are formed. Therefore, gametes have only 23 chromosomes, not 23 pairs.

Alleles are alternate forms of genes found on chromosomes. Since the separation of chromosomes into gametes is random, it results in different combinations of chromosomes (and alleles) in each gamete. With 23 pairs of chromosomes, there is a possibility of over 8 million different combinations of chromosomes in a gamete.

Haploid vs. Diploid

A cell with two sets of chromosomes is **diploid**, referred to as *2n,* where *n* is the number of sets of chromosomes. Most of the cells in a human body are diploid. A cell with one set of chromosomes, such as a gamete, is **haploid,** referred to as *n*. Sex cells are haploid. When a haploid sperm (*n*) and a haploid egg (*n*) combine, a diploid zygote will be formed (*2n*). In short, when a diploid zygote is formed, half of the DNA comes from each parent.

Meiosis

Before meiosis begins, DNA replication occurs, so each chromosome contains two sister chromatids that are identical to the original chromosome.

Meiosis is divided into two divisions: Meiosis I and Meiosis II. Each division is similar to mitosis and can be divided into the same phases: prophase, metaphase, anaphase, and telophase. Between the two divisions, DNA replication does not occur. Through this process, one diploid cell will divide into four haploid cells.

The phases of meiosis are discussed at `http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/9/ijLc52LmFQg` (27:23).

Figure 3.14: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/130

Meiosis I

During meiosis I, the pairs of homologous chromosomes are separated from each other.

1. Prophase I: The homologous chromosomes line up together. During this time, a process that only happens in meiosis can occur. This process is called **crossing-over** (**Figure** 3.15), which is the exchange of DNA between homologous chromosomes. Crossing-over increases the new combinations of alleles in the gametes. Without crossing-over, the offspring would always inherit all of the many alleles on one of the homologous chromosomes. Also during prophase I, the spindle forms, the chromosomes condense as they coil up tightly, and the nuclear envelope disappears.
2. Metaphase I: The homologous chromosomes line up in pairs in the middle of the cell. Chromosomes from the mother or from the father can each attach to either side of the spindle. Their attachment is random, so all of the chromosomes from the mother or father do not end up in the same gamete. The gamete will contain some chromosomes from the mother and some chromosomes from the father.
3. Anaphase I: The homologous chromosomes separate.
4. Telophase I: The spindle fibers dissolves, but a new nuclear envelope does not need to form. This is because the nucleus will divide again. No DNA replication happens between meiosis I and meiosis II because the chromosomes are already duplicated.

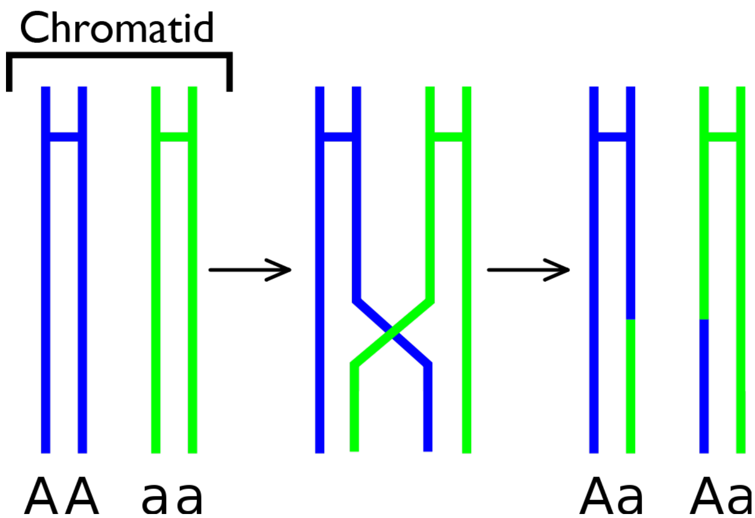


Figure 3.15: During crossing-over, segments of DNA are exchanged between sister chromatids. Notice how this can result in an allele (A) on one sister chromatid being moved onto the other sister chromatid.

Meiosis II

During meiosis II, the sister chromatids are separated and the gametes are generated.

The steps are outlined below:

1. Prophase II: The chromosomes condense.
2. Metaphase II: The chromosomes line up one on top of the next along the middle of the cell.
3. Anaphase II: The sister chromatids separate.
4. Telophase II: Nuclear envelopes form around the chromosomes in all four cells.

After cytokinesis, each cell has divided again. Therefore, meiosis results in four daughter cells with half the DNA of the parent cell (**Figure** 3.16). In human cells, the parent cell has 46 chromosomes, so the cells produced by meiosis have 23 chromosomes. These cells will become gametes.

Mitosis vs. Meiosis: A Comparison

Mitosis, meiosis and sexual reproduction are discussed at http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/7/kaSIjIzAtYA (18:23).

Figure 3.18 is a comparison between binary fission, mitosis, and meiosis. Mitosis and meiosis are also compared in **Table** 3.1.

Animations of meiosis can be found at the following sites:

- http://www.cellsalive.com/meiosis.htm
- http://www.youtube.com/watch?v=MqaJqLL49a0&NR=1

Table 3.1: **Mitosis vs. Meiosis: A Comparison**

	Mitosis	Meiosis
Purpose:	To produce new cells	To produce gametes

Table 3.1: (continued)

	Mitosis	**Meiosis**
Number of cells produced:	2	4
Rounds of Cell Division:	1	2
Haploid or Diploid:	Diploid	Haploid
Daughter cells identical to parent cells?	Yes	No
Daughter cells identical to each other?	Yes	No

Lesson Summary

- Organisms can reproduce sexually or asexually.
- The gametes in sexual reproduction must have half the DNA of the parent.
- Meiosis is the process of nuclear division that forms gametes.

Review Questions

Recall

1. What is parthogenesis?
2. During what phase of meiosis do homologous chromosomes separate?
3. What is the purpose of meiosis?
4. In what phase of meiosis do homologous chromosomes pair up?

Apply Concepts

5. Explain how organisms reproduce asexually.
6. Explain how birds fertilize their eggs.
7. How do most plants reproduce sexually?
8. Compare and contrast the process of mitosis and the process of meiosis.

Critical Thinking

9. How would sexual reproduction in a lizard be different than in a fish?
10. What is the advantage of sexual reproduction over asexual reproduction?
11. If an organism has 12 chromosomes in its cells, how many chromosomes will be in its gametes?

Further Reading / Supplemental Links

- http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookmeiosis.html
- http://www.biology.arizona.edu/Cell_BIO/tutorials/meiosis/page3.html

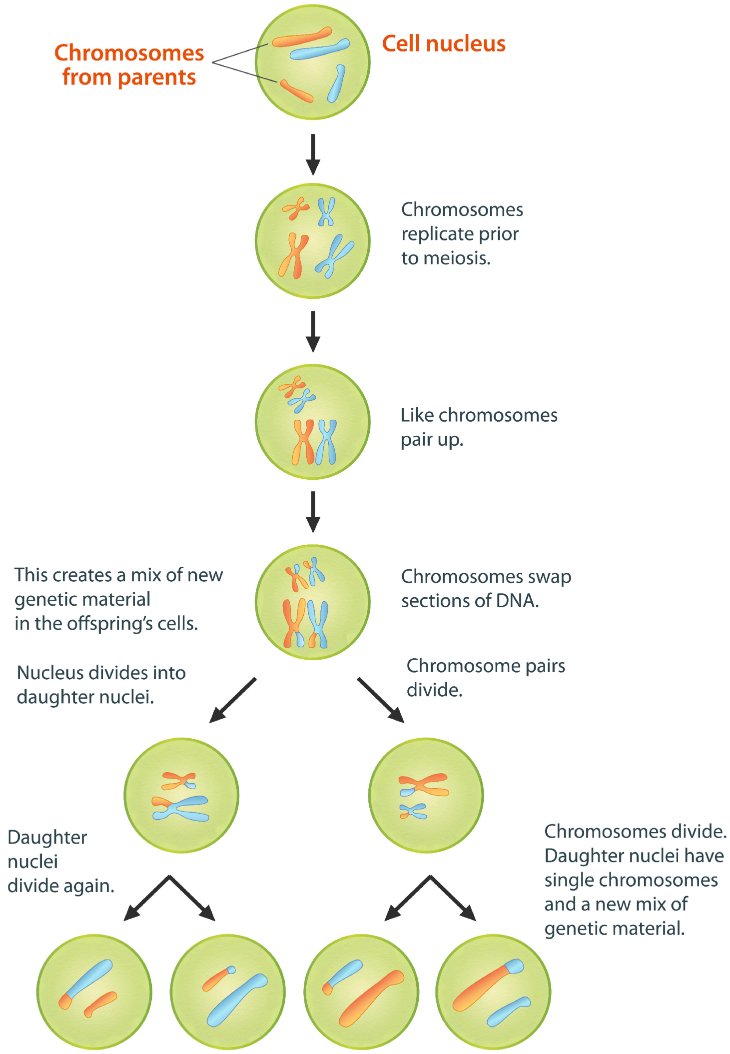


Figure 3.16: An overview of meiosis.

Figure 3.17: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/129

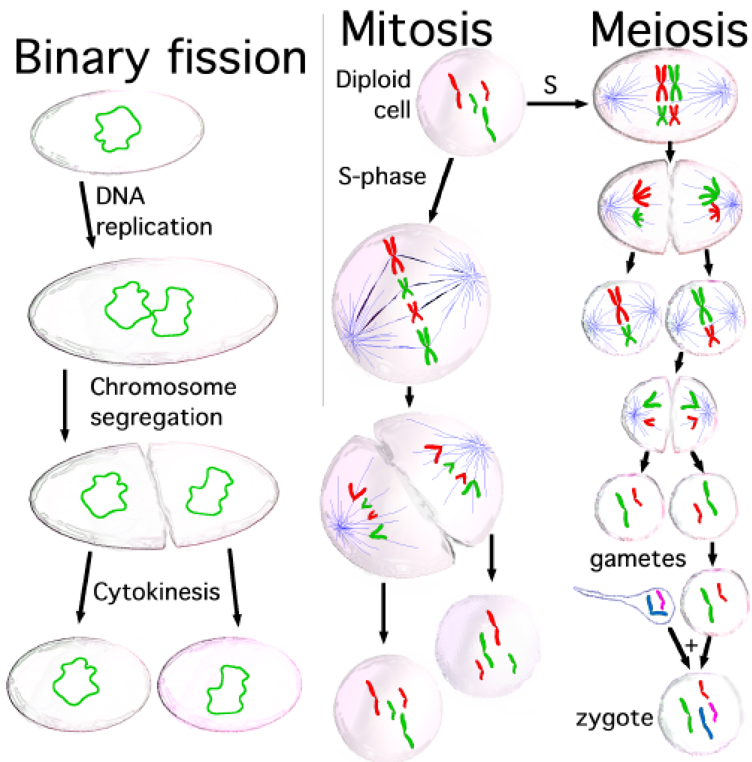


Figure 3.18: A comparison between binary fission, mitosis, and meiosis.

- http://en.wikipedia.org/

Points to Consider

- What must be replicated prior to mitosis?
- How do you think DNA might be replicated?
- What might happen if there is a mistake during DNA replication?

3.3 DNA, RNA, and Protein Synthesis

Lesson Objectives

- Explain the chemical composition of DNA.
- Explain how DNA synthesis works.
- Explain how proteins are coded for and synthesized.
- Describe the three types of RNA and the functions of each.

Check Your Understanding

- What is the purpose of DNA?
- When is DNA replicated?

Vocabulary

- amino acid
- DNA
- DNA replication
- double helix
- gene
- mutagen
- mutation
- nucleotide
- RNA
- semiconservative replication
- transcription
- translation

What is DNA?

DNA, is the material that makes up our chromosomes and stores our genetic information. When you build a house, you need a blueprint, a set of instructions that tells you how to build. The DNA is like the blueprint for living organisms. The genetic information is a set of instructions that tell your cells what to do.

DNA is an abbreviation for deoxyribonucleic acid. As you may recall, nucleic acids are a type of macromolecule that store information. The *deoxyribo* part of the name refers to the name of the sugar that is contained in DNA, deoxyribose. DNA may provide the instructions to make up all living things, but it is actually a very simple molecule. DNA is made of a long chain of nucleotides.

Nucleotides are composed of 3 main parts:

1. Phosphate group
2. 5-carbon sugar
3. Nitrogen-containing base

The only difference between each nucleotide is the identity of the base. There are only four possible bases that make up each DNA nucleotide: adenine (A), guanine (G), thymine (T), and cytosine (C).

The various sequences of these four bases make up the genetic code of your cells. It may seem strange that there are only four letters in the "alphabet" of DNA. But since your chromosomes contain millions of nucleotides, there are many, many different combinations possible with those four letters.

But how do all these pieces fit together? James Watson and Francis Crick won the Nobel Prize in 1962 for piecing together the structure of DNA. Together with the work of Rosalind Franklin and Maurice Wilkins, they determined that DNA is made of two strands of nucleotides formed into a **double helix**, or a two-stranded spiral, with the sugar and phosphate groups on the outside, and the paired bases connecting the two strands on the inside of the helix (**Figure** 3.19 and **Figure** 3.20).

Base-Pairing

The bases in DNA do not pair randomly. When Erwin Chargaff looked closely at the bases in DNA, he noticed that the percentage of adenine (A) in the DNA always equaled the percentage of thymine (T), and the percentage of guanine (G) always equaled the percentage of cytosine (C). Watson and Crick's model explained this result by suggesting that A always pairs with T and G always pairs with C in the DNA helix.

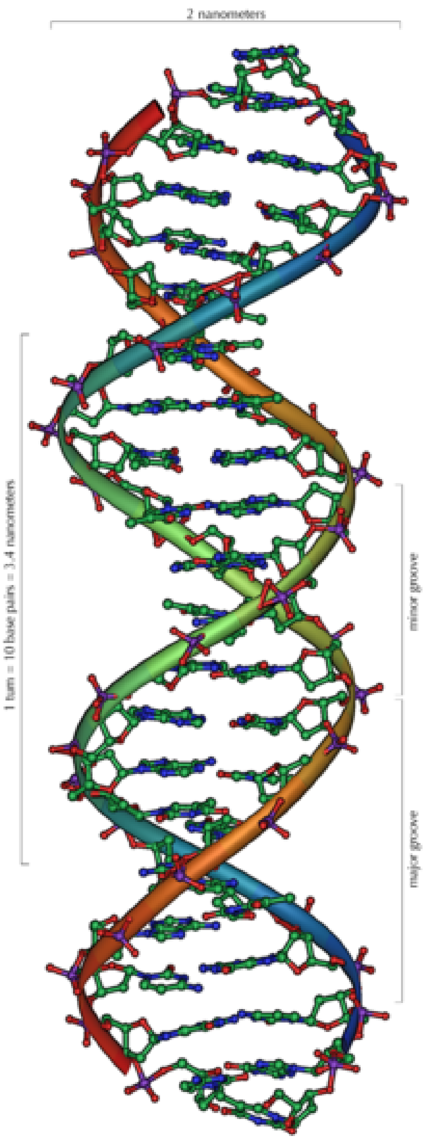


Figure 3.19: DNA's three-dimensional structure is a double helix. The hydrogen bonds between the bases at the center of the helix hold the helix together.

Therefore A and T, and G and C, are "complementary bases," or bases that always pair together. For example, if one DNA strand reads ATGCCAGT, the other strand will be made up of the complementary bases: TACGGTCA.

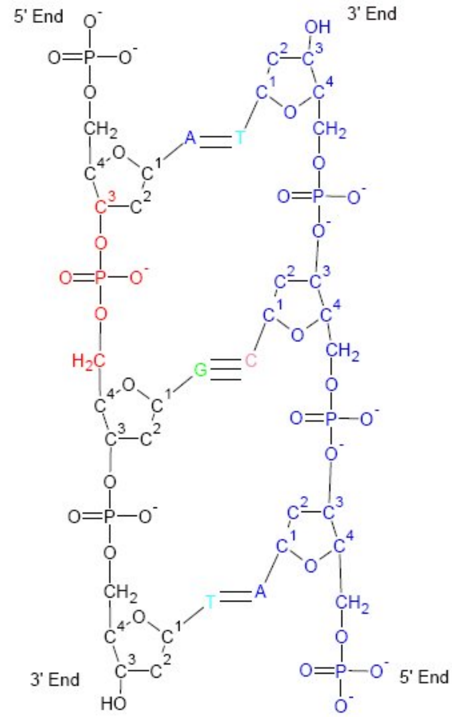


Figure 3.20: The chemical structure of DNA includes a chain of nucleotides consisting of a 5-carbon sugar, a phosphate group, and a nitrogen base. Notice how the sugar and phosphate form the backbone of DNA (one strand in blue), with the hydrogen bonds between the bases joining the two strands.

The vocabulary of DNA, including chromosomes, chromatids, chromatin, transcription, translation, and replication, is discussed at http://www.youtube.com/user/khanacademy#p/c/7A9646BC5110CF64/6/s9HPNwXd9fk (18:23).

Figure 3.21: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/127

DNA Replication

The base pairing rules are crucial for the process of replication. **DNA replication** occurs when DNA is copied to form an identical molecule of DNA. DNA replication happens before cell division. Below are the steps involved in DNA replication:

1. The DNA helix unwinds like a zipper, as the bonds between the base pairs are broken.
2. The two single strands of DNA then each serve as a template for a new stand to be created. Using DNA as a template means that the bases are placed in the right order because of the base pairing rules. If ATG is on the "template strand," then TAC will be on the new DNA strand.
3. The new set of nucleotides then join together to form a new strand of DNA. The process results in two DNA molecules, each with one old strand and one new strand of DNA.

This process is known as **semiconservative replication** because one strand is conserved (kept the same) in each new DNA molecule (**Figure** 3.22).

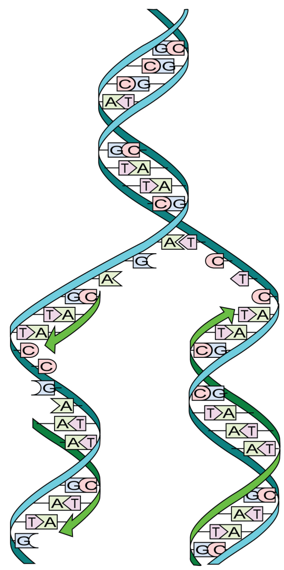


Figure 3.22: DNA replication occurs when the DNA strands "unzip", and the original strands of DNA serve as a template for new nucleotides to join and form a new strand.

Protein Synthesis

The DNA sequence contains the instructions to make units called amino acids, which are assembled in a specific order to make proteins. In short, DNA contains the instructions to create proteins. Each strand of DNA has many separate sequences that code for a specific protein. Units of DNA that contain code for the creation of one protein are called **genes.** An overview of protein synthesis can be seen at this animation: http://www.biostudio.com/demo_freeman_protein_synthesis.htm

Cells Can Turn Genes On or Off

There are about 22,000 genes in every human cell. Does every human cell have the same genes? Yes. Does every human cell use the same genes to make the same proteins? No. In a multicellular organism, such as us, cells have specific functions because they have different proteins. They have different proteins because different genes are expressed in different cell types.

Imagine that all of your genes are "turned off." Each cell type only "turns on" (or expresses) the genes that have the code for the proteins it needs to use. So different cell types "turn on" different genes, allowing different proteins to be made, giving different cell types different functions.

Three Types of RNA

DNA contains the instructions to create proteins, but it does not make proteins itself. DNA is located in the nucleus, while proteins are made on ribosomes in the cytoplasm. So DNA needs a messenger to bring its instructions to a ribosome located outside of the nucleus. DNA sends out a message, in the form of **RNA** (ribonucleic acid), describing how to make the protein.

There are three types of RNA directly involved in protein synthesis:

- Messenger RNA (mRNA) carries the instructions from the nucleus to the cytoplasm.
- The other two forms of RNA, ribosomal RNA (rRNA) and transfer RNA (tRNA) are involved in the process of ordering the amino acids to make the protein.

All three RNAs are nucleic acids, made of nucleotides, similar to DNA. The RNA nucleotide is different from the DNA nucleotide in the following ways:

- RNA contains a different kind of sugar, called ribose.
- In RNA, the base uracil (U) replaces the thymine (T) found in DNA.
- RNA is a single strand.

DNA Transcription

mRNA is created by using DNA as a template. The process of constructing an mRNA molecule from DNA is known as **transcription** (**Figure** 3.24 and **Figure** 3.25). The double helix of DNA unwinds and the nucleotides follow basically the same base pairing rules to form the correct sequence in the mRNA. This time, however, U pairs with each A in the DNA. In this manner, the genetic code is passed on to the mRNA.

Two multimedia links of protein synthesis are provided below.

- http://www-class.unl.edu/biochem/gp2/m_biology/animation/gene/gene_a2.html

Transcription and Translation can be viewed at http://www.youtube.com/watch?v=41_Ne5mS2ls (4:06).

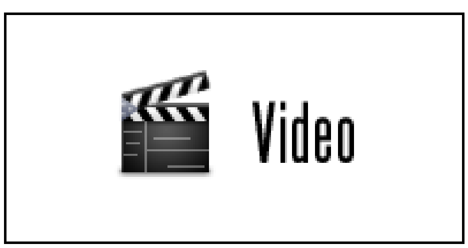


Figure 3.23: (Watch Youtube Video)
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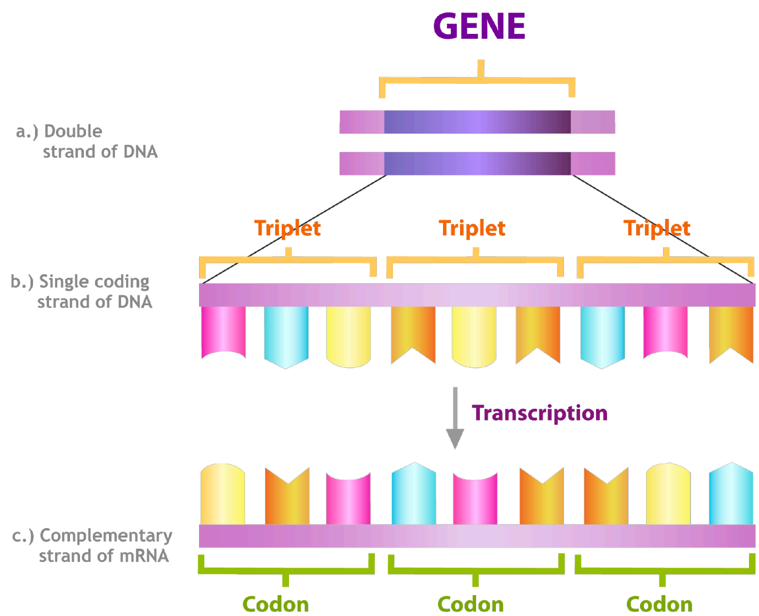

Figure 3.24: Each gene (a) contains triplets of bases (b) that are transcribed into RNA (c). Every triplet, or codon, encodes for a unique amino acid.

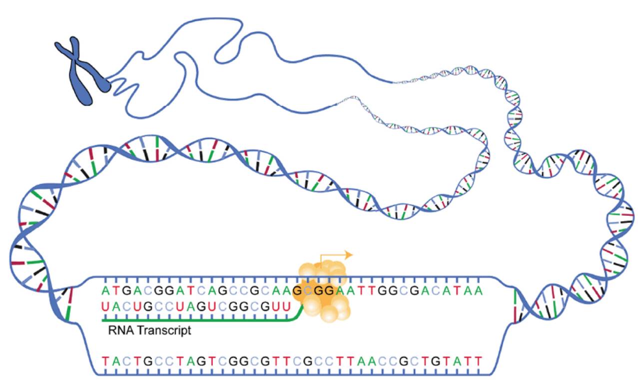

Figure 3.25: Base-pairing ensures the accuracy of transcription. Notice how the helix must unwind for transcription to take place.

RNA Translation

The mRNA is directly involved in the protein-making process. mRNA tells the ribosome (**Figure** 3.26) how to create a protein. The process of reading the mRNA code in the ribosome to make a protein is called **translation** (**Figure** 3.27). Sets of three bases, called codons, are read in the ribosome, the organelle responsible for making proteins.

The following are the steps involved in translation:

1. mRNA travels to the ribosome from the nucleus.
2. The base code in the mRNA determines the order of the amino acids in the protein. The genetic code in mRNA is read in "words" of three letters (triplets), called **codons.** There are 20 amino acids and different codons code for different ones. For example, GGU codes for the amino acid glycine, while GUC codes for valine.
3. tRNA reads the mRNA code and brings a specific amino acid to attach to the growing chain of amino acids. Each tRNA carries only one type of amino acid and only recognizes one specific codon.
4. tRNA is released from the amino acid.
5. Three codons, UGA, UAA, and UAG, indicate that the protein should stop adding amino acids. They are called "stop codons" and do not code for an amino acid. Once tRNA comes to a stop codon, the protein is set free from the ribosome.

The chart in **Figure** 3.28 is used to determine which amino acids correspond to which codons. An interactive activity for transcribing and translating a gene can be found at `http://learn.genetics.utah.edu/units/basics/transcribe/`.

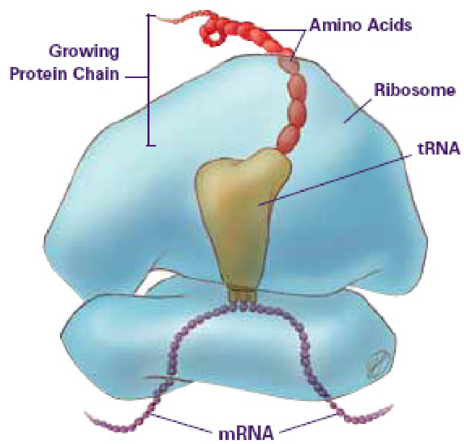

Figure 3.26: Ribosomes translate RNA into a protein with a specific amino acid sequence. The tRNA binds and brings to the ribosome the amino acid encoded by the mRNA. Ribosomes are made of rRNA and proteins.

Mutations

The process of DNA replication is not always 100% accurate, and sometimes the wrong base is inserted in the new strand of DNA. A permanent change in the sequence of DNA is known as a **mutation**. Small changes in the DNA sequence are usually point mutations, which is a change in a single nucleotide. A mutation may have no effect. Sometimes, a mutation can cause the protein to be made incorrectly, which can affect how well the protein works, or whether it works at all. Usually the loss of a protein function is detrimental to the organism.

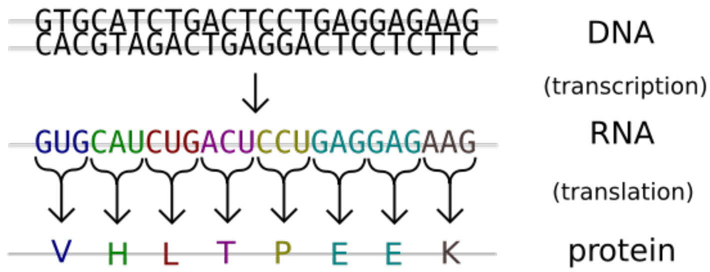

Figure 3.27: This summary of how genes are expressed shows that DNA is transcribed into RNA, which is translated in turn to protein.

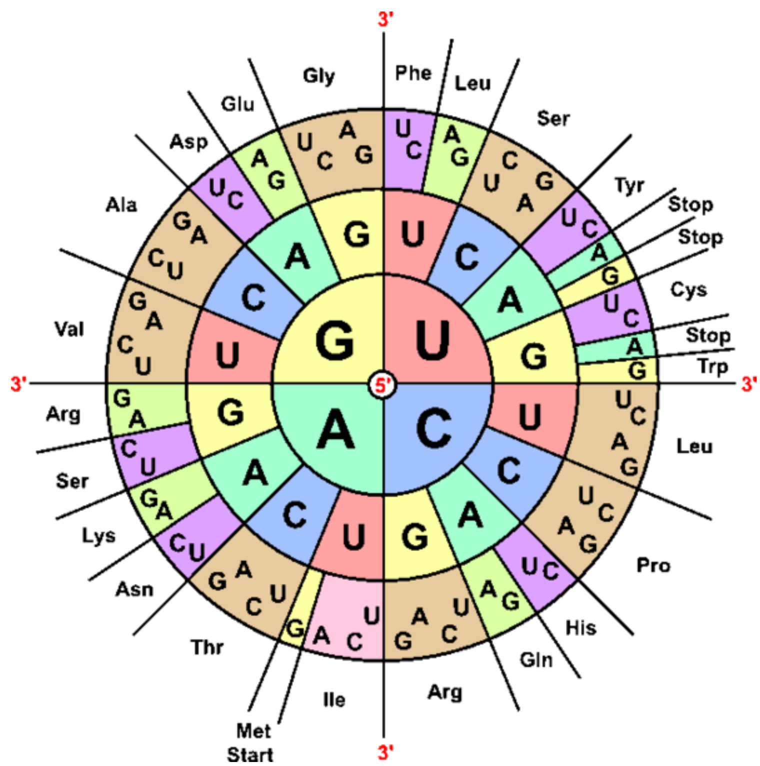

Figure 3.28: This chart shows the genetic code used by all organisms. For example, an RNA codon reading GUU would encode for a valine (Val) according to this chart. Start at the center for the first base of the three base codon, and work your way out. Notice for valine, the second base is a U and the third base of the codon may be either a G, C, A, or U. Similarly, glycine (Gly) is encoded by a GGG, GGA, GGC, and GGU.

However, in rare circumstances, the mutation can be beneficial. For example, suppose a mutation in an animal's DNA causes the loss of an enzyme that makes a dark pigment in the animal's skin. If the population of animals has moved to a light colored environment, the animals with the mutant gene would have a lighter skin color and be better camouflaged. So in this case, the mutation is beneficial.

Mutations may also occur in chromosomes. Possible types of mutations in chromosomes (**Figure** 3.29) include:

1. Deletion: When a segment of DNA is lost, so there is a missing segment in the chromosome.
2. Duplication: When a segment of DNA is repeated, creating a longer chromosome.
3. Inversion: When a segment of DNA is flipped and then reattached to the chromosome.
4. Insertion: When a segment of DNA from one chromosome is added to another, unrelated chromosome.
5. Translocation: When two segments from different chromosomes change positions.

If a single base is deleted (called a point mutation), there can be huge effects on the organism because this may cause a "frameshift mutation." Remember that the bases are read in groups of three by the tRNA. If the reading frame gets off by one base, the resulting sequence will consist of an entirely different set of codons. The reading of an mRNA is like reading three letter words of a sentence. Imagine you wrote "the big dog ate the red cat". If you take out the second letter from "big", the frame will be shifted so now it will read " the bgd oga tet her edc at." One single deletion makes the whole "sentence" impossible to read.

Many mutations are not caused by errors in replication. Mutations can happen spontaneously and they can be caused by **mutagens** in the environment. Some chemicals, such as those found in tobacco smoke, can be mutagens. Sometimes mutagens can also cause cancer. Tobacco smoke, for example, is often linked to lung cancer.

Lesson Summary

- DNA stores the genetic information of the cell in the sequence of its 4 bases: adenine, thymine, guanine, and cytosine.
- The information in a small segment of DNA, a gene, is sent by mRNA to the ribosome to synthesize a protein.
- Within the ribosome, tRNA reads the mRNA in sets of three bases (triplets), called codons, which encode for the specific amino acids that make up the protein.
- A mutation is a permanent change in the sequence of bases in DNA.

Review Questions

Recall

1. What is a nucleotide made out of?

2. Describe the process of DNA replication.

3. What is made in the process of transcription?

4. What is made in the process of translation?

5. Name a mutagen.

Apply Concepts

6. Translate the following segment of DNA into RNA: AGTTC

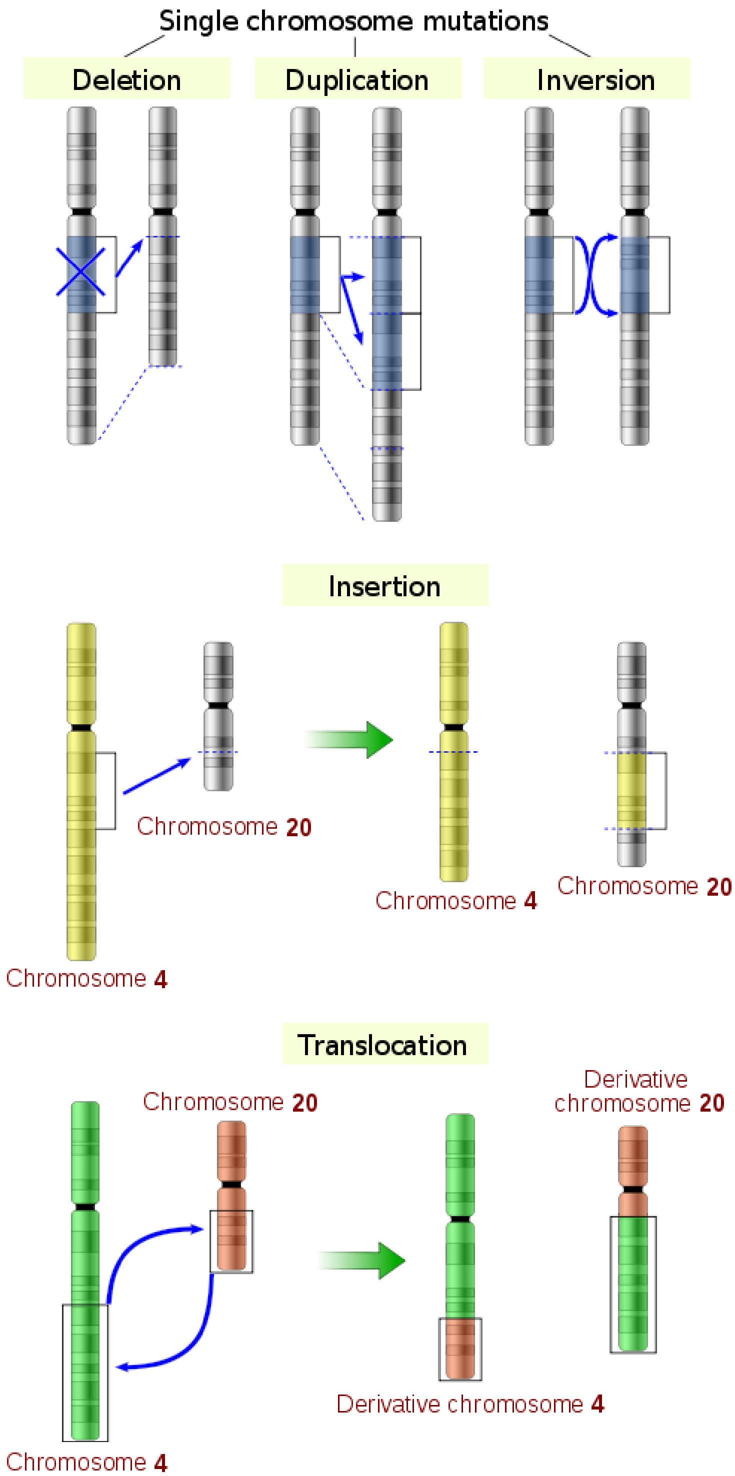

Figure 3.29: Mutations can arise in DNA through deletion, duplication, inversion, insertion, and translocation within the chromosome.

7. Write the complimentary DNA nucleotides to this strand of DNA: GGTCCA

8. Nucleotides are subunits of which two macromolecules?

9. Amino acids are subunits that make up what macromolecule?

10. How does RNA encode for proteins?

Critical Thinking

11. How does a mutation in a strand of DNA affect translation and transcription?

12. Given the DNA sequence, ATGTTAGCCTTA, what is the mRNA sequence? What is the amino acid sequence?

Further Reading / Supplemental Links

- http://nobelprize.org/educational_games/medicine/dna_double_helix/readmore.html
- http://learn.genetics.utah.edu/units/basics/builddna/
- http://enwikipedia.org/
- http://sickle.bwh.harvard.edu/scd_background.html

Points to Consider

- Your cells have "proofreaders" that replace mismatched pairs that occurred during DNA synthesis. How would that affect the rate of mutation in your body?
- There are many diseases due to mutations in the DNA. These are known as genetic diseases, and many can be passed onto the next generation. Think about how a single base change cause a huge medical problem.
- Your DNA contains the instructions to make you. So is everyone's DNA different? Can it be used to distinguish individuals, like a fingerprint?

Image Sources

(1) YassineMrabet. *[hhttp://commons.wikimedia.org/wiki/File:Chromosomes_mutations-en.svg]*. Public Domain.

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(3) James Steidl. *[www.shutterstock.com]*. purchased by CK12.

(4) National Human Genome Research Institute. http://commons.wikimedia.org/wiki/Image:DNA_transcription.gif. Public Domain.

(5) CK-12 Foundation. http://commons.wikimedia.org/wiki/Image:Transcription.png. Public Domain.

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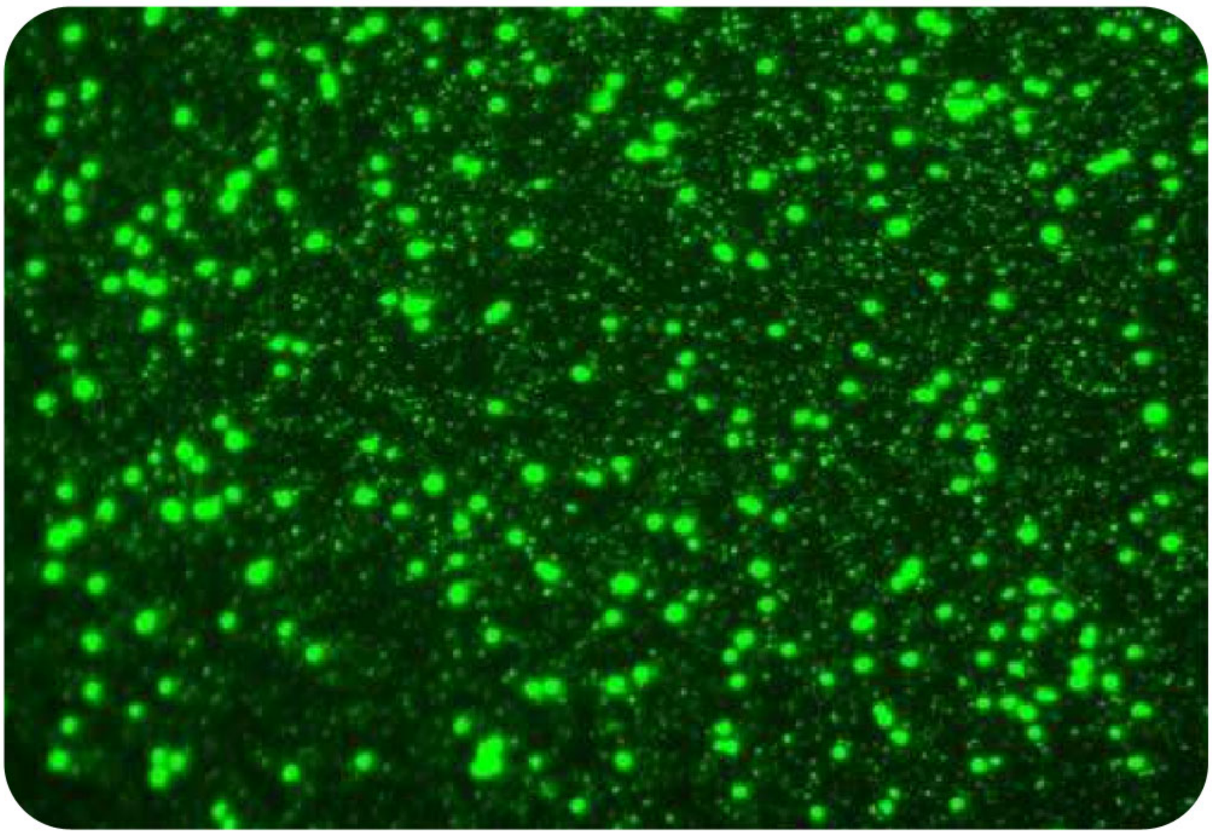
Chapter 4

MS Prokaryotes



The above image shows bacteria dyed with a fluorescent color. They look just like little cells. Well, that's exactly what they are.

Bacteria are prokaryotic organisms. About 3.5 billion years ago, long before the first plants, people, or other animals appeared, prokaryotes were the first life forms on Earth. For at least a billion years, prokaryotes ruled the Earth as the only existing organisms.

What do you think of when you think of bacteria? Germs? Diseases? Bacteria can be harmful, but they can also help you. How do you think bacteria can help humans and other organisms?

Did you know that bacteria are not the only type of prokaryote? There is another type, called archaea, which we will explore in addition to the questions asked above.

4.1 Bacteria

Lesson Objectives

- Describe the cellular features of bacteria.
- Explain the ways in which bacteria can obtain energy.
- Explain how bacteria reproduce themselves.
- Identify some ways in which bacteria can be helpful.
- Identify some ways in which bacteria can be harmful.

Check Your Understanding

- How do prokaryotic and eukaryotic cells differ?
- What are some components of all cells, including bacteria?

Vocabulary

- bacilli
- chemotroph
- cocci
- conjugation
- cyanobacteria
- decomposer
- flagella
- nucleoid
- peptidoglycan
- spirilli
- transduction

Characteristics of Bacteria

Even though life is much more diverse on Earth today, bacteria (singular: bacterium) are still the most abundant organisms on Earth. Recall that prokaryotes are single-celled organisms that lack a nucleus, and that the prokaryotes include bacteria and archaea.

Size and Shape

Bacteria are so small that they can only be seen with a microscope. When viewed under the microscope, they have three distinct shapes (**Figure" 4.1,** Figure 4.2**, and** Figure 4.3**). Bacteria can be classified by their shape:**

1. **Bacilli** are rod-shaped.
2. **Cocci** are sphere-shaped.
3. **Spirilli** are spiral-shaped.

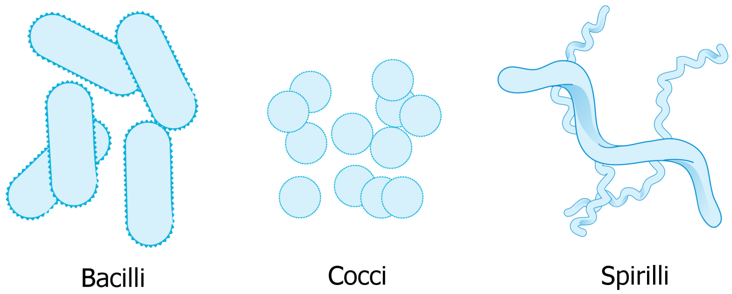


Figure 4.1: Bacteria come in many different shapes. Some of the most common shapes are bacilli (rods), cocci (spheres), and spirilli (spirals). Bacteria can be identified and classified by their shape.

Figure 4.2: Escherichia coli is an example of bacteria that are rod-shaped, or bacilli.

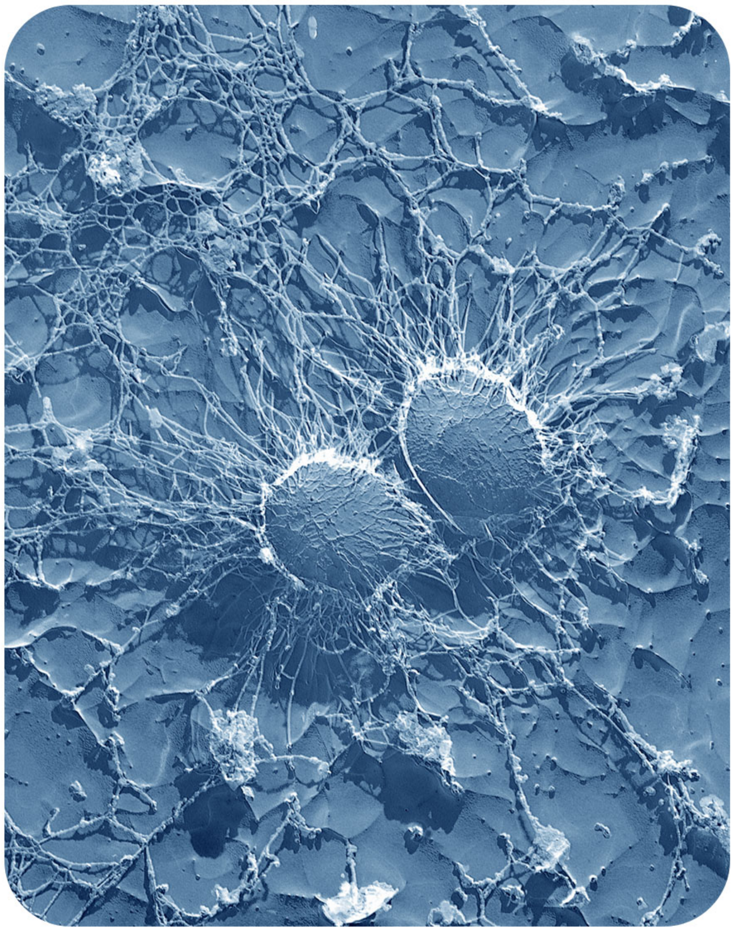


Figure 4.3: Staphylococcus aureus is an example of bacteria that are sphere-shaped, or cocci.

The Cell Wall

Bacteria are surrounded by a cell wall consisting of **peptidoglycan**, a complex molecule consisting of sugars and amino acids. The cell wall is important for protecting bacteria. The cell wall is so important that some antibiotics, such as penicillin, kill bacteria by preventing the cell wall from forming.

Another type of bacteria, called parasitic bacteria, depends on a host organism for energy and nutrients. If the host starts attacking the bacteria, the bacteria release a layer of slime that surrounds the cell wall for an extra layer of protection.

Differences between Eukaryotes and Prokaryotes

Recall that all prokaryotes, including bacteria, lack many of the things that eukaryotes contain, such as membrane-bound organelles (like mitochondria or chloroplasts) or a nucleus (**Figure** 4.4).

Similarities to Eukaryotes

Like eukaryotic cells, prokaryotic cells do have:

1. Cytoplasm, the fluid inside the cell.
2. A plasma membrane, which acts as another barrier.
3. Ribosomes, where proteins are assembled.
4. DNA, contained in a large circular strand, forming a single chromosome, that is compacted into a structure called the **nucleoid**. Many bacteria also have additional small rings of DNA known as **plasmids**.

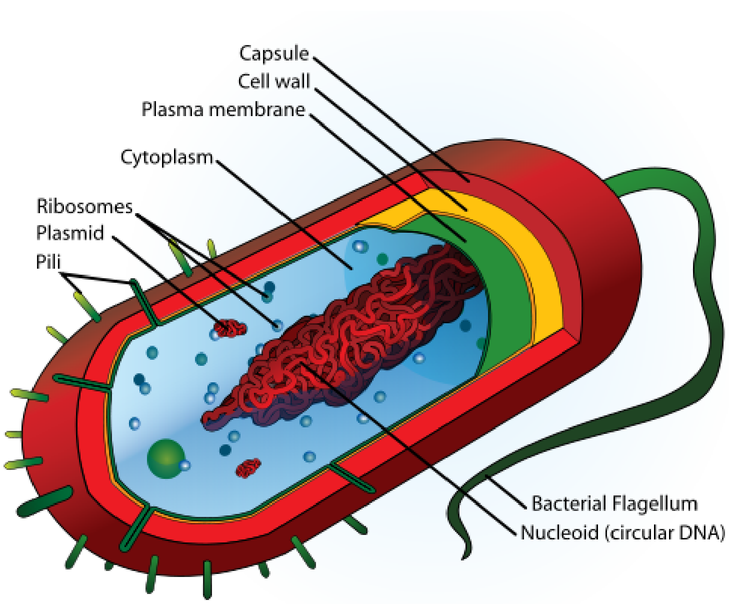


Figure 4.4: The structure of a bacterial cell is distinctive from a eukaryotic cell because of features such as an outer cell wall and the circular DNA of the nucleoid, and the lack of membrane-bound organelles.

Flagella

Some bacteria also have tail-like structures called **flagella** (**Figure** 4.5). Flagella help bacteria move. As the flagella rotate, they spin the bacteria and propel them forward.

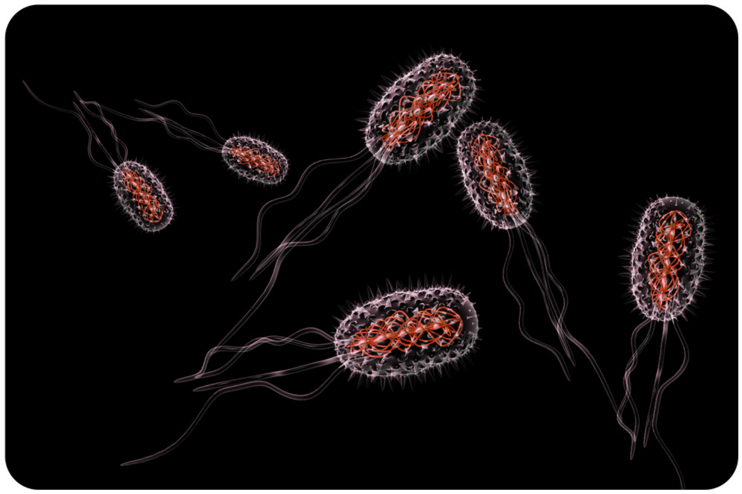


Figure 4.5: The flagella facilitate movement in bacteria. Bacteria may have one, two, or many flagella - or none at all.

Obtaining Food and Energy

Bacteria obtain energy and nutrients in a variety of different ways:

- Bacteria known as decomposers break down wastes and dead organisms into smaller molecules to get the energy they need to survive.
- Photosynthetic bacteria use the energy of the sun, together with carbon dioxide, to make their own food. Briefly, in the presence of sunlight, carbon dioxide and water is turned into glucose and oxygen. The glucose is then turned into usable energy. Glucose is like the "food" of the bacteria. An example of photosynthetic bacteria is **cyanobacteria**, as seen in **Figure** 4.6.

- Bacteria can also be chemotrophs. **Chemotrophs** obtain energy by breaking down chemical compounds in their environment, such as nitrogen-containing ammonia. They do not use the energy from the sun. Nitrogen cannot be made by living organisms, so it must be continually recycled. The bacteria help cycle the nitrogen through the environment for other living things to use. Organisms need nitrogen to make organic compounds, such as DNA.
- Some bacteria depend on other organisms for survival. For example, mutualistic bacteria live in nutrient-rich part of the roots of legumes, such as pea plants. The bacteria turn nitrogen-containing molecules into nitrogen that the plant can use. In this relationship, both the bacteria and the plant benefit.
- Other bacteria are parasitic and can cause illness. In a parasitic relationship, the bacteria benefit and the other organism is harmed. Harmful bacteria will be discussed later in the lesson.

Figure 4.6: Cyanobacteria are photosynthetic bacteria. These bacteria carry out all the reactions of photosynthesis within the cell membrane and in the cytoplasm; they do not need chloroplasts.

Reproduction in Bacteria

Bacteria reproduce through a process called binary fission. During binary fission, the chromosome copies itself, forming two genetically identical copies. Then, the cell enlarges and divides into two new daughter cells. The two daughter cells are identical to the parent cell (**Figure** 4.7). Binary fission can happen very rapidly. Some species of bacteria can double their population in less than ten minutes! (**Figure** 4.8)

Sexual reproduction does not occur in bacteria. But not all new bacteria are clones. This is because bacteria can still combine and exchange DNA. This exchange occurs in three different ways:

1. **Conjugation**: In conjugation, DNA passes through an extension on the surface of one bacterium and travels to another bacterium.
2. Transformation: In transformation, bacteria pick up pieces of DNA from their environment.
3. **Transduction**: In transduction, viruses that infect bacteria carry DNA from one bacterium to another.

Helpful Bacteria

Bacteria are helpful to humans and to other living things because they can:

1. Recycle essential nutrients in the soil.
2. Aid in animal digestion.
3. Produce food for consumption.
4. Produce chemicals used in medicines.

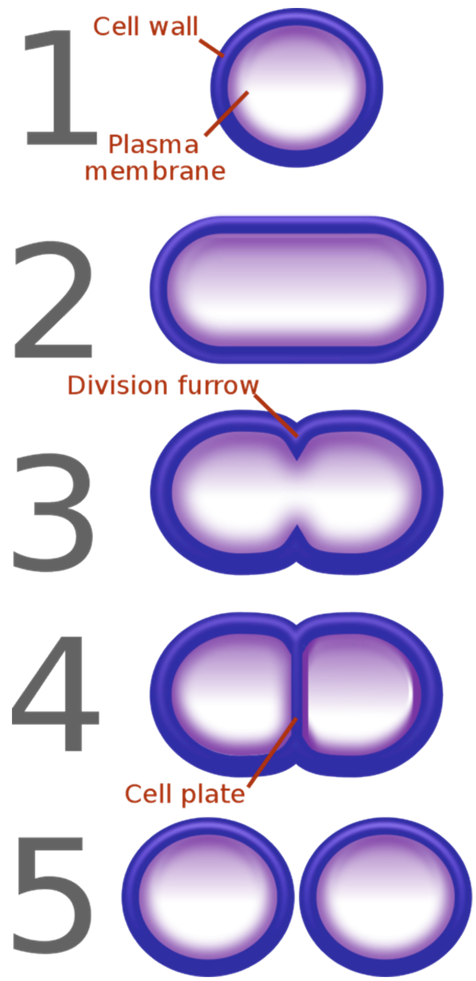


Figure 4.7: Bacteria cells reproduce by binary fission, resulting in two daughter cells identical to the parent cell.

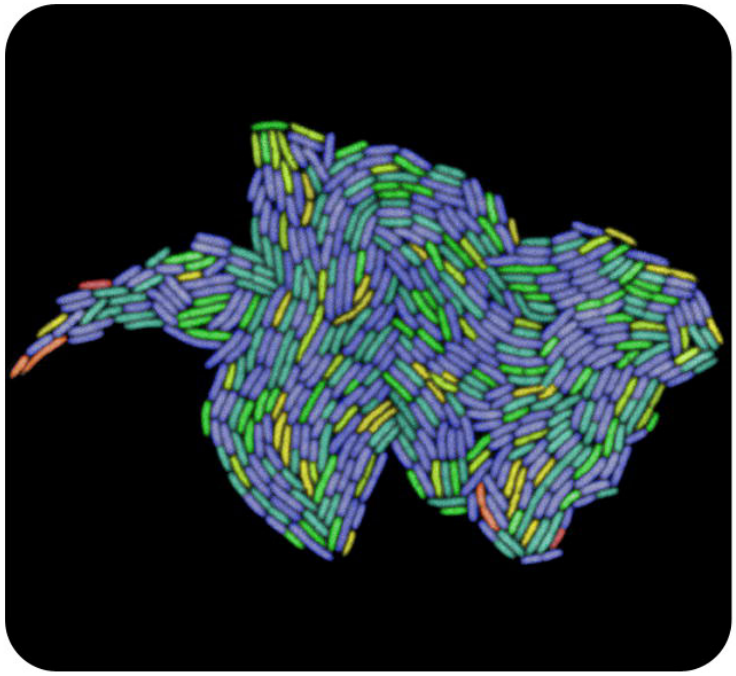


Figure 4.8: Bacteria can divide rapidly. This image is of a growing colony of E. coli bacteria. In the right environment the growth and division of two can form a colony of hundreds of bacteria in just a few hours.

Decomposers

Bacteria are important because many bacteria are decomposers. They break down dead materials and waste products and recycle nutrients back into the environment. This recycling of nutrients, such as nitrogen, is essential for living organisms. Organisms cannot produce nutrients, so they must come from other sources.

We get nutrients from the food we eat; plants get them from the soil. How do these nutrients get into the soil? One way is from the actions of decomposers. Without decomposers, we would eventually run out of the materials we need to survive. We also depend on bacteria to decompose our wastes in sewage treatment plants.

Digestion

Bacteria also help you digest your food. Several species of bacteria, such as *E. coli*, are found in your digestive tract. In fact, bacteria cells outnumber your own cells in your gut!

Food Production

Bacteria are involved in producing some foods. Yogurt is made by using bacteria to ferment milk. Cheese can also be made from milk with the help of bacteria (**Figure** 4.9). Fermenting cabbage with bacteria produces sauerkraut.

Figure 4.9: Yogurt is made from milk fermented with bacteria. The bacteria ingest natural milk sugars and release lactic acid as a waste product, which causes proteins in the milk to form into a solid mass, which becomes the yogurt.

Medicines

In the laboratory, bacteria can be changed to provide us with a variety of useful materials. Bacteria can be used as tiny factories to produce desired chemicals and medicines. For example, insulin, which is necessary to treat people with diabetes, can be produced using bacteria.

Through the process of transformation, the human gene for insulin is placed into bacteria. The bacteria then use that gene to make a protein. The protein can be separated from the bacteria, and then used to treat patients. The mass production of insulin by bacteria made this medicine much more affordable.

Harmful Bacteria

There are also ways that bacteria can be harmful to humans and other animals.

Diseases

Bacteria are responsible for many types of human illness, including:

- Strep throat.
- Tuberculosis.
- Pneumonia.
- Leprosy.
- Lyme disease.

The Black Death, which killed at least one third of Europe's population in the 1300s, is believed to have been caused by the bacterium *Yersinia pestis*.

Food Contamination

Bacterial contamination can also lead to outbreaks of food poisoning. Raw eggs and undercooked meats can contain bacteria that can cause digestive problems. Foodborne infection can be prevented by cooking meat thoroughly and washing surfaces that have been in contact with raw meat. Washing of hands before and after handling food also helps stop contamination.

Weapons

Some bacteria also have the potential to be used as biological weapons by terrorists. An example is anthrax, a disease caused by the bacterium *Bacillus anthracis*. Since inhaling the spores of this bacterium can lead to a deadly infection, it is a dangerous weapon. In 2001, an act of terrorism in the United States involved *B. anthracis* spores sent in letters through the mail.

Lesson Summary

- Bacteria contain a cell wall containing peptidoglycan and a single chromosome contained in the nucleoid.
- Bacteria can obtain energy through several means including photosynthesis, decomposition, and parasitism, symbiosis, and chemosynthesis.
- Bacteria reproduce through binary fission.
- Bacteria are important decomposers in the environment and aid in digestion.
- Some bacteria can be harmful when they contribute to disease, food poisoning, or biological warfare.

Review Questions

Recall

1. What are prokaryotes?
2. What are the possible shapes that bacteria can have?
3. What is the purpose of the flagella?
4. What is a chemotroph?

Apply Concepts

5. How is the DNA in prokaryotes different from the DNA in eukaryotes?
6. How do bacteria reproduce without having sex?
7. What are the ways bacteria can go through genetic recombination?
8. How are cyanobacteria similar to plants?
9. How are bacteria important in nature?
10. How can you avoid becoming sick from bacteria that cause food poisoning?

Think Critically

11. If a species of bacteria lives in the roots of a plant and supplies the plant with nitrogen, is this a parasitic bacteria? Explain why or why not.

12. How might you genetically modify bacteria so that they produce a chemical they do not normally produce?

Further Reading / Supplemental Links

- http://www.bt.cdc.gov/agent/anthrax
- http://www.cdc.gov/ncidod/dvbid/plague/index.htm
- http://www.cdc.gov/nczved/dfbmd/disease_listing/salmonellosis_gi.html
- http://www.ucmp.berkeley.edu/bacteria/bacteria.html
- http://commtechlab.msu.edu/sites/dlc-me/zoo
- http://www.cellsalive.com/cells/bactcell.htm

Points to Consider

- In the next section we will discuss the Kingdom Archaea. "Archae" shares the same root word as "archives" and "archaic," so what do you think it means?
- What do you think the earliest life forms on Earth looked like?
- How do you think these early life forms obtained energy?

4.2 Archaea

Lesson Objectives

- Identify the differences between archaea and bacteria.
- Explain how the archaea can obtain energy.
- Explain how the archaea reproduce.
- Discuss the unique habitats of the archaea.

Check Your Understanding

- What are the three shapes of bacteria?
- How do bacteria reproduce?
- How can bacteria be harmful?

Vocabulary

- halophiles
- methanogens
- thermophiles

What are Archaea?

For many years, archaea were classified as bacteria. However, when scientists compared the DNA of the two prokaryotes, they found that there were two distinct types of prokaryotes, which they named archaea and bacteria.

Even though the two groups might seem similar, archaea have many features that distinguish them from bacteria:

1. The cell walls of archaea are distinct from those of bacteria. In most archaea, the cell wall is assembled from proteins, providing both chemical and physical protection. In contrast to bacteria, most archaea do not have peptidoglycan in their cell walls.
2. The plasma membranes of the archaea also are made up of lipids that are distinct from those in bacteria.
3. The ribosomal proteins of the archaea are similar to those in eukaryotic cells, not those in bacteria.

Although archaea and bacteria share some fundamental differences, they are still similar in many ways:

1. They both are single-celled, microscopic organisms that can come in a variety of shapes (**Figure** 4.10).
2. Both archaea and bacteria have a single circular chromosome of DNA and lack membrane-bound organelles.
3. Like bacteria, archaea can have flagella to assist with movement.

Figure 4.10: Archaea shapes can vary widely, but some are bacilli, or rod-shaped.

Obtaining Food and Energy

Most archaea are chemotrophs and derive their energy and nutrients from breaking down molecules in their environment. A few species of archaea are photosynthetic and capture the energy of sunlight. Unlike bacteria, which can be parasites and are known to cause a variety of diseases, there are no known archaea that act as parasites. Some archaea do live within other organisms. But these archea form mutualistic relationships with their host, where both the archaea and the host benefit. In other words, they assist the host in some way, for example by helping to digest food.

Reproduction

Like bacteria, reproduction in archaea is asexual. Archaea can reproduce through binary fission, where a parent cell divides into two genetically identical daughter cells. Archaea can also reproduce asexually through budding and fragmentation, where pieces of the cell break off and form a new cell, also producing genetically identical organisms.

Types of Archaea

The first archaea described were unique in that they could survive in extremely harsh environments where no other organisms could survive.

Halophiles

The **halophiles**, which means "salt-loving," live in environments with high levels of salt (**Figure** 4.11). They have been identified in the Great Salt Lake in Utah and in the Dead Sea between Israel and Jordan, which have salt concentrations several times that of the oceans.

Figure 4.11: Halophiles, like the Halobacterium shown here, require high salt concentrations.

Thermophiles

The **thermophiles** live in extremely hot environments (**Figure** 4.12). For example, they can grow in hot springs, geysers, and near volcanoes. Unlike other organisms, they can thrive in temperatures near 100ºC, the boiling point of water!

Figure 4.12: Thermophiles can thrive in hot springs and geysers, such as this one, the Excelsior Geyser in the Midway Geyser Basin of Yellowstone National Park, Wyoming.

Methanogens

Methanogens can also live in some strange places, such as swamps, and inside the guts of cows and termites. They help these animals break down cellulose, a tough carbohydrate made by plants (**Figure** 4.13). This is an example of a mutualistic relationship. Methanogens are named for their waste product, a gas called methane.

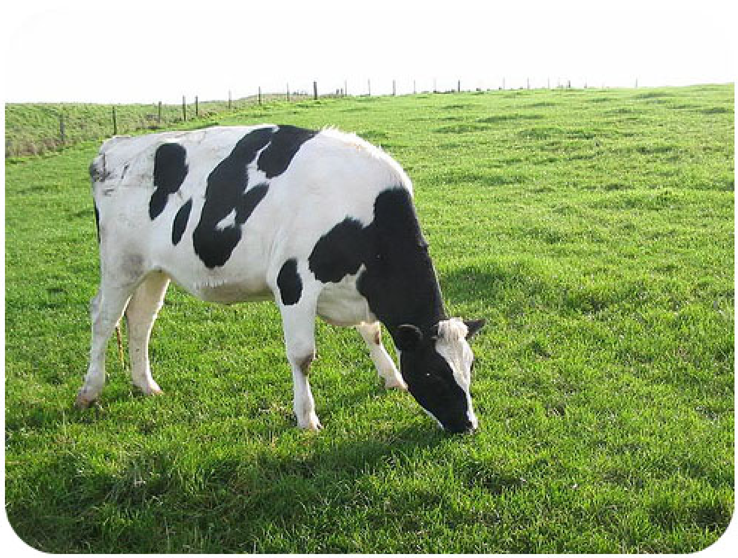


Figure 4.13: Cows are able to digest grass with the help of the methanogens in their gut.

Although archaea are known for living in unusual environments, like the Dead Sea, inside hot springs, and in the guts of cows, they also live in more common environments. For example, new research shows that archaea are abundant in the soil and among the plankton in the ocean (**Figure** 4.14. Therefore, scientists are just beginning to discover some of the important roles that archaea have in the environment.

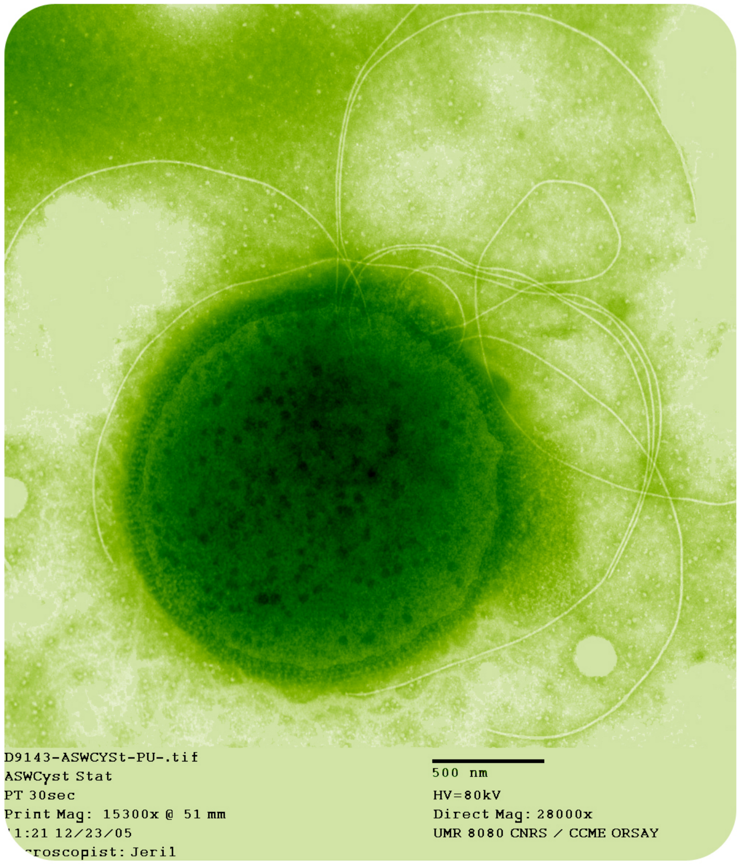


Figure 4.14: Thermococcus gammatolerans are another type of archaea.

Lesson Summary

- Archaea are prokaryotes that differ from bacteria somewhat in their DNA and biochemistry.
- Most archaea are chemotrophs, but some are photosynthetic or form mutualistic relationships.
- Archaea reproduce asexually through binary fission, fragmentation, or budding.
- Archaea are known for living in extreme environments.

Review Questions

Recall

1. What are the two types of prokaryotes?
2. How are the cell walls of archaea different from those of bacteria?
3. How do archaea obtain energy?
4. How do archaea reproduce?

5. Where do halophiles live?
6. Where do thermophiles live?

Apply Concepts

7. How could you tell the difference between archaea and bacteria?
8. If an organism is classified as a methanogen, what does this mean?
9. What is an example of a mutualistic relationship between archaea and another organism?

Think Critically

10. A teacher tells you she wants you to do a project on parasitic archaea. Why will you be unable to complete the project?

11. You find bacteria at the bottom of the Great Salt Lake, and another scientist calls them methanogens. Explain why that scientist is incorrect.

Further Reading / Supplemental Links

- http://www.ncbi.nlm.nih.gov/pubmed/2112744?dopt=Abstract
- http://www.popsci.com/environment/article/2008-07/they-came-underseas
- http://www.sciencedaily.com/releases/2006/06/060605191500.htm
- http://en.wikipedia.org/wiki/Archaea

Points to Consider

In the next chapter we will move on to the protists and fungi. How do you think they are different from archaea and bacteria?

- Can you think of some ways that fungi can be helpful?
- Can you think of some ways that fungi can be harmful?

Image Sources

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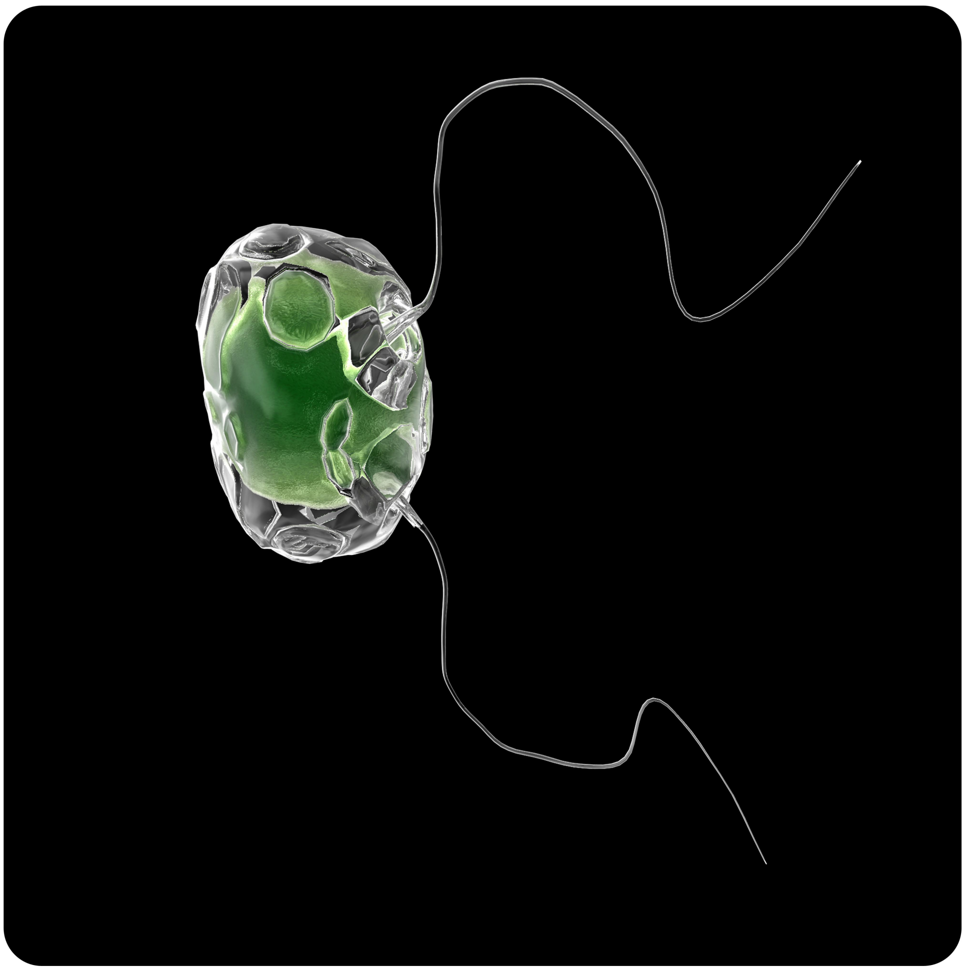
Chapter 5

MS Protists and Fungi



What does the above image look like to you? A bacteria? An animal? A plant? Actually, it is not found in any of those categories. The above organism is called a "protist."

Protists are a unique category of organisms because they are very different when compared to each other, but they can be very similar to plants, animals, and fungi.

What are fungi? They are another kingdom of organisms that are not related to protists, but are equally interesting. There are estimated to be 1.5 million species of fungi, although only 5% of them are classified.

5.1 Protists

Lesson Objectives

- Explain why protists cannot be classified as plants, animals, or fungi.
- List the similarities that exist between most protists.
- Identify the three subdivisions of the organisms in the kingdom Protista.

Check Your Understanding

- What are some basic differences between a eukaryotic cell and a prokaryotic cell?
- List some characteristics that all cells have.

Vocabulary

- autotroph
- cilia
- filter-feeder
- heterotroph
- protist
- protozoa
- pseudopodia

What are Protists?

Protists are eukaryotes, and most are single-celled. You can think about protists as all eukaryotic organisms that are neither animals, nor plants, nor fungi.

Even among themselves, they have very little in common. Although theses organisms were put in the category *Protista* by Ernst Haeckel in 1866, the Kingdom Protista was not an accepted classification in the scientific world until the 1960s. These unique organisms can be so different from each other that sometimes Protista is called the "junk drawer kingdom." This kingdom contains the eukaryotes that cannot be put into any other kingdom.

Unicellular or Multicellular?

Most protists, such as the ones shown in **Figure** 5.1, are so small that they can be seen only with a microscope. Protists are mostly unicellular (one-celled) eukaryotes that exist as independent cells. A few protists are multicellular (many-celled) and surprisingly large. These protists do not, however, show cellular specialization or differentiation into tissues. For example, kelp is a multicellular protist and can be over 100-meters long with cells that perform mostly the same jobs.

Characteristics of Protists

A few characteristics are common between protists:

1. They are eukaryotic, which means they have a nucleus.

2. Most have mitochondria.
3. They can be parasites.
4. They all prefer aquatic or moist environments.

For classification, the protists are divided into three groups:

1. Animal-like protists
2. Plant-like protists
3. Fungi-like protists.

But remember, protists are not animals, nor plants, nor fungi (**Figure** 5.2).

Classification of Protists

As there are many different types of protists, the classification of protists can be difficult. Recently, scientists confirmed that the protists are related by analyzing their DNA. Protists with more common DNA sequences are more closely related to each other then those with fewer common DNA sequences.

Find information on different types of protists here: http://www.ucmp.berkeley.edu/alllife/eukaryotasy.html

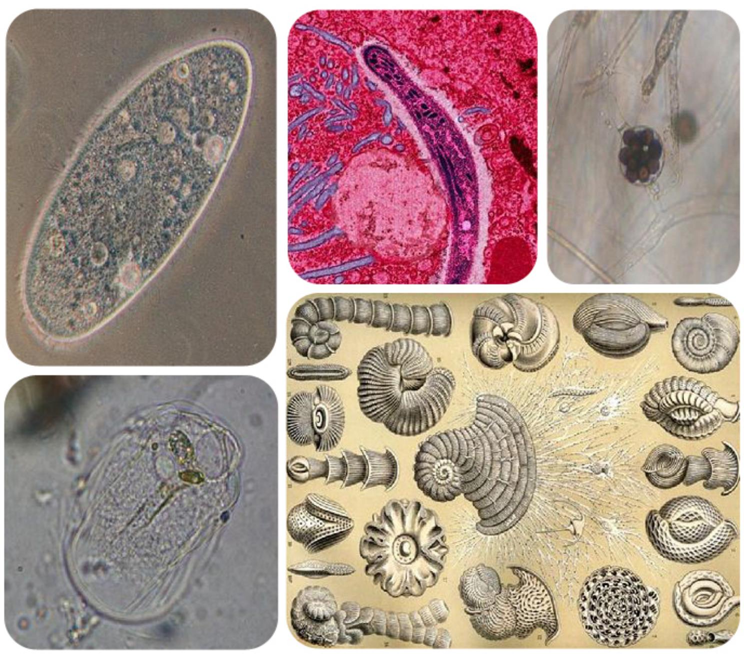


Figure 5.1: Protists come in many different shapes.

How Protists Obtain Food

The cells of protists need to perform all of the functions that other cells do, such as grow and reproduce, maintain homeostasis, and obtain energy. They also need to obtain food to provide the energy to perform these functions.

For such simple organisms, protists get their food in a complicated process. Although there are many photosynthetic protists, such as algae, that get their energy from sunlight, many others must ”swallow”

Figure 5.2: This slime mold is a protist. Slime molds had previously been classified as fungi but are now placed in the Kingdom Protista. Slime molds live on decaying plant life and in the soil.

their food through a process called endocytosis. Endocytosis happens when a cell takes in substances through its membrane. The process is described below:

1. The protist wraps its cell wall and cell membrane around its prey, which is usually bacteria.
2. It creates a food vacuole, a sort of "food storage compartment," around the bacteria.
3. The protist produces toxins which paralyze its prey.
4. Once paralyzed, the food material moves through the vacuole and into the cytoplasm of the protist.

Other protists are parasitic and absorb nutrients meant for their host, harming the host in the process.

Animal-like Protists

Animal-like, plant-like, and fungi-like protists are different from each other mainly because they have different ways of getting carbon. Carbon is important in the formation of organic compounds like carbohydrates, lipids, proteins, and nucleic acids. You get it from eating, as do other animals.

Animal-like protists are called protozoa. **Protozoa** are single-celled eukaryotes that share certain traits with organisms in the animal kingdom. Like animals, they can move, and they they get their carbon from outside sources. They are **heterotrophs**, which means they eat things outside of themselves instead of producing their own food.

Animal-like protists are very small, measuring only about 0.01–0.5mm. Animal-like protists include the zooflagellates, ciliates, and the sporozoans (**Figure** 5.3).

Some animal-like protists literally "eat with their tails." The tail of a protist is a flagellum. These protists are called flagellates. Flagellates are **filter-feeders**. They acquire oxygen and nitrogen by constantly whipping the flagellum back and forth, a process called filter-feeding. The whipping of the flagellum creates a current that brings food into the protist. Recall that prokaryotes can also have flagella (the plural of flagellum).

Different Kinds of Animal-like Protists

Are there different types of animal-like protists? Yes. They are different because they move in different ways.

Figure 5.3: Euglena are animal-like protists. Over 1000 species of Euglena exist. They are used in industry in the treatment of sewage.

- Flagellates have long flagella, or tails. Flagella rotate in a propeller-like fashion. An example of a flagellate is the *Trypanosoma*, which causes African sleeping sickness.
- Other protists have what are called transient **pseudopodia**, which are like temporary feet. The cell surface extends out a membrane, and the force of this membrane moves the cell forward. An example of a protist with a pseudopod is the amoeba.
- Another way protists move is by the movement of cilia. **Cilia** are thin, very small tail-like projections that extend outward from the cell body. Cilia beat back and forth, moving the protist along. The *paramecium* has cilia that propel it.
- A few protists are do not move at all, such as the *toxoplasma*. These protists form spores that become new protists, and are known as sporozoa.

Plant-like Protists

Plant-like protists are **autotrophs.** This means that they produce their own food. They perform photosynthesis to produce sugar by using carbon dioxide and the energy from sunlight, just like plants. Plant-like protists live in soil, in seawater, on the outer covering of plants, and in ponds and lakes (**Figure** 5.4). Protists like these can be unicellular or multicellular. Some protists, such as kelp, live in huge colonies in the ocean.

Plant-like protists are essential to the environment because they produce oxygen through photosynthesis, which helps other organisms, like animals, survive.

Plant-like protists are classified into a number of basic groups (**Table** 5.1).

Table 5.1: **Plant-like Protists**

Phylum	Description	Number (approximate)	Example
Chlorophyta	green algae - related to higher plants	7,500	*Chlamydomnas, Ulva, Volvox*
Rhodophyta	red algae	5,000	*Porphyra*

Table 5.1: (continued)

Phylum	Description	Number (approximate)	Example
Phaeophyta	brown algae	1,500	*Macrocystis*
Chrysophyta	diatoms, golden-brown algae, yellow-green algae	12,000	*Cyclotella*
Pyrrophyta	dinoflagellates	4,000	*Gonyaulax*
Euglenophyta	euglenoids	1,000	*Euglena*

Figure 5.4: Red algae are a very large group of protists making up about 5,000–6,000 species. They are mostly multicellular, live in the ocean. Many red algae are seaweeds and help create coral reefs.

Fungus-like Protists

Fungus-like protists are heterotrophs that have cell walls and reproduce by forming spores (see Lesson 9.2 for more information about spores). Fungus-like protists usually do not move, but some develop movement at some point in their lives.

There are essentially three types of fungus-like protists (see **Table** 5.2):

1. Water molds.
2. Downy mildews.
3. Slime molds.

Slime molds represent the characteristics of the fungus-like protists. Most slime molds measure about one or two centimeters, but a few slime molds are as big as several meters. They often have bright colors, such as a vibrant yellow. Others are brown or white.

Stemonitis is a kind of slime mold which forms small brown bunches on the outside of rotting logs. *Physarum polycephalum* lives inside rotting logs and is a gooey mesh of yellow "threads" that are a several centimeters long. *Fuligo*, sometimes called "vomit mold," is a yellow slime mold found in decaying wood.

Table 5.2: **Fungus-like Protists**

Protist	Source of Carbon	Environment	Characteristics
omycetes: water molds (**Figure** 5.5)	decomposed remains, parasites of plants and animals	most live in water	Causes a range of diseases in plants; common problem in greenhouses where the organism kills new seedlings (plants from seeds); includes the downy mildews, which are easily identifiable by the appearance of white "mildew" on leaves.
Mycetozoa: slime molds (**Figure** 5.6)	dispose of dead plant material, feed on bacteria	common in soil, on lawns, and in the forest commonly on deciduous logs	Includes the cellular slime mold, which involves numerous individual cells attached to each other, forming one large "supercell," essentially a bag of cytoplasm containing thousands of individual nuclei. The plasmodial slime molds spend most of their lives as individual cells, but when a chemical signal is released, they form a cluster that acts as one organism.

Importance of Protists

Humans could not live on Earth if it were not for protists. Why? Protists produce almost one-half of the oxygen on the planet, decompose and recycle nutrients that humans need to live, and make up a huge part of the food chain.

Humans use protists for many other reasons:

- Many protists are also commonly used in medical research. For example, medicines made from protists are used in treatment of high blood pressure, digestion problems, ulcers, and arthritis.
- Other protists are used in scientific studies. For example, slime molds are used to analyze the chemical signals used in cells.
- Protists are also valuable in industry. Look on the back of a milk carton. You will most likely see carrageenan, which is extracted from red algae. This is used to make puddings and ice cream solid. Chemicals from other kinds of algae are used to produce many kinds of plastics.

Figure 5.5: An example of a slime mold.

Figure 5.6: An aquatic insect nymph attacked by water mold.

Lesson Summary

- Protists are highly diverse organisms that belong to the Kingdom Protista.
- Protists are divided into three subgroups: animal-like protists, plant-like protists and fungus-like protists.
- Animal-like protists are unicellular eukaryotes that share certain traits with animals, such as mobility and heterotrophy.
- Plant-like protists are unicellular or multicellular autotrophs that live in soil, in seawater, on the outer covering of plants, and in ponds and lakes.
- Fungus-like protists, such as water molds, downy mildews, and slime molds, are heterotrophs that reproduce by forming spores.

Review Questions

Recall

1. List the characteristics that all protists share.
2. List two ways that protists obtain food.
3. Describe the characteristics of an animal-like protist.
4. Describe the characteristics of a plant-like protist.
5. Describe the characteristics of a fungi-like protist.
6. Name three kinds of fungi-like protists.

Apply Concepts

7. Explain why protists are important to life on Earth.

8. You find a protist that is a heterotroph and lives in the ocean. Is this protist most similar to a plant, animal, or fungus? Why or why not?

Critical Thinking

9. Imagine that you are a scientist delivering a paper called *Protists: the Junk-Drawer Kingdom.* Explain your reasoning for this title?

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Points to Consider

- Fungi comprise one of the eukaryotic kingdoms. Think about what might distinguish a fungi-like protist from a true fungus?
- Given the vast differences between the protists discussed in this lesson, think about the possibilities of dividing this kingdom into additional kingdoms. How might that division be accomplished? Is that a good idea or would it just lead to confusion?

5.2 Fungi

Lesson Objectives

- Describe the characteristics of fungi.
- Identify structures that distinguish fungi from plants and animals.
- Explain how fungi can be used in industry.

Check Your Understanding

- What is a significant difference between a protist and other eukaryotic organisms?
- What are some of the distinguishing characteristics of fungus-like protists?

Vocabulary

- budding
- chitin
- fruiting body
- hyphae
- mycelial fragmentation
- mycelium
- mycorrhizal symbiosis
- parasite
- spore

What are Fungi?

Ever notice blue-green mold growing on a loaf of bread? Do you like your pizza with mushrooms? Has a physician ever prescribed an antibiotic for you?

If so, then you have encountered fungi. Fungi are organisms that belong to the Kingdom Fungi (**Figure** 5.7). Our environment needs fungi. Fungi help decompose matter and make nutritious food for other organisms. Fungi are all around us and are useful in many ways.

Figure 5.7: These many different kinds of organisms that demonstrate the huge diversity within the Kingdom Fungi.

If you had to guess, would you say a fungus is a plant or animal? Scientists used to debate about which kingdom to place fungi in. Finally they decided that fungi were plants. But they were wrong. Now, scientists know that fungi are not plants at all. Fungi are very different from plants.

The main difference between plants and fungi is how they obtain energy. Plants are autotrophs, meaning that they make their own "food" using the energy from sunlight. Fungi are heterotrophs, which means that they obtain their "food" from outside of themselves. In other words, they must "eat" their food like animals and many bacteria do.

Yeasts, molds, and mushrooms are all different kinds of fungi (**Figure** 5.8). There may be as many as 1.5 million species of fungi. You can easily see bread mold and mushrooms without a microscope, but most fungi you cannot see. Fungi are either too small to be seen without a microscope, or they live where you cannot see them easily - deep in the soil, under decaying logs, or inside plants or animals. Some fungi even live in or on top of other fungi.

Figure 5.8: The blue in this blue cheese is actually mold.

Fungi and Symbiotic Relationships

If it were not for fungi, many plants would go hungry. In the soil, fungi grow closely around the roots of plants, and they begin to help each other. This form of helping each other out is called **mycorrhizal symbiosis.** Mycorrhizal means "roots" and symbiosis means "relationship" between organisms (**Figure** 5.9).

As the plants and fungi form the close relationship, the plant and the fungus "feed" one another. The plant provides glucose and sucrose to the fungus that the plant makes through photosynthesis, which the fungus cannot do. The fungi then provides minerals and water to the roots of the plant.

Lichens

Have you ever seen an organism called a lichen? Lichens are crusty, hard growths that you might find on trees, logs, walls, and rocks. Although lichens may not be the prettiest organisms in nature, they are unique. A lichen is really two organisms that live very closely together: a fungus and a bacteria or algae.

Figure 5.9: This mushroom and tree live in symbiosis with each other.

The cells from the algae or bacteria live inside the fungus. Each organism provides nutrients for the other.

What is it called when two organisms live close together and form a relationship? Symbiosis. A lichen is the result of symbiosis between a fungus and another organism. Because this relationship helps both organisms, it is called a mutualistic relationship.

Fungi and Insects

Many insects have a symbiotic relationship with certain types of fungi:

- Ants and termites grow fungi in underground "fungus gardens" that they create. When the ants or termites have eaten a big meal of wood or leaves, they also eat some fungi from their gardens. The fungi help them digest the wood or leaves.
- Ambrosia beetles live in the bark of trees. Like ants and termites, they grow fungi inside the bark of trees and use it to help digest their food.

Fungi as Parasites

Although lots of symbiotic relationships help both organisms, sometimes one of the organisms is harmed. When that happens, the organism that benefits and is not harmed is called a **parasite**.

Examples of parasitic fungi include the following:

- Beginning in 1950, Dutch Elm trees in the United States began to die. Since then much of the species has been eliminated. The disease was caused by a fungus that acted as a parasite. The fungus that killed the trees was carried by beetles to the trees. The tree tried to stop the growth of the fungus by blocking its own ability to gain water. However, without water the tree soon died.
- Some parasitic fungi cause human diseases such as athlete's foot and ringworm. These fungi feed on the outer layer of warm, moist skin.

Fungi as Predators

Fungi growing on a tree trunk does not seem very dangerous. But some fungi are actually hunters. For example, some fungi trap nematodes. A nematode is a worm that some fungi like to eat. These hungry fungi live deep in the soil where they set traps for unsuspecting nematodes by making a circle with their hyphae. **Hyphae** are like arms and legs. They look like cobwebs and can be sticky. Fungi set out circular rings of hyphae with a lure inside, which brings the nematode inside the fungus (**Figure** 5.10).

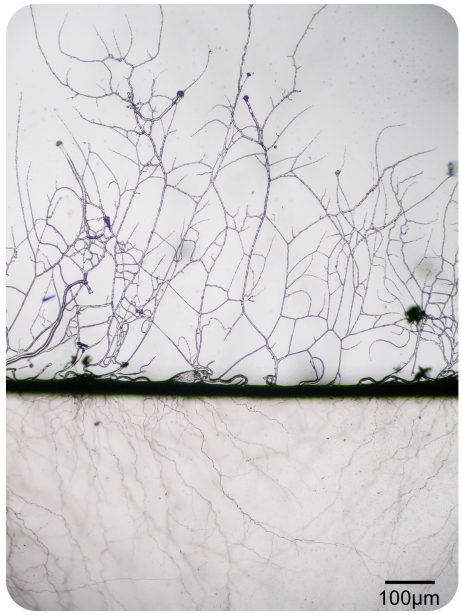

Figure 5.10: Hyphae are the cobweb-like arms and legs of fungi.

Fungi are Good Eaters

Fungi can grow fast because they are such good eaters. Fungi have lots of surface area and this large surface area "eats." Surface area is how much exposed area an organism has compared to their overall volume. Most of a mushroom's surface area is actually underground.

These are the steps involved in fungi eating:

1. Fungi squirt special enzymes into their environment.
2. The enzymes help digest large organic molecules, similar to cutting up your food before you eat.
3. Cells of the fungi then absorb the broken-down nutrients.

Why do you think a large surface area allows fungi to obtain more nutrients?

Fungi Body Parts

The most important body parts of a fungi include:

1. Cell wall: A layer around the cell membrane of fungi cells, similar to that found in plant cells.
2. Hyphae: These are thread-like structures which interconnect and bunch up into a **mycelium.** Ever see mold on a damp wall or on old bread? The things that you are seeing are really mycelia. The hyphae and mycelia help the fungi absorb nutrients from other organisms.
3. Specialized structures for reproduction: One example is a fruiting body. A mushroom is a **fruiting body**, which is the part of the fungus that produces spores (**Figure** 5.11). Those spores, discussed in the next section, are the basic reproductive units of fungi.

Figure 5.11: A mushroom is a fruiting body.

Fungi Reproduction

Reproduction of fungi is different for different fungi. Many fungi reproduce both sexually or asexually, while some reproduce only sexually and some only asexually. Asexual reproduction takes only one parent and sexual reproduction takes two parents.

Asexual Reproduction

Fungi reproduce asexually through three methods:

1. **Spores**: Spores are formed by the fungi and released to create new fungi. Have you ever seen a puffball? A puffball is a kind of fungus that has thousands of spores in a giant ball. Eventually the puffball bursts and releases the spores in a huge "puff."
2. **Budding**: The fungus grows part of its body, which eventually breaks off. The broken-off piece becomes a "new" organism.
3. **Mycelial fragmentation**: In this method, a piece of the mycelium splits off of the fungi. A fragmented piece of the mycelium can eventually produce a new colony of fungi.

Asexual reproduction is faster and produces more fungi than sexual reproduction. Some species of fungi can only perform asexual reproduction. This form of reproduction is controlled by many different factors, including environmental conditions such as the amount of sunlight and carbon dioxide the fungus receives, as well as the availability of food.

Sexual Reproduction

Almost all fungi can reproduce through the process of meiosis. Meiosis is a type of cell division where haploid cells are produced (discussed in chapter titled *Cell Division, Reproduction and DNA*). But meiosis in fungi is really different from sexual reproduction in plants or animals.

In plants and animals, meiosis occurs in diploid cells and is a process that produces haploid cells. Remember, a diploid cell is a cell with two sets of chromosomes, one from each parent. A haploid cell has one set of chromosomes. In meiosis, four haploid cells are produced. Each haploid cell has half the chromosome number of the parent cell.

However, in fungi, meiosis occurs right after two haploid cells fuse, producing four haploid cells. Mitosis then produces a haploid multicellular "adult" organism or haploid unicellular organisms. Mitosis is cell division that creates two genetically identical offspring cells (**Figure** 5.12).

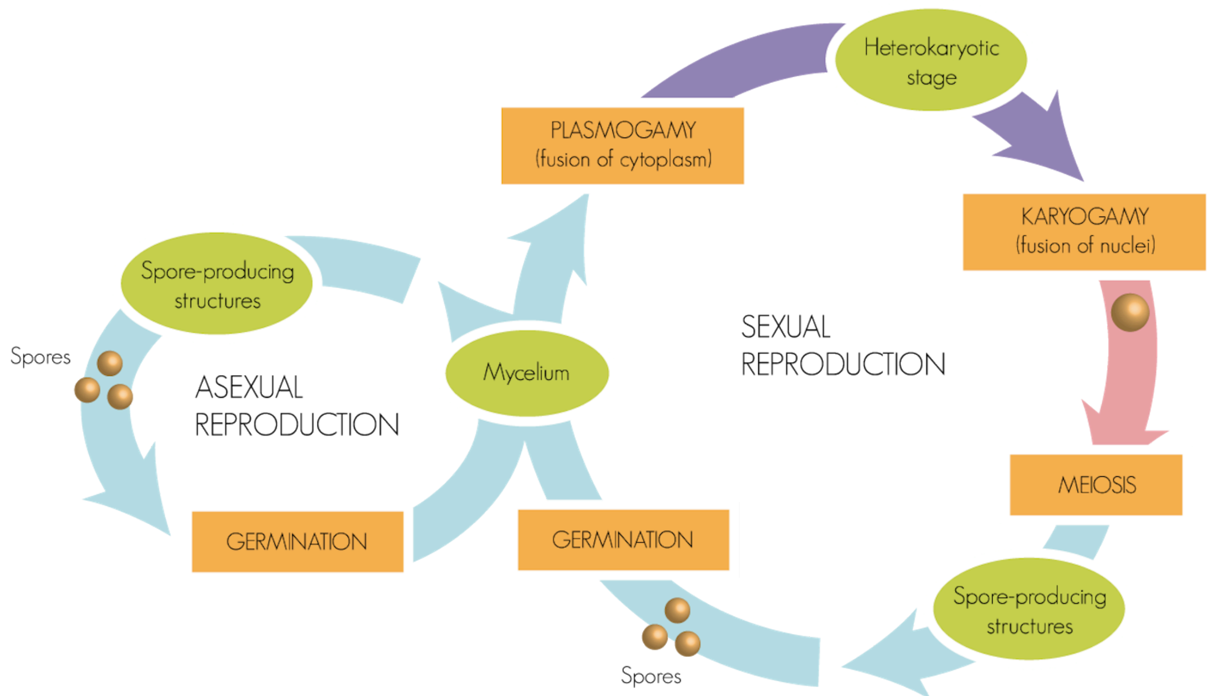

Figure 5.12: A diagram of how asexual and sexual reproduction work in fungi.

Classification of Fungi

Scientists used to think that fungi were members of the plant kingdom. They thought this because fungi had several similarities to plants. For example, fungi and plants usually have a leaf or flower that is attached to a stem. Also:

- Fungi and plants have similar structures.
- Plants and fungi live in the same kinds of habitats, such as growing in soil.
- Plants and fungi both have a cell wall, which animals do not have.

Structure of Fungi

There are a number of characteristics that make fungi different from other eukaryotic organisms:

1. Fungi cannot make their own food like plants can, since they do not have chloroplasts and cannot carry out photosynthesis. Fungi are more like animals because they have to obtain their food from outside sources.
2. The cell walls in many species of fungi contain chitin. **Chitin** is a nitrogen-containing material found in the shells of animals such as beetles and lobsters. The cell wall of a plant is made of cellulose, not chitin.

3. Unlike many plants, most fungi do not have structures that transfer water and nutrients.
4. One characteristic that is unique to fungi is the presence of hyphae, which combine in groups called mycelia, as described above.

The Evolution of Fungi

Fungi appeared during the Paleozoic Era, a geologic time period lasting from about 570 million to 248 million years ago. This is also the time when fish, insects, amphibians, reptiles, and land plants appeared. The first fungi most likely lived in water and had flagella that released spores. The first land fungi probably appeared in the Silurian period (443 million years ago to about 416 million years ago), the same time period that land plants also first appeared. See different types of fungi here: http://www.tolweb.org/Fungi.

Roles of Fungi

Fungi are found all over the globe in many different kinds of habitats. Fungi even thrive in deserts. Most fungi are found on land rather than in the ocean, though some species live only in ocean habitats. Fungi are extremely important to these ecosystems because they are one of the major decomposers of organic material. Scientists have estimated that there are nearly 1.5 million species of fungi.

Importance of Fungi for Human Use

Humans use fungi for food preparation or preservation and other purposes.

- Yeasts are help ferment beer, wine and bread (**Figure** 5.13).
- Some fungi are used in the production of soy sauce and tempeh, a source of protein used in Southeast Asia.
- Mushrooms are used in the diet of people all over the globe.
- Fungi can produce antibiotics, such as penicillin.
- The chitin in the cell walls of fungi has been said to have healing properties.

Edible and Poisonous Fungi

Some of the best known types of fungi are mushrooms, which can be edible or poisonous (**Figure** 5.14).

Many species are grown commercially, but others are harvested from the wild. When you order a pizza with mushrooms or add them to your salad, you are most likely eating *Agaricus bisporus*, the most commonly eaten species. Other mushroom species are gathered from the wild for people to eat or for commercial sale. Many mushroom species are poisonous to humans. Some mushrooms will simply give you a stomach ache, while others may kill you. Some mushrooms you can eat when they are cooked but are poisonous when raw.

Have you ever eaten blue cheese? Do you know what makes it blue? You guessed it. Fungus. For certain types of cheeses, producers add fungus spores to milk curds to promote the growth of mold, which makes the cheese blue. Molds used in cheese production are safe for humans to eat.

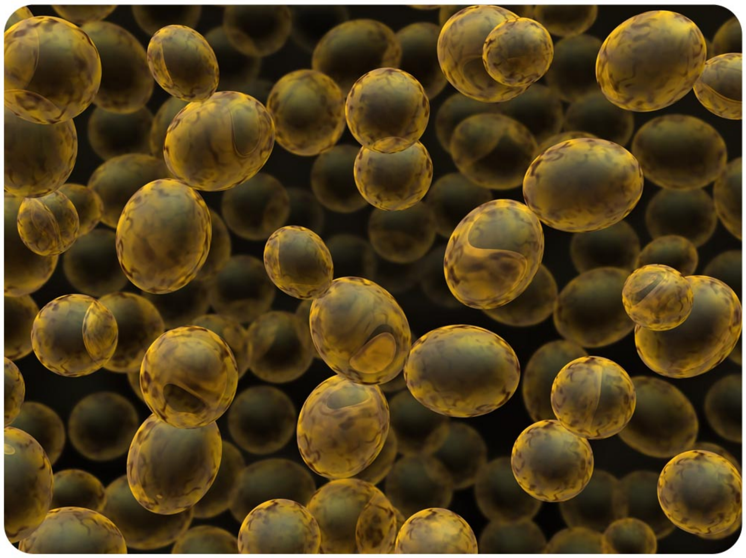

Figure 5.13: , a single-celled fungus called Brewer's or Baker's yeast, is used in the baking of bread and in making wine and beer through fermentation. There are several other species of yeast used in brewing beer. Each can impart a distinctive taste.

Figure 5.14: Some of the best known types of fungi are the edible and the poisonous mushrooms.

Fungi Control of Pests

Some fungi work as natural pesticides. For example, some fungi may be used to limit or kill harmful organisms like mites, pest insects, certain weeds, worms, and other fungi that harm or kill crops.

Lesson Summary

- Fungi are classified in their own kingdom based on their structures, ways of obtaining food, and on they reproduce.
- Fungi live with other organisms in symbiotic relationships.
- Fungi reproduce asexually and sexually.
- Fungi appeared during the Paleozoic Era.
- Fungi are widely used in foods, industry, and medicine.

Review Questions

Recall

1. What are two characteristics distinguishes fungi from plants?
2. How many species of fungi exist?
3. Name two human diseases caused by fungus.
4. What is a lichen?

Apply Concepts

5. Explain how mycorrhizal symbiosis works.
6. Describe the relationship between the ambrosia beetle and fungi.
7. If you see mold on your bread, what part of the fungus are you observing?
8. Describe the three methods of asexual reproduction in fungi.

Critical Thinking

9. "Sexual reproduction in fungi is similar to sexual reproduction in animals." Explain why this statement is true or false.

10. You go back in time to talk with scientists who believe that fungi are a type of plant. What will you tell them?

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Points to Consider

- Plants are fascinating, diverse organisms. Although scientists used to think that fungi were plants, we now know that plants and fungi are separate. In this lesson we have discussed fungi. Next we start discussing plants. What do you think sets plants apart from fungi?

Image Sources

(1) Dominik Hundhammer. *The blue in this blue cheese is actually mold.*. GNU-FDL.

(2) EPA. http://en.wikipedia.org/wiki/File:Euglena_EPA.jpg. Public Domain.

(3) BorgQueen. http://en.wikipedia.org/wiki/Image:Fungi_collage.jpg. CC-BY-SA 2.5.

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Chapter 6

MS Plants

How many questions can you ask about flowers? Why are they so brightly colored? Why are there so many different kinds? Do all plants have flowers? What are plants with flowers called? Why did plants evolve to have flowers?

What other structure is included in the above image on the plant? Those are berries, or the fruits of the plant. What is a fruit? Why is the fruit important for a plant? Why did plants evolve to have fruit?

Scientists and naturalists have been asking these questions for centuries. While reading, see if you can answer some of the above questions and ask some more of your own.

6.1 Introduction to Plants

Lesson Objectives

- Describe the major characteristics that of organisms in Kingdom Plantae.
- Describe plants' major adaptations for life on land.
- Explain plants' reproductive cycle.
- Explain how plants are classified.

Check Your Understanding

- What are the major differences between a plant cell and an animal cell?
- What is photosynthesis?

Vocabulary

- alternation of generations
- angiosperms
- cuticle
- gymnosperms
- nonvascular plants
- phloem
- seedless vascular plants
- vascular tissue
- xylem

What Are Plants?

Plants have adapted to a variety of environments, from the desert to the tropical rain forest to our lakes and oceans. In each environment, plants have become crucial to supporting animal life. From tiny mosses to extremely large trees (**Figure** 6.1), the organisms in this kingdom, Kingdom Plantae, have three main features. They are all:

1. Eukaryotic.
2. Photosynthetic.
3. Multicellular.

Recall that eukaryotic organisms also include animals, protists, and fungi. Eukaryotes have cells with nuclei that contain DNA and membrane-bound organelles, such as mitochondria. As discussed in the *Cell Functions* chapter, photosynthesis is the process by which plants capture the energy of sunlight and use carbon dioxide from the air to make their own food. Lastly, plants must be multicellular. Recall that some protists are eukaryotic and photosynthetic, but are not considered plants because they are mostly unicellular.

Adaptations For Life On Land

Before plants evolved, most photosynthetic organisms lived in the water. So, where did plants come from? Evidence shows that plants evolved from freshwater green algae (**Figure** 6.2). The similarities between

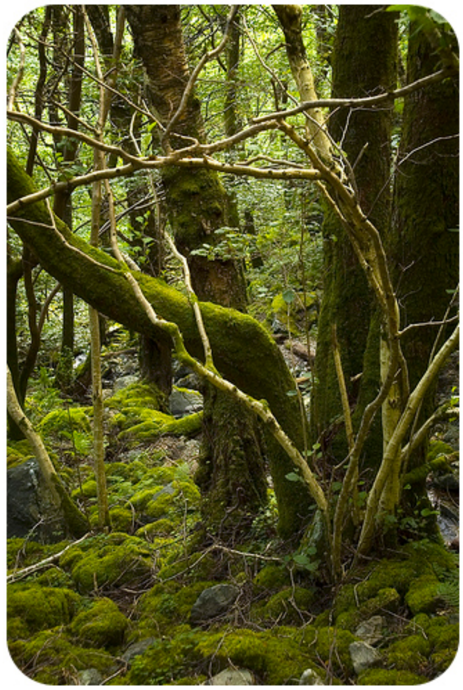

Figure 6.1: There is great diversity in the plant kingdom, from tiny mosses to huge trees.

green algae and plants is one piece of evidence. They both have cellulose in their cell walls, and they share many of the same chemicals that give them color. (For a review of plant cells, see the *Cells and Their Structures* chapter.) So what separates green algae, which are protists, from green plants?

Figure 6.2: The ancestor of plants is green algae. This picture shows a close up of algae on the beach.

There are four main ways that plants adapted to life on land, and as a result became different from algae:

1. In plants, the embryo develops inside of the female plant after fertilization. Algae do not keep the embryo inside of themselves, but release it into water. This was the first feature to evolve that separated plants from green algae. This is also the only adaptation shared by all plants.

2. Over time, plants had to evolve from living in water to living on land. In early plants, a waxy layer called a **cuticle** evolved to help seal water in the plant and prevent water loss. However, the cuticle also prevents gases from entering and leaving the plant easily. Recall that the exchange of gasses - taking in carbon dioxide and releasing oxygen - occurs during photosynthesis.
3. To allow the plant to retain water and exchange gases, small pores (holes) in the leaves called stomata also evolved (**Figure** 6.3). The stomata can open and close depending on weather conditions. When it's hot and dry, the stomata close to keep water inside of the plant. When the weather cools down, the stomata can open again to let carbon dioxide in and oxygen out.
4. A later adaption for life on land was the evolution of vascular tissue. **Vascular tissue** is specialized tissue that transports water, nutrients, and food in plants. In algae, vascular tissue is not necessary since the entire body is in contact with the water and the water simply enters the algae. But on land, water may only be found deep in the ground. Vascular tissues take water and nutrients from the ground up into the plant, while also taking food down from the leaves into the rest of the plant. The two vascular tissues are:
   (a) **Xylem**: Responsible for the transport of water and nutrients from the roots to the rest of the plant. Generally (not always), xylem carries water from the roots up to the rest of the plant.
   (b) **Phloem**: Carries the sugars made during photosynthesis (in the leaves) to the parts of the plant where they are needed. Generally (not always), phloem carries sugars down to the rest of the plant.

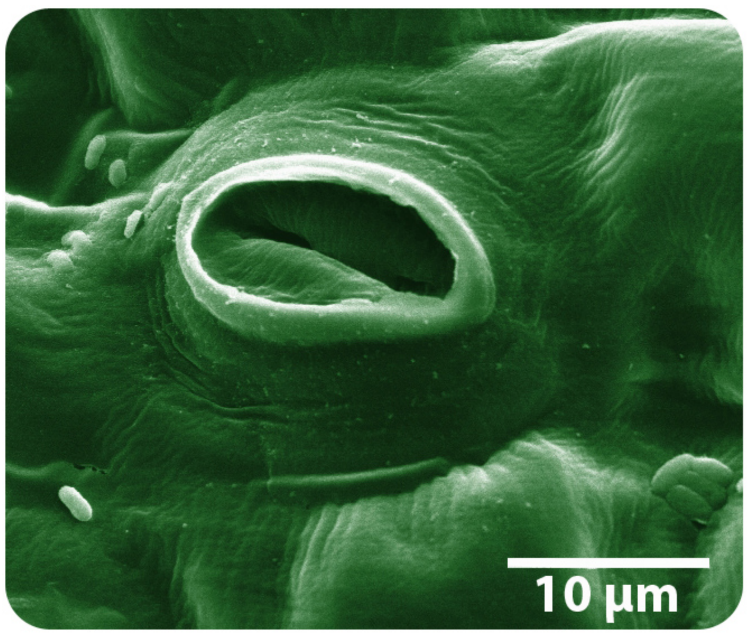

Figure 6.3: Stomata are pores in leaves that allow gasses to pass through, but they can be closed to conserve water.

Plant Reproduction and Life Cycle

The life cycle of a plant is very different from the life cycle of an animal. A human cannot exist unless it is made entirely of diploid cells (cells with two sets of chromosomes). Plants can live, however, when they are made up of diploid cells or haploid cells (cells with one set of chromosomes).

Plants alternate between diploid-cell plants and haploid-cell plants. This is called **alternation of generations** because the plant type alternates from generation to generation. In alternation of generations, the plant alternates between a sporophyte that has diploid cells and a gametophyte that has haploid cells.

Briefly, alternation of generations can be summarized in the following four steps: follow along in **Figure** 6.4 as you read through the steps.

1. The gametophyte produces the gametes, or sperm and egg, by mitosis. Remember, gametes are haploid.
2. Then the sperm fertilizes the egg, producing a diploid zygote that develops into the sporophyte.
3. The diploid sporophyte produces haploid spores by meiosis.
4. The haploid spores go through mitosis, developing into the gametophyte.

As we will see in the following lessons, the generation in which the plant spends most of its life cycle is different between various plants. In the plants that first evolved, the gametophyte takes up the majority of the life cycle of the plant. During the course of evolution, the sporophyte became the major stage of the life cycle of the plant.

In flowering plants, the female gametophyte, the ovary, is found within the sporophyte. The male gametophyte is the pollen.

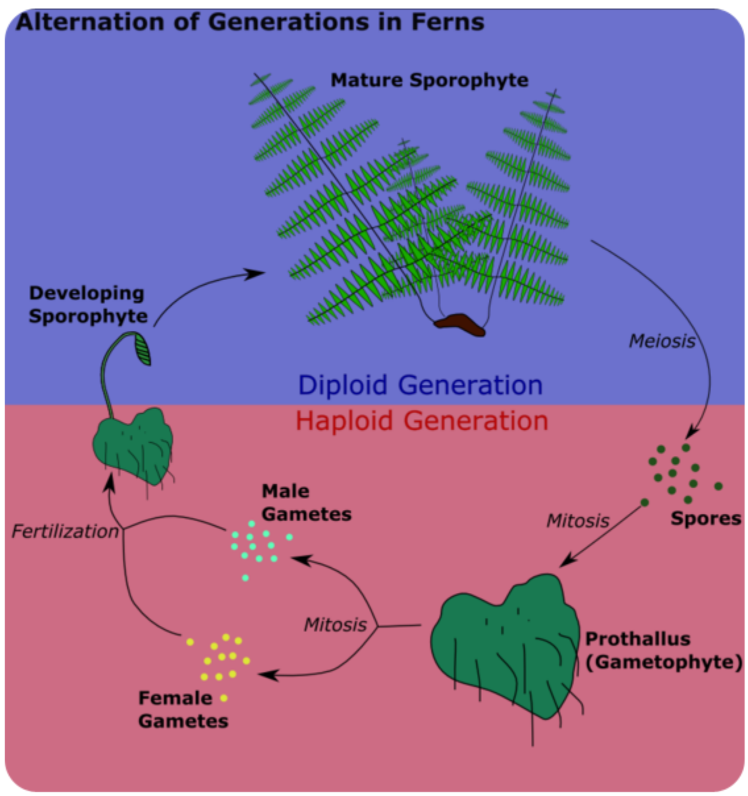

Figure 6.4: In ferns, the sporophyte is dominant and produces spores that germinate into a gametophyte. After fertilization the sporophyte is produced. Ferns will be discussed in further detail in the next lesson.

Classification of Plants

Plants are formally divided into 12 phyla (plural for phylum), and these phyla are gathered into four groups. These four groups are based on the evolutionary history of significant features in plants:

1. **Nonvascular plants** evolved first, and keep the embryo inside of the reproductive structure after fertilization. These plants do not have vascular tissue (xylem and phloem).
2. **Seedless vascular plants** evolved to have vascular tissue after the nonvascular plants, but do not have seeds.
3. Non-flowering plants, or **gymnosperms**, evolved to have seeds, but do not have flowers.
4. Flowering plants, or **angiosperms**, evolved to have vascular tissue, seeds, and flowers.

These four groups are the focus of the next two lessons. **Figure** 6.5 shows some of the rich diversity of the plant kingdom.

Figure 6.5: The plant kingdom contains a diversity of organisms. Note that in the upper left is a protist, not a plant.

Lesson Summary

- Plants are multicellular photosynthetic eukaryotes that evolved from green algae.
- Plants have several adaptive features for living on land, including a cuticle, stomata, and vascular tissue.

- Plants are informally divided into four groups: the nonvascular plants, the seedless vascular plants, the nonflowering plants (gymnosperms) and the flowering plants (angiosperms).

Review Questions

Recall

1. What is the purpose of the stomata?
2. What term describes the plant life cycle?
3. What is the diploid stage of the alternation of generations?
4. What is the term for plants that lack vascular tissue?
5. What is the term for plants that have flowers and bear fruit?

Apply Concepts

6. Plants evolved from green algae. How are they different from green algae?
7. Describe how plants evolved from water-living organisms to organisms that live on land.

Critical Thinking

8. A scientist mistakes a photosynthetic protist from a plant. However, the protist is not a plant. Explain why.
9. Why do you think plants are necessary for animal life?

Further Reading / Supplemental Links

- http://www.ucmp.berkeley.edu/plants/plantae.html
- http://www.bioedonline.org/slides/slide01.cfm?q=%22Plantae%22
- http://www.wisc-online.com/objects/index_tj.asp?objID=BIO804
- http://www.perspective.com/nature/plantae
- http://plants.usda.gov
- http://en.wikipedia.org/wiki

Points to Consider

Next we discuss seedless plants.

- Can you think of examples of plants that do not have seeds?
- If a plant does not have seeds, how can it reproduce?

6.2 Seedless Plants

Lesson Objectives

- Name examples of nonvascular seedless plants.
- Name examples of vascular seedless plants.
- Explain the reproduction strategies of seedless plants.
- Describe the ways seedless plants impact humankind.

Check Your Understanding

- What is a plant?
- How are plants classified?

Vocabulary

- club mosses
- ferns
- hornworts
- horsetails
- liverworts
- mosses
- sporangium
- whisk ferns

Seedless Plants

What do you think a forest looked like millions of years ago? Or tens of millions of years ago? Or hundreds of millions of years ago? Probably very different than today.

Nonvascular seedless plants and vascular seedless plants have had a great impact on all our lives. More than 300 million years ago, during the Carboniferous period, forests looked very different than they do today. Seedless plants grew as tall as today's trees in large swampy forests (**Figure** 6.6). The remains of these forests formed the coal that we depend on today. Although most of these giant seedless plants are now extinct, smaller relatives still remain.

Nonvascular Seedless Plants

Nonvascular seedless plants, as their name implies, lack vascular tissue. Of course, they don't have seeds either. As they lack vascular tissue, they also do not have true roots, stems or leaves. Nonvascular plants do often have a "leafy" appearance though, and can have stem-like and root-like structures. These plants are very short because they cannot move nutrients and water up a stem.

Nonvascular plants are classified into three phyla:

1. Mosses
2. Hornworts
3. Liverworts

Figure 6.6: Seedless plants were dominant during the Carboniferous period, as illustrated by this drawing.

Mosses

Mosses have a scientific name, *Bryophyta*. They are most often recognized as the green "fuzz" on damp rocks and trees in a forest. If you look closely, you will see that most mosses have tiny stem-like and leaf-like structures. This is the gametophyte stage. Remember that a gametophyte is haploid. The gametophyte produces the gametes that, after fertilization, develop into the diploid sporophyte. The sporophyte forms a capsule, called the **sporangium**, which releases spores (**Figure** 6.7).

Figure 6.7: Sporophytes sprout up on stalks from this bed of moss gametophytes. Notice that both the sporophytes and gametophytes exist at the same time.

Hornworts

Hornworts are part of the phylum *Anthocerophyta*. The "horn" part of the name comes from their hornlike sporophytes, and "wort" comes from the Anglo-Saxon word for herb. The hornlike sporophytes grow from a base of flattened lobes, which are the gametophytes (**Figure** 6.8). They usually grow in moist and humid areas.

Liverworts

Liverworts are in the phylum *Hepatophyta*. They have two distinct appearances: they can either be leafy like mosses, or flattened and ribbon-like. Liverworts get their name from the type with the flattened bodies, which can resemble a liver (**Figure** 6.9). Liverworts can often be found along stream beds.

Vascular Seedless Plants

For these plants, the name says it all. Vascular seedless plants have vascular tissue but do not have seeds. Remember that vascular tissue is specialized tissue that transports water and nutrients throughout the plant. The development of vascular tissue allowed these plants to grow much taller than nonvascular plants, forming the ancient swamp forests mentioned previously. Most of these large vascular seedless plants are now extinct, but their smaller relatives still remain.

Figure 6.8: In hornworts, the “horns” are the sporophytes that rise up from the leaflike gametophyte.

Figure 6.9: Liverworts with a flattened, ribbon-like body are called thallose liverworts.

Seedless vascular plants include:

1. Club mosses.
2. Ferns.
3. Horsetails.
4. Whisk ferns.

Clubmosses

Clubmosses, in the phylum *Lycophyta*, are so named because they can look similar to mosses (**Figure** 6.10). Clubmosses are not true mosses, though, because they have vascular tissue. The "club" part of the name comes from club-like clusters of sporangia found on the plants. One type of clubmoss is called the "resurrection plant" because it shrivels and turns brown when it dries out, but then quickly turns green when watered again.

Figure 6.10: Clubmosses can resemble mosses, but clubmosses have vascular tissue, while mosses do not.

Ferns

Ferns, in the phylum *Pterophyta*, are the most common seedless vascular plants (**Figure** 6.11). They usually have large divided leaves called fronds. In most ferns, fronds develop from a curled-up formation called a fiddlehead (**Figure** 6.12). The fiddlehead looks like the curled decoration on the end of a stringed instrument, such as a fiddle. Leaves unroll as the fiddleheads grow and expand. Ferns grow in a variety of habitats, ranging in size from tiny aquatic species to giant tropical plants.

Horsetails

Horsetails, in the phylum *Sphenophyta*, have hollow, ribbed stems and are often found in marshes (**Figure** 6.13). Whorls of tiny leaves around the stem make the plant look like a horse's tail, but these soon fall off and leave a hollow stem that can perform photosynthesis (mostly, photosynthesis occurs in leaves). The stems are rigid and rough to the touch because they are coated with a scratchy mineral. Because of their scratchy texture, these plants were once used as scouring pads for cleaning dishes.

Figure 6.11: Ferns are common in the understory of the tropical rainforest.

Figure 6.12: The first leaves of most ferns appear curled up into fiddleheads.

Figure 6.13: Horsetails are common in marshes.

Whisk Ferns

Whisk ferns, in the phylum *Psilophyta*, have green branching stems with no leaves, so they resemble a whisk broom (**Figure** 6.14). Another striking feature of the whisk ferns is its spherical yellow sporangia.

Figure 6.14: Whisk ferns have no leaves and bear yellow sporangia.

Reproduction of Seedless Plants

Seedless plants can reproduce asexually or sexually. Some seedless plants, like hornworts and liverworts, can reproduce asexually through fragmentation. When a small fragment of the plant is broken off, it can form a new plant.

Reproduction in Nonvascular Seedless Plants

Like all plants, nonvascular plants have an alternation of generations life cycle. In the life cycle of the nonvascular seedless plants, the gametophyte stage is the longest part of the cycle. The gametophyte is photosynthetic.

The life cycle of nonvascular seedless plants can be described as follows:

1. The male gametophyte produces flagellated sperm that must swim to the egg formed by the female gametophyte. For this reason, sexual reproduction must happen in the presence of water. Therefore, nonvascular plants tend to live in moist environments.
2. Following fertilization, the sporophyte forms. The sporophyte is connected to and dependent on the gametophyte.
3. The sporophyte produces spores that will develop into gametophytes and start the cycle over again.

Reproduction in Seedless Vascular Plants

For the seedless vascular plants, the sporophyte stage is the longest part of the cycle, but the cycle is similar to nonvascular plants. For example, in ferns, the gametophyte is a tiny heart-shaped structure, while the leafy plant we recognize as a fern is the sporophyte (see **Figure** 6.14).

The sporangia of ferns are often on the underside of the fronds (**Figure** 6.15). Like nonvascular plants, ferns also have flagellated sperm that must swim to the egg. Unlike nonvascular plants, once fertilization takes place, the gametophyte will die and the sporophyte will live independently.

Figure 6.15: This fern is producing spores underneath its fronds.

Why Seedless Plants Are Important

Seedless Plants Became Coal

The greatest influence of seedless plants have had on human society is in the formation of coal millions of years ago. When the seedless plants died, became buried deep in the earth, and were exposed to heat and pressure, coal formed. Now coal is burned to provide energy, such as electricity.

Current Uses

But some seedless plants still have uses in society today. Peat moss, is commonly used by gardeners to improve soils since it is really good at absorbing and holding water (**Figure** 6.16).

Ferns are also found in many gardens as ornaments. The fiddleheads of certain species of ferns are used in gourmet food. Some species of ferns, like the maidenhair fern, are used as medicines.

Figure 6.16: Sphagnum, or peat moss, is commonly added to soil to help absorb water and keep it in the soil.

Lesson Summary

- Nonvascular seedless plants include mosses, liverworts, and hornworts.
- Vascular seedless plants include clubmosses, ferns, whisk ferns, and horsetails.
- Nonvascular seedless plants spend most of their life cycle in the gametophyte stage, while vascular seedless plants spend most of their life as a sporophyte.
- The death of seedless plants millions of years ago produced coal.
- Mosses and ferns are used commonly in gardening.

Review Questions

Recall

1. What is vascular tissue?

2. What is an example of a nonvascular seedless plant?

3. What is an example of a vascular seedless plant?

4. Compare and contrast the fern gametophyte and sporophyte.

5. What are some of the distinguishing features of horsetails?

6. What does the sporophyte of the hornwort look like?

Apply Concepts

7. Your friend finds a whisk fern and insists it is the same as a fern. Explain why it is different.

8. Explain why the following quote is true: ”Clubmoss is not a type of moss.”

Critical Thinking

9. ”After they died, many seedless plants have been a great benefit to humans.” Explain why you agree or disagree with the statement.

10. Explain to a group of gardeners how they may use seedless plants.

Further Reading / Supplemental Links

- http://www.cavehill.uwi.edu/FPAS/bcs/bl14apl/bryo1.htm
- http://www.microscopy-uk.org.uk/mag/indexmag.html
- http://www.microscopy-uk.org.uk/mag/artjul98/jpmoss.html
- http://www.biologycorner.com/bio2/notes_plants.html
- http://forestencyclopedia.com/p/p1893
- http://www.hiddenforest.co.nz/plants/clubmosses/clubmosses.htm
- [http://amerfernsoc.org/ http://amerfernsoc.org/
- http://en.wikipedia.org/wiki

Points to Consider

Next we discuss plants with seeds.

- Can you think of examples of plants that have seeds?
- Can you think of a plant that has seeds but no flowers or fruits?
- Why do you think having flowers is beneficial to a plant?

6.3 Seed Plants

Lesson Objectives

- Describe the importance of the seed.
- Explain the ways in which seeds are dispersed.
- Define and give examples of gymnosperms.
- Define and give examples of angiosperms.
- Explain some uses of seed plants.

Check Your Understanding

- What are the two types of seedless plants?
- How do seedless plants reproduce?

Vocabulary

- anther
- calyx
- carpel
- complete flowers
- conifers
- corolla
- dormant
- ginko
- incomplete flowers
- ovary
- sepals
- stamen
- stigma

Seeds and Seed Dispersal

What is a Seed?

If you've ever seen a plant grow from a tiny seed, then you might realize that seeds are amazing structures. The seed allows a plant embryo to survive droughts, harsh winters, and other conditions that would kill an adult plant. The tiny plant embryo can simply stay **dormant**, in a resting state, and wait for the perfect environment to begin to grow. In fact, some seeds can stay dormant for hundreds of years!

Another impressive feature of the seed is that it stores food for the young plant after it sprouts. This greatly increases the chances that the tiny plant will survive. So being able to produce a seed is a very beneficial adaptation, and as a result, seed plants have been very successful. Although the seedless plants were here on Earth first, today there are many more seed plants than seedless plants.

How are Seed Plants Successful?

For a seed plant species to be successful, the seeds must be dispersed, or scattered around in various directions. If the seeds are spread out in many different areas, there is a better chance that some of the seeds will find the right conditions to grow. But how do seeds travel to places they have never been before? To aid with seed dispersal, some plants have evolved special features that help their seeds travel over long distances.

One such strategy is to allow the wind to carry the seeds. With special adaptations in the seeds, the seeds can be carried long distances by the wind. For example, you might have noticed how the "fluff" of a dandelion moves in the wind. Each piece of fluff carries a seed to a new location. If you look under the scales of pine cone, you will see tiny seeds with "wings" that allow these seeds to be carried away by the wind. Maple trees also have specialized fruits with wing-like parts that help seed dispersal, as shown in **Figure** 6.17.

Figure 6.17: Maple trees have fruits with “wings” that help the wind disperse the seeds.

Some flowering plants grow fleshy fruit that helps disperse their seeds. When animals eat the fruit, the seeds pass through an animal’s digestive tract unharmed. The seeds germinate after they are passed out with the animal’s feces. Berries, citrus fruits, cherries, apples, and a variety of other types of fruits are all adapted to be attractive to animals, so the animals will eat them and spread the seed (**Figure** 6.18).

Figure 6.18: Fleshy fruits aid in seed dispersal since animals eat the fruits and carry the seeds to a new location.

Some non-fleshy fruits are specially adapted for animals to carry them on their fur. You might have returned from a walk in the woods to find burrs stuck to your socks. These burrs are actually specialized fruits designed to carry seeds to a new location.

Gymnosperms

Plants with ”naked” seeds, meaning they are not enclosed by a fruit, are called gymnosperms. Instead, the seeds of gymnosperms are usually found in cones.

There are four phyla of gymnosperms:

1. Conifers.
2. Cycads.
3. Ginkgoes.
4. Gnetophytes.

Conifers

Conifers, members of the phylum *Coniferophyta*, are probably the gymnosperms that are most familiar to you. Conifers include pines, firs, spruces, cedars, and the coastal redwood trees in California that are the tallest living vascular plants.

Conifers have their reproductive structures in cones, but they are not the only plants to have that trait (**Figure** 6.19). Conifer pollen cones are usually very small, while the seed cones are larger. Pollen contains gametophytes that produce the male gamete of seed plants. The pollen, which is a powder-like material, is carried by the wind to fertilize the seed cones that contain the female gamete (**Figure** 6.20).

Figure 6.19: A red pine, which bears seeds in cones, is an example of a conifer.

Conifers have many uses. They are important sources of lumber and are also used to make paper. Resins, the sticky substance you might see oozing out of a wound on a pine tree, are collected from conifers to make a variety of products, such as the solvent turpentine and the rosin used by musicians and baseball players. The sticky rosin improves the pitcher’s hold on the ball or increases the friction between the bow and the strings to help create music from a violin or other stringed instrument.

Figure 6.20: The end of a pine tree branch bears the male cones that produce the pollen.

Cycads

Cycads, in the phylum *Cycadophyta*, are also gymnosperms. They have large, finely-divided leaves and grow as short shrubs and trees in tropical regions. Like conifers, they produce cones, but the seed cones and pollen cones are always on separate plants (**Figure** 6.21). One type of cycad, the Sago Palm, is a popular landscape plant. During the Age of the Dinosaurs (about 65 to 200 million years ago), cycads were the dominant plants. So you can imagine dinosaurs grazing on cycad seeds and roaming through cycad forests.

Figure 6.21: Cycads bear their pollen and seeds in cones on separate plants.

Ginkgoes

Ginkgoes, in the phylum *Ginkgophyta*, are unique because they are the only species left in the phylum. Many other species in the fossil record have gone extinct (**Figure** 6.22). The ginkgo tree is sometimes called a "living fossil," because it is the last species from its phylum.

One reason the ginkgo tree may have survived is because it was often grown around Buddhist temples, especially in China. The ginkgo tree is also a popular landscape tree today in American cities because it can live in polluted areas better than most plants.

Ginkgoes, like cycads, has separate female and male plants. The male trees are usually preferred for landscaping because the seeds produced by the female plants smell terrible when they ripen.

Figure 6.22: Ginkgo trees are gymnosperms with broad leaves.

Gnetophytes

Gnetophytes, in the phylum *Gnetophyta*, are a very small and unusual group of plants. *Ephedra* is an important member of this group, since this desert shrub produces the ephedrine used to treat asthma and other conditions. *Welwitschia* produces extremely long leaves and is found in the deserts of southwestern Africa (**Figure** 6.23). Overall, there are about 70 different species in this diverse phylum.

Angiosperms

Angiosperms, in the phylum *Anthophyta*, are the most successful phylum of plants. This category also contains the largest number of individual plants (see **Figure** 6.24). Angiosperms evolved the structure of the flower, so they are also called the flowering plants. Angiosperms live in a variety of different environments. A water lily, an oak tree, and a barrel cactus, although different, are all angiosperms.

The Parts of a Flower

Even though flowers may look very different from each other, they do have some structures in common. Follow along in **Figure** 6.25 as the structures are explained below:

Figure 6.23: One type of gnetophyte is Welwitschia.

Figure 6.24: Angiosperms are the flowering plants.

- The green outside of a flower that often looks like a leaf is called the **sepal** (**Figure** 6.26). All of the sepals together are called the **calyx**, which is usually green and protects the flower before it opens.
- All of the petals (**Figure** 6.26) together are called the **corolla**. They are bright and colorful to attract a particular pollinator, an animal that carries pollen from one flower to another.
- The next structure is the **stamen**, consisting of the stalk-like filament that holds up the **anther**, or pollen sac. The pollen is the male gametophyte.
- At the very center is the **carpel,** which is divided into three different parts: (1) the sticky **stigma**, where the pollen lands, (2) the tube of the style, and (3) the large bottom part, known as the **ovary**.

The ovary holds the ovules, the female gametophytes. When the ovules are fertilized, the ovule becomes the seed and the ovary becomes the fruit.

When flowers have all of these parts, they are known as **complete flowers**. Other flowers may be missing one or more of these parts and are known as **incomplete flowers. Table** 6.1 summarizes the parts of the flower.

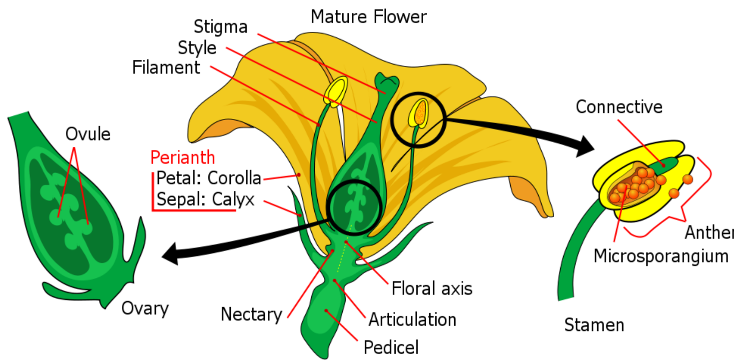

Figure 6.25: A complete flower has sepals, petals, stamens, and one or more carpels.

Table 6.1: **The Parts of a Flower**

Flower part	Definition
sepals	The green outside of the flower.
calyx	All of the sepals together, or the outside of the flower.
corolla	The petals of a flower collectively.
stamens	The part of the flower anther that produces pollen.
filament	Stalk that holds up the anther.
anther	The structure that contains pollen in a flower.
carpel	"Female" part of the flower; includes the stigma, style, and ovary.
stigma	The part of the carpel where the pollen must land for fertilization to occur.
style	Tube that makes up part of the carpel.
ovary	Larged bottom part of the carpel where the ovules are contained.

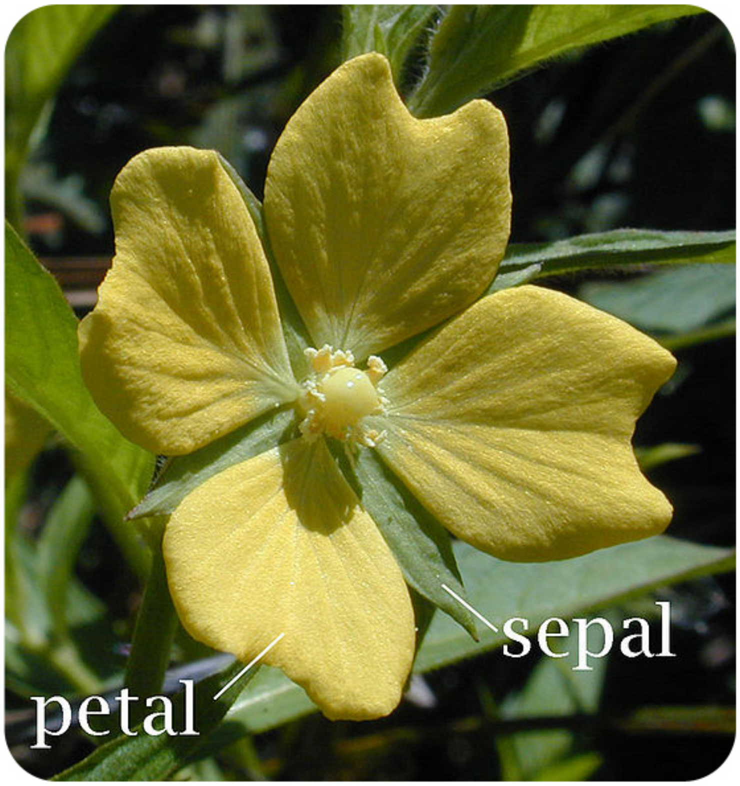

Figure 6.26: This image shows the difference between a petal and a sepal.

How Do Angiosperms Reproduce?

Flowering plants can reproduce two different ways:

1. Self-pollination: Pollen falls on the stigma of the same flower. This way, a seed will be produced that can turn into a genetically identical plant.
2. Cross-fertilization: Pollen from one flower travels to a stigma of a flower on another plant. Pollen travels from flower to flower by wind or by animals. Flowers that are pollinated by animals such as birds, butterflies, or bees are often colorful and provide nectar, a sugary reward, for their animal pollinators.

Why Are Angiosperms Important to Humans?

Angiosperms are important to humans in many ways, but the most significant role of angiosperms is as food. Wheat, rye, corn, and other grains are all harvested from flowering plants. Starchy foods, such as potatoes, and legumes, such as beans, are also angiosperms. And as mentioned previously, fruits are a product of angiosperms to increase seed dispersal and are also nutritious foods.

There are also many non-food uses of angiosperms that are important to society. For example, cotton and other plants are used to make cloth, and hardwood trees are used for lumber.

Lesson Summary

- Seeds consist of a dormant plant embryo and stored food.

- Seeds can be dispersed by wind or by animals that eat fleshy fruits.
- Gymnosperms, seed plants without flowers, include conifers, cycads, gingkoes, and gnetophytes.
- Angiosperms are flowering plants.
- Seed plants provide many foods and products for humans.

Review Questions

Recall

1. How do seeds help plants adapt to their environment?
2. What are two ways that plants disperse their seeds?
3. What are some examples of gymnosperms?
4. Firs, spruces, and pines belong to what group of gymnosperms?
5. Where is the pollen stored in a flower?
6. How are plants pollinated?

Apply Concepts

7. What is the purpose of a plant developing a fruit?
8. How are gymnosperms and angiosperms different?
9. What are some uses that seed plants have for humans?
10. Why is the ginkgo tree considered a "living fossil"?

Think Critically

11. Why did angiosperms evolve the ability to produce flowers? Use the terms "adaptation" and "environment" in your explanation.

Further Reading / Supplemental Links

- http://www.ucmp.berkeley.edu/seedplants/seedplants.html
- http://hcs.osu.edu/hcs300/gymno.htm
- http://biology.clc.uc.edu/Courses/bio106/gymnospr.htm
- http://www.biologie.uni-hamburg.de/b-online/e02/02d.htm
- http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookflowers.html
- http://en.wikipedia.org/wiki

Points to Consider

Now that we have discussed the types of plants, we turn to plant responses.

- Do you think plants can respond to their environment? Why or why not?
- How might plants and fruit change colors?
- How do you think trees know when it's time to lose their leaves?

6.4 Plant Responses

Lesson Objectives

- List the major types of plant hormones and the main functions of each.
- Define tropism and explain examples of tropisms.
- Explain how plants sense the changes of seasons.

Check Your Understanding

- Why do plants need sunlight?

Vocabulary

- abscisic acid
- apical dominance
- auxin
- cytokinins
- ethylene
- gibberellins
- gravitropism
- hormones
- phototropism
- thigmotropism
- tropism

Plant Hormones

Plants may not move, but that does not mean they don't respond to their environment. Plants can sense gravity, light, touch, and seasonal changes. For example, you might have noticed how a house plant bends towards a bright window. Plants can sense and then grow toward the source of light. Scientists say that plants are able to respond to "stimuli," or something-usually in the environment-that results in a response. For instance, light is the stimulus, and the plant moving toward the light is the "response."

Hormones are special chemical messengers that help plants respond to stimuli in their environment. In order for plants to respond to the environment, their cells must be able to communicate with other cells. Hormones send messages between the cells. Animals, like humans, also have hormones, such as testosterone or estrogen, to carry messages from cell to cell. Animal hormones will be discussed in the *Controlling the Body* chapter. In both plants and animals, hormones travel from cell to cell in response to a stimulus and also activate a specific response.

Types of Plant Hormones

Five different types of plant hormones are involved in the main responses of plants. Their functions are listed in **Table** 6.2.

Table 6.2: **Each plant hormone has a specific function**

Hormone	Function
Ethylene	Fruit ripening and abscission
Gibberellins	Break the dormancy of seeds and buds; promote growth
Cytokinins	Promote cell division; prevent senescence
Abscisic Acid	Close the stomata ; maintain dormancy
Auxins	Involved in tropisms and apical dominance

Ethylene

Ethylene has two functions. It (1) helps ripen fruit and is (2) involved in the process of abscission, the dropping of leaves, fruits and flowers. When a flower is done blooming or a fruit is ripe and ready to be eaten, ethylene causes the petals or fruit to fall from a plant (**Figure** 6.27 and **Figure** 6.28).

Ethylene is an unusual plant hormone because it is a gas. That means it can move through the air, and a ripening apple can cause another apple to ripen, or even over-ripen. That's why one rotten apple spoils the whole barrel! Some farmers spray their green peppers with ethylene gas to cause them to ripen faster-and become red peppers.

You can try to see how ethylene works by putting a ripe apple or banana with another unripe fruit in a closed container or plastic bag–what do you think will happen to the unripe fruit?

Figure 6.27: The hormone ethylene is signaling these tomatoes to ripen.

Figure 6.28: The hormone ethylene causes flower petals to fall from a plant, a process known as abscission.

Gibberellins

Gibberellins are hormones that cause the plant to grow.

When gibberellins are applied to plants by scientists, the stems grow longer. Some gardeners or horticulture scientists add gibberellins to increase the growth of plants. Dwarf plants (small plants), on the other hand, have low levels of gibberellins (**Figure** 6.29). Another function of gibberellins is to stop dormancy (resting) time of seeds and buds. Gibberellins signal that it's time for a seed to germinate (grow) or for a bud to open.

Figure 6.29: Dwarf plants like this bonsai tree often have unusually low concentrations of gibberellins.

Cytokinins

Cytokinins are hormones that cause plant cells to divide. Cytokinins were discovered from attempts to grow plant tissue in artificial (unnatural) environments (**Figure** 6.30). Cytokinins prevent senescence, or the process of aging. So florists sometimes apply cytokinins to cut flowers, so they do not get old and die.

Figure 6.30: Cytokinins promote cell division and are necessary for growing plants in tissue culture. A small piece of a plant is placed in sterile conditions to regenerate a new plant.

Abscisic Acid

Abscisic Acid is misnamed because it was once believed to play a role in abscission (the dropping of leaves, fruits and flowers), but we now know abscission is caused by ethylene. The actual role of abscisic acid is to close the stomata and maintain dormancy (resting). When a plant is stressed due to lack of water, abscisic acid tells the stomata to close. This prevents water loss through the stomata.

When the environment is not good for a seed to germinate (begin to grow), abscisic acid signals for the dormancy period of the seed to continue. Abscisic acid also tells the buds of plants to stay in the dormancy stage. When conditions improve, the levels of abscisic acid drop and the levels of gibberellins increase, signaling that is time to break dormancy (**Figure** 6.31).

Auxins

Auxins are hormones that play a role in plant growth.

Auxins produced at the tip of the plant are involved in **apical dominance**, when the main central stem grows more strongly than other stems and branches. When the tip of the plant is removed, the auxins are no longer present and the side branches begin to grow. This is why pruning (cutting off branches) helps produce a fuller plant with more branches. You actually need to cut off branches off a plant for it to grow more branches! Auxins are also involved in tropisms, which will be discussed in the next section.

Figure 6.31: A decrease in levels of abscisic acid allows these buds to break dormancy and put out leaves.

Tropisms

Plants may not be able to move, but they are able to change how they grow in response to their environment. Growth toward or away from a stimulus is known as a **tropism** (**Table** 6.3). The auxins allow plants to curve its growth specific directions. The auxin moves to one side of the stem, where it starts a chain of events that cause cell growth on just that one side of the stem. With one side of the stem growing faster than the other, the plant begins to bend.

Table 6.3: **Tropisms**

Type of Tropism	Stimulus
Phototropism	light
Gravitropism	gravity
Thigmotropism	touch

Phototropism

You might have noticed that plants bend towards the light. This is an example of a tropism where light is the stimulus, known as **phototropism** (**Figure** 6.32). To obtain more light for photosynthesis, leaves and stems grow towards the light. On the other hand, roots grow away from light. This is beneficial for the roots because they need to obtain water and nutrients from deep within the ground.

Figure 6.33: These shoots are exhibiting gravitropism because they are growing against the pull of gravity.

Thigmotropism

Plants also have a touch response, called **thigmotropism**. If you have ever seen a morning glory or the tendrils of a bean plant twist around a pole, then you know that plants must be able to sense the pole. Thigmotropism works much like the other tropisms. The plant grows straight until it comes in contact with the pole. Then the side of the stem in contact with the pole grows slower than the opposite side of the stem. This causes the stem to bend around the pole.

See the following link for an example of thigmotropism: http://biology.kenyon.edu/edwards/project/steffan/b45sv.htm.

Seasonal Changes

Have you seen the leaves of plants change colors? What time of year does this happen? What causes it to happen? Plants can sense changes in the seasons. Leaves change color and drop each autumn in certain climates (**Figure** 6.34).

Certain flowers, like poinsettias, only bloom during the winter. And in the spring, the winter buds on the trees break open and the leaves start to grow. How do plants detect time of year?

Although you might detect the change of seasons by the change in temperature, this is not the way plants know the seasons are changing. Plants determine the time of year by the length of the day. Because of the tilt of the Earth, during winter days, there are less hours of light than during summer days. That's why during the winter it may start getting dark very early during the evening and even stay dark while you're getting ready for school the next morning. But in the summer it will be bright early in the morning and the sun may not set until late that night. With their hormones, plants can sense the differences in day length.

For example, in the fall when the days start to get shorter, the trees sense that there is less sunlight. The hormones are stimulated and they send messages telling the leaves to change colors and fall from the plant.

If a plant kept it leaves over the winter, would it be able to perform photosynthesis? Not very much because it would be too dark. So, the plant sheds its leaves during the winter to rest and then regrows the leaves during the spring and summer months to make use of the increase in sunlight.

Figure 6.34: Leaves changing color is a response to the shortened length of the day in autumn.

Lesson Summary

- Plant hormones are chemical signals that control different processes in plants.
- A plant tropism is growth towards or away from a stimulus such as light or gravity.
- Many plants go through seasonal changes after detecting differences in day length.

Review Questions

Recall

1. What is the term for dropping fruits, flowers, or
2. What hormone is involved with fruit ripening?
3. What hormone is involved in tropisms?
4. What is phototropism?

Apply Concepts

5. Explain how are hormones involved in seed germination.
6. Cells begin to divide in the stem of the plant. What hormones are involved in this process?
7. The tendril of a bean meets the a metal pole. What will happen to the tendril and why?
8. How do plants detect the change in seasons?
9. Explain two seasonal responses in plants.

Critical Thinking

10. A scientist hypotheses that plants lose their leaves due to a colder temperatures in the winter. Explain why this hypothesis is untrue.

Further Reading / Supplemental Links

www.plantphysiol.org/cgi/reprint/116/1/329.pdf

- http://plantphys.info/apical/apical.html
- http://www.cals.ncsu.edu/nscort/outreach_exp_gravitrop.html
- http://en.wikipedia.org/wiki

Points to Consider

In the next chapter we will turn our attention to animals.

- List some ways you think animals are different from plants.
- What characteristics do you think define an animal?
- Can you think of examples of animals that do not have hard skeletons?

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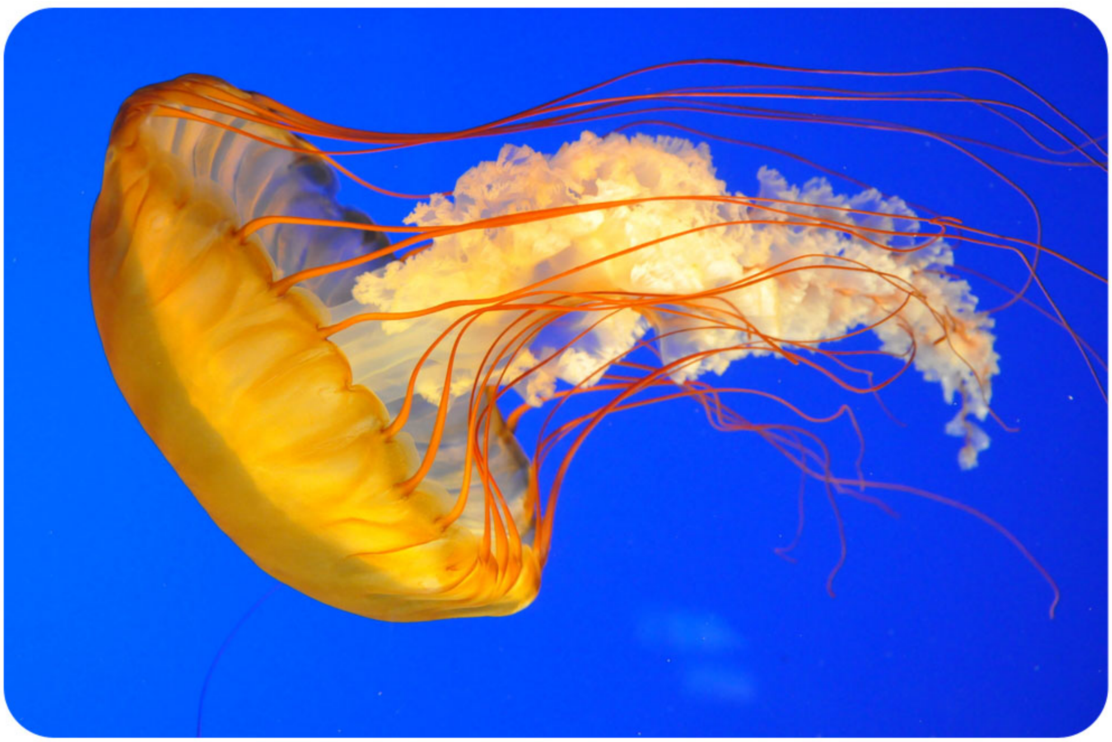
Chapter 7

MS Introduction to Invertebrates



The above image shows an organism from the phylum Cnidaria. What does that mean? Good question.

You may call the above organism a jellyfish. But a jellyfish is not a fish at all, although it is a part of the animal kingdom. Kingdoms are divided up into phyla, and this organism is classified in the phylum called Cnidaria.

How is the above organism different from you? What is its body shape? Does it have a brain? Does it have a way to digest food? Can it eat like us? Can it breathe? These are the types of questions scientists ask when they classify organisms, or put them into categories.

This chapter will explore how different invertebrates, organisms without a backbone, are classified into different categories. After reading this chapter, see if you can do a better job asking the right questions to put organisms into specific categories.

7.1 Overview of Animals

Lesson Objectives

- List the characteristics that define the animal kingdom.
- Define and give examples of the invertebrates.

Check Your Understanding

- What are the main differences between an animal cell and a plant cell?
- How do animals get their energy?

Vocabulary

- bilateral symmetry
- complete digestive tract
- incomplete digestive tract
- invertebrate
- radial symmetry
- segmentation

Classification of Animals

How are animals different from other forms of life? Recall that all animals are eukaryotic, meaning that they have cells with true nuclei and membrane-bound organelles. Animals are also multicellular. Remember that protists can be unicellular. Because animals are multicellular, animal cells can be organized into tissues, organs, and organ systems. Finally, animals are heterotrophic, meaning they must eat nutrients (food) that come from outside of their bodies in order to create energy (**Figure** 7.1).

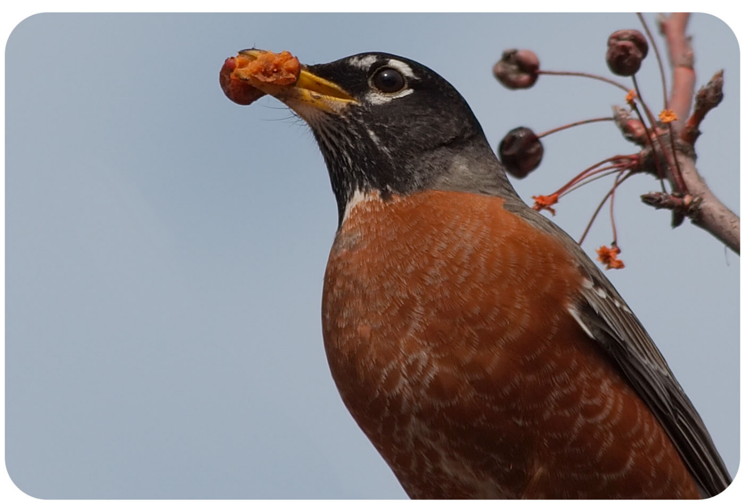


Figure 7.1: Animals are heterotrophs, meaning they must eat to get molecules necessary for their growth and energy.

How Are Animals Classified?

Recall that each kingdom of life, including the animal kingdom, is divided into smaller groups called phyla (singlular = phylum) based on their shared characteristics. There are 38 animal phyla. For example, the phylum Mollusca largely consists of animals with shells, like snails and clams. Animals were classfied by how they look, and now DNA evidence is used to confirm that organisms in a particular phylum are related.

What characteristics are used to classify animals?

1. Body Symmetry: One example of a physical characteristic used to classify animals is body symmetry. In organisms that show **radial symmetry**, such as sea stars, the body is organized like a circle (**Figure** 7.2). Therefore, any cut through the center of the animal creates two identical halves.

Other animals, such as humans and worms, show **bilateral symmetry,** meaning their left and right sides are mirror images.

Figure 7.2: Sea stars are radially symmetrical.

2. Animals are also often classified by their body structure. For example, **segmentation**, the repetition of body parts, defines one phylum of worms (**Figure** 7.3). Animals that have a true body cavity, defined as a fluid-filled space, and internal organs (like humans) are also classified in separate phyla from those animals that do not have a true body cavity.

3. The structure of the digestive system of animals can also be used as a characteristic for classification. Animals with **incomplete digestive tracts** have only one opening in their digestive tracts, while animals with **complete digestive tract** have two openings, the mouth and anus.

In this chapter we will focus on **invertebrates**, animals that do not have a backbone.

What Are Invertebrates?

Besides being classified into phyla, animals are also often characterized as being invertebrates or vertebrates. These are terms based on the skeletons of the animals. **Vertebrates** have a backbone made of bone or cartilage, while invertebrates have no backbone. All vertebrate organisms are in the phylum Chordata, while invertebrates make up several diverse phyla, some of which are listed in **Table** 7.1.

Figure 7.3: A segmented body plan defines the phylum that includes the earthworms.

Table 7.1: **Invertebrate Phyla**

Phylum	Examples
Porifera	Sponges
Cnidaria	Jellyfish, corals
Platyhelminthes	Flatworms, tapeworms
Nematoda	Nematodes, heartworm
Mollusca	Snails, clams
Annelida	Earthworms, leeches
Arthropoda	Insects, crabs
Echinodermata	Sea stars, sea urchins

Invertebrates include insects, earthworms, jellyfish, sea stars, and a variety of other animals. **Figure** 7.4 shows an example of a familiar invertebrate, the snail.

In the next lessons we will discuss some of phyla within the animal kingdom that contain invertebrates.

Figure 7.4: Snails are an example of invertebrates, animals without a backbone.

Lesson Summary

4. What are some examples of invertebrates?

Apply Concepts

5. What is the difference between animals that show radial and bilateral symmetry?

6. Name two examples of animals, not included in this lesson, which show bilateral symmetry.

7. What are some examples of animals that show radial symmetry that are not included in this lesson?

8. Do humans have a body cavity? What kind of organs are found there?

9. What is the difference between an incomplete and complete digestive system?

10. How is segmentation used to classify animals?

Critical Thinking

11. While diving in the ocean, you find a circular squishy animal that does not contain bones. How will you describe this animal to a scientist? What kind of symmetry does it show? Is it an invertebrate or vertebrate?

Further Reading

- http://animaldiversity.ummz.umich.edu/site/index.html
- http://animals.nationalgeographic.com/animals/invertebrates.html
- http://en.wikipedia.com

Points to Consider

The first invertebrates we will look at are the sponges and cnidarians.

- What do you think that jellyfishes and corals have in common?
- Think of some examples of animals that show bilateral symmetry, meaning that the left side is a mirror image of the right?

7.2 Sponges and Cnidarians

Lesson Objectives

- Describe the key features of sponges.
- Describe the key features of cnidarians.
- List examples of cnidarians.

Check Your Understanding

- How are animals classified?
- What is an invertebrate?

Vocabulary

- cnidarians
- corals
- gastrovascular cavity
- medusa
- nematocysts
- polyp
- sessile

Ocean Invertebrates

The ocean is home to many different types of organisms, including phytoplankton, zooplankton, fish. Phytoplankton, tiny photosynthetic organisms that float in the water, make their own food from the energy of the sun. Small water animals, known as zooplankton, and larger animals, such as fish, use phytoplankton as a source of food. These animals can then be eaten by larger water animals, such as larger fish and sharks.

Among the different types of animals that live in the ocean, the **sponges** and **cnidarians** are important invertebrates. The Sponges are believed to be one of the most ancient forms of animal life on earth. The cnidarians, which include the jellyfish, also are among the oldest and most unusual animals on earth.

Sponges

What do you think of when you think of a sponge? Something to wash the dishes with? Well, you are right. Up until recently, people took sponges out of the ocean and used them to clean their dishes. Now, we make sponges out of unnatural materials. But the organisms still live in the ocean.

Sponges are classified in the phylum *Porifera*, from the Latin words meaning "having pores." These pores allow the movement of water into the sponges' sac-like bodies (**Figure** 7.5). Sponges pump water through their bodies because they are **sessile**, meaning they cannot move, and filter feeders, meaning they must filter the water to separate organisms and nutrients they want to eat from those they do not.

Sponges evolved earlier than other animals, so they do not have brains, stomachs, or other organs. In fact, sponges do not even have true tissues. Instead, their bodies are made up of specialized cells that do specific jobs. For example, some cells control the flow of water into and out of the sponge by increasing or decreasing the size of the pores.

Cnidarians

Cnidarians, in the phylum *Cnidaria*, include organisms such as the jellyfish (**Figure** 7.6) and sea anemones (**Figure** 7.7 and **Figure** 7.8) that are found in shallow ocean water. You might recognize that these animals can give you a painful sting if you step on them. That's because cnidarians have stinging cells known as **nematocysts**. When touched, the nematocysts release a thread of poison that can be used to paralyze prey-usually food for the jellyfish.

The body plan of cnidarians is unique because these organisms show radial symmetry, meaning that they have a circular body plan, and any cut through the center of the animal leaves two equal halves.

The cnidarians have two basic body forms:

1. **Polyp**: The polyp is a cup-shaped body with the mouth facing upward, such as a sea anemone.

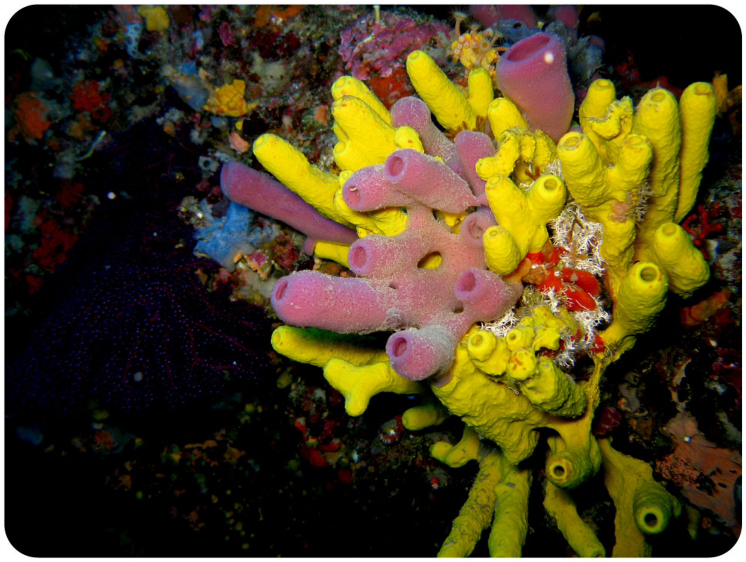


Figure 7.5: Sponges have tube-like bodies with many pores.

2. **Medusa**: The medusa is a bell-shaped body with the mouth and tentacles facing downward, such as a jellyfish.

Unlike the sponges, the cnidarians are made up of true tissues. The inner tissue of a cnidarian is called the **gastrovascular cavity**, a large space that helps the organism digest and move nutrients around the body. The cnidarians also have nerve tissue organized into a net-like structure. Cnidarians do not have true organs, however.

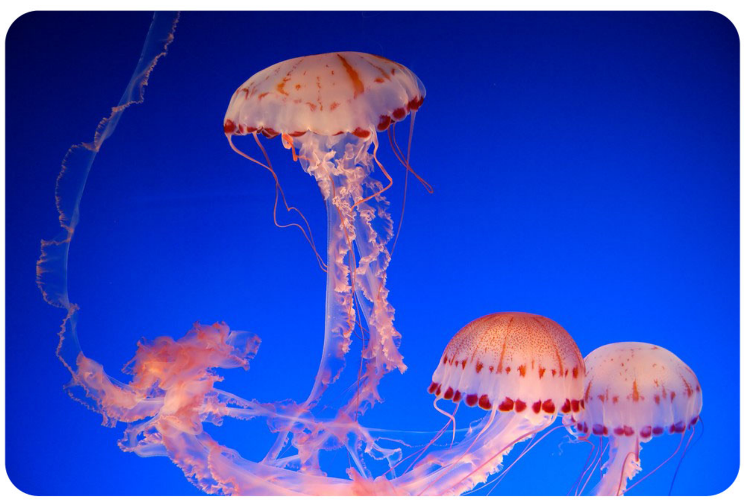


Figure 7.6: Jellyfish have bell-shaped bodies with tenticles.

Cnidarian Colonies

Some types of cnidarians are also known to form colonies. Two examples are described below.

1. The Portuguese Man o' War looks like a single organism but is actually a colony of polyps (**Figure** 7.9). One polyp is filled with air to help the colony float, while several feeding polyps hang below with

Figure 7.7: Sea anemones can sting and trap fish with their tentacles.

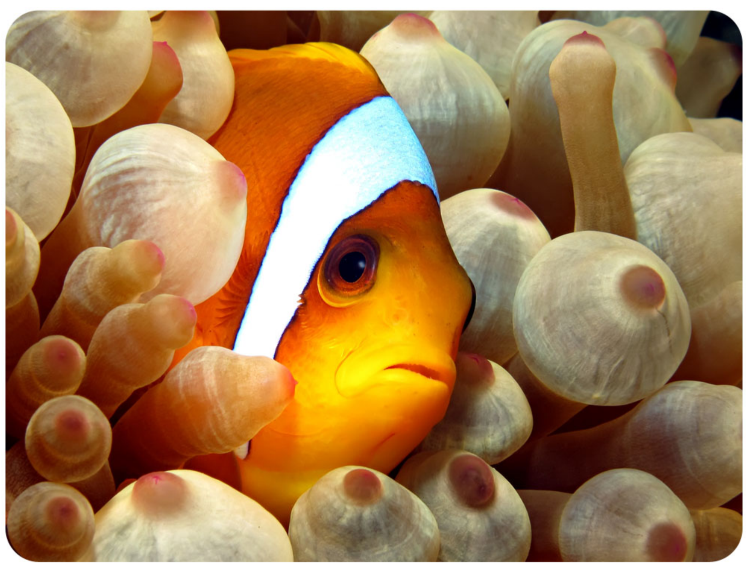


Figure 7.8: One type of sea anemone is home to the clownfish. The clownfish and the sea anemone help each other survive. Clownfish are the only fish that do not get stung by the tentacles of the sea anemone. The clownfish, while being provided with food, cleans away fish and algae leftovers from the anemone.

tentacles, full of nematocysts. The Portuguese Man o' War is known to cause extremely painful stings to swimmers and surfers who accidentally brush up against them in the water.

Figure 7.9: The Portuguese Man o' War can deliver debilitating stings with its tentacles.

2. Coral reefs look like big rocks, but they are actually alive. They are built from cnidarians called corals (**Figure** 7.10). The corals are sessile polyps that can use their tentacles to feed on ocean creatures that pass by. Their skeletons are made up of calcium carbonate, which is also known as limestone. Over long periods of time, their skeletons build on each other to produce large structures known as coral reefs. Coral reefs are important habitats for many different types of ocean life.

Figure 7.10: Corals are colonial cnidarians.

Lesson Summary

- Sponges are sessile filter feeders without true tissues.
- Cnidarians, such as jellyfish, have radial symmetry and true tissues.
- Some cnidarians form colonies, such as the Portuguese Man o' War and corals.

Review Questions

Recall

1. What is the only animal to lack true tissues?
2. In what phylum are the sponges?
3. How do sponges gain nutrition?
4. Where are most cnidarians found?
5. What are some examples of cnidarians?

Apply Concepts

6. Cnidarians show radial symmetry. What does this mean?
7. How do cnidarians sting their prey?
8. Describe the nervous system of the cnidarians.
9. How is a jellyfish different from a Portuguese Man o' War?
10. How are coral reefs built?

Critical Thinking

11. Which organisms do you think evolved first–the sponge or the cnidarian? Explain your answer with two pieces of evidence from the lesson.

Further Reading / Supplemental Links

- http://www.ucmp.berkeley.edu/porifera/porifera.html
- http://animaldiversity.ummz.umich.edu
- http://www.pbs.org/kcet/shapeoflife/animals/cnidaria.html
- http://www.ucmp.berkeley.edu/cnidaria/cnidaria.html http://tolweb.org/tree?group=Cnidaria&contgroup=Animals http://www.ucmp.berkeley.edu/cnidaria/cnidaria.html
- http://animaldiversity.ummz.umich.edu/site/accounts/information/Porifera.html
- http://en.wikipedia.org/wiki/Cnidaria

Points to Consider

Next we discuss worms.

- How do you think that worms are different from sponges and cnidarians?
- How do you think that worms might be similar to sponges and cnidarians?

7.3 Worms

Lesson Objectives

- Describe the major features of the flatworms.
- Describe the major features of the roundworms.
- Describe the major features of the segmented worms.

Check Your Understanding

- In terms of body structure, what does segmentation refer to?
- What is a body cavity?

Vocabulary

- cephalization
- hydroskeleton
- tapeworms

What are Worms?

The word "worm" is not very scientific. But it is a word that informally describes animals that have long bodies with no arms or legs. Worms show bilateral symmetry, meaning that the right side of their bodies is a mirror of the left. Worms live in many different types of environments, including in the ocean, in fresh water, on land, and as parasites of plants and animals.

Three types of worms with different body types will be explored in this lesson:

1. Flatworms, which have ribbon-like bodies with no body cavity.
2. Roundworms, which have a body cavity but no segments.
3. Segmented worms, which have both a body cavity and segmented bodies.

Flatworms

Worms in the phylum *Platyhelminthes* are called flatworms because they have flattened bodies. Some species of flatworms are free-living organisms that feed on small organisms and rotting matter. These types of flatworms include marine flatworms and fresh-water flatworms such as *Dugesia* (**Figure** 7.11 and **Figure** 7.12).

Other types of flatworms are parasitic and live inside another organism, called a host, in order to get the food and energy they need. For example, **tapeworms** have a head-like area with tiny hooks that help the worm attach to the intestines of an animal host (**Figure** 7.13 and **Figure** 7.14).

Characteristics of Flatworms

The main characteristics of flatworms can be summarized as follows:

1. Flatworms have no true body cavity and an incomplete digestive system, meaning that the digestive tract has only one opening.

Figure 7.11: Dugesia is a type of flatworm with a head region and eyespots.

Figure 7.12: Marine flatworms can be brightly colored.

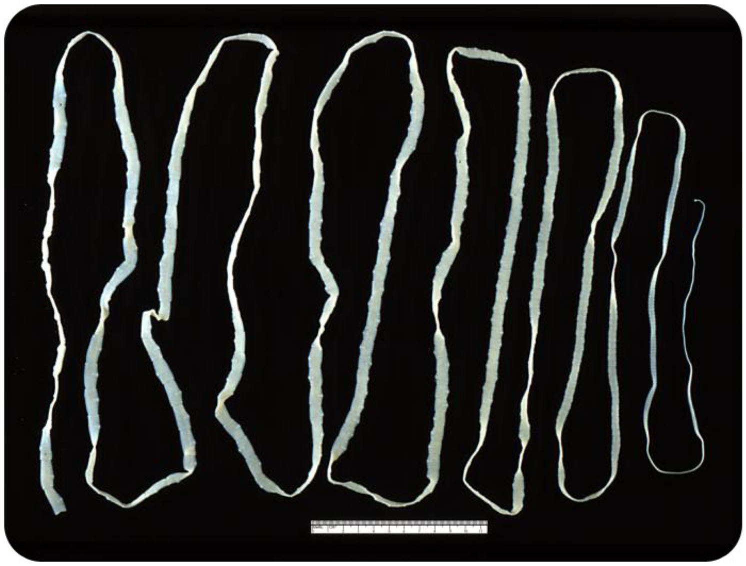


Figure 7.13: Tapeworms are parasitic flatworms that live in the intestines of their hosts. They can be very long.

Figure 7.14: Tapeworms attach to the intestinal wall with a head region that has hooks and suckers.

2. Flatworms do not have a respiratory system, so they have pores that allow oxygen to enter through their body.
3. There are no blood vessels in the flatworms. Their gastrovascular cavity helps them to digest food and to send nutrients throughout the body.
4. The flatworms have a ladder-like nervous system with a distinct head region that includes nerve cells and sensory organs, such as eyespots. The development of a head region, called **cephalization**, evolved at the same time as bilateral symmetry in animals.

Roundworms

The phylum *Nematoda* includes non-segmented worms known as nematodes or roundworms (**Figure** 7.15).

Characteristics of Flatworms

There are specific differences between the flatworms and the roundworms.

1. Unlike the flatworms, the roundworms have a body cavity with internal organs.
2. A roundworm has a complete digestive system, which includes both a mouth and an anus. They also include a large digestive organ known as the gut.
3. Roundworms also have a simple nervous system with a primitive brain. The nerves are connected from the top to the bottom of the body.

Figure 7.15: Nematodes can be parasites of plants and animals.

Roundworms can be free-living organisms, but they are probably best known for their role as significant plant and animal parasites. Heartworms, which cause serious disease in dogs while living in the heart and blood vessels, are a type of roundworm. Roundworms can also cause disease in humans. Elephantiasis, a disease characterized by the extreme swelling of the limbs, is caused by infection with a type of roundworm (**Figure** 7.16).

Figure 7.16: One roundworm parasite causes elephantiasis, a disease characterized by swelling of the limbs.

Segmented Worms

The phylum *Annelida* includes segmented worms, such as the common earthworm, some marine worms, and leeches (**Figure** 7.17 and **Figure** 7.18). These worms are known as the segmented worms because their bodies are segmented, or separated into repeating units. Most segmented worms feed on dead organic matter, while leeches can live in freshwater and suck blood from host organisms.

Characteristics of Segmented Worms

1. Segmented worms have a well-developed body cavity filled with fluid, which serves as a **hydroskeleton**, a supportive structure that helps move the worm's muscles.
2. Segmented worms also tend to have organ systems that are more developed than the roundworms or flatworms. Earthworms, for example, have a complete digestive tract, including an esophagus and intestines. The circulatory system consists of paired hearts and blood vessels, while the nervous system consists of the brain and a ventral nerve cord.

Table 7.2 compares the three worm phyla.

Table 7.2: **Comparison of the Three Worm Phyla**

Type of Worm	Body Cavity	Segmented	Digestive System	Example
Flatworm	No	No	Incomplete	Tapeworm
Roundworm	Yes	No	Complete	Heartworm
Segmented	Yes	Yes	Complete	Earthworm

Figure 7.17: Earthworms are segmented worms.

Figure 7.18: Leeches are parasitic segmented worms.

Lesson Summary

- The flatworms have no true body cavity and include free-living *Dugesia* and parasitic tapeworms.
- The roundworms, which can also be parasitic or free-living, are non-segmented worms with a complete digestive tract and a primitive brain.
- The segmented worms include the common earthworm and leeches.

Review Questions

Recall

1. What is cephalization?
2. Name a parasitic flatworm.
3. Name a parasitic segmented worm.
4. Earthworms are in what phylum?

Apply Concepts

5. Are all worms classified into a single phylum?
6. Describe the respiratory system of the flatworms.
7. How does the body plan of the roundworms differ from that of the flatworms?
8. Describe the digestive system of roundworms.
9. What features distinguish Phylum Annelida from the other worms?
10. Describe the skeletal system of a segmented worm.

Critical Thinking

11. Which phylum includes worms with organs that are most similar to the organs found in humans? Support your answer with three pieces of evidence.

Further Reading / Supplemental Links

- http://animaldiversity.ummz.umich.edu/site/accounts/information/Annelida.html
- http://animaldiversity.ummz.umich.edu/site/accounts/information/Nematoda.html
- http://animaldiversity.ummz.umich.edu/site/accounts/information/Platyhelminthes.html
- http://www.ucmp.berkeley.edu/platyhelminthes/platyhelminthes.html
- http://www.ucmp.berkeley.edu/phyla/ecdysozoa/nematoda.html
- http://www.ucmp.berkeley.edu/annelida/annelida.html
- http://animaldiversity.ummz.umich.edu
- http://en.wikipedia.org/wiki/Annelida

Points to Consider

Next we further our discussing of the invertebrates.

- Can you think of some invertebrates other than those discussed in this chapter?
- How would these other invertebrates be more advanced compared to worms?

Image Sources

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Chapter 8

MS Other Invertebrates

What do spiders, clams, and grasshoppers all have in common? They are all invertebrates. So is the above organism, commonly known as a starfish. As you know, even though all of these organisms are invertebrates, they are very different from each other. They are in four different phyla.

You may know where a spider lives and you may even know some things about how it catches its prey. But where does a starfish live? Does it move? How does it reproduce? How does it eat? If a starfish is an invertebrate, how come it looks so different from other invertebrates? These are all questions that scientists ask when they are classifying an organism.

Scientists and naturalists now classify starfish in a phylum called *Echinodermata*, one of four phyla explored in this chapter.

8.1 Mollusks

Lesson Objectives

- Discuss what characteristics define mollusks.
- Describe the different types of mollusks.
- Explain why mollusks are important.

Check Your Understanding

- What is an invertebrate?
- How are animals classified?

Vocabulary

- mantle
- nacre
- pearl
- radula

What are Mollusks?

When you take a walk along a beach, what do you find there? Sand, the ocean, lots of sunlight. You may also find shells. The shells you find are most likely left by organisms in the phylum *Mollusca*. On the beach, you can find the shells of many different mollusks, including clams, mussels, scallops, oysters, and snails. Their glossy pearls, mother of pearl, and abalone shells are like pieces of jewelry (see **Figure** 8.1, **Figure** 8.2, **Figure** 8.3, and **Figure** 8.4).

Figure 8.1: On the beach, you can find a wide variety of mollusks.

Figure 8.2: Pearls being removed from oysters.

Figure 8.3: The inside of a bivalve, one of the mollusk classes described in "Types of Mollusks" below, showing mother of pearl.

Figure 8.4: Shells of marine mollusks, including abalone.

The Phylum Mollusca

Mollusks belong to the phylum *Mollusca*. The mollusk body is often divided into different parts:

1. A head with eyes or tentacles
2. A muscular foot and a mass housing the organs. In most species, the muscular foot helps the mollusk move.
3. A **mantle**, or fold of the outer skin lining the shell. The mantle also releases calcium carbonate that creates the external shell, just like the ones you find on the beach.
4. The majority of ocean mollusks have a gill or gills to absorb oxygen from the water.
5. All species have a complete digestive tract that begins at the mouth and runs to the anus.
6. Many species have a feeding structure, the **radula**, found only in mollusks. The radula is made mostly of chitin, a tough, semitransparent substance. Radulae range from structures used to scrape algae off rocks to the beaks of squid and octopuses.

What Are the Mollusks Related to?

Mollusks are most likely related to organisms in the phylum *Annelida*, like the earthworm and leech. Scientists believe they are related because when they are in the early stage of development, they look very similar. Unlike annelids, however, mollusks do not have body segmentation, and their body shape is usually quite different as well.

How Big Are Mollusks?

The giant squid (**Figure** 8.5), which until recently had not been observed alive in its adult form, is one of the largest organisms in the phylum *Mollusca*. However, the colossal squid is even larger and can grow up to 46 feet long. The smallest mollusks are snails that are microscopic in size.

Figure 8.5: The colossal squid, one of the largest invertebrates, here measures 30 feet in length.

Types of Mollusks

There are approximately 160,000 living species and probably 70,000 extinct species of mollusks. They are typically divided into ten classes, of which two are extinct. The living classes are listed in **Table** 8.1. Which classes are you most familiar with?

As you can see, the majority of mollusk species live in ocean environments, and many of them are found in the shallow waters. Freshwater species are mostly bivalves and gastropods. Some gastropods, like land snails and slugs, live on land.

Table 8.1: **Living Molluscan Classes**

Molluscan Class	Number of Species	Habitat	Features of Class/Examples
Caudofoveata	70	Deep ocean	Worm-like organisms
Aplacophora	250	Deep ocean	Worm-like organisms
Polyplacophora	600	Rocky marine shorelines	Chitons (**Figure** 8.6)
Monoplacophora	11	Deep ocean	Limpet (cone shaped)-like organisms
Gastropoda	150,000 (80% of living molluscan diversity)	Marine (some limpets live in deep ocean around hot hydrothermal vents), freshwater, and terrestrial	Abalone, limpets, conch, nudibranchs (sea slugs), sea hares (large sea-slug), sea butterfly, snails, and slugs (**Figure** 8.7, **Figure** 8.8, and **Figure Figure** 8.9).
Cephalopoda	786	Marine	Most neurologically advanced of all invertebrates; include squid, octopus, cuttlefish, and nautilus (**Figure Figure** 8.10).

Table 8.1: (continued)

Molluscan Class	Number of Species	Habitat	Features of Class/Examples
Bivalvia	8,000	Marine (some clams live in deep ocean around hot hydrothermal vents) and freshwater.	Most bivalves are filter feeders (matter and food particles are filtered from the water, typically by passing the water over a specialized filtering structure); bivalves include clams, oysters, scallops, and mussels.
Scaphopoda	350	Marine	Tusk shells

Figure 8.6: A chiton and sea anemones at a tide pool.

Figure 8.7: An example of a gastropod species, the ostrich foot.

Importance of Mollusks

Mollusks are important in a variety of ways, including as food, for decoration, in jewelry, and in scientific studies. They are even used as roadbed material and in vitamin supplements.

Figure 8.8: A picture of limpets

Figure 8.9: A sea slug underwater

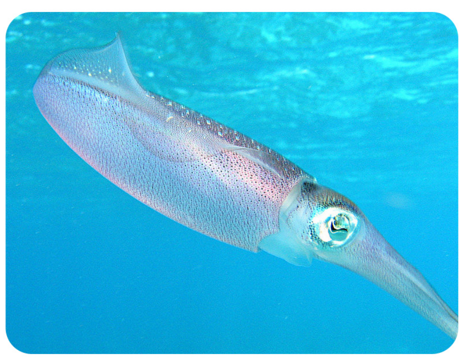

Figure 8.10: A Caribbean reef squid, an example of a cephalopod.

Mollusks as Food

Edible species of mollusks include numerous species of clams, mussels, oysters, scallops, marine and land snails, squid, and octopus. Many species of mollusks, such as oysters, are farmed in order to produce more than could be found in the wild (**Figure** 8.11).

Figure 8.11: An oyster harvest in France.

Mollusks in Decoration and Jewelry

Two natural products of mollusks used for decorations and jewelry are pearls and nacre, or mother of pearl. A **pearl** is the hard, round object produced within the mantle of a living shelled mollusk. Fine quality natural pearls have been highly valued as gemstones and objects of beauty for many centuries. The most desirable pearls are produced by oysters and river mussels.

Nacre is an iridescent inner shell layer produced by some bivalves, some gastropods, and some cephalopods. It has been used in sheets on floors, walls, countertops, doors, and ceilings. It is also inserted into furniture; it can be found in buttons, watch faces, knives, guns, and jewelry; and is used as decorations on various musical instruments.

Mollusks in Scientific Studies

Several mollusks are ideal subjects for scientific investigation, especially in the area of neurobiology. The giant squid has a sophisticated nervous system and a complex brain for study. The California sea slug, also called the California sea hare, is used in studies of learning and memory because it has a simple nervous system, consisting of just a few thousand large, easily identified neurons. These neurons are also responsible for a variety of learning tasks. Some slug brain studies have even allowed scientists to better understand human brains!

Lesson Summary

- The mollusk body often has a head with eyes or tentacles, a muscular foot, a mass with organs inside, and a mantle, which creates the external shell.
- Other mollusk structures include a gill or gills for absorbing oxygen, a complete digestive tract, and a radula.
- Mollusks are divided into ten living classes, including the familiar gastropods, cephalopods, and bivalves.
- Mollusks live in marine and freshwater habitats, as well as on land.
- Mollusks are important as food, for decoration, and in scientific studies.

Review Questions

Recall

1. What are the main characteristics of mollusks?
2. What are mollusk shells made out of?

Apply Concepts

3. What evidence shows that mollusks and annelids are related? How are they different?
4. What habitats do marine mollusks live in?
5. What makes the California sea slug ideal for studies of learning and memory?

Critical Thinking

6. Oysters, one of the bivalve filter feeders, filter up to five liters of water per hour. Oysters filter these pollutants and either eat them or shape them into small packets that are left on the bottom where they are harmless. When there is a high concentration of bacteria in the water from sewage run-off, this can kill the oysters and make them risky to eat. What do you think happens to the pollutants after the bacteria enter the environment?

Further Reading / Supplemental Links

- http://www.manandmollusc.net/links_educational.html
- http://www.oceanicresearch.org/education/wonders/mollusk.html
- http://www.manandmollusc.net/links_medicine.html
- http://en.wikipedia.org

Points to Consider

- Many mollusks demonstrate bilateral symmetry. How do you think this differs from the radial symmetry evident in echinoderms, in the next lesson?
- As we have seen, some species of mollusks live in the deep ocean around hot hydrothermal vents. In the next lesson we will learn that many echinoderms also live in the deep sea. What adaptations do you think both groups might have for living in such a unique environment?

- Mollusks have an exoskeleton, which is primarily external and composed of calcium carbonate. As a result many of these are preserved in the fossil record. How do you think this compares to the type of skeleton that an echinoderm has and to its fossil record?

8.2 Echinoderms

Lesson Objectives

- Discuss the traits of echinoderms.
- List the types of echinoderms.
- Explain the roles echinoderms play.

Check Your Understanding

- What is meant by body symmetry?
- What is radial symmetry?
- What is bilateral symmetry?

Vocabulary

- nerve net
- water vascular system

What are Echinoderms?

We're all familiar with starfish (**Figure** 8.12). But sea urchins (**Figure** 8.13) and sand dollars (**Figure** 8.14) are in the same phylum. What's similar between these three organisms? They all have radial symmetry. This means that the body is arranged around a central point.

Echinoderms belong to the phylum *Echinodermata*. This phylum includes 7,000 living species. It is the largest phylum without freshwater or land-living members.

Characteristics of Echinoderms

As mentioned earlier, echinoderms show radial symmetry. Other key echinoderm features include:

1. Despite the fact that echinoderms have a hard exterior appearance, they do not have an external skeleton. Instead, a thin outermost skin covers an internal endoskeleton made of tiny plates and spines, contained within tissues of the organism. This provides rigid support.
2. Some groups, such as sea urchins, have spines (**Figure** 8.13) that protect the organism from predators and from colonization by encrusting (covering or coating) organisms. Sea cucumbers also use these spines, or warts, to help them move (**Figure** 8.15).

3. Echinoderms have a unique **water vascular system**, a network of fluid-filled tubes, that helps the organism absorb oxygen and release carbon dioxide, eat, and move. This system allows them to function without gill slits.

4. Echinoderms have a very simple digestive system, often leading directly from mouth to anus.

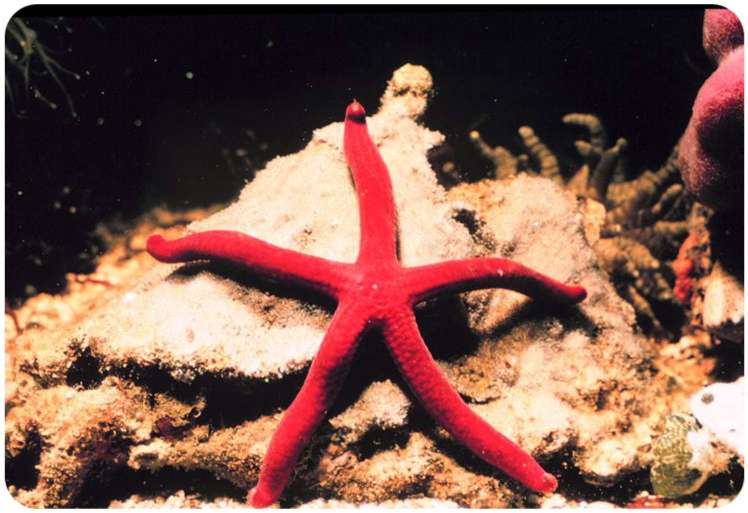

Figure 8.12: A starfish, showing the radial symmetry characteristic of the echinoderms.

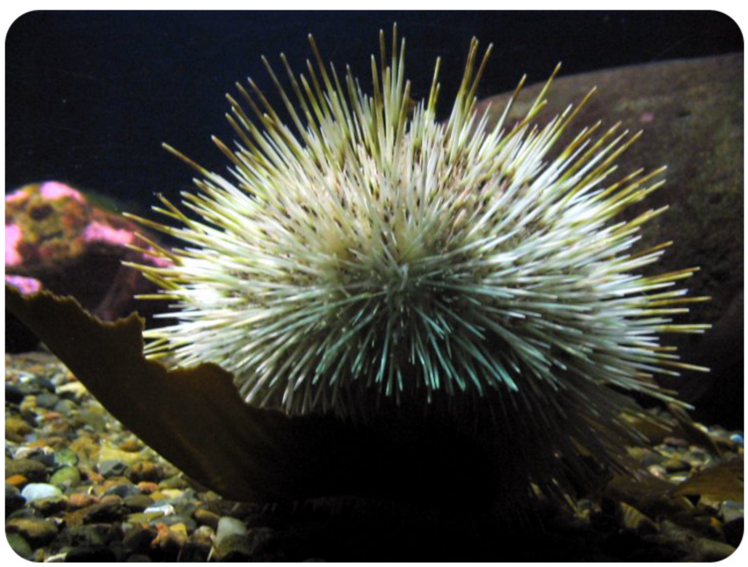

Figure 8.13: Another echinoderm, a sea urchin, showing its spines.

Figure 8.14: An echinoderm, the keyhole sand dollar.

Figure 8.15: An echinoderm, the giant California sea cucumber.

5. Echinoderms have an open circulatory system, meaning that fluid moves freely in the body cavity, but no heart.

6. The echinoderm nervous system is a **nerve net**, or interconnected neurons with no central brain.

Types of Echinoderms

The echinoderms are subdivided into two major groups:

1. Eleutherozoa, which contains the echinoderms that can move, like starfish and most other echinoderms.
2. Pelmatozoa, including immobile crinoids such as feather stars (**Figure** 8.16).

Figure 8.16: This passion flower feather star is an echinoderm.

Table 8.2 lists the four main classes of echinoderms present in the Eleutherozoa Group:

Table 8.2: **Eleutherozoa Echinoderms**

Echinoderm Class	Representative Organisms
Asteroidea	Starfish and sea daisies
Ophiuroidea	Brittle stars (**Figure** 8.17)
Echinoidea	Sea urchins and sand dollars
Holothuroidea	Sea cucumbers

Echinoderms are spread all over the world at almost all depths, latitudes, and environments in the ocean. Most echinoderms are found in reefs, but some, like crinoids, live on shallow shores around the poles. In the deep ocean, sea cucumbers are common, sometimes making up 90% of organisms.

While almost all echinoderms live on the sea floor, some sea-lilies can swim at great speeds for brief periods of time, and a few sea cucumbers are fully floating.

Figure 8.17: The giant red brittle star, an ophiuroid echinoderm.

Some echinoderms find other ways of moving. For example, crinoids attach themselves to floating logs, and some sea cucumbers move by attaching to the sides of fish.

How Do Echinoderms Reproduce?

In most species, eggs and sperm cells are released into open water, where fertilization takes place when the eggs and sperm meet. The release of sperm and eggs is often occurs when organisms are in the same place at the same time. Internal fertilization takes place in a few species. Some species even take care of their offspring, like parents!

Many echinoderms have amazing powers of regeneration. Some sea stars are capable of regenerating lost arms, and in some cases, lost arms have been observed to regenerate a second complete sea star! Sea cucumbers often release parts of their internal organs if they perceive danger. The released organs and tissues are then quickly regenerated.

How Do Echinoderms Eat?

Feeding strategies vary greatly among the different groups of echinoderms. Different eating-methods include:

1. Passive filter-feeders, which are organisms that absorb suspended nutrients from passing water.
2. Grazers, which are organisms that feed on available plants.
3. Deposit feeders, which are organisms that feed on small pieces of organic matter, usually in the top layer of soil.
4. Active hunters, which actively hunt their prey.

Ecological Role

Echinoderms play numerous ecological roles. Most bare rock is covered in mussels and barnacles, but the echinoderm sea urchin creates a more complex ecosystem when it also lives on the rock. Sand dollars and sea cucumbers that burrow into the sand provides more oxygen at greater depths of the sea floor. This allows more organisms to live there. In addition, starfish prevent the growth of algae on coral reefs, so the coral can have an easier time filter-feeding.

Echinoderms are also the staple diet of many organisms, including the sea otter. Many sea cucumbers provide a habitat for parasites, including crabs, worms, and snails.

Recently, some marine ecosystems have been overrun by seaweed, which caused the destruction of entire reefs. Scientists believe that the extinction of large quantities of echinoderms caused the destruction.

Echinoderms as Food

In some countries, echinoderms are considered delicacies. Around 50,000 tons of sea urchins are captured each year, and consumed mostly in Japan, Peru, and France. Sea cucumbers are considered a delicacy in some southeastern Asian countries.

Echinoderms as Medicine

Echinoderms are also used as medicines, and in scientific research. For example, some sea cucumber toxins slow down the growth rate of tumor cells, so there is an interest in using these in cancer research.

Echinoderms in Farming

The external covering of echinoderms is used as a source of lime by farmers in some areas where limestone is unavailable. About 4,000 tons of the animals are used each year for this purpose.

Lesson Summary

- Echinoderms belong to the phylum *Echinodermata*, the largest phylum without freshwater or land-living members.
- Echinoderms show radial symmetry and have an endoskeleton, and a unique water vascular system. Some have spines.
- Fertilization is generally external, and regeneration is fairly common among echinoderms.
- Echinoderms consist of two main subdivisions: the mobile Eleutherozoa and the immobile Pelmatazoa.
- Echinoderms are found all over the world at almost all depths, latitudes, and marine environments.
- Echinoderms play an important ecological and ecnomical roles in the community.

Review Questions

Recall

1. What are three important characteristics of echinoderms?
2. What three different feeding strategies of echinoderms?
3. What protection do echinoderms have against predators?

Apply Concepts

4. Chemical elements within their skeletons makes echinoderms stronger. How could this be an advantage in echinoderms that must move to find food?

Critical Thinking

5. The larvae of many echinoderms, especially starfish and sea urchins, are pelagic, meaning they live in the open ocean. How does being pelagic allow echinoderms to be found throughout the entire world?

Further Reading / Supplemental Links

- http://dictionary.reference.com
- http://www.oceanicresearch.org/education/wonders/echinoderm.html
- http://www.junglewalk.com/info/echinoderm-information.htm
- [http://invertebrates.si.edu/echinoderm/ http://invertebrates.si.edu/echinoderm/
- http://en.wikipedia.org

Points to Consider

Next we discuss arthropods, which have more advanced tissues and organs.

- Why might there be an advantage to having a heart as part of the circulatory system?

8.3 Arthropods

Lesson Objectives

- Define arthropods.
- Describe the features of crustaceans.
- Describe the characteristics of centipedes and millipedes.
- List the features of arachnids.
- Explain why arthropods are important.

Check Your Understanding

- What is an invertebrate?
- What do mollusks and echinoderms have in common?

Vocabulary

- carapace
- cephalothorax
- ganglia
- gastric mill
- molting

- pedipalps
- silk

What are Arthropods?

Have you ever seen an ant? A spider? A fly? A moth? With over a million described species in the phylum containing arthropods, chances are you encounter one of these organisms every day, even without leaving your house. They may be pests to some people, but arthropods play beneficial roles in ecosystems and economically for humans.

Arthropods belong to the phylum *Arthropoda*, which means "jointed feet," and includes four living subphyla. These are:

- Chelicerata, including spiders (**Figure** 8.18), mites, scorpions (**Figure** 8.19) and related organisms.
- Myriapoda, including centipedes (**Figure** 8.20) and millipedes (**Figure** 8.21) and their relatives.
- Hexapoda, including insects and three small orders of insect-like animals.
- Crustacea, including lobsters (**Figure** 8.22), crabs (**Figure** 8.23), barnacles (**Figure** 8.24), crayfish (**Figure** 8.25), and shrimp.

Figure 8.18: A species of spider in its web.

Figure 8.19: A species of scorpion.

Figure 8.20: A centipede, from the subphyla of myriapods.

Figure 8.21: A species of millipede found in Hawaii.

Figure 8.22: The blue American lobster illustrates the segmented body plan of the arthropods.

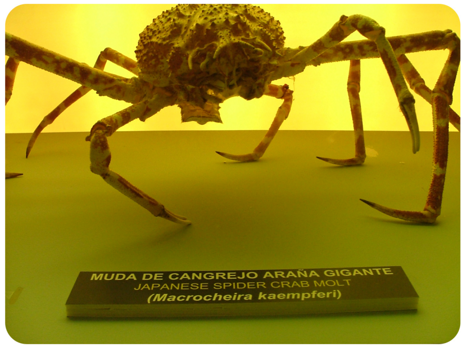

Figure 8.23: Giant spider crabs.

Figure 8.24: The sessile barnacles shown here feeding.

Figure 8.25: A crayfish.

Characteristics of Arthropods

Characteristics of arthropods include:

1. A segmented body with appendages on at least one segment.
2. Appendages that are used for feeding, sensory reception, defense, and locomotion.
3. A nervous system.
4. A hard exoskeleton made of chitin, which gives them physical protection and resistance to drying out. In order to grow, arthropods shed this covering in a process called **molting**.
5. An open circulatory system with haemolymph, a blood-like fluid. A series of hearts (more than one) move the haemolymph into the body cavity where it comes in direct contact with the tissues.
6. A complete digestive system with a mouth and anus.
7. Both aquatic and land-living arthropods have gas exchange or breathing systems. Aquatic arthropods use gills to exchange gases. These gills have a large surface area in contact with the water, so they can absorb more oxygen.
8. Land-living arthropods have internal surfaces that help exchange gasses. Insects and most other terrestrial species have a tracheal system, where air sacs lead into the body from pores in the exoskeleton. Others use book lungs, or gills modified for breathing air, as seen in species like the coconut crab. Some areas of the legs of soldier crabs are covered with an oxygen absorbing skin. Land crabs sometimes have two different structures: one that used for breathing underwater, and another used to absorb oxygen from the air.

How Many Species?

It is the largest phylum in the animal kingdom, with more than a million described species, making up more than 80% of all described living species. Arthropods are found commonly in marine, freshwater, land, and even air environments. They range in size from microscopic plankton (approximately ¼ mm) up to the largest living arthropod, the Japanese spider crab, with a leg span up to 12 feet.

Crustaceans

Crustaceans are a large group of arthropods, consisting of almost 52,000 species. The majority of crustaceans are aquatic, living in either ocean or freshwater habitats. A few groups have adapted to living on land, such as land crabs, hermit crabs, and woodlice (**Figure** 8.26). Crustaceans are among the most successful animals and are found as much in the oceans as insects are on land.

Classes of Crustaceans

Six classes of crustaceans are generally recognized. These are listed in **Table** 8.3.

Table 8.3: **Classes of Crustaceans**

	Class	Examples
1	Branchiopoda	Includes brine shrimp
2	Remipedia	A small class or organisms found in deep caves connected to salt water
3	Cephalocarida	The horseshoe shrimp

Table 8.3: (continued)

	Class	Examples
4	Maxillopoda	Includes barnacles and copepods
5	Ostracoda	Small animals with bivalve shells
6	Malacostraca	The largest class, with the largest and most familiar animals: crabs, lobsters, shrimp, krill, and woodlice

Can Crustaceans Move?

The majority of crustaceans can move, although a few groups are parasitic and live attached to their hosts. Adult barnacles cannot move, so they attach themselves headfirst to a rock or log.

Characteristics of Crustaceans

Characteristics of crustaceans include:

1. An exoskeleton that may be bound together, such as in the **carapace**, the thick back shield seen in many crustaceans that often forms a protective space for the gills.
2. A main body cavity with an expanded circulatory system. Blood is pumped by a heart located near the back.
3. A digestive system consisting of a straight tube that has a **gastric mill** for grinding food, and a pair of digestive glands that absorb food.
4. Structures that function like kidneys to remove wastes. These are located near the antennae.
5. A brain that exists in the form of **ganglia**, or connections between nerve cells, close to the antennae and a collection of major ganglia below the gut.
6. Crustaceans periodically shed the outer skeleton, grow rapidly for a short time, and then form another hard skeleton. They cannot grow underneath their outer exoskeleton.

Crustaceans Reproduction

Most crustaceans have separate sexes, so they reproduce sexually using eggs and sperm. Many land crustaceans, such as the Christmas Island red crab, mate every season and return to the sea to release the eggs. Others, such as woodlice, lay their eggs on land when the environment is damp. In other crustaceans, the females keep the eggs until they hatch into free-swimming larvae.

Centipedes and Millipedes

Centipedes and millipedes belong to the subphylum Myriapoda, which contains 13,000 species, all of which live on land and are divided among four classes, (1) centipedes, (2) millipedes, (3) Symphyla, and (4) Pauropods. They range from having over 750 legs (a species of millipede) to having fewer than ten legs. They have a single pair of antennae and simple eyes.

Figure 8.26: A terrestrial arthropod, a species of woodlice.

The Myriapoda Habitat

Myriapoda are mostly found in moist forests, where they help to break down decaying plant material. A few live in grasslands, semi-arid habitats, or even deserts. The majority are herbivores, but centipedes are nighttime predators. They roam around looking for small animals to bite and eat. They eat insects, spiders, and other small invertebrates. If the centipede is large enough it will even attack small vertebrates, like lizards. Although not generally considered dangerous to humans, many from this group can cause temporary blistering and discoloration of the skin.

Centipedes

Centipedes (**Figure** 8.27) are fast, predatory, and venomous. There are around 3,300 described species, ranging from one tiny species (less than half an inch in length) to one giant species, which may grow larger than 12 inches. Learn more about centipedes at http://www.enchantedlearning.com/subjects/invertebrates/arthropod/Centipede.shtml.

Millipedes

Most millipedes are slower than centipedes and feed on leaf litter and loose organic material. Around 8,000 species have been described, although there may be as many as 80,000 or more species actually alive.

Symphyla and Pauropods

The third class, Symphyla, contains 200 species. They resemble centipedes but are smaller and translucent. Many spend their lives in the soil, but some live in trees. The pauropods are typically 0.5-2.0mm long and live in the soil of all continents except Antarctica. Over 700 species have been described, and they are believed to be closely related to millipedes.

Figure 8.27: Centipede

Arachnids

Arachnids are a class of joint-legged invertebrates in the subphylum Chelicerata. They live mainly on land, but are also found in freshwater and in all marine environments, except for the open ocean. There are over 100,000 named species, including spiders, scorpions, daddy-long-legs, ticks, and mites (**Figure** 8.28, **Figure** 8.29, and **Figure** 8.30). There may be up to 600,000 species in total, including unknown ones.

Figure 8.28: A daddy-long-legs with a captured woodlouse.

Characteristics of Arachnids

Arachnids have the following characteristics:

1. Four pairs of legs (eight total). You can tell the difference between an arachnid and an insect because insects have three pairs of legs (six total).
2. Arachnids also have two additional pairs of appendages. The first pair, the **chelicerae**, serve in feeding and defense. The next pair, the **pedipalps**, help the organisms feed, move, and reproduce.
3. Arachnids do not have antennae or wings.
4. The arachnid body is organized into the **cephalothorax**, a fusion of the head and thorax, and the abdomen.
5. To adapt to living on land, arachnids have internal breathing systems, like a trachea or a book lung.

Figure 8.29: Various diseases are caused by species of bacteria that are spread to humans by "hard" ticks, like the one shown here.

Figure 8.30: A female crab spider sharing its flower with velvet mites.

6. Arachnids are mostly carnivorous, feeding on the pre-digested bodies of insects and other small animals.
7. Several groups are venomous. They release the venom from specialized glands to kill prey or enemies. Several mites are parasitic and some of those are carriers of disease.
8. Arachnids usually lay eggs, which hatch into immature arachnids that are similar to adults. Scorpions, however, give birth to live young.

Arachnid Subgroups

The arachnids are divided into eleven subgroups. **Table** 8.4 shows the four most familiar subgroups, with a description of each.

Table 8.4: **Subgroups of Arachnids**

Subgroup of Arachnid	Representative Organisms	Approximate Number of Species	Description
Araneae	Spiders	40,000	Found all over the world, ranging from tropics to the Arctic, some in extreme environments; All produce **silk**, used for trapping insects in webs, aiding in climbing, forming smooth walls for burrows, producing egg sacs, and wrapping prey Nearly all spiders inject venom to protect themselves or to kill prey; only about 200 species have bites that can be harmful to humans

Table 8.4: (continued)

Subgroup of Arachnid	Representative Organisms	Approximate Number of Species	Description
Opiliones	Daddy-long-legs	6,300	Known for extremely long walking legs; no silk nor poison glands Many are omnivores, eating small insects, plant material and fungi; some are scavengers, eating decaying animal and other matter Mostly nocturnal (come out at night), colored in hues of brown; a number of diurnal (come out during the day) species have vivid patterns of yellow, green, and black

Table 8.4: (continued)

Subgroup of Arachnid	Representative Organisms	Approximate Number of Species	Description
Scorpiones	Scorpions	2,000	Characterized by a tail with six segments, the last bearing a pair of venom glands and a venom-injecting barb Predators of small arthropods and insects, they use pincers to catch prey, then either crush it or inject it with a fast-acting venom, which is used to kill or paralyze the prey; only a few species are harmful to humans Nocturnal; during the day find shelter in holes or under rocks Unlike the majority of arachnids, scorpions produce live young, which are carried about on the mother's back until they have molted at least once; they reach an age of between four to 25 years

Table 8.4: (continued)

Subgroup of Arachnid	Representative Organisms	Approximate Number of Species	Description
Acarina	Mites and ticks	30,000	Most are small (no more than 1.0 mm in length), but some ticks and one species of mite may become 10-20 mm in length Live in nearly every habitat, including aquatic and terrestrial Many are parasitic, affecting both invertebrates and vertebrates, and may transit diseases to humans and other mammals; those that feed on plants may damage crops

Why Arthropods are Important

Arthropods as Food

Many species of crustaceans, especially crabs, lobsters, shrimp, prawns, and crayfish, are consumed by humans. Nearly 10,000,000 tons of arthropods as food were produced in 2005. Over 70% by weight of all crustaceans caught for consumption are shrimp and prawns, and over 80% is produced in Asia, with China producing nearly half the world's total.

Arthropods in Pest Control

Humans use mites to prey on unwanted arthropods on farms or in homes. Other arthropods are used to control weed growth. Populations of whip scorpions added to an environment can limit the populations of cockroaches and crickets.

Ecological Roles

Mites, ticks, centipedes, and millipedes are decomposers, meaning they break down dead plants and animals and turn them into soil nutrients. This is an extremely important role because it supplies the plants with the minerals and nutrients necessary for life. Plants pass along those minerals and nutrients to animals.

Lesson Summary

- The phylum Arthropoda includes four living subphyla: chelicerates, including spiders, mites, and scorpions; myriapods, including centipedes and millipedes; hexapods, including insects; and crustaceans.
- Arthropods are characterized by a segmented body, appendages used for feeding, sensory structures, defense, and locomotion, a dorsal heart, ventral nervous system, and hard exoskeleton.
- Arthropods are the largest phylum in the animal kingdom with more than a million described species; they are found in all environments.
- Crustaceans consist of almost 52,000 species, the majority of which are aquatic.
- Arachnids mainly live on land and comprise over 100,000 named species. Adaptations for life on land include specialized breathing structures and appendages for movement.
- Arthropods are used for food, in pest and weed control, and as decomposers, enriching the soil.

Review Questions

Recall

1. What are arthropod appendages used for?

2. What breathing systems do land-living arthropods use?

Apply Concepts

3. How is the scorpions' method of producing young different from most other arachnids?

4. How are arthropods useful? Pick one example and explain how they are useful to humans or other organisms.

Critical Thinking

5. Arachnids have several adaptations for living on land. Pick one adaptation and explain how it is beneficial for a land-living existence.

Further Reading / Supplemental Links

- http://cybersleuth-kids.com/sleuth/Science/Animals/Arthropods/index.htm
- http://www.oceanicresearch.org/education/wonders/arthropods.htm
- http://www.biokids.umich.edu/critters/Crustacea

Points to Consider

Insects are the focus of the next lesson.

- Arthropods are characterized by the possession of a segmented body with appendages on at least one segment and they are covered by a hard exoskeleton made of chitin. How do you think the general

arthropod body plan is specialized in insects?
- Insects are the only group of invertebrates to have developed flight. Compare this mode of locomotion to those discussed in the groups of arthropods already discussed. What advantages might there be to using flight for a method of locomotion?

8.4 Insects

Lesson Objectives

- Describe the characteristics of insects.
- Explain how insects obtain food.
- Describe reproduction and the life cycle of insects.
- Explain how insects are important.
- Describe how insect pests are controlled.

Check Your Understanding

- What is an arthropod?
- Is a spider an insect? Why or why not?

Vocabulary

- exocuticle
- homing
- larvae
- metamorphosis
- nymphs
- pheromones
- pupa
- spiracles
- sponging

What Are Insects?

Insects, with over a million described species, are the most diverse group of animals on Earth. They may be found in nearly all environments on the planet. No matter where you travel, you will see organisms from this group. Adult insects range in size from a minuscule fairy fly to a 21.9 inch-long stick insect (**Figure** 8.31).

Characteristics of Insects

Characteristics of Insects include:

- Segmented bodies with an exoskeleton. The outer layer of the exoskeleton is called the cuticle. It is made up of two layers, a thin and waxy water-resistant outer layer (the **exocuticle**), and an inner, much thicker layer. The exocuticle is thinner in many soft-bodied insects and especially in caterpillars (**Figure** 8.32).

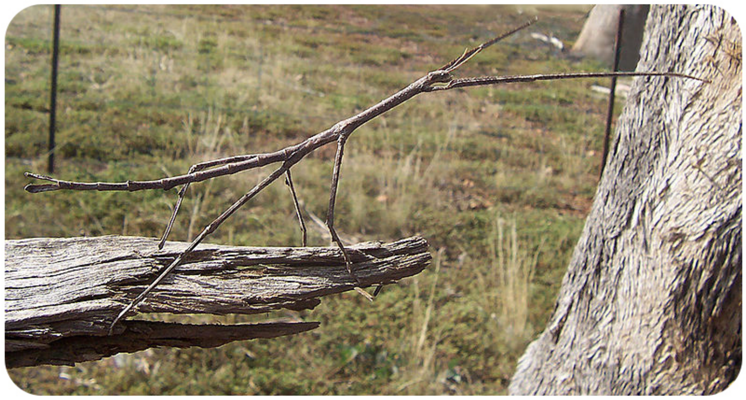

Figure 8.31: A stick insect, showing how well it blends in to its environment.

Figure 8.32: Caterpillars feeding on a host plant.

- The segments of the body are organized into three distinct but joined units: a head, a thorax, and an abdomen (see **Figure** 8.33 and **Table** 8.5).

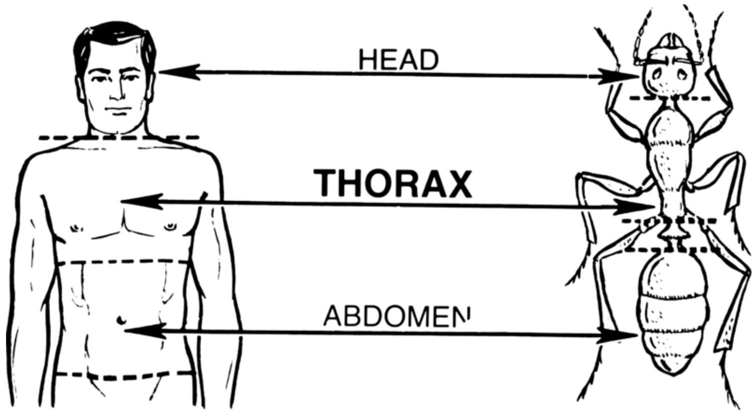

Figure 8.33: A diagram of a human and an insect, comparing the three main body parts: head, thorax, and abdomen.

Table 8.5: **Insect Structures**

Head	Thorax	Abdomen
A pair antennae, a pair of compound eyes (one to three simple eyes) and three sets of appendages that form the mouthparts	Six segmented legs and two or four wings	Has most of the digestive, respiratory, excretory, and reproductive structures

- The nervous system is divided into a brain and a ventral nerve cord.

- Respiration occurs without lungs. Insects do have a system of internal tubes and sacs that oxygen travels through to reach body tissues. Air is taken in through the **spiracles**, openings on the sides of the abdomen.

- The circulatory system is simple and consists of only a single tube with openings. The tube pulses and circulates blood-like fluids inside the body cavity.

- Insect movement includes flight, walking, and swimming. Insects are the only invertebrates to develop the ability to fly and this has played an important role in their success. Insect flight is not very well understood. Primitive insect groups use muscles that act directly to move the wings. More advanced groups have foldable wings and their muscles act on the wall of the thorax and give power to the wings indirectly.

- Many adult insects use six legs for walking and walk in alternate triangles touching the ground. This allows the insect to walk quickly while staying stable. A few insects have evolved to walk on the surface of the water, especially water striders (**Figure** 8.34). A large number of insects live parts of their lives underwater. Water beetles and water bugs have legs adapted to paddle in the water. Young dragonflies use jet propulsion, sending water out of their back end to move.

Figure 8.34: A pair of water striders mating, showing how water surface tension allows for them to stand on the water.

Insects use many different senses for both communicating and receiving information. Many insects have special sensory organs. **Table** 8.6 summarizes five types of communication that are used by various insects.

Table 8.6: **Insect Communication**

Types of Communication	Representative Organisms	Description
Visual Ultraviolet wavelengths (light most animals cannot see) Polarized light (light most animals cannot see)	Bees Bees Fireflies	Perceive ultraviolet wavelengths of light (outside of what humans can see) Detect polarized light Reproduction and Predation Some species produce flashes to attract mates; other species to attract prey (food).

Table 8.6: (continued)

Types of Communication	Representative Organisms	Description
Sound Production Mostly by moving appendages Ultrasound clicks Hearing	Cicadas Moths Moths Some predatory and parasitic insects	Loudest sounds among insects; have special muscles to produce sounds. Predation Produced mostly by moths to warn bats. Predation Some nocturnal species can hear the ultrasonic sounds of bats, which help them avoid predators. Can detect sounds made by prey or hosts.
Chemical Wide range of insects have evolved chemical communication; chemicals are used to attract, repel, or provide other kinds of information; use of scents is especially well developed in social insects.	Moths	Antennae of males can detect **pheromones** (chemicals released by animals, especially insects, that influence the behavior of others within the same species) of female moths over distances of many miles (**Figure** 8.35).
Infrared	Blood-sucking insects	Have special sensory structures that can detect infrared light in order to find their hosts.
"Dance Language"	Honey bees	Honey bees are the only invertebrates to have evolved this type of communication; length of dance represents distance to be flown.

Figure 8.35: A yellow-collared scape moth, showing its feathery antennae.

Insects are Social

Social insects, such as termites (**Figure** 8.36), ants, and many bees and wasps (**Figure** 8.37), are the most familiar social species. They live together in large well-organized colonies. Only those insects which live in nests or colonies can home. **Homing** means that an insect can return to a single hole among many other apparently identical holes, after a long trip or after a long time.

A few insects migrate, such as the monarch butterfly, which flies from Mexico to North America every winter (**Figure** 8.38).

Figure 8.36: Damage to this nest, brings the workers and soldiers of this social insect, the termite, to repair it.

Figure 8.37: A wasp building its nest.

Figure 8.38: Monarch butterflies in an overwintering cluster.

Two Major Groups of Insects

Insects are divided into two major groups:

1. Wingless: Consists of two orders, the bristle tails and the silverfish.
2. Winged insects: All other orders of insects. They are named below. How many winged orders are there?

Mayflies; dragonflies and damselflies; stoneflies; webspinners; angel insects; earwigs; grasshoppers, crickets, and katydids; stick insects; ice-crawlers and gladiators; cockroaches and termites; mantids; lice; thrips; true bugs, aphids, and cicadas; wasps, bees, and ants; beetles; twisted-winged parasites; snakeflies; alderflies and dobsonflies; lacewings and antlions; Scorpios and hangingflies (including fleas); true flies; caddisflies; and butterflies, moths, and skippers.

How Insects Obtain Food

Insects have different types of appendages (arms and legs) adapted for capturing and feeding on prey. They also have special senses that help them detect prey. Insects have a wide range of mouthparts used for feeding. Examples include:

- Insects like mosquitoes and aphids have special mouthparts that help them pierce and suck. Some are herbivorous, like aphids and leafhoppers, while others eat other insects, like assassin bugs and female mosquitoes.
- Examples of chewing insects include dragonflies, grasshoppers, and beetles. Some larvae have chewing mouthparts, as in moths and butterflies (**Figure** 8.39).
- Some insects use siphoning, as if sucking through a straw, like moths and butterflies. You may have seen a butterfly or moth putting a long mouth-tube into at a flower while it siphons the nectar of the flower.
- Some moths, however, have no mouthparts at all.
- Some insects obtain food by **sponging**, like the housefly. Sponging means that the mouthpart can absorb liquid food and send it to the esophagus. The housefly is able to eat solid food by releasing saliva and dabbing it over the food. As the saliva dissolves the food, the sponging mouthpart absorbs the liquid food.

Reproduction and Life Cycle of Insects

Most insects can reproduce very quickly within a short period of time. With a short generation time, they evolve faster and can adjust to environmental changes faster. Most insects reproduce by sexual reproduction. The female produces eggs, which are fertilized by the male, and then the eggs are usually placed in a precise microhabitat at or near the required food. Most insects are oviviparous, where the young hatch after the eggs have been laid. In some insects, there is asexual reproduction. In the most common type, the offspring are almost identical to the mother. This is most often seen in aphids and scale insects.

Three Types of Metamorphosis

An insect can have one of three types of metamorphosis and life cycle (**Table** 8.7). **Metamorphosis** describes how insects transform from an immature or young insect into an adult insect (in at least two stages).

Figure 8.39: The mouth of a butterfly up close.

Table 8.7: (continued)

Type of Metamorphosis	None	Incomplete	Complete

Table 8.7:

Type of Metamorphosis	None	Incomplete	Complete
Characteristics	Only difference between adult and **larvae** (young or non-adult insects) is size	• Young, called **nymphs** (**Figure** 8.40), usually similar to adult • Wings then appear as buds on nymphs or early forms • When last molt is completed, wings expand to full adult size	• Insects have different forms in immature and adult stages, have different behaviors, and live in different habitats • Immature form is called larvae and remains similar in form but increases in size • Larvae usually have chewing mouthparts even if adult mouthparts are sucking ones • At last larval stage of development, insect forms into pupa (**Figure** 8.41), and does not eat or move • During **pupa** stage, wing development begins, after which the adult emerges
Example	Silverfish	Dragonflies	Butterflies and Moths

Importance of Insects

Many insects are considered to be pests by humans. At the same time, insects are very important.

Figure 8.40: Heteroptera nymphs and egg cases.

Figure 8.41: The chrysalis (pupal stage) of a monarch butterfly.

Ecological Importance

In the environment, some insects pollinate flowering plants, as in wasps, bees, butterflies, and ants. Many insects, especially beetles, are scavengers, feeding on dead animals and fallen trees. As decomposers, insects help create top soil, the nutrient-rich layer of soil that helps plants grow.

Economic Importance

Insects also produce useful substances, such as honey, wax, lacquer, and silk. Honeybees have been raised by humans for thousands of years for honey. The silkworm has greatly affected human history. When the Chinese used worms to develop silk, the silk trade connected China to the rest of the world. Adult insects, such as crickets and insect larvae, are also commonly used as fishing bait.

Insects as Food

In some parts of the world, insects are used for human food. Some people support this idea to provide a source of protein in human nutrition. From South America to Japan, people eat roasted insects, like grasshoppers or beetles (**Figure** 8.42).

Figure 8.42: Grasshoppers have been added to this taco.

Insects in Medicine

In the past, fly larvae (maggots) were used to treat wounds to prevent or stop gangrene. Gangrene is caused by infection of dead flesh. Maggots only eat dead flesh, so when they are placed on the dead flesh of humans, they actually clean the wound and can prevent infection. Some hospitals still use this type of treatment.

Controlling Insect Pests

Though insects can be important, some are also considered pests. Common insect pests include:

1. Parasitic insects (mosquitoes, lice, bed bugs).

2. Insects that transmit diseases (mosquitoes, flies).
3. Insects that damage structures (termites).
4. Insects that destroy crops (locusts, weevils).

Many scientists who study insects are involved in various forms of pest control, often using insect-killing chemicals, but more and more rely on other methods. Ways to control insect pests are described below.

- Biological control of pests in farming is a method of controlling pests by using other insects. Insect predators, such as lady beetles and lacewings, consume a large number of other insects during their lifetime. If you add ladybugs to your farm or garden, then they will act like a pesticide, or insect-killing chemical.

- Insecticides are most often used to kill insects. Insecticides are chemicals that kill insects. The U.S. spends $9 billion each year on pesticides. Disadvantages to using pesticides include human poisonings, killing of fish, honeybee poisonings, and the contamination of meat and dairy products.

Lesson Summary

- Insects are the most diverse group of animals on Earth.
- They have segmented bodies with an exoskeleton, and relatively simple nervous, respiratory, and circulatory systems.
- Insects are the only invertebrates to have developed flight.
- Some insects, like termites, ants, and many bees and wasps, are social and live together in large well-organized colonies.
- Insect movement includes flight, walking, and swimming.
- There are two major groups of insects, the wingless and the winged, and these are subdivided into various orders.
- Insects obtain food with the use of specialized appendages for capturing and eating.
- Most insects can rapidly reproduce within a short period of time.
- An insect can have one of three types of metamorphosis and life cycle.
- Insects are beneficial both environmentally and economically.
- Insect pests can be controlled with chemical or biological means.

Review Questions

Recall

1. What are the three main parts of the insect body?
2. Why is the insect's circulatory system said to be "simple"?
3. What does metamorphosis mean?

Apply Concepts

4. Describe the difference between the life cycle of a silverfish and the life cycle of a butterfly.
5. What makes parasitoids especially effective at killing other insect pests?
6. Describe what it means when an insect is said to be "social."

Critical Thinking

7. Why do you think an exoskeleton allowed insects to better adapt to their environments than some other invertebrates?

Further Reading / Supplemental Links

- http://homeschooling.gomilpitas.com/explore/bugs.htm
- http://rusinsects.com/links/view.php?id=20
- http://www.kidsolr.com/science/page18.html
- http://pestworldforkids.org/learninggames.html

Points to Consider

Next we begin the discussion of fishes, amphibians, and reptiles.

- Some of the adaptations that insects have evolved for life on land are also displayed in amphibians and reptiles. What could be some of these? How are they similar and different?
- Insects have some very specialized sensory capabilities. How do you think these compare to those found in fish, amphibians, and reptiles?

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(36) Cornelius Herget. *A crayfish.*. GNU-FDL.

(37) Eric Guinther. *A species of millipede found in Hawaii.*. GNU-FDL.

(38) Tomasz Sienicki. http://commons.wikimedia.org/wiki/Image:Woda-3_ubt.jpeg. CC-BY-SA 2.5.

(39) Sharon Mooney. *An echinoderm, the keyhole sand dollar.*. CC-BY-SA 2.5.

(40) Daniel Ullrich. *A daddy-long-legs with a captured woodlouse.*. GNU-FDL.

(41) Mila Zinkova.
http://commons.wikimedia.org/wiki/Image:Monarch_butterflies_cluster_in_SC_3.jpg.
GNU-FDL.

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Chapter 9

MS Fishes, Amphibians, and Reptiles

Vertebrates have a backbone. But there are many organisms that have backbones, including fish, amphibians, reptiles, birds, and mammals! So, how do we distinguish between them? We put them in categories.

But sometimes it is difficult to put organisms into specific categories. Observe the above image. What kind of organism is it? A snake? A lizard? A newt? It looks like a snake because it does not have legs. But it is also has the head of a lizard. What other information do you need to know before you can classify the above organism? What questions do you need to ask?

You may ask: Does it have ears? What other organisms have similar hearts or lungs? Are the organism's genes more like those of lizards or to those of snakes? Do they live in water, on land, or both?

These are the type of questions scientists ask when they encounter an organism not easily classified. Consider the differences amongst organisms who are closely related as you read about vertebrate creatures. And then see if you can identify the above organism.

9.1 Introduction to Vertebrates

Lesson Objectives

- Describe the general features of chordates.
- List the three groups of chordates and their characteristics.
- List the general features of vertebrates.
- Describe the classification of vertebrates.

Check Your Understanding

- What is a invertebrate?
- What is a vertebrate?

Vocabulary

- cranium
- endostyle
- notochord

Chordates

Did you know that fish, amphibians, reptiles, birds and mammals are all related? They are all chordates. Chordates are a group of animals that includes vertebrates, as well as several closely related invertebrates. All chordates (phylum *Chordata*) have a **notochord**, a hollow nerve cord along the back.

They also have:

1. Pharyngeal slits, which help to filter out food particles.
2. An **endostyle**, which has small hairs and is used to gather food particles and move them along the digestive tract.
3. A post-anal tail, which is present during the lifetimes of some chordates and during the development of others.

The chordate phylum is broken down into three subphyla:

1. Urochordata (represented by tunicates): Urochordates have a notochord and nerve cord only during the larval stage (**Figure** 9.1). The urochordates consist of 3,000 species of tunicates, sessile marine animals with sack-like bodies and tubes for water movement.
2. Cephalochordata (represented by lancelets): Cephalochordates have a notochord and nerve cord but no vertebrae, or bones in the backbone (**Figure** 9.2). Cephalochordates consist of 30 species of lancelets (burrowing marine animals).
3. Vertebrata (the vertebrates): Humans fall in this category. In all vertebrates except for hagfish, the notochord is smaller and surrounded by vertebrae. Vertebrates all have backbones or spinal columns. About 58,000 species have been described, including many familiar groups of large land animals.

The origin of chordates is currently unknown. The first clearly identifiable chordates appear in the Cambrian Period (about 542 - 488 million years ago) as lancelet-like specimens.

Figure 9.1: Tunicate colonies of (subphylum Urochordata) have tentacles at openings of tubes that take in food and water and release waste and water.

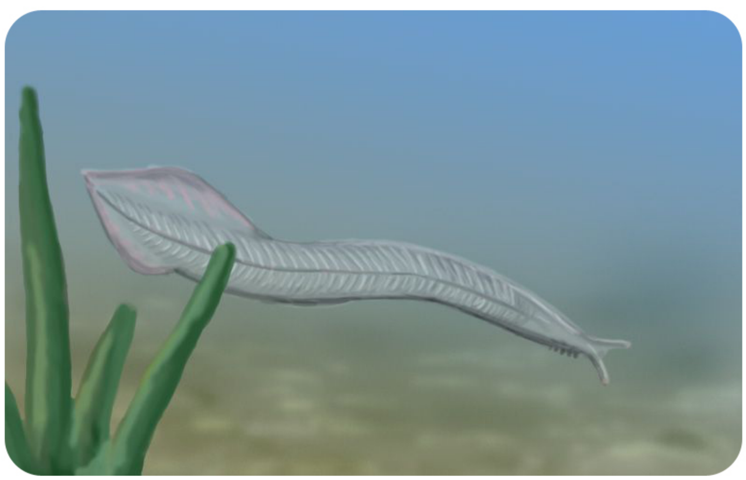

Figure 9.2: (subphylum Cephalochordates), perhaps the oldest known ancestor of modern vertebrates, resembled a living chordate, known as a lancelet, and perhaps swam much like an eel. What other modern-day organisms does a pikaia look like?

What are Vertebrates?

Vertebrates, in the subphylum Vertebrata, are chordates with a backbone. Vertebrates have a braincase, or **cranium**, and an internal skeleton (except for lampreys). You can tell the difference between verebrates and other chordates by looking at their head. Vertebrates have cephalization. Cephalization means an organism's nervous tissue is found toward one end of the organism. In other words, this is like having eyes in your head. Why do you think this type of body design is an advantage?

Typical vertebrate traits include:

- A backbone or spinal column.
- Cranium.
- Internal skeleton.
- Defined head with pronounced cephalization.
- Sensory organs, especially eyes.

Living vertebrates range in size from a carp species (**Figure** 9.3), as little as 0.3 inches, to the blue whale, as large as 110 feet (**Figure** 9.4).

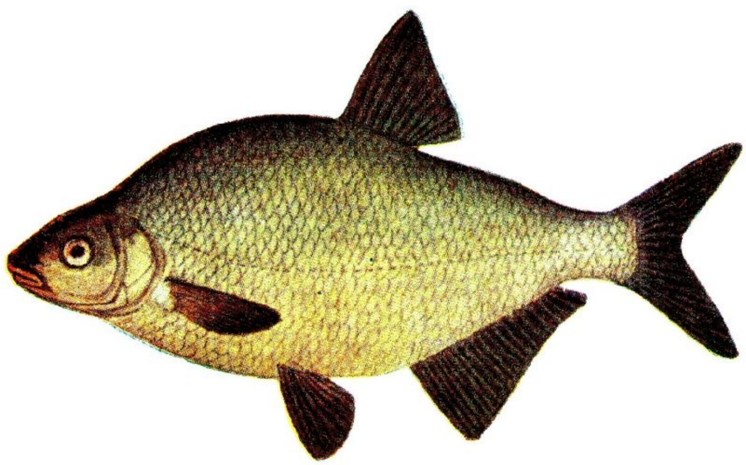

Figure 9.3: A species of carp.

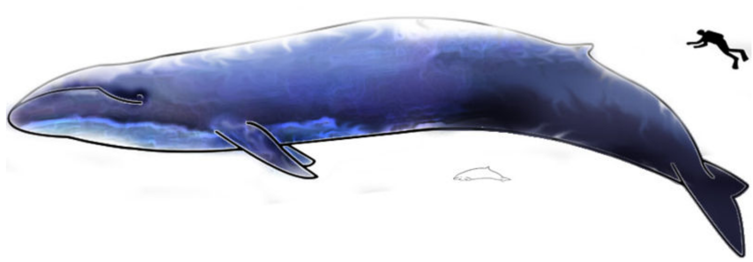

Figure 9.4: An image of the blue whale (a mammal), the largest living vertebrate, reaching up to 110 feet long. Shown below it is the smallest whale species, Hector's dolphin (about 5 feet in length), and beside it a human.

Classification of Vertebrates

Vertebrates can be divided into two major groups: those with or without jaws. There are more than 100 species of jawless vertebrate. There are more than 50,000 species of vertebrate with jaws.

The jawed vertebrates include species of fish with cartilage, the strong, flexible tissue found in human ears, bony fish, and four-limbed animals. These animals are known as tetrapods. Some tetrapods include amphibians, reptiles, birds, and mammals (**Table** 9.1).

Table 9.1: **Species of the Main Groups of Tetrapods**

Type of Tetrapod	Number of Species
Amphibians	6,000
Reptiles	8,225
Birds	10,000
Mammal-like Reptiles	4,500
Mammals	5,800

Lesson Summary

- Chordates are characterized by a notochord.
- There are three main groups of chordates, including tunicates, lancelets and vertebrates.
- Vertebrates are distinguished by having a backbone or spinal column.
- Vertebrates are classified into two major groups: those without jaws and those with jaws.

Review Questions

Recall

1. What is the main feature that characterizes the chordates?

2. What are the main features of vertebrates?

Apply Concepts

3. Which two structures that all chordates possess sometime during their life cycle (during development or otherwise) are used for food gathering, and how are these structures used?

4. Why do you think cephalization is not necessary in urochordates and cephalochordates? Explain how this is illustrated in tunicates.

Critical Thinking

5. The first clearly-identifiable chordates are lancelet-like (small, burrowing marine animals with a lancet shape) specimens. Propose one way that these first chordates could have evolved into a swimming-like animal.

Further Reading / Supplemental Links

- http://www.ucmp.berkeley.edu/chordata/chordata.html
- http://www.ucmp.berkeley.edu/vertebrates/vertintro.html
- http://en.wikipedia.org/wiki

Points to Consider

- How do you think a notochord could help fish adapt to swimming?
- How do you think cephalization could be an advantage in movement and feeding in fish?

9.2 Fishes

Lesson Objectives

- List the general traits of fish.
- Describe the features of jawless fish.
- List the general features of the cartilaginous fish.
- Describe the features of bony fish and the significance of this superclass.
- List some of the reasons why fish are important.

Check Your Understanding

- What are the unique characteristics of vertebrates?
- What are the two main groups of vertebrates?

Vocabulary

- aquaculture
- barbels
- cartilaginous skeleton
- ectothermic
- pineal eye
- placoid

Characteristics of Fish

What exactly is a fish? You probably think the answer is obvious. You may say that a fish is an animal that swims in the ocean or a lake. Fish are aquatic vertebrates, which became a dominant form of sea life and eventually evolved into land vertebrates.

They have a number of characteristic traits and are classified into two major groups: jawless fish and jawed fish. Jawed fish are further divided into those with bones and those with just cartilage. Fish, in general, are important to humans in many ways. Can you think of some of these ways?

Some characteristics of fish include:

1. They are **ectothermic**, meaning their temperature depends on the temperature of their environment. This is unlike humans, whose temperature is controlled inside of the body.

2. They are covered with scales.
3. They have two sets of paired fins and several unpaired fins.
4. Fish also have a streamlined body that allows them to swim rapidly (**Figure** 9.5).

Figure 9.5: The humphead or Napoleon wrasse shows some of the general traits of fish, including scales, fins and a streamlined body.

How do Fish Breathe?

In order to absorb oxygen from the water, fish use gills (**Figure** 9.6). Gills take dissolved oxygen from water as the water flows over the surface of the gill.

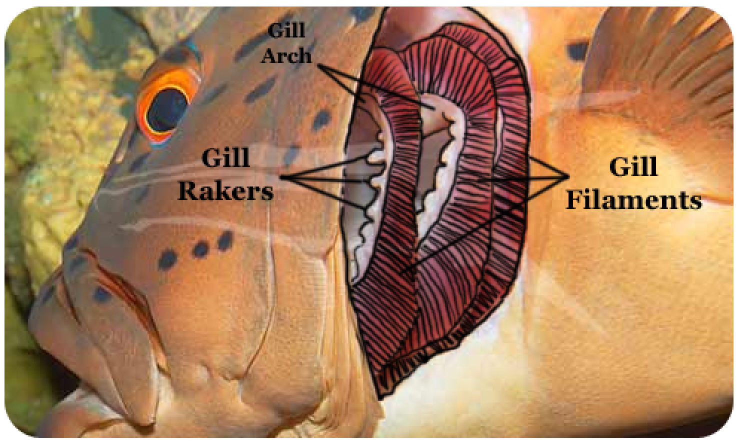

Figure 9.6: Gills help a fish breathe.

How Do Fish Reproduce?

Fish reproduce sexually. They lay eggs that can be fertilized either inside or outside the body. In most fish, the eggs develop outside the mother's body. In the majority of these species, fertilization takes place outside the mother's body. The male and female fish release their gametes into the surrounding water, where fertilization occurs. Female fish release very high numbers of eggs to increase the chances of fertilization.

How Big Are Fish?

Fish range in size from the 51-foot whale shark (**Figure** 9.7) to the stout infantfish, which is about 0.5 inches.

Exceptions to Common Fish Traits

There are exceptions to many of these fish traits. For example, tuna, swordfish, and some species of shark show some warm-blooded adaptations, and are able to raise their body temperature significantly above that of the water around them.

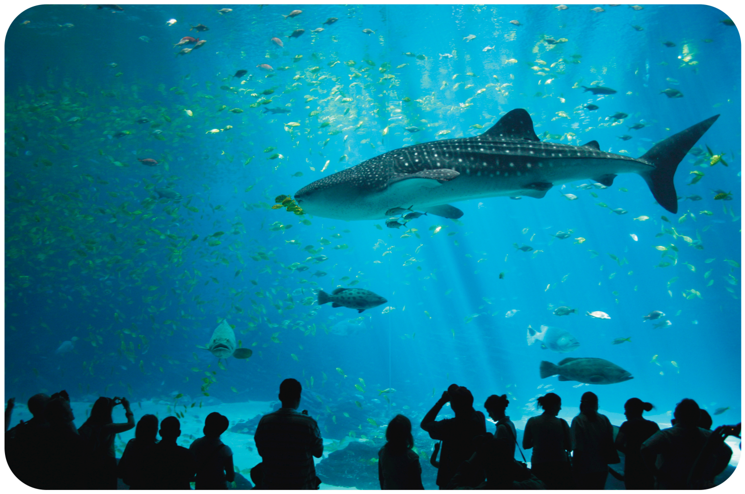

Figure 9.7: One of two male whale sharks at the Georgia Aquarium. Whale sharks are the largest cartilaginous fish.

Some species of fish have a slower, more maneuverable, swimming style, like eels and rays (**Figure** 9.8). Body shape and the arrangement of fins are highly variable, and the surface of the skin may be naked, as in moray eels, or covered with scales. Scales can be of a variety of different types.

Figure 9.8: One of the cartilaginous fish, a stingray, shows very flexible pectoral fins connected to the head.

Although most fish live in aquatic habitats, such as ocean, lakes, and rivers, there are some that spend a lot of time out of water. Mudskippers, for example, feed and interact with each other on mudflats for up to several days at a time and only go underwater when digging burrows (**Figure** 9.10). They breathe by absorbing oxygen across the skin, similar to how frogs breathe.

See `http://www.youtube.com/watch?v=ZUsARF-CBcI&feature=channel` for further information (5:35).

Figure 9.9: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/609

Figure 9.10: A mudskipper, shown on the mudflats, where it spends time feeding and interacting with other individuals.

Agnatha: Jawless Fishes

Jawless fish, part of the class Agnatha, belong to the phylum Chordata, subphylum Vertebrata. There are two living groups of jawless fish, with about 100 species in total: lampreys and hagfish (**Figure** 9.11). Although hagfish belong to the subphylum Vertebrata, they do not technically have vertebrae.

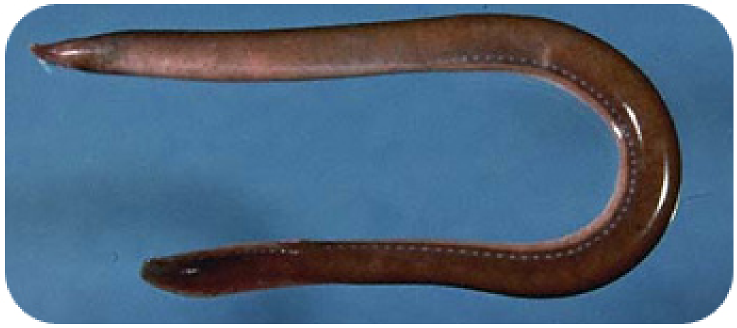

Figure 9.11: A hagfish

In addition to the absence of jaws, fish in this class are characterized by the absence of paired fins or an identifiable stomach. Characteristics they do have include:

1. A notochord, both in larvae and adults.
2. Seven or more paired gill pouches.
3. The branchial arches, a series of arches that support the gills of aquatic amphibians and fishes, lie close to the body surface.
4. A light sensitive **pineal eye**, an eye-like structure that develops in some cold-blooded vertebrates.
5. A **cartilaginous skeleton**, or a skeleton made of bone-like material called cartilage.
6. A heart with two chambers.
7. Reproduction using external fertilization.
8. They are ectothermic.

Many jawless fish in the fossil record were armored with heavy bony-spiky plates. The first armored fish in this class evolved before bony fish and tetrapods, including humans.

Cartilaginous Fishes

So why did fish eventually evolve to have jaws? Such an adaptation would allow fish to eat a much wider variety of food, including plants and other organisms. The cartilaginous fishes are jawed fish with paired fins, paired nostrils, scales, two-chambered hearts, and skeletons made of cartilage rather than bone. Cartilage does not have as much calcium as bones, which makes bones rigid. Cartilage is softer and more flexible than bone.

The 1,000 or so species of cartilaginous fish are subdivided into two subclasses: the first includes sharks, rays, and skates; the second includes chimaera, sometimes called ghost sharks. Fish from this group range in size from the dwarf lanternshark, at 6.3 inches, to the 50-foot whale shark shown in **Figure ??**.

Blood, Skin, and Teeth

Since they do not have bone marrow (as they have no bones), red blood cells are produced in the spleen, in special tissue around the gonads, and in an organ called Leydig's Organ, only found in cartilaginous fishes.

The tough skin of this group of fish is covered with dermal teeth, or **placoid** scales. In adult chimaera, the placoids are very small, making it feel like sandpaper. The teeth found in the mouth of cartilaginous fish evolved from teeth found on the skin.

Superorders

The sharks, rays and skates are further broken into two superorders:

1. Rays and skates.
2. Sharks (**Figure** 9.12).

Sharks are some of the most frequently studied cartilaginous fish. Sharks are distinguished by such features as:

- The number of gill slits.
- The numbers and types of fins.
- The type of teeth.
- Body shape.
- Their activity at night.
- An elongated, toothed snout used for slashing the fish that they eat, as seen in sawsharks.
- Teeth used for grasping and crushing shellfish, a characteristic of bullhead sharks.
- A whisker-like organ named **barbels**, a characteristic of carpet sharks.
- A long snout (or nose-like area), characteristic of groundsharks.
- Large jaws and ovoviviparous reproduction, where the eggs develop inside the mother's body after internal fertilization, and the young are born alive. This trait is characteristic of mackerel sharks.

Figure 9.12: A spotted Wobbegong shark, at Shelly Beach, Sydney, Australia, showing skin flaps around the mouth and camouflage coloration.

Bony Fishes

There are almost 27,000 species of bony fish, which are divided into two classes: ray-finned fish and lobe-finned fish. Most bony fish are ray-finned. There are only eight living species of lobe-finned fish, including lungfish (**Figure** 9.13) and coelacanths (**Figure** 9.14).

Figure 9.13: One of the only eight living species of lobe-finned fish, the lungfish.

Figure 9.14: One of the eight living species of lobe finned fish, the coelacanth.

Most fish are bony fish, making them the largest group of vertebrates in existence today. They are characterized by:

1. A head and pectoral girdles (arches supporting the forelimbs) that are covered with bones derived from the skin.
2. A lung or swim bladder, which helps the body create a balance between sinking and floating by either filling up with or emitting gases such as oxygen
3. Jointed, segmented rods supporting the fins.
4. A cover over the gill, which helps them breathe without having to swim.
5. The ability to see in color, unlike most other fish.

One of the most interesting adaptations of these fish is their ability to produce replacement, bone, by replacing cartilage from within, with bone. They also produce "spongy," bone. This means that the fish have a lightweight, flexible bone on the inside, surrounded by stronger and more rigid bone on the outside. This type of bone allows the fish to move in different ways compared to the cartilaginous fish.

How Big Are Bony Fish?

The ocean sunfish is the most massive bony fish in the world, up to 11 feet long, and weighing up to 5,070 pounds (**Figure** 9.15). Other very large bony fish include the Atlantic blue marlin, the black marlin, some sturgeon species, the giant grouper and the goliath grouper. In contrast, the dwarf pygmy goby measures only 0.6 inches.

Figure 9.15: An ocean sunfish, the most massive bony fish in the world, up to 11 feet long and weighing 5,070 pounds!

Why Fish are Important

How are fish important? Of course, they are used as food (**Figure** 9.16). In fact, people all over the world either catch fish in the wild or farm them in much the same way as cattle or chickens, a type of farming known as **aquaculture**. Fish are also caught for recreation to display in the home and or in public aquaria.

Figure 9.16: Workers harvest catfish from the Delta Pride Catfish farms in Mississippi.

Lesson Summary

- The general traits of fish help adapt them for living in an aquatic environment, mostly for swimming, and also for absorbing oxygen.
- Fish are ectothermic (cold-blooded), although some show warm-blooded adaptations.

- Jawless fish do not have bone, but they do have cartilage.
- Fish with jaws consist of both the cartilaginous fish and the bony fish.
- Cartilaginous fishes include sharks, rays, skates and chimaera.
- Bony fish form the largest group of vertebrates in existence today, and have true bone that can regenerate.
- Fish are an important food source for humans.

Review Questions

Recall

1. What are three traits that all fish have in common?

2. What is an example of one exception to the general traits of fish?

3. What are three characteristics of jawless fish?

4. List three ways that fish are important.

Apply Concepts

5. Between the hagfish and a cartiliaginous fish, the structure of the jaw evolved? Why do you think this major structure evolved in fish? How does it benefit them?

6. What is the major difference between cartilaginous fish and bony fish? Why do you think the bony fish evolved to be different?

Critical Thinking

7. Mudskippers are an example of a fish species that must absorb oxygen across the skin, instead of through gills, since they spend most of their time out of water. What kind of environment would pressure fish to evolve to breathe in air instead of breathing in the water?

Further Reading / Supplemental Links

- http://kids.nationalgeographic.com/Animals
- http://www.fws.gov/educators/students.html
- http://www.pbs.org/emptyoceans/educators/activities/fish-youre-eating.html
- http://en.wikipedia.org

Points to Consider

Amphibians are next.

- How do you think the gills of fish relate to the lungs of other animals?
- Lungfish have paired lungs similar to those of tetrapods. How do you think the breathing systems of lungfish could be similar to and different from tetrapods in the way they breathe?
- What structures are different between fish and amphibians, that allow amphibians to live on land?

9.3 Amphibians

Lesson Objectives

- Describe amphibian traits.
- List the features of salamanders.
- Compare and contrast frogs and toads with other amphibians.
- Describe the roles of amphibians.

Check Your Understanding

- What are some adaptations that amphibians, like fish, have for living in the water?
- What are the characteristics that amphibians share with all other vertebrates?

Vocabulary

- convergent adaptation
- ecdysis
- hyoid bone
- tympanum
- valarian respiration

Characteristics of Amphibians

What group of animals begins its life in the water, but then spends most of its life on land? Amphibians! Amphibians are a group of vertebrates that has adapted to live in both water and on land. Their ancestors evolved from living in the sea to living on land. There are approximately 6,000 species of amphibians, of many different body types, physiologies, and habitats, ranging from tropical to subarctic regions. Frogs, toads, salamanders, newts, and caecilians are all types of amphibians (**Figure** 9.17).

Figure 9.17: One of the many species of amphibian is this dusky salamander.

Like fish, amphibians are ectothermic vertebrates. They belong to the class Amphibia. There are three orders:

1. Urodela, containing salamanders and newts.

2. Anura, containing frogs and toads.
3. Apoda, containing caecilians.

Amphibian larvae are born and live in water, and they breathe using gills. The adults live on land for part of the time, and breathe both through their skin and using lungs.

Where do Amphibians Live?

Most amphibians live in fresh water, not salt water. Although there are no true saltwater amphibians, a few can live in brackish (slightly salty) water. Some species do not need any water at all, and several species have also adapted to live in drier environments. Most amphibians still need water to lay their eggs.

How do Amphibians Reproduce?

Amphibians reproduce sexually. The life cycle of amphibians happens in the following stages:

1. Egg Stage: Amphibian eggs are fertilized in a number of ways. External fertilization, employed by most frogs and toads, involves a male gripping a female across her back, almost as if he is squeezing the eggs out of her. The male releases sperm over the female's eggs as they are laid. Another method is used by salamanders, whereby the male deposits a packet of sperm onto the ground. The female then pulls it into her cloaca, where fertilization occurs internally. By contrast, caecilians and tailed frogs use internal fertilization, just like reptiles, birds and mammals. The male deposits sperm directly into the female's cloaca.
2. Larval stage: When the egg hatches, the organism is legless, lives in water and breathes with gills.
3. During the larval stage, the amphibian slowly transforms into an adult by losing its gills and growing four legs. Once development is complete, it can live on land.

How did Amphibians Adapt to Living on Land?

In order to live on land, amphibians replaced gills with another respiratory organ, the lungs.

Other adaptations include:

- A glandular skin that prevents loss of water.
- Eyelids that allow them to adapt to vision outside of the water.
- An eardrum developed to separate the external ear from the middle ear.
- In frogs and toads, the tail disappears in adulthood.

Salamanders

Salamanders belong to a group of approximately 500 species of amphibians. The order Urodela, containing salamanders and newts, is divided into three suborders:

1. Giant salamanders (including the hellbender and Asiatic salamanders).
2. Advanced salamanders (including lungless salamanders, mudpuppies, and newts).
3. Sirens.

Salamanders are characterized by slender bodies, short legs, and long tails. They are most closely related to the caecilians, little-known legless amphibians (**Figure** 9.18 and **Figure** 9.19). Since they have moist skin, salamanders live in or near water or on moist ground, often in a swamp. Some species live in water most of their life, some live their entire adult life on land, and some live in both habitats. Salamanders are carnivorous, eating only other animals, not plants. They will eat almost any smaller animal. Finally, salamanders have the ability to grow back lost limbs, as well as other body parts. This process is known as **ecdysis**.

Figure 9.18: The marbled salamander shows the typical salamander body plan: slender body, short legs, long tail and moist skin.

Figure 9.19: A species of African caecilian, , a legless amphibian most closely related to salamanders.

How Do Salamanders Breathe?

Different salamanders breathe in different ways. In those that have gills, breathing occurs through the gills as water passes over the gill slits. Species that live on land have lungs that are used in breathing, much like breathing in mammals. Other land-living salamanders do not have lungs or gills. Instead, they ”breathe”, or exchange gases, through their skin. This is known as **valarian respiration**, and requires blood vessels that exchange gases to be spread throughout the skin.

How Big Are Salamanders?

Salamanders are found in most moist or arid habitats in the northern hemisphere. They are generally small, but some can reach a foot or more, as in the mudpuppy of North America. In Japan and China, the giant salamander reaches 6 feet and weighs up to 66 pounds (**Figure** 9.20).

Figure 9.20: The Pacific giant salamander can reach up to 6 feet in length and weigh up to 66 pounds.

Frogs and Toads

Frogs and toads (**Figure** 9.21) are amphibians in the order Anura. In terms of classification, there is actually not a big difference between frogs and toads. Some amphibians that are called ”toads” have leathery, brown colored, wart covered skin, but they are still in the same order as frogs.

Frogs are found in many areas of the world, from the tropics to subarctic regions, but most species are found in tropical rainforests. Consisting of more than 5,000 species (about 88% of amphibian species are frogs), they are among the most diverse groups of vertebrates. Frogs range in size from less than 0.5 inches in species in Brazil and Cuba to 1-foot goliath frog of Cameroon.

Characteristics of Frogs

Adult frogs are characterized by long hind legs, a short body, webbed finger-like parts, and the lack of a tail (**Figure** 9.22). They also have a three-chambered heart, as do all tetrapods except birds and mammals. Most frogs live part of the time in water and part of the time on land, and move easily on land by jumping or climbing. To become great jumpers, frogs evolved long hind legs and long ankle bones. They also have a short backbone with only 10 vertebrae. Frog and toad skin hangs loosely on the body, and skin texture can be smooth, warty, or folded.

Figure 9.21: A toad, showing typical characteristics of leathery and warty skin, and brown coloration.

In order to live on land and in water, frogs have three eyelid membranes: one is see-through to protect the eyes underwater, and two other ones let them see on land. Frogs also have a **tympanum**, which acts like a simple ear. They are found on each side of the head. In some species, the tympanum is covered by skin.

Figure 9.22: A tree frog. Notice the powerful muscles in the limbs, and the coverings around the eyes.

”Ribbiting”

Frogs typically lay their eggs in puddles, ponds or lakes. Their larvae, or tadpoles, have gills, and the frogs develop in water. You may hear males ”ribbiting,” producing a mating call used to attract females to the bodies of water best for mating and breeding. Frogs calls can occur during the day or night.

Listen here http://www.youtube.com/watch?v=mISMwN-0ggE&feature=fvw for these distinctive sounds (3:30).

Figure 9.23: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/610

Eating

Adult frogs are meat-eaters and eat mostly arthropods, annelids, and gastropods. Frogs do not have teeth on their lower jaw, so they usually swallow their food whole, using the teeth they do have to hold the prey in place. Other frogs do not have any teeth, so they must swallow their prey whole.

Roles of Amphibians

Amphibians as Foods

Frogs are raised as a food source. Frog legs are a delicacy in China, France, the Philippines, northern Greece and the American south, especially Louisiana.

Amphibians in Research

Amphibians are used in cloning research and other branches of embryology, because their eggs lack shells, so it is easy to watch their development.

The African clawed frog, *Xenopus laevis,* is a species that is studied to understand certain biological phenomena in developmental biology, because it is easy to raise in a lab and has a large and easy to study embryo. Many *Xenopus* genes have been identified and cloned, especially those involved in development.

Many environmental scientists believe that amphibians, including frogs, indicate when an environment is damaged. Since they live on land and water, when species of frogs begin to decline, it often indicates that there is a bigger problem with the ecosystem.

Amphibians in Popular Culture

Amphibians can be found in folklore, fairy tales and popular culture. Numerous legends have developed over the centuries around the salamander (its name originates from the Persian, for "fire" and "within") , many related to fire. This connection likely originates from the tendency of many salamanders to live inside rotting logs. When placed into the fire, salamanders would escape from the logs, lending to the belief that the salamander was created from flames.

Lesson Summary

- Amphibians have adaptations for both aquatic (gills), and terrestrial (lungs and moist skin) lifestyles.
- Most amphibians must reproduce in water.

- Development includes a shell-less egg, larval stage, and adult stage.
- Salamanders have some unique features, including the use of the hyoid bone in hunting prey, and the process of ecdysis.
- Adult frogs and toads have features for living in the water (such as webbed finger-like parts) and for living on the land (such as long hind legs for jumping).
- Frogs are well known for their mating calls, which are used to attract females to aquatic breeding grounds.
- Amphibians play a role as a food source, are used in various types of biological research, can serve as indicators of ecosystem health, and are found in folklore and popular culture.

Review Questions

Recall

1. Describe three general traits of amphibians.
2. Describe the life cycle of amphibians from egg stage to adult stage.

Apply Concepts

3. What are two ways that amphibians have adapted to living on land?
4. Why would a scientist want to use a frog for research?
5. Name one way amphibians have evolved to avoid predation.

Critical Thinking

6. A frog's skin must remain moist at all times in order for oxygen to pass through the skin and into the blood. Why does this fact make frogs susceptible to many toxins in the environment?

Further Reading / Supplemental Links

- http://en.wikipedia.org/wiki
- http://kids.nationalgeographic.com/Animals
- http://amphibiaweb.org
- http://helpafrog.org
- http://www.epa.gov/gmpo/education/photo/amphibians.html

Points to Consider

Future studies of molecular genetics should soon provide further insights to the evolutionary relationships among frog families. These studies will also clarify relationships among families belonging to the rest of vertebrates. We discuss reptiles next.

- Although care of offspring is poorly understood in frogs, it is estimated that up to 20% of amphibian species care for their young, and that there is a great diversity of parental behaviors. As you begin to examine the reproductive system of reptiles in the next lesson, think about what kinds of parental behaviors reptiles might have and how they compare to that of amphibians.

9.4 Reptiles

Lesson Objectives

- List reptile traits.
- Describe the general features of lizards and snakes.
- List the characteristics of alligators and crocodiles.
- Describe the traits of turtles.
- Explain the importance of reptiles.

Check Your Understanding

- How have amphibians adapted to living on land?
- What features in amphibians are also useful to reptiles who live in water?

Vocabulary

- amniotes
- nictitating membrane
- poikilothermic

Traits of Reptiles

What reptiles do you know? Snakes, alligators, and crocodiles are all reptiles. Reptiles are tetrapods and **amniotes**, which means their embryos are surrounded by a thin membrane. Modern reptiles live on every continent except Antarctica. They range in size from the newly-discovered Jaragua Sphaero, at 0.6 inches, to the saltwater crocodile, at up to 23 feet.

There are four living orders of reptiles:

1. Squamata, which includes lizards, snakes, and amphisbaenids (or "worm-lizards").
2. Crocodilia, which include crocodiles, gharials (**Figure** 9.24), caimans, and alligators.
3. Testudines, which includes turtles and tortoises.
4. Sphenodontia, which includes tuatara (**Figure** 9.25).

Reptiles are air-breathing, ectothermic vertebrates that have skin covered in scales. Most reptiles have a closed circulatory system with a three-chambered heart. All reptiles breathe using lungs. They also have two small kidneys. Usually their sense organs, like ears, are well developed, though snakes do not have external ears (middle and inner ears are present). All reptiles have advanced eyesight.

How do Reptiles Reproduce?

The majority of species are egg-laying, although certain species of squamates can give birth to live young. This is achieved either by oviparity (the egg stays in the female until birth), or viviparity (offspring born without eggs). Many of the viviparous species feed their fetuses by a placenta, similar to those of mammals. Some reptiles provide care for their young.

All reptiles have a cloaca, a single exit and entrance for sperm, eggs, and waste, located at the base of the tail. Most reptiles lay amniotic eggs covered with leathery or calcium-containing shells. An amnion

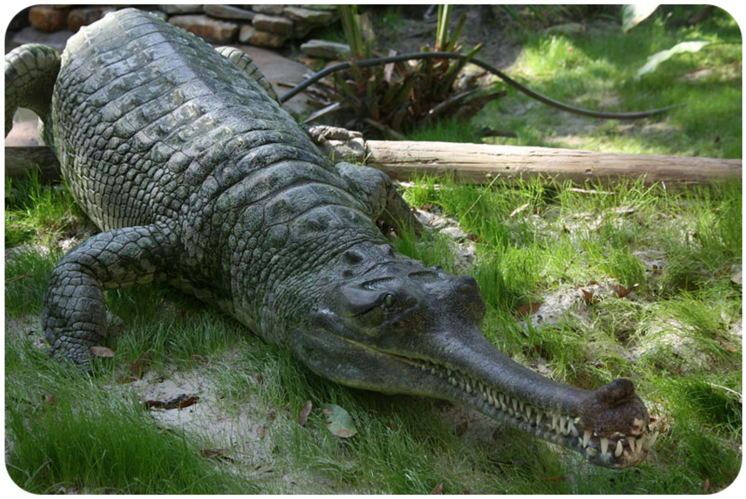

Figure 9.24: An Indian gharial crocodile.

Figure 9.25: A tuatara.

(the innermost of the embryonic membranes), chorion (the outermost of the membranes surrounding the embryo), and allantois (a vascular embryonic membrane) are present during embryonic life. There are no larval stages of development.

Most reptiles reproduce sexually, although six families of lizards and one snake are capable of asexual reproduction. In some species of squamates, a population of females is able to produce a nonsexual diploid clone of the mother. This asexual reproduction, called parthenogenesis, also occurs in several species of gecko.

Lizards and Snakes

Lizards and snakes belong to the largest order of reptiles, Squamata. Lizards are a large group of reptiles, with nearly 5,000 species, living on every continent except Antarctica.

Characteristics of Squamata

Members of the order are distinguished by horny scales or shields and movable quadrate bones, which make it possible to open the upper jaw very wide. Quadrate bones are especially visible in snakes, which are able to open their mouths very wide to eat large prey (**Figure** 9.26).

Figure 9.26: A corn snake swallowing a mouse.

Characteristics of Lizards

Key features of lizards include:

- Four limbs.
- External ears.
- Movable eyelids.
- A short neck.
- A long tail, which they can shed in order to escape from predators.
- They eat insects.

Vision, including color vision, is well-developed in lizards. You may have seen a lizard camouflaged to blend in with its surroundings. Since they have great vision, lizards communicate by changing the color of their bodies. They also communicate by chemical signals called pheromones.

Adult lizards range from 1 inch in length, like some Caribbean geckos, to nearly 10 feet (**Figure** 9.27).

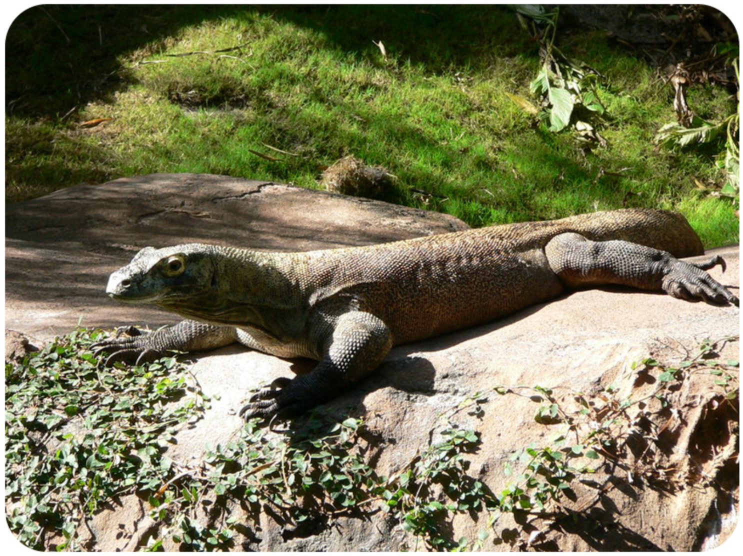

Figure 9.27: A Komodo dragon, the largest of the lizards, attaining a length of 10 feet.

With 40 lizard families, there is an extremely wide range of color, appearance and size of lizards. Many lizards are capable of regenerating lost limbs or tails. Almost all lizards are carnivorous, although most are so small that insects are their primary prey. A few species are omnivorous or herbivorous, and others have reached sizes where they can prey on other vertebrates, such as birds and mammals.

Lizard Behavior

Many lizards are good climbers or fast sprinters. Some can run on two feet, such as the collared lizard. Some, like the basilisk, can even run across the surface of water to escape. Many lizards can change color in response to their environments or in times of stress (**Figure** 9.28). The most familiar example is the chameleon, but more subtle color changes can occur in other lizard species.

Legless Lizards

Some lizard species, including the glass lizard and flap-footed lizards, have evolved to lose their legs, or their legs are so small that they no longer work. Legless lizards almost look like snakes, though structures leftover from earlier stages of evolution remain. For example, flap-footed lizards can be distinguished from snakes by their external ears.

Characteristics of Snakes

All snakes are meat-eaters, and are different from legless lizards because they do NOT have eyelids, limbs, external ears, or forelimbs. The more than 2,700 species of snake can be found on every continent except Antarctica and range in size from the tiny, 4-inch-long thread snake to pythons and anacondas that are over 17 feet long (**Figure** 9.29).

In order to fit inside of snakes' narrow bodies, paired organs (such as kidneys) appear one in front of the

Figure 9.28: A species of lizard, showing general body form and camouflage against background.

other instead of side by side. Snakes' eyelids are transparent "spectacle" scales which remain permanently closed. Most snakes are not venomous, but some have venom capable of causing painful injury or death to humans. However, snake venom is primarily used for killing prey rather than for self-defense.

Figure 9.29: A species of anaconda, one of the largest snakes, which can be as long as 17 feet.

Most snakes use specialized belly scales, which grip surfaces, to move. The body scales may be smooth, keeled or granular (**Figure** 9.30). In the shedding of scales, known as molting, the complete outer layer of skin is shed in one layer (**Figure** 9.31). Molting replaces old and worn skin, allows the snake to grow, and helps it get rid of parasites such as mites and ticks.

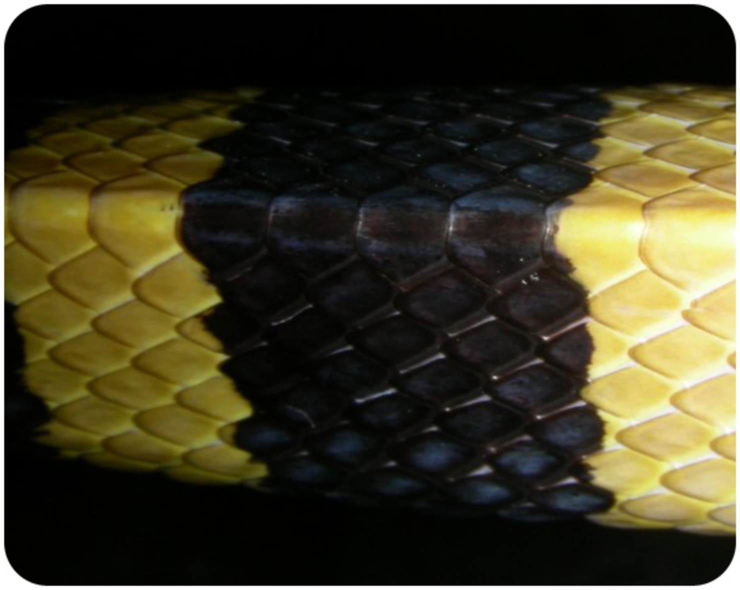

Figure 9.30: A close up of snake scales of a banded krait, showing black and yellow alternating bands and spaces between scales.

Figure 9.31: A northern water snake shedding its skin.

Although different snake species reproduce in different ways, all snakes use internal fertilization. The male uses sex organs stored in its tail to transfer sperm to the female. Most species of snakes lay eggs, and most species abandon these eggs shortly after laying.

How do Snakes Eat?

All snakes are strictly carnivorous, eating small animals including lizards, other snakes, small mammals, birds, eggs, fish, snails or insects. Because snakes cannot bite or tear their food to pieces, prey must be swallowed whole. The body size of a snake has a major influence on its eating habits. The snake's jaw is unique in the animal kingdom. Snakes have a very flexible lower jaw, the two halves of which are not rigidly attached. They also have many other joints in their skull, allowing them to open their mouths wide enough to swallow their prey whole.

Some snakes have a venomous bite, which they use to kill their prey before eating it. Other snakes kill their prey by strangling them, and still others swallow their prey whole and alive. After eating, snakes enter a resting stage, while the process of digestion takes place. The process is highly efficient, with the snake's digestive enzymes dissolving and absorbing everything but the prey's hair and claws, even when the prey is swallowed whole!

Alligators and Crocodiles

Crocodilia, containing both alligators and crocodiles, is an order of large reptiles. Reptiles belonging to Crocodilia are the closest living relatives of birds. Reptiles and birds are the only known living descendants of the dinosaurs. Think about how organisms with the same ancestors can evolve to be so different.

The basic crocodilian body plan (**Figure** 9.32) is a very successful one, and has changed little over time. Modern species actually look very similar to their Cretaceous ancestors of 84 million years ago.

Figure 9.32: Nile crocodiles display the basic crocodilian body plan.

Characteristics of Crocodiles

Crocodilians have a flexible, semi-erect posture. They can walk in low, sprawled "belly walk," or hold their legs more directly underneath them to perform the "high walk." Most other reptiles can only walk in a sprawled position.

All crocodilians have, like humans, teeth set in bony sockets, but unlike mammals, they replace their teeth throughout life. Crocodilians also have a secondary bony palate that enables them to breathe when under water, even if the mouth is full of water. Their internal nostrils open in the back of their throat, where a special part of the tongue called the palatal valve closes off their respiratory system when they are underwater, allowing them to breathe.

Crocodiles and gharials (large crocodilians with longer jaws) have salivary glands on their tongue, which are used to remove salt from their bodies. Crocodilians are often seen lying with their mouths open, a behavior called gaping. One of its functions is probably to cool them down, but it may also have a social function.

Crocodilians are known to swallow stones, known as gastroliths, which help digest their prey. The crocodilian stomach is divided into two chambers. The first is powerful and muscular. The other stomach is the most acidic digestive system of any animal. It can digest mostly everything from their prey, including bones, feathers, and horns!

The sex of developing crocodilians is determined by the temperature of the eggs during incubation (eggs are kept warm before they hatch). This means that the sex of crocodilians is not determined genetically. If the eggs are kept at a cold or a hot temperature, then their offspring may be all male or all female. To get both male and female offspring, the temperature must be kept within a narrow range.

Evolving More Complex Structures

Like all reptiles, crocodilians have a relatively small brain, but the crocodilian brain is more advanced than those of other reptiles. As in many other aquatic or amphibian tetrapods, the eyes, ears, and nostrils are all located on the same "face" in a line one after the other. They see well during the day and may even have color vision, but they have excellent night vision. A third transparent eyelid, the **nictitating membrane**, protects their eyes underwater.

While birds and most reptiles have a ring of bones around each eye which supports the eyeball, crocodiles lack these bones, just like mammals and snakes. The eardrums are located behind the eyes and are covered by a movable flap of skin. This flap closes, along with the nostrils and eyes, when they dive, preventing water from entering their external head openings. The middle ear cavity has a complex of bony air-filled passages and a branching tube.

The upper and lower jaws are covered with "sensory pits," which hold bundles of nerve fibers that respond to the slightest disturbance in surface water. Crocodiles can detect vibrations and small pressure changes in water, making it possible for them to sense prey and danger even in total darkness.

Like mammals and birds, and unlike other reptiles, crocodiles have a four-chambered heart. But, unlike mammals, blood with and without oxygen can be mixed.

Turtles

Turtles are reptiles in the order Testudines. If you have seen turtles before, what is the most noticeable thing about them? Their shells. Most turtle bodies are covered by a special bony or cartilaginous shell developed from their ribs. About 300 species are alive today, and some are highly endangered. Like other reptiles, turtles are **poikilothermic**, meaning their temperature changes in response to their environment.

Turtles are broken down into two groups, based on how they bring their neck back into their shell:

1. Cryptodira, which can draw their neck inside and under their spine.
2. Pleurodira, which fold their necks to one side.

Characteristics of Turtles

Although many turtles spend large amounts of their lives underwater, they can also spend much of their lives on dry land and breathe air. Turtles cannot breathe in water, but can hold their breath for long periods of time. Turtles must surface at regular intervals to refill their lungs.

Turtles don't lay eggs underwater. Turtles lay slightly soft and leathery eggs, like other reptiles. The eggs of the largest species are spherical, while the eggs of the rest are longer in shape (**Figure** 9.33).

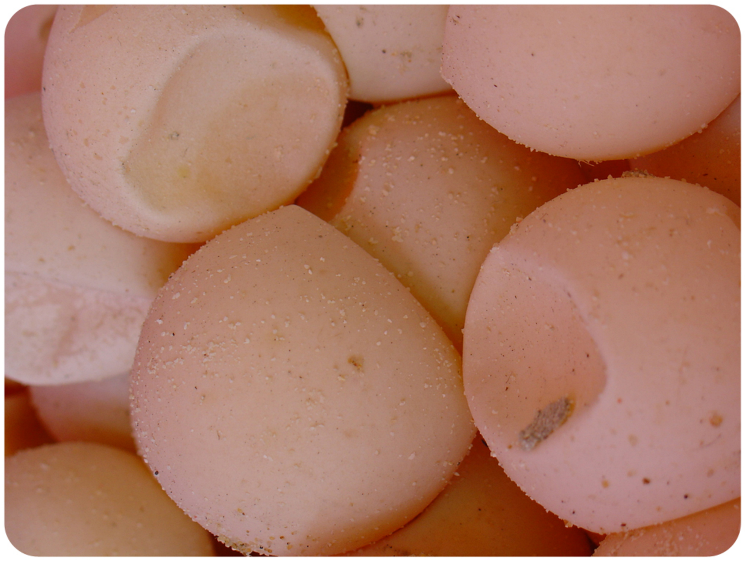

Figure 9.33: Turtle eggs.

Most turtles that spend most of their life on land have their eyes looking down at objects in front of them. Some aquatic turtles, such as snapping turtles and soft-shelled turtles, have eyes closer to the top of the head. These species of turtles can hide from predators in shallow water, where they lie entirely submerged in water except for their eyes and nostrils.

Sea turtles (**Figure** 9.34) have glands near their eyes that produce salty tears, which remove excess salt taken in from the water they drink.

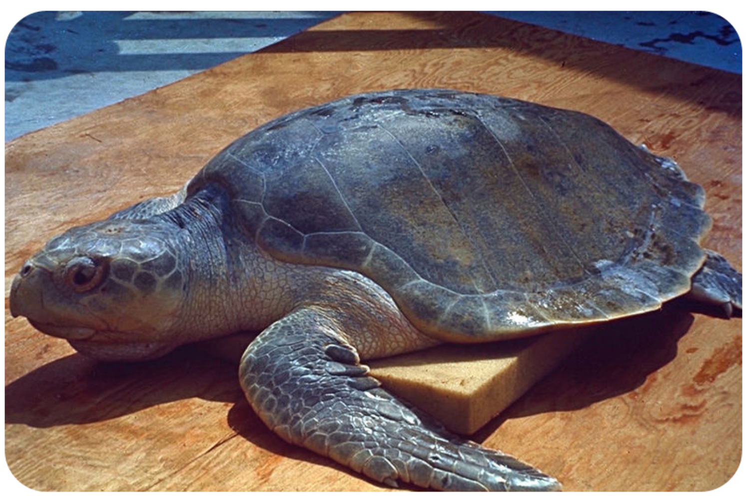

Figure 9.34: A species of sea turtle, showing placement of eyes, shell shape, and flippers.

Turtles have exceptional night vision due to the unusually large number of cells that sense light in their eyes. Turtles have color vision.

In some species, temperature determines whether an egg develops into a male or female. Large numbers of eggs are placed by the female in holes dug into mud or sand. They are then covered and left to grow and develop by themselves. When the turtles hatch, they squirm their way to the surface and head toward the water.

How do Turtles Eat?

Turtles have a rigid beak and use their jaws to cut and chew food. Instead of teeth, the upper and lower jaws of the turtle are covered by horny ridges. Carnivorous turtles usually have knife-sharp ridges for slicing through their prey. Herbivorous turtles have serrated ridges that help them cut through tough plants.

How Big Are Turtles?

The largest turtle is the great leatherback sea turtle (**Figure** 9.35), which can have a shell length of 7 feet and can weigh more than 2,000 pounds. The only surviving giant tortoises are on the Seychelles and Galapagos Islands and can grow to over 4 feet in length and weigh about 670 pounds (**Figure** 9.36). The smallest turtle is the speckled padloper tortoise of South Africa, measuring no more than 3 inches in length, and weighing about 5 ounces.

Figure 9.35: The leatherback turtle can reach up to 7 feet in length and weigh over 2,000 pounds.

Importance of Reptiles

The chief impact of reptiles on humans is their role as predators of pest species. For example, in many different countries, like India, snakes kill rats that can be pests and carriers of disease. Also, since turtles live for hundreds of years, genetic researchers are examining the turtle's DNA for possible genes involved in a long life.

Reptiles as Food

Reptiles are also important as food sources:

- Green iguanas are eaten in Central America.

Figure 9.36: A Galapagos giant tortoise can grow to over 4 ft in length and weigh about 670 lb.

- The tribals of Irulas from Andhra Pradesh and Tamil Nadu in India are known to eat some of the snakes they catch.
- Cantonese snake soup is consumed by local people in the fall to prevent colds.
- Cooked rattlesnake meat is commonly consumed in parts of the Midwestern United States.
- Turtle soup is consumed throughout the world.

Reptiles as Pets

Reptiles also make good pets. In the Western world, some snakes, especially less aggressive species, like the ball python or corn snake, are kept as pets. Turtles, particularly small land-dwelling and freshwater turtles, are also common pets. Among the most popular are Russian tortoises, Greek spur-thighed tortoises and terrapins.

Reptiles in Art and Culture

Finally, reptiles play a significant role in folklore, religion and popular culture. The Moche people of ancient Peru worshipped reptiles and often put lizards in their art. Snakes or serpents are connected to healing and to the Devil. Since snake's shed and then heal again, they are a symbol of healing and medicine, as shown in the Rod of Asclepius (**Figure** 9.37).

In Egyptian history, the Nile cobra is found on the crown of the pharaoh. This snake was worshipped as one of the gods.

Lesson Summary

- Reptiles are air-breathing, cold-blooded vertebrates characterized by a scaly skin.
- Reptiles have a variety of reproductive systems, with different strategies for providing nutrition to developing young.
- Lizards and snakes are distinguished by a unique type of scaly skin and movable quadrate bones.
- Lizards have some unique adaptations, including regeneration of lost limbs or tails and changing color.
- Snakes are distinguished by lack of eyelids, limbs, external ears and vestiges of forelimbs.

Figure 9.37: The Rod of Asclepius, where the snake is a symbol of healing and medicine.

- Snakes have various adaptations for killing and eating their prey.
- Crocodilia have a flexible semi-erect posture, lifelong replacement of teeth, and a secondary bony palate.
- The sex of developing crocodilians is determined by the incubation temperature of the eggs.
- Other crocodilian traits, such as salt glands, nictitating membranes, ear flaps, and sensory pits, are adaptations for aquatic living.
- Turtles are characterized by a special bony or cartilaginous shell. They have specialized adaptations for aquatic living, such as eye placement and salt glands, and adaptations for terrestrial living as well, like placement of eyes and protection of eggs.
- Reptiles play important roles as predators of pest species, food sources, pets, in medical and scientific research, and in folklore, religion and popular culture.

Review Questions

Recall

1. Describe three general traits of reptiles.

2. Describe two different types of reproduction in reptiles.

3. How are snakes different from legless lizards?

Apply Concepts

4. Name two adaptations of a crocodilian stomach which help it in digestion.

5. Name two organs that a turtle or a snake have that closely resemble organs in humans. Why are they similar?

Critical Thinking

6. The shape and structure of a turtle's shell can give its inhabitant advantages for avoiding predators, aid in swimming and diving, and for walking on land. Given what you know about a turtle's shell, explain how the structure and shape could help the turtle in the above situations.

Further Reading / Supplemental Links

- http://kids.nationalgeographic.com/Animals
- http://www.amnh.org/exhibitions/lizards
- http://teacher.scholastic.com/activities/explorations/lizards/index.htm
- http://www.turtles.org
- http://www.gma.org/turtles
- http://www.flmnh.ufl.edu/cnhc/cbd.html

Points to Consider

Next, we continue our discussions with birds and mammals

- What colorful displays do you think are used to attract mates in birds and mammals?

- How do you think the hearts of fish, amphibians, and reptiles compare to that of birds and mammals?
- How do birds or mammals reproduce? By eggs like fish and amphibians? Or do they have live births?

Chapter 10

MS Birds and Mammals

Observe the above organism. It has a bill like a duck. Does that make it a bird? It has fur like a dog or beaver, so is it a mammal? But it also has webbed feet. What is this creature? These are the questions scientists asked when they first discovered the duck-billed platypus. It is classified as a mammal, but it also has some bird and even reptile DNA. Surprisingly, it also lays eggs, while almost all other mammals give birth to live young.

The platypus shows how great the diversity of life is on Earth. Organisms are not always easily classifiable, but most warm-blooded vertebrates can be classified as either a bird or a mammal.

10.1 Birds

Lesson Objectives

- List and describe general traits of birds.
- Explain how birds are adapted for flight.
- List different breeding systems in birds and describe nesting, incubation and parental care.
- Illustrate the diversity of birds with examples of some of the varied groups.
- Explain how birds are important, both economically and ecologically.

Check Your Understanding

- Birds and reptiles have some traits in common. For example, birds are egg-layers and most reptiles are also oviparous. What do the eggs of both groups have in common?
- What traits do birds have as a result of their being warm-blooded?

Vocabulary

- aerofoil
- altricial
- monogamous
- polygamous
- precocial

Characteristics of Birds

How many different types of birds can you think of? Robins, ostriches, hummingbirds, chickens. All of these are birds, but they are also all very different from each other. There is an amazingly wide diversity of birds. Like amphibians, reptiles, mammals, and fish, they are vertebrates. What does that mean? It means they have a backbone. Birds have forelimbs modified as wings, but not all birds can fly.

Birds are in the class Aves. All birds have the following key features: they are endothermic (warm-blooded), have two legs, and lay eggs.

Birds range in size from the tiny 2-inch bee hummingbird to the 9-foot ostrich (**Figure** 10.1). With approximately 10,000 living species, birds are the most numerous vertebrates with four limbs. They live in diverse habitats around the globe, from the Arctic to the Antarctic.

The digestive system of birds is unique, with a gizzard that contains swallowed stones for grinding food. Birds do not have teeth. What do you think the stones do? They help them digest their food. Defining characteristics of modern birds also include:

- Feathers.
- High metabolism.
- A four-chambered heart.
- A beak with no teeth.
- A lightweight but strong skeleton.
- Production of hard-shelled eggs.

Which of the above traits do you think might be of importance to flight?

Figure 10.1: The ostrich can reach a height of 9 feet! Pictured here are ostriches with young in Namibia, Africa.

Adaptations for Flight

In comparing birds with other vertebrates, what do you think distinguishes them the most? In most birds, flight is the most obvious difference. Birds have adapted their body plan for flight:

- Their skeleton is especially lightweight, with large air-filled spaces connecting to their respiratory system.
- Their neck bones are flexible. Birds that fly have a bony ridge along the breastbone that the flight muscles attach to (**Figure** 10.2). This allows them to remain stable in the air as they fly.
- Birds also have wings that function as an **aerofoil**. The surface of the aerofoil is curved to help the bird control and use the air currents to fly. Aerofoils are also found on planes.

What other traits do you think might be important for flight? Feathers help because they more lightweight than scales or fur. A bird's wing shape and size will determine how a species flies. For example, many birds have powered, flapping flight at certain times, while at other times they soar, using up less energy (**Figure** 10.3).

About 60 living bird species are flightless, such as penguins, as were many extinct birds. Flightlessness often evolves when birds live on isolated islands, probably due to limited resources and the absence of land predators. For example, the flightless cormorant can no longer fly, but its wings are now adapted to swim in the sea (**Figure** 10.4).

Reproduction in Birds

How do birds reproduce? We know that chickens lay eggs. But how do they do that?

It all starts with behavior aimed at attracting a mate. In birds, this will involve a type of display, usually performed by the male. If successful, it will lead to breeding. Most male birds sing a type of song to attract females. Some displays are very elaborate and may include dancing, aerial flights, or wing or tail drumming.

Listen here http://www.youtube.com/watch?v=rL4Z9d9oObY&feature=related for singing birds

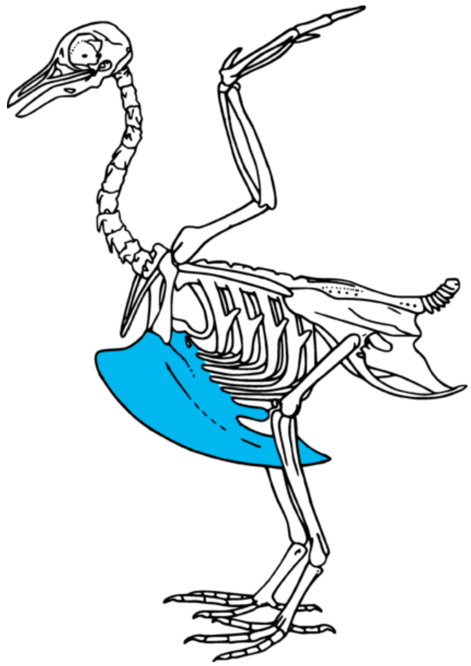

Figure 10.2: A bony ridge along the breastbone (blue) allows birds to remain stable as they fly.

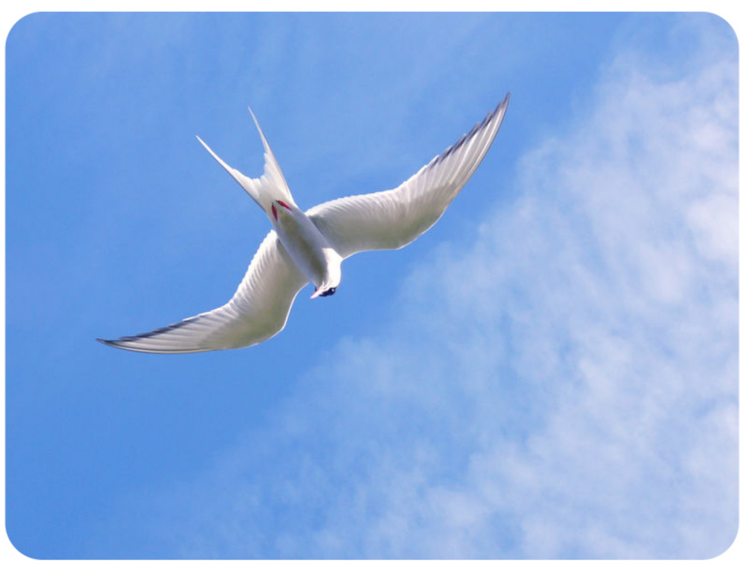

Figure 10.3: One bird's flight, as seen in a tern species.

Figure 10.4: A flightless cormorant can no longer fly, but uses its wings for swimming.

(4:53).

Figure 10.5: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/611

Birds reproduce by internal fertilization. Like reptiles, birds have cloaca, or a single exit and entrance for sperm, eggs, and waste. The male brings his sperm to the female cloaca. The sperm fertilizes the egg. The hard-shelled eggs have a fluid-filled amnion, a thin membrane forming a closed sac around the embryo. Eggs are usually laid in a nest.

How Do Birds Protect Their Offspring?

Why do you think eggs come in so many different colors? If an egg is hidden in a hole or burrow, away from predators, then the eggs are most often pale or white.

Birds that make nests in the open have camouflaged eggs (**Figure** 10.6). This gives the eggs protection against predation. Some species, like ground-nesting nightjars, have pale eggs, but the birds camouflage the eggs with their feathers. To protect their young, different species of birds make different nests. Many are elaborate, shaped like cups, domes, plates, mounds or burrows. The albatross, however, makes a nest that is simply a scrape on the ground. Still others, like the common guillemot, do not use nests. Instead, they lay their eggs on bare cliffs. Male emperor penguins do not have a nest at all: they sit on eggs to keep them warm before they hatch, a process called incubation.

How else might a bird help protect its young from predators? Most species locate their nests in areas that are hidden, in order to avoid predators. Large birds, or those that nest in groups, may build nests in the open, since they are more capable of defending their young.

Figure 10.6: Nest and eggs of the common moorhen, showing camouflaged eggs.

Young Birds and Parental Care

In birds, 95% of species are **monogamous**, meaning the male and female remain together for breeding for a few years or until one mate dies. Usually, the parents take turns incubating the eggs. Birds usually incubate their eggs after the last one has been laid. In **polygamous** species, where there is more than one mate, one parent does all of the incubating.

The length and type of parental care varies widely amongst different species of birds. At one extreme, in a group of birds called the magapodes, parental care ends at hatching. In this case, the newly-hatched chick digs itself out of the nest mound without parental help and can take care of itself right away. These birds are called **precocial**. At the other extreme, many seabirds care for their young for extended periods of time, the longest being that of the great frigatebird. Their chicks receive parental care for six months, or until they are ready to fly, and then take an additional 14 months of being fed by the parents (**Figure** 10.7). These birds are the opposite of precocial birds, and are called **altricial**.

In most animals, male parental care is rare. But it is very common in birds. Often tasks are shared between parents, like defense of territory and nest site, incubation, and the feeding of chicks. Since birds often take great care of their young, some birds have evolved a behavior called "brood parasitism." This happens when a bird leaves her eggs in another bird's nest. The host bird often accepts and raises the parasite bird's eggs.

Some chicks, like those of the ancient murrelet, follow their parents out to sea the night after they hatch, in order to avoid land predators. In most species, however, the young do not leave the nest until they can fly.

Diversity of Birds

About 10,000 bird species belong to 29 different orders within the class Aves. They live and breed on all seven continents. The tropics are home to the greatest biodiversity of birds.

Figure 10.7: Great frigatebird adults are known to care for their young for up to 20 months after hatching, the longest in a bird species. Here, a young bird is begging for food.

Birds that live in different environments will encounter different foods and different predators. The feeding habits of birds are related to the beak shape and size, as well as the shape of the feet. Birds can be carnivores, insectivores, or generalists, feeding on a variety of foods. Some, such as hummingbirds, feed on nectar. Can you think of some examples of beak shape and size that are adapted to the type of food a bird eats?

Beaks

As mentioned above, the size and shape of the beak is related to the food the bird eats, and can vary greatly among different birds. Parrots have down-curved, hooked bills, which are well-adapted for cracking seeds and nuts (**Figure** 10.8). Hummingbirds, on the other hand, have long, thin, pointed bills, which are adapted for getting the nectar out of flowers (**Figure** 10.9).

Figure 10.8: The down-curved, hooked bill of a scarlet macaw, a large colorful parrot.

Figure 10.9: A long, thin and pointed bill of the Swallow-tailed Hummingbird.

Feet

Bird feet can also vary greatly among different birds. Some birds, like gulls and terns, have webbed feet used for swimming or floating (**Figure** 10.10). Other birds, such as herons, gallinules, and rails, have four long spreading toes, which are adapted for walking delicately in the wetlands (**Figure** 10.11). Now you can predict how the beaks and feet of birds will look depending on where they live and the type of food they eat.

Figure 10.10: The webbed feet of a great black-backed gull.

Figure 10.11: The long spreading toes of an American purple gallinule.

Why Birds are Important

We are probably most familiar with birds as food. Around the world, people consume chicken, turkey, and even more exotic birds, like ostriches. Can you think of other ways that birds are important?

1. In agriculture, humans harvest bird droppings for use as fertilizer.
2. Chickens are also used as an early warning system of human diseases, such as West Nile virus. Mosquitoes carry the West Nile virus, bite young chickens and other birds, and infect them with the virus. When chickens or other birds become infected, this warns humans that they may also become infected in the near future.
3. Nectar-feeding birds are important pollinators, meaning they move the pollen from flower to flower to help fertilize the sex cells and create new plants. Many fruit-eating birds help disperse seeds.
4. Birds are often important to island ecology. In New Zealand, the Kereru and Kokako are important browsers, or animals that eat or nibble on leaves, tender young shoots, or other vegetation (**Figure** 10.12 and **Figure** 10.13). Seabirds add nutrients to soil and to water with their production of guano.
5. Birds have important cultural relationships with humans. Birds are common pets in the Western world. Sometimes, people act cooperatively with birds. For example, the Borana people in Africa use birds to guide them to honey that they use in food.
6. Birds also play prominent and diverse roles in folklore, religion, and popular culture, and have been featured in art since prehistoric times, as in early cave paintings.

Lesson Summary

- Birds are warm-blooded.
- Adaptations for flight involve features that are lightweight, flexible, strong and that take advantage of air currents.
- Reproduction usually involves a courtship display, nest production, egg laying, incubation and parental care.
- With 10,000 bird species, there is a lot of diversity. Specialized structures are adapted for specific habitats or living requirements.
- Birds are important economically, ecologically, and in human culture.

Figure 10.12: The kereru is an important browser species in New Zealand.

Figure 10.13: The kokako, another important browser species of New Zealand.

Review Questions

Recall

1. List three traits which are important for flight.

2. Give an example of how a bird's breeding system is adapted to avoid predators.

Apply Concepts

3. Explain how the absence of land predators on islands results in flightlessness in birds.

4. A large bird that nests with other birds has pale eggs even though the environment is brown and the eggs stand out to predators. Why have these birds not evolved camouflaged eggs?

Critical Thinking

5. You detect the presence of antibodies to the West Nile Virus in young chickens. How did the chickens get the virus? What does this mean about human West Nile infections?

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Points to Consider

Mammals are next.

- Birds and mammals are the only warm-blooded vertebrates. As in birds, mammals exhibit wide diversity and live in varied habitats. Based on what you know about adaptations in birds, how do you think mammalian limbs are adapted for movement in different habitats?
- As in birds, mammals have different foods they eat depending on their environment. Instead of beaks, mammals have different kinds of teeth. In what way(s) do you think teeth in mammals are adapted for different kinds of diets?

10.2 Mammals

Lesson Objectives

- List and describe general traits of mammals.
- Compare reproduction in monotremes, marsupials and placental mammals.
- Describe how mammals can be grouped according to their anatomy and their habitats.

- Explain how non-human mammals can benefit people and how they play an ecological role.

Check Your Understanding

- Mammals are warm-blooded, like birds. What traits do you think they have in common because of this?
- Describe courtship displays in birds. As you learn about mammals, think about how their courtship is similar to or differs from that seen in birds.

Vocabulary

- harem
- mammary glands
- marsupial
- monotremes
- neocortex
- placental
- sexual dimorphism

Characteristics of Mammals

What is a mammal? These animals range from bats, cats and rats to dogs, monkeys and whales. They walk, run, swim and fly. They live in the ocean, fly in the sky, walk on the prairies, and run in the savanna.

What allows them to live in such diverse environments? They have evolved specialized traits, unlike any other group of animal. There is a tremendous amount of diversity within the group in terms of reproduction, habitat, and adaptation for living in those different habitats. Some of their traits directly benefit people, while also playing important ecological roles.

Mammals (class Mammalia) are endothermic (warm-blooded) vertebrate animals with a number of unique characteristics. In most mammals, these include:

- The presence of hair or fur.
- Sweat glands.
- Glands specialized to produce milk, known as **mammary glands**.
- Three middle ear bones.
- A **neocortex** region in the brain, which specializes in seeing and hearing.
- Specialized teeth.
- A four-chambered heart.

All mammals, except for one, are viviparous, meaning they produce live young instead of laying eggs. The **monotremes**, however, have birdlike and reptilian characteristics, such as laying eggs and a cloaca.

There are approximately 5,400 mammalian species, ranging in size from the tiny 1-2 inch bumblebee bat to the 108-foot blue whale. These are distributed in about 1,200 genera, 153 families and 29 orders.

Mammals are also the only animal group that evolved to live on land and then back to live in the ocean! Whales, dolphins and porpoises have all adapted from land-dwelling creatures to a life of swimming and reproducing in the water (**Figure** 10.14). Whales have evolved into the largest mammals.

Figure 10.14: Dolphins have all adapted to swimming and reproducing in water.

Reproduction in Mammals

There are similarities between the reproductive habits or mammals and those of reptiles, birds, and amphibians. See if you can spot them.

The egg-laying monotremes, such as echidnas (**Figure** 10.15) and platypuses (**Figure** 10.16), use one opening, the cloaca, to urinate, release waste, and reproduce, just as lizards and birds do. They lay leathery eggs, similar to those of lizards, turtles and crocodilians. Monotremes feed their young by "sweating" milk from patches on their bellies, since they lack the nipples present on other mammals.

Figure 10.15: The echidna is a member of the monotremes, the most primitive order of mammals.

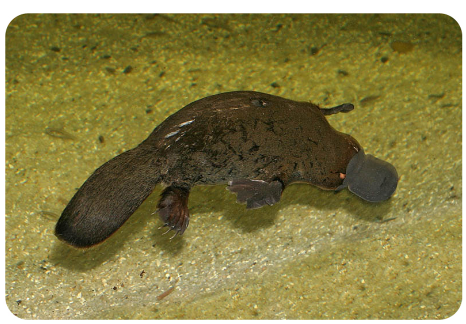

Figure 10.16: Another monotreme, the platypus, like other mammals in this order, lays eggs and has a single opening for the urinary, genital, and digestive organs.

All other mammals give birth to live young and belong to one of two different categories:

1. **Marsupial**: most female marsupials have an abdominal pouch or skin fold where there are mammary glands and a place for raising the young (**Figure** 10.17).
2. **Placental**: female placentals have a placenta that feeds the fetus and removes waste products.

Some mammals are alone until a female can become pregnant. Others form social groups with big differences between sexes, a trait called **sexual dimorphism**. Dominant males are those that are largest or best-armed. These males usually have an advantage in mating. They may also keep other males from mating with females within a group. This is seen in elephant seals (**Figure** 10.18). This group of females is called a **harem**.

Figure 10.17: A marsupial mammal, this Eastern grey kangaroo has a joey (young kangaroo) in its abdominal pouch.

Figure 10.18: A mating system with a harem of many females and one male, as seen in the seal species. Think back to what you learned about courtship displays in birds. How is such conduct in mammals similar or different?

Groups of Mammals

As is true for most animal groups, mammal groups can be characterized a number of ways: according to their anatomy, the habitats where they live, or their feeding habits.

Most mammals belong to the placental group. Within this group are several subgroups including:

1. Lagomorphs, such as hares and rabbits.
2. Rodents, including rats, mice and other small, gnawing mammals.
3. Carnivores, such as cats, dogs, bears and other meat eaters (**Figure** 10.19).
4. Insectivores, including moles and shrews (**Figure** 10.20).
5. Bats and primates.
6. Ungulates, including hoofed animals such deer, sheep, goats, pigs, buffalo and elephants, as well as marine mammals, such as whales and manatees (**Figure** 10.21).

Figure 10.19: A caracal, hunting in the Serengeti.

Figure 10.20: One of the subgroups of placental mammals is the insectivores, including moles and shrews. Pictured here is the Northern short-tailed shrew.

Why do you think the above groups of animals are placed together? Can you think of some examples of tooth type that are adapted for a mammal's diet? Or types of limbs that are adapted for living in different types of habitats?

Mammals can also be grouped according to the adaptations they form to live in a certain habitat.

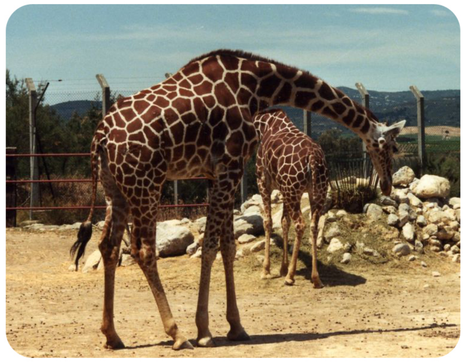

Figure 10.21: The ungulates (hoofed animals), like the giraffe here, is one of the subgroups belonging to the placental mammals.

For example, terrestrial mammals with leaping kinds of movement, as in some marsupials and in lagomorphs, typically live in open habitats. Other terrestrial mammals are adapted for running, such as dogs or horses.

Still others, such as elephants, hippopotamuses, and rhinoceroses, move slowly.

Other mammals are adapted for living in trees, such as many monkeys (**Figure** 10.22). Others live in water, such as manatees, whales, dolphins, and seals. Still others are adapted for flight, like bats, or for gliding, like some marsupials and rodents.

Figure 10.22: This howler monkey shows adaptations for an arboreal existence.

Importance of Mammals

Mammals are significant in the ways they benefit people, the economy, and ecosystems. Ecologically, nectar-feeding and fruit-eating bats (**Figure** 10.23) play an important role in plant pollination and seed dispersal, respectively.

Figure 10.23: Bats, like this Egyptian fruit bat, belong to another subgroup of placental mammals. Ecologically, fruit bats play an important role in seed dispersal.

Importance to Humans

We see examples of mammals (other than people!) serving our needs everywhere. We have pets that are mammals, most commonly dogs and cats. Mammals are also used for transport (horses, donkeys, mules, and camels), food (cows and goats), and work (dogs, horses, and elephants). See a working dog in **Figure** 10.24.

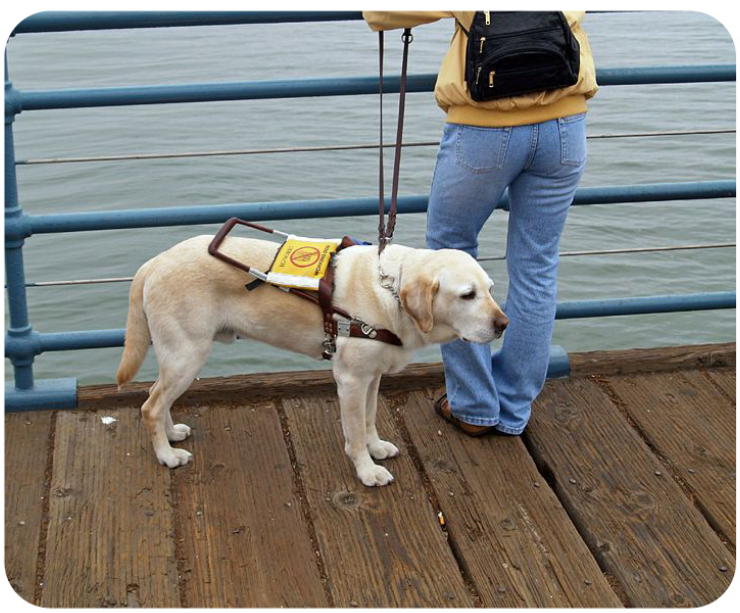

Figure 10.24: A Labrador retriever working as an assistance dog.

Mammals' more highly developed brains have made them ideal for use by scientists in studying such things as learning, as seen in maze studies of mice and rats.

Cultural Importance

Mammals have also played a significant role in different cultures' folklore and religion. For example, the grace and power of the cougar have been admired in the cultures of the native peoples of the Americas. The Inca city of Cuzco is designed in the shape of a cougar, and the thunder god of the Inca, Viracocha, has been associated with the animal. In North America, mythological descriptions of the cougar have appeared in stories of a number of Native American tribes.

Lesson Summary

- Organisms in the class Mammalia are distinguished by the presence of hair, sweat glands, three middle ear bones and a neocortex area in the brain.
- There is a lot of variation in mammalian reproductive systems. Mammals consist of both the egg-laying monotremes and those that are viviparous. The latter group includes marsupial and placental mammals.
- The 5,400 species of mammals can be grouped according to physical features as well as the type of habitat.
- Mammals have specific adaptations for living on land, in trees, in water and for flight.
- Non-primate mammals have an form important relationships with humans and play key ecological roles.

Review Questions

Recall

1. What are three main characteristics of mammals?

2. What are two ways that monotremes are different from viviparous mammals?

Apply Concepts

3. With respect to characteristics of feet, limbs and tails, what features would you expect mammals to have for:

- Jumping?
- Living in trees?

4. Give examples of two different adaptations of limbs in mammals, naming a mammal species, a structure, and how it is adapted.

Critical Thinking

5. Instead of beaks, as in birds, mammals have different kinds of teeth. Incisors are specialized for cutting and nipping, premolars for shearing and grinding, and canines for piercing. Based on what you know about mammal diets, name two mammal species, the kind of diet they eat, and one type of specialized teeth that would be best adapted for the diet.

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Points to Consider

Next we turn to primates.

- Think of some significant similarities between the mammals you read about in this lesson with those in the next lesson, particularly human beings.
- What do you think are some of the significant adaptations in the evolution of primates?

10.3 Primates and Humans

Lesson Objectives

- List and describe general traits of primates.
- Summarize mating systems of primates.
- Review the types of habitats primates can be found in.
- Describe the three main groupings of primates.
- List the traits of the hominids, their diet, reproduction and social system.

Check Your Understanding

- What are general traits of mammals?
- Describe the mating systems in mammals.

Vocabulary

- hybrid
- omnivorous
- pentadactyl
- quadrupedal

What are Primates?

If primates are mammals, what makes them seem so different? Primates, including humans, have several unique features only belonging to this group of mammals. Some adaptations give primates advantages that allow them to live in certain habitats, such as in trees. Other features have allowed them to adapt to complex social and cultural situations.

The biological order primates are mostly **omnivorous**, meaning they eat both plant and animal material. The order contains all of the species commonly related to the lemurs (**Figure** 10.25), monkeys (**Figure** 10.26) and apes (**Figure** 10.27). The order of primates includes humans (**Figure** 10.28).

Figure 10.25: A ring tailed lemur and twins. Lemurs belong to the prosimian group of primates.

Figure 10.26: One of the New World monkeys, a squirrel monkey.

Figure 10.27: Chimpanzees, pictured here, belong to the great apes, one of the groups of primates.

Key features of primates include:

- Five fingers, known as **pentadactyl**.
- Similar teeth.
- A nonspecialized body plan,
- Certain eye orbit characteristics, such as a **postorbital bar**, or a bone that runs around the eye socket.

Figure 10.28: Reconstruction of a Neanderthal man, belonging to an extinct subspecies of , humans, who are part of the great apes. This subspecies lived in Europe and western and central Asia from about 100,000 – 40,000 B.C.

An **opposable thumb** is a finger that allows a grip that can hold objects. While this opposable thumb is a characteristic feature of this group, other orders, such as opossums, also have this feature.

Big Brains

In intelligent mammals, such as primates, the cerebrum is larger compared to the rest of the brain. A larger cerebrum allows primates to develop higher level of intelligence. Primates have the ability to learn new behaviors. They also engage in complex social interactions, such as fighting and play.

Social Relationships

Old World species, such as apes and some monkeys as seen in **Figure** 10.27 and **Figure** 10.29), tend to have significant size differences between the sexes. This is known as sexual dimorphism. Males tend to be slightly more than twice as heavy as females. This dimorphism may have evolved when one male had to defend many females.

New World species, including tamarins (**Figure** 10.30) and marmosets (**Figure** 10.31), form pair bonds, which is a partnership between a mating pair that lasts at least one season. The pair cooperatively raise the young and generally do not show significant size difference between the sexes.

Where do Non-human Primates Live?

Non-human primates live mostly in Central and South America, Africa and South Asia. Since primates evolved from arboreal (living in trees) animals, many modern species live mostly in trees.

Other species live on land most of the time, such as baboons (**Figure** 10.32) and the Patas monkey. Only a few species live on land all of the time, for example, the gelada and humans.

Figure 10.29: An Old World monkey, a species of macaque, in Malaysia.

Figure 10.30: A New World species of monkey, a tamarin.

Figure 10.31: Another New World species of monkey, the common marmoset.

Primates live in a diverse number of forested habitats, including rain forests, mangrove forests and mountain forests to altitudes of over 9,800 feet. The combination of opposable thumbs, short fingernails and long, inward-closing fingers has allowed some species to develop **brachiation**, or the ability to move by swinging their arms from one branch to another (**Figure** 10.33). Another feature for climbing are expanded finger-like parts, such as those in tarsiers, which improve grasping (**Figure** 10.34).

A few species, such as the proboscis monkey, De Brazza's monkey and Allen's swamp monkey evolved webbed fingers so they can swim and live in swamps and aquatic habitats. Some species, such as the rhesus macaque and the Hanuman langur, can even live in cities by eating human garbage.

Figure 10.32: Baboons are partially terrestrial. Pictured here is a mother baboon and her young in Tanzania.

Primate Classification

The primate order is divided informally into three main groupings:

Figure 10.33: A gibbon shows how its limbs are modified for hanging from trees.

Figure 10.34: A species of tarsier, with expanded digits used for grasping branches.

1. **Prosimians**: The prosimians constitute species whose bodies most closely resemble that of the early proto-primates, the earliest examples of primates (**Figure** 10.35). Prosimians include the lemurs.
2. New World monkeys: The New World monkeys include the capuchin, howler and squirrel monkeys, who live exclusively in the Americas.
3. Old World monkeys and apes: The Old World monkeys and the apes (all except for humans, who inhabit the entire earth) inhabit Africa and southern and central Asia.

Figure 10.35: One of the prosimians, a greater bush baby, Kenya.

The Human Family

The great apes are the members of the biological family Hominidae, which includes four living genus: chimpanzees, gorillas, humans, and orangutans.

Characteristics

Hominids are large, tailless primates, ranging in size from the pygmy chimpanzee, at 66-88 pounds in weight, to the gorilla, at 300-400 pounds (**Figure** 10.36). In all species, the males are, on average, larger and stronger than the females.

Most living primate species are four-footed, but all are able to use their hands for gathering food or nesting materials. In some cases, hands are used as tools, such as when gorillas use sticks to measure the depth of water. Chimpanzees sharpen sticks to use as spears in hunting; they also use sticks to gather food and to "fish" for termites (**Figure** 10.37).

Most primate species eat both plants and meat (omnivorous), but fruit is the preferred food among all but humans. In contrast, humans eat a large amount of highly processed, low fiber foods, and unusual proportions of grains and vertebrate meat.

Human teeth and jaws are markedly smaller for our size than those of other apes. Humans may have been eating cooked food for a million years or more, so perhaps their teeth adapted to eating cooked food.

Gestation (pregnancy) lasts 8-9 months and usually results in the birth of a single offspring. The young are born helpless, and thus they need parental care for long periods of time.

Compared with most other mammals, great apes have a long adolescence and are not fully mature until 8-13 years of age (longer in humans). Females usually give birth only once every few years.

Gorillas and chimpanzees live in family groups of approximately five to ten individuals, although larger groups are sometimes observed. The groups include at least one dominant male, and females leave the group when they can mate. Orangutans, however, generally live alone.

Genetic and Behavioral Similarities

Gorillas, chimpanzees and humans are classified together in the subfamily, the Hominidae, because they have more than 97% of their DNA in common!

All organisms in the Hominidae also communicate with some kind of language or create simple cultures beyond the family or band (a group of animals functioning together).

Can you think of human characteristics that are unique to humans? Some say that only humans have the capacity for empathy, or the ability to understand and share the feelings of others. Do you think there are other characteristics that only humans have?

Figure 10.36: A gorilla mother and baby, members of the great apes, at Volcans National Park, Rwanda. The gorilla is the largest of the hominids, weighing up to 309-397 lbs.

Lesson Summary

- Primates are characterized by pentadactyly, similar teeth and certain eye orbit features. Primates also have opposable thumbs and a large cerebrum relative to the rest of the brain.
- Old World species tend to have significant sexual dimorphism, whereas New World species generally do not show significant sexual differences.
- Many primates live in a variety of forested habitats, whereas others are partially terrestrial, and some, like the gelada and humans, are fully terrestrial. A few species are adapted for living in aquatic habitats.
- There are three subgroups within the primates order: prosimians, including the lemurs; New World monkeys, and the Old World monkeys and the apes.
- The great apes, consisting of seven species, are large, tailless primates, with sexual dimorphism. Most species are quadrupedal, but all are able to use their hands.

Figure 10.37: Tool using in a primate. A chimpanzee uses a stick to "fish" for termites, and then, pictured here, extracts the insects.

- Most great apes are omnivorous, but fruit is the preferred food among all species but humans.
- The great apes have unique reproductive and parental care features, especially when compared with most other mammals.
- Gorillas, chimpanzees and humans share some common characteristics.

Review Questions

Recall

1. Name three characteristics of Primates?

2. What theory might explain why human teeth and jaws are smaller for our size than those of other apes?

Apply Concepts

3. All primates have opposable thumbs. List two ways in which non-human primates might use opposable thumbs.

4. Primates are thought to have developed several of their traits and habits while living in trees. What primate features might be an advantage in an arboreal (tree) habitat?

Critical Thinking

5. Gorillas and chimpanzees live in family groups of around five to 10 individuals. What might be two of their possible strategies for feeding, when fruit is hard to find?

Further Reading / Supplemental Links

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Points to Consider

The behavior of animals is next.

- What do you think the "behavior" of animals refers to? Give some examples.

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Chapter 11

MS Skin, Bones, and Muscles

What are human skeletons made out of? Bone. What is connected to the bone? Muscle. What layer rests on top of muscle to protect your body? Skin. Bones, muscle, and skin form the foundation of your body.

The person in the above figure is moving. How do his bones help him to move? How are his muscles working with his bones? What would happen if the he did not have skin? What would happen if his bones were removed? Human bodies cannot work without a collection of different tissues and organs. If you remove one, the others will not operate in the same way.

While reading this chapter, think about the individual functions of bones, muscles, and skin. But also remember to consider how they work together to form a whole human.

11.1 Organization of Your Body

Lesson Objectives

- List the levels of organization in the human body.
- Identify the four types of tissues that make up the body.
- Identify 12 organ systems.
- Describe how organs and organ systems work together to maintain homeostasis.

Check Your Understanding

- What is a cell?
- What are some of the differences between a prokaryotic cell and an eukaryotic cell?
- What are some of the basic functions of animal cells?

Vocabulary

- cardiovascular system
- connective tissue
- epithelial tissue
- feedback regulation
- muscular tissue
- negative feedback loop
- nervous tissue
- positive feedback loop

Cells, Tissues, Organs

Homeostasis

The men in **Figure** 11.1 just jumped into freezing icy water. They are having fun, but imagine how cold they must feel! What happens to their bodies when one moment they are warm and the next they are freezing? If their bodies are working right, they will begin to shiver. Shivering helps the body return to a stable temperature.

The ability of the body to maintain a stable internal environment in response to change is called homeostasis. Homeostasis allows your body to adapt to change. Change might be from jumping into cold water or running in hot weather. Or it might be from not getting enough food when you are hungry. Homeostasis is a very important characteristic of living things.

Homeostasis and Cells

Cells are the most basic units of life in your body. They must do many jobs to maintain homeostasis, but each cell does not have to do every job. Cells have specific jobs to maintain homeostasis. For example, nerve cells move electrical messages around the body, and white blood cells patrol the body and attack invading bacteria.

Figure 11.1: The bodies of these swimmers are working hard to maintain homeostasis while they are in the icy pool water. Otherwise, their life processes would stop working as soon as they got into the water.

There are many additional different types of cells. Other cells include red blood cells, skin cells, cells that line the inside of your stomach, and muscle cells.

Groups of Cells Form Tissues

Cells are grouped together to carry out specific functions. A group of cells that work together is called a tissue. Your body has four main types of tissues, as do the bodies of other animals. These tissues make up all structures and contents of your body. An example of each tissue type is shown in **Figure** 11.2.

1. **Epithelial tissue** is made up of layers of tightly packed cells that line the surfaces of the body. Examples of epithelial tissue include the skin, the lining of the mouth and nose, and the lining of the digestive system.
2. **Connective tissue** is made up of many different types of cells that are all involved in structure and support of the body. Examples include tendon, cartilage, and bone. Blood is also classified as a specialized connective tissue.
3. **Muscle tissue** is made up of bands of cells that contract and allow bodies to move. There are three types of muscle tissue: smooth muscle, skeletal muscle, and cardiac muscle.
4. **Nervous tissue** is made up of the nerve cells that together form the nervous system. Nervous tissue is found in nerves, the spinal cord, and the brain.

Groups of Tissues Form Organs

A single tissue alone cannot do all the jobs that are needed to keep you alive and healthy. Two or more tissues working together can do a lot more. An organ is a structure made of two or more tissues that work together. The heart, shown in **Figure** 11.3, is made up of the four types of tissues.

Groups of Organs Form Organ Systems

Your heart pumps blood around your body. But how does your heart get blood to and from every cell in your body? Your heart is connected to blood vessels such as veins and arteries. Organs that work together

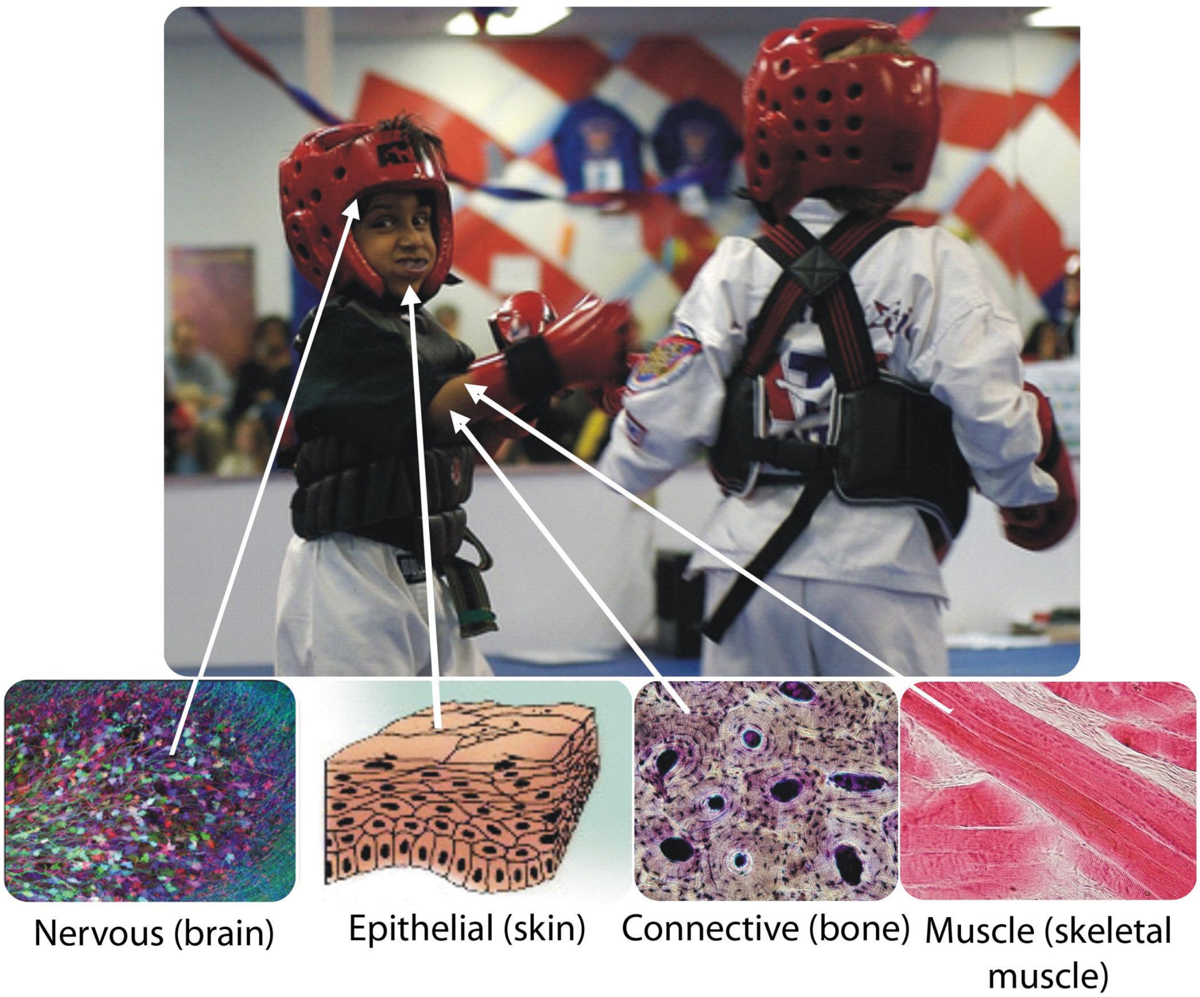


Figure 11.2: Your body has four main types of tissue: nervous tissue, epithelial tissue, connective tissue, and muscle tissue. They are found throughout your body.

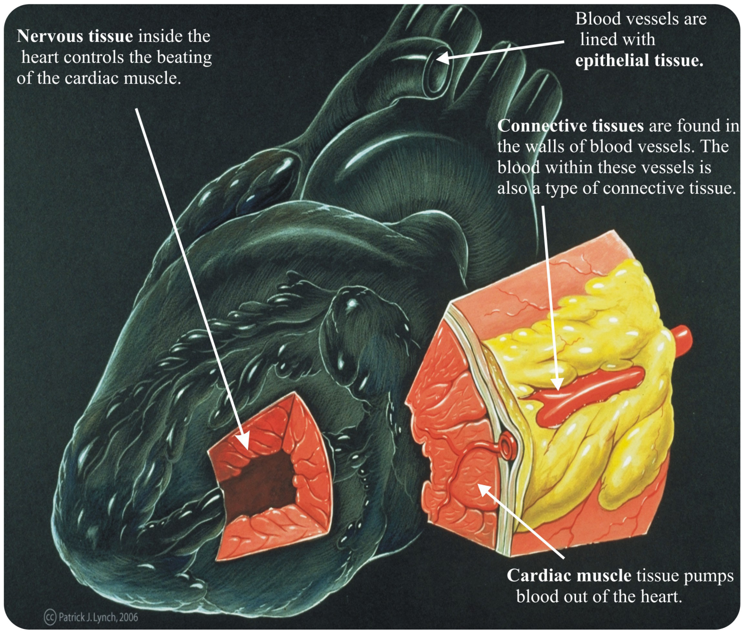


Figure 11.3: The four different tissue types work together in the heart as they do in the other organs.

form an organ system. Together, your heart, blood, and blood vessels form your **cardiovascular system**. What other organ systems can you think of?

Organ Systems Work Together

Your body's 12 organ systems are shown in **Table** 11.1. Your organ systems do not work alone in your body. They must all be able to work together to maintain homeostasis.

For example, when the men in **Figure** 11.1 jumped into the cold water, their integumentary system (skin), cardiovascular system, muscular system, and nervous system worked quickly together to ensure the icy water did not cause harm to their bodies.

For example, the nervous system sent nerve messages from the skin to tell the cardiovascular system to reduce the blood flow to the skin. Blood flow is then increased to the internal organs and large muscles to help keep them warm and supply them with oxygen. The nervous system also sent messages to the respiratory system to breathe faster. This allows for more oxygen to be delivered by the blood to the muscular system.

One of the most important functions of organ systems is to provide cells with oxygen and nutrients and to remove toxic waste products such as carbon dioxide. A number of organ systems, including the cardiovascular and respiratory systems, all work together to do this.

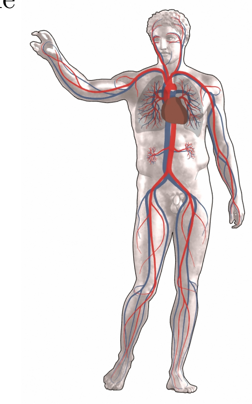
Table 11.1: **Major Organ Systems of the Human Body**

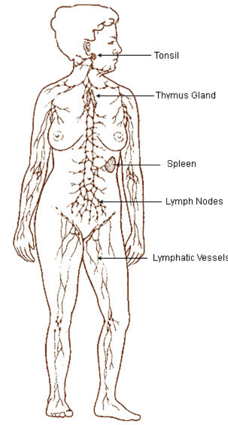
Organ System	Major Tissues and Organs	Function
Cardiovascular	Heart; blood vessels; blood	Transports oxygen, hormones and nutrients to the body cells. Moves wastes and carbon dioxide away from cells

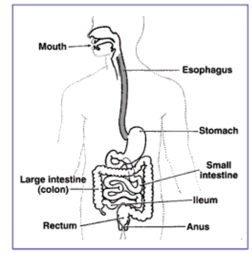
Table 11.1: (continued)

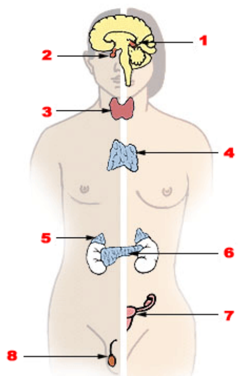
Organ System	Major Tissues and Organs	Function
Lymphatic	Lymph nodes; lymph vessels	Defense against infection and disease, moves lymph between tissues and the blood stream
Digestive	Esophagus; stomach; small intestine; large intestine	Digests foods and absorbs nutrients, minerals, vitamins, and water
Endocrine	Pituitary gland, hypothalamus; adrenal glands; Islets of Langerhans; ovaries; testes	Hormones communicate between cells to maintain homeostasis
Integumentary	Skin, hair, nails	Protection from injury and water loss; physical defense against infection by microorganisms; temperature control
Muscular	Cardiac (heart) muscle; skeletal muscle; smooth muscle; tendons	Movement, support, heat production
Nervous	Brain, spinal cord; nerves	Collects, transfers and processes information
Reproductive	Female: uterus; vagina; fallopian tubes; ovaries Male: penis; testes; seminal vesicles	Production of gametes (sex cells) and sex hormones; production of offspring
Respiratory	Trachea, larynx, pharynx, lungs	Brings air to sites where gas exchange can occur between the blood and cells (around body) or blood and air (lungs)
Skeletal	Bones, cartilage; ligaments	Supports and protects soft tissues of body; movement at joints; produces blood cells; stores minerals
Urinary	Kidneys; urinary bladder	Removes extra water, salts, and waste products from blood and body; control of pH; controls water and salt balance
Immune	Skin; bone marrow; spleen; white blood cells	Defense against diseases

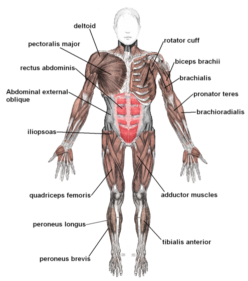
Organ System Cardiovascular Lymphatic Digestive Endocrine Integumentary Muscular Nervous Reproductive Respiratory Skeletal Urinary Immune Example

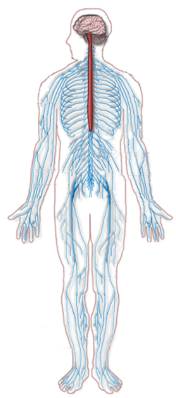


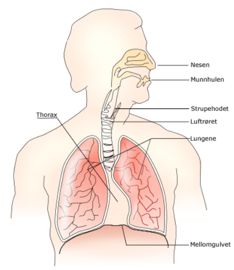


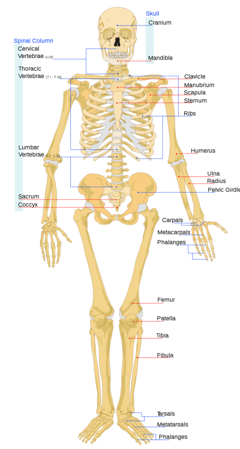


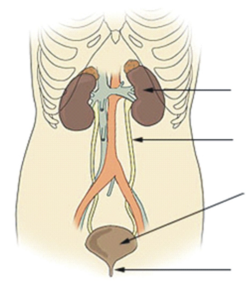












You can watch overviews of the human organ systems at the link below.

- http://www.youtube.com/watch?v=KidJ-2H0nyY&feature=player_embedded#!

Figure 11.4: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/489

Homeostasis and Feedback Regulation

As described above, homeostasis is an organism's ability to keep a constant internal environment. Keeping a stable internal environment requires constant adjustments as conditions change inside and outside of cells.

The endocrine system plays an important role in homeostasis because hormones, which are the messengers of the endocrine system, regulate the activity of body cells. The release of hormones into the blood is controlled by a stimulus, or signal. For example, the stimulus either causes an increase or a decrease in the amount of hormone released. Then, the response to the signal changes the internal conditions and may itself become a new stimulus. This kind of control is called feedback regulation or a feedback loop.

Feedback regulation occurs when the response to a stimulus has an effect of some kind on the original stimulus. The type of response determines what the feedback is called. Take the men jumping in the water as an example. When the nervous system reduced blood flow to the skin, this was caused by a feedback loop sensing the change in environment. Feedback loops return body systems back to "normal."

A **negative feedback loop** is one in which the response to a stimulus decreases the effect of the original stimulus. A **positive feedback loop** is one in which the response to a stimulus increases the original stimulus. These are explained in more detail below.

Thermoregulation: A Negative Feedback Loop

Negative feedback is the most common feedback loop in the body. Negative feedback decreases the effect of a stimulus on the body (**Figure** 11.5). For instance, if you get stuck in a smoky environment during a fire, the amount of carbon dioxide in your body will increase. In the negative feedback loop, your lungs will be signaled to increase your breathing rate and exhale more carbon dioxide. The effect is to reduce the amount of carbon dioxide in your body. You can remember that this is a negative feedback loop because you are decreasing the effect of the stimulus.

Thermoregulation is another example of negative feedback. When body temperature rises, receptors in the skin and the brain sense the temperature change. The temperature change triggers a command from the brain. This command causes a response — the skin makes sweat and blood vessels near the skin surface dilate. This response helps decrease body temperature.

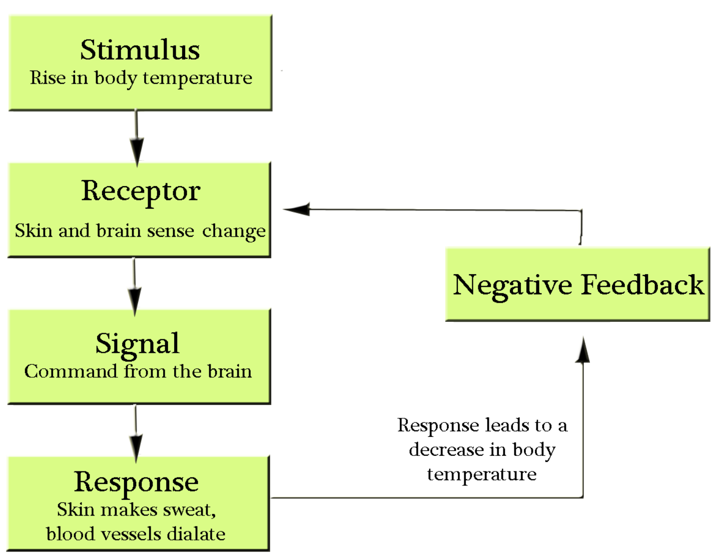


Figure 11.5: Feedback Regulation.

Positive feedback is less common than negative feedback. Positive feedback acts to increase the effect of a stimulus. An example of positive feedback is milk production. As the baby drinks its mother's milk, nerve messages from the mammary glands cause a hormone, prolactin, to be released. The more the baby suckles, the more prolactin is released, which causes more milk to be produced.

Lesson Summary

- The levels of organization in the human body include: cells, tissues, organs, and organ systems.
- A tissue is a group of cells that work together.
- An organ is made of two or more tissues that work together.
- Organs that work together make up organ systems.
- There are four tissue types in the body: epithelial tissue, connective tissue, muscle tissue, and nervous tissue.
- There are 12 major organ systems in the body.
- Organs and organ systems work together to maintain homeostasis.

Review Questions

Recall

1. What is homeostasis?

2. What are the four levels of organization in an organism?

3. List the four types of tissues that make up the human body.

Apply Concepts

4. What is the difference between a tissue and an organ?

5. Identify the organ system to which the following organs belong: skin, stomach, brain, lungs, and heart.

6. Give an example of how two organ systems work together to maintain homeostasis.

Critical Thinking

7. A classmate says that all four tissue types are never found together in an organ. Do you agree with your classmate? Explain your answer.

8. Why do you think an organ is able to do many more jobs than a single tissue?

Further Reading / Supplemental Links

- http://en.wikipedia.org/wiki/Tissue_%28biology%29

Points to Consider

The first system we will discuss is the integumentary system.

- What organs do you think makes up the integumentary system?
- What other body systems might the integumentary system work with to maintain homeostasis?

11.2 The Integumentary System

Lesson Objectives

- List the functions of skin.
- Describe the structure of skin.
- Describe the structure of hair and nails.
- Identify two types of skin problems.
- Describe two ways to take care of your skin.

Check Your Understanding

- What is homeostasis?
- What is epithelial tissue?

Vocabulary

- dermis
- epidermis
- integumentary system
- keratin
- melanin
- oil gland
- sunburn
- sweat gland

Your Skin and Homeostasis

Did you know that you see the largest organ in your body every day? You wash it, dry it, cover it up to stay warm or uncover it to cool off. In fact, you see it so often it is easy to forget the important role your skin plays in keeping you healthy.

Your skin is part of your **integumentary system** (**Figure** 11.6), which is the outer covering of your body. The integumentary system is made up of your skin, hair, and nails. Your integumentary system has many roles in homeostasis, including protection, the sense of touch, and controlling body temperature.

Functions of Skin

Your skin covers the entire outside of your body. Your skin is your body's largest organ, yet it is only about 2 millimeters thick. It has many important functions. The skin:

- Provides a barrier. It keeps organisms that could harm the body out. It stops water from leaving the body, and stops water from getting into the body.
- Controls body temperature. It does this by making sweat, a watery substance that cools the body when it evaporates.
- Gathers information about your environment. Special nerve endings in your skin sense heat, pressure, cold and pain.
- Helps the body get rid of some types of waste, which are removed in sweat.

Figure 11.6: Skin acts as a barrier that stops water and other things, like soap and dirt, from getting into your body.

- Acts as a sun block. A chemical called melanin is made by certain skin cells when they are exposed to sunlight. Melanin blocks sun light from getting to deeper layers of skin cells, which are easily damaged by sunlight.

Structure of Skin

Your skin is always exposed to your external environment, so it gets cut, scratched, and worn down. You also naturally shed many skin cells every day. Your body replaces damaged or missing skin cells by growing more of them. Did you know that the layer of skin you can see is actually dead? The dead cells are filled with a tough, waterproof protein called **keratin**. As the dead cells are shed or removed from the upper layer, they are replaced by the skin cells below them.

As you can see in **Figure** 11.7, two different layers make up the skin — the epidermis and the dermis. A fatty layer, called subcutaneous tissue, lies under the dermis, but it is not part of your skin.

The color, thickness and texture of skin vary over the body. There are two general types of skin:

1. Thin and hairy, which is the most common type on the body.
2. Thick and hairless, which is found on parts of the body that experience a lot of contact with the environment, such as the palms of the hands or the soles of the feet.

The Epidermis

The **epidermis** is the outermost layer of the skin. It forms the waterproof, protective wrap over the body's surface. The epidermis is divided into several layers of epithelial cells. The epithelial cells are formed by mitosis in the lowest layer. These cells move up through the layers of the epidermis to the top. Although the top layer of epidermis is only about as thick as a sheet of paper, it is made up of 25 to 30 layers of cells.

The epidermis also contains cells that produce melanin. **Melanin** is the brownish pigment that gives skin and hair their color. Melanin-producing cells are found in the bottom layer of the epidermis.

The epidermis does not have any blood vessels. The lower part of the epidermis receives blood by diffusion

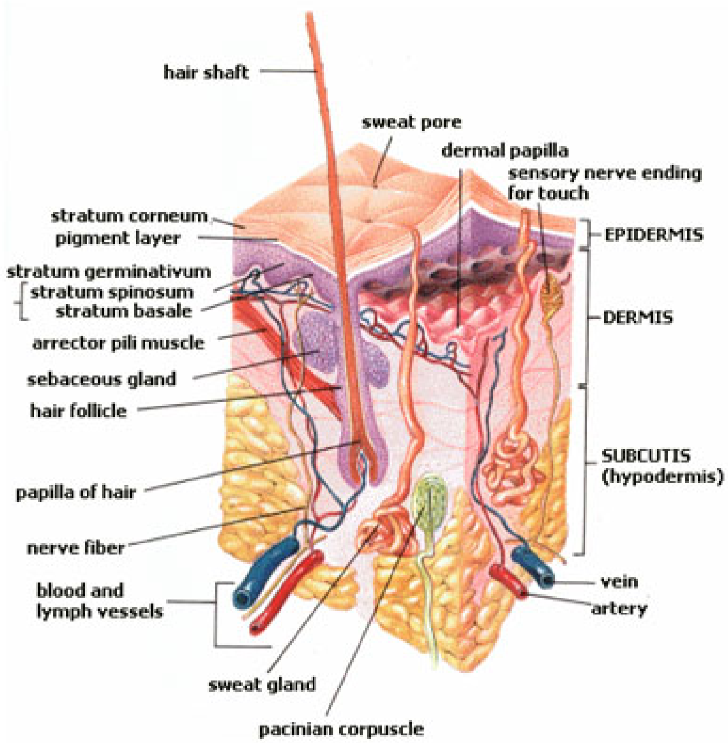


Figure 11.7: Skin is made up of two layers, the epidermis on top and the dermis below. The tissue below the dermis is called the hypodermis, but it is not part of the skin.

from blood vessels of the dermis.

The Dermis

The **dermis** is the layer of skin directly under the epidermis. It is made of a tough connective tissue that contains the protein collagen. Collagen is a long, fiber-like protein that is very strong. The dermis is tightly connected to the epidermis by a thin wall of collagen fibers.

As you can see in **Figure** 11.7, the dermis contains hair follicles, sweat glands, oil glands, and blood vessels. It also holds many nerve endings that give you your sense of touch, pressure, heat, and pain.

Do you ever notice how your hair stands up when you are cold or afraid? Tiny muscles in the dermis pull on hair follicles which cause hair to stand up. The resulting little bumps in the skin are commonly called "goosebumps," shown in **Figure** 11.8.

Oil Glands and Sweat Glands

Glands and follicles open out into the epidermis, but they start in the dermis. **Oil glands** release, or secrete, an oily substance, called sebum, into the hair follicle. An oil gland is shown in **Figure** 11.7. Sebum "waterproofs" hair and the skin surface to prevent them from drying out. It can also stop the growth of bacteria on the skin. It is odorless, but the breakdown of sebum by bacteria can cause odors. If an oil gland becomes plugged and infected, it develops into a pimple. Up to 85% of teenagers get pimples, which usually go away by adulthood. Frequent washing can help decrease the amount of sebum on the skin.

Figure 11.8: Goosebumps are caused by tiny muscles in the dermis that pull on hair follicles, which causes the hairs to stand up straight.

Sweat glands open to the skin surface through skin pores. They are found all over the body. Evaporation of sweat from the skin surface helps to lower skin temperature. This is why sweat can help maintain homeostasis. The skin also releases excess water, salts, and other wastes in sweat. A sweat gland is shown in **Figure** 11.7.

Nails and Hair

Nails and hair are made of the same types of cells that make up skin. Hair and nails contain the tough protein keratin.

Nails

Fingernails and toenails both grow from nail beds. A nailbed is thickened to form a lunula, or little moon, which you can see in **Figure** 11.9. Cells forming the nail bed are linked together to form the nail. As the nail grows, more cells are added at the nail bed. Older cells get pushed away from the nail bed and the nail grows longer. There are no nerve endings in the nail, which is a good thing, otherwise cutting your nails would hurt a lot!

Nails act as protective plates over the fingertips and toes. Fingernails also help in sensing the environment. The area under your nail has many nerve endings, which allow you to receive more information about objects you touch. Nails are made up of many different parts, as shown in **Figure** 11.9.

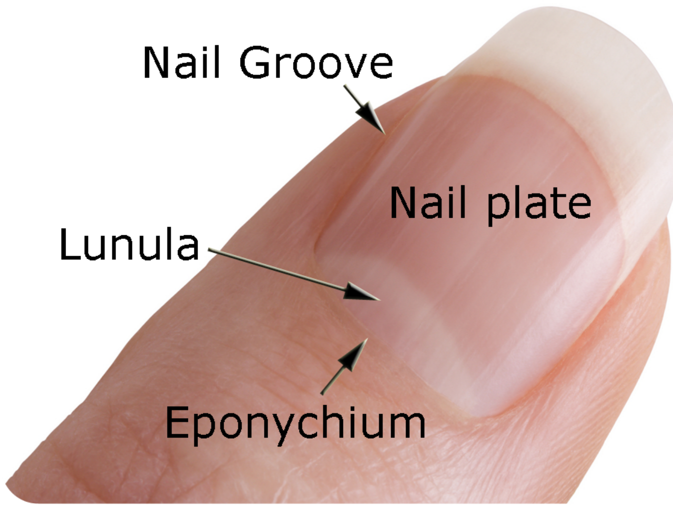


Figure 11.9: The structure of fingernails is similar to toenails. The free edge is the part of the nail that extends past the finger, beyond the nail plate. The nail plate is what we think of when we say "nail," the hard portion made of the tough protein keratin. The lunula is the crescent shaped whitish area of the nail bed. The cuticle is the fold of skin at the end of the nail.

Hair

Hair sticks out from the epidermis, but it grows from the dermis, as shown in **Figure** 11.10. Hair is also made of keratin, the same protein that makes up skin and nails. Hair grows from inside the hair follicle. New cells grow in the bottom part of the hair, called the bulb. Older cells get pushed up, and the hair grows longer. Similar to nails and skin, the cells that make up the hair strand are dead and filled with keratin.

Hair color is caused by different types of melanin in the hair cells. In general, the more melanin in the cells, the darker the hair color; the less melanin, the lighter the hair color.

Hair helps to keep the body warm. When you feel cold, your skin gets a little bumpy. These bumps are caused by tiny muscles that pull on the hair, causing the hair to stick out. The erect hairs help to trap a thin layer of air that is warmed by body heat. In mammals that have much more hair than humans, the hair traps a layer of warm air near the skin and acts like warm blanket. Hair also protects the skin from ultraviolet (UV) radiation from the sun.

Hair also acts as a filter. Nose hair helps to trap particles in the air that may otherwise travel to the lungs. Eyelashes shield eyes from dust and sunlight. Eyebrows stop salty sweat and rain from flowing into the eye.

Keeping Skin Healthy

Some sunlight is good for health. Vitamin D is made in the skin when it is exposed to sunlight. But getting too much sun can be unhealthy. A **sunburn** is a burn to the skin that is caused by overexposure to UV radiation from the sun's rays or tanning beds.

Light-skinned people, like the girl in **Figure** 11.11, get sunburned more quickly than people with darker skin. This is because melanin in the skin acts as a natural sunblock that helps to protect the body from UV radiation. When exposed to UV radiation, certain skin cells make melanin, which causes skin to tan.

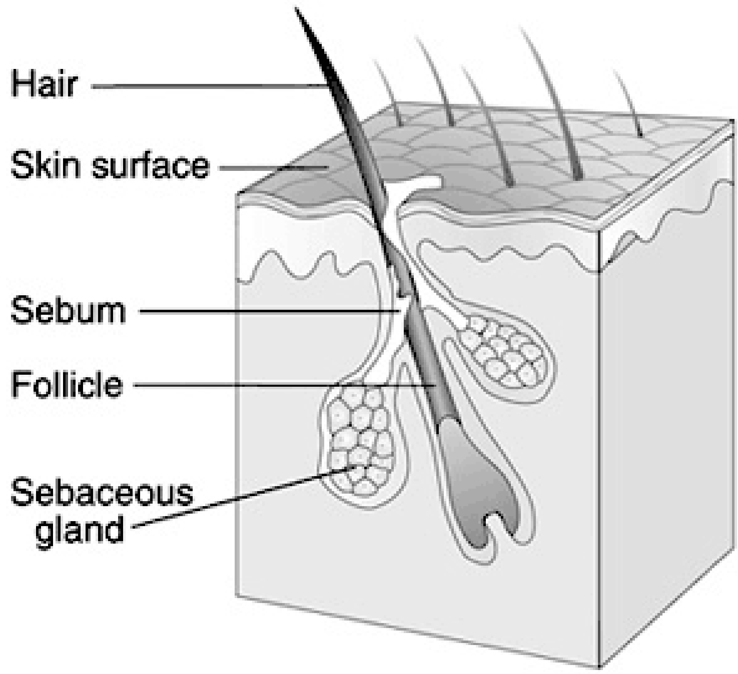


Figure 11.10: Hair, hair follicle, and oil glands. The oil, called sebum, helps to prevent water loss from the skin.

Children and teens who have gotten sunburned are at a greater risk of developing skin cancer later in life.

Long-term exposure to UV radiation is the leading cause of skin cancer. About 90 percent of skin cancers are linked to sun exposure. UV radiation damages the genetic material of skin cells. This damage can cause the skin cells to grow out of control and form a tumor. Some of these tumors are very difficult to cure. For this reason you should always wear sunscreen with a high sun protection factor (SPF), a hat, and clothing when out in the sun. As people age, their skin gets wrinkled. Wrinkles are caused mainly by UV radiation and by the loosening of the connective tissue in the dermis due to age.

Figure 11.11: Sunburn is caused by overexposure to UV rays. Getting sunburned as a child or a teen, especially sunburn that causes blistering, increases the risk of developing skin cancer later in life.

Bathing and Skin Hygiene

During the day, your skin can collect many different things. Sweat, oil, dirt, dust, and dead skin cells can build up on the skin surface. If not washed away, the mix of sweat, oil, dirt, and dead skin cells can encourage the excess growth of bacteria. These bacteria feed on these substances and cause a smell that is commonly called body odor. Dirty skin is also more prone to infection. Bathing every day helps to remove dirt, sweat and extra skin cells, and helps to keep your skin clean and healthy.

Injury

Your skin can heal itself even after a large cut. Cells that are damaged or cut away are replaced by cells that grow in the bottom layer of the epidermis and the dermis. When an injury cuts through the epidermis into the dermis, bleeding occurs. A blood clot and scab soon forms. After the scab is formed, cells at the bottom of the epidermis begin to divide by mitosis and move to the edges of the scab. A few days after the injury, the edges of the wound are pulled together.

If the cut is large enough, the production of new skin cells will not be able to heal the wound. Stitching the edges of the injured skin together can help the skin to repair itself. The person in **Figure** 11.12 had a large cut that needed to be stitched together. When the damaged cells and tissues have been replaced, the stitches can be removed.

Figure 11.12: Sewing the edges of a large cut together allows the body to repair the damaged cells and tissues, and heal the tear in the skin.

Lesson Summary

- Skin acts as a barrier that keeps particles and water out of the body.
- The skin helps to cool the body in hot temperatures, and keep the body warm in cool temperatures.
- Skin is made up of two layers, the epidermis and the dermis.

- Pimples occur when the skin produces too much sebum.
- Hair and nails are made of keratin, the same protein as skin.
- Nails grow from nail beds and hairs grow from hair follicles in the skin.
- Skin cancer can be caused by excess exposure to ultraviolet light from the sun or tanning beds.
- Frequent bathing helps keep the skin clean and healthy.
- Wearing sun block and a hat when outdoors can help prevent skin cancer.

Review Questions

Recall

1. Identify two functions of skin.
2. How does the integumentary system help maintain homeostasis?
3. What are the two layers of the skin?
4. Identify the layer of skin from which hair grows.
5. Name two functions of nails.
6. Name two functions of hair.

Apply Concepts

7. In what way are hair and nails similar to skin?
8. The skin makes too much sebum, what type of skin problem might this cause?
9. How does washing your skin help to keep you healthy?
10. Why are stitches sometimes needed if a person gets a deep or long cut in their skin?

Critical Thinking

11. The World Health Organization recommends that no person younger than 18 years old use a tanning bed. Why do you think using a tanning bed is not recommended?

Further Reading / Supplemental Links

- http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5540a9.htm
- http://www.cdc.gov/Features/SkinCancer
- http://en.wikipedia.org/wiki

Points to Consider

Next we turn to the skeletal system.

- How might what you eat affect your bones?
- What do you think is the most important function of your skeletal system?

11.3 The Skeletal System

Lesson Objectives

- Identify the main tissues and organs of the skeletal system.
- List four functions of the skeletal system.
- Describe three movable joints.
- Identify two nutrients that are important for a healthy skeletal system.
- Describe two skeletal system injuries.

Check Your Understanding

- What is an organ system?
- What is connective tissue?

Vocabulary

- ball and socket joint
- bone marrow
- cartilage
- fracture
- gliding joint
- hinge joint
- joint
- ligament
- movable joint
- pivot joint
- skeletal system
- skeleton
- sprain

Your Skeleton

How important is your skeleton? Can you imagine your body without it? You would be a wobbly pile of muscle and internal organs, and you would not be able to move.

Your skeleton is important for many different things. Bones are the main organs of the skeletal system. They are made up of living tissue. Humans are vertebrates, which are animals that have a backbone. The sturdy set of bones and cartilage that is found inside vertebrates is called a **skeleton**.

The adult human skeleton has 206 bones, some of which are named in **Figure** 11.13. Strangely, even though they are smaller, the skeletons of babies and children have many more bones and more cartilage than adults have. As a child grows, these "extra" bones grow into each other, and cartilage slowly hardens to become bone tissue.

Living bones are full of life. They contain many different types of tissues. **Cartilage** is found at the end of bones and is made of tough protein fibers called collagen. Cartilage creates smooth surfaces for the movement of bones that are next to each other, like the bones of the knee.

Ligaments are made of tough protein fibers and connect bones to each other. Your bones, cartilage, and ligaments make up your **skeletal system**.

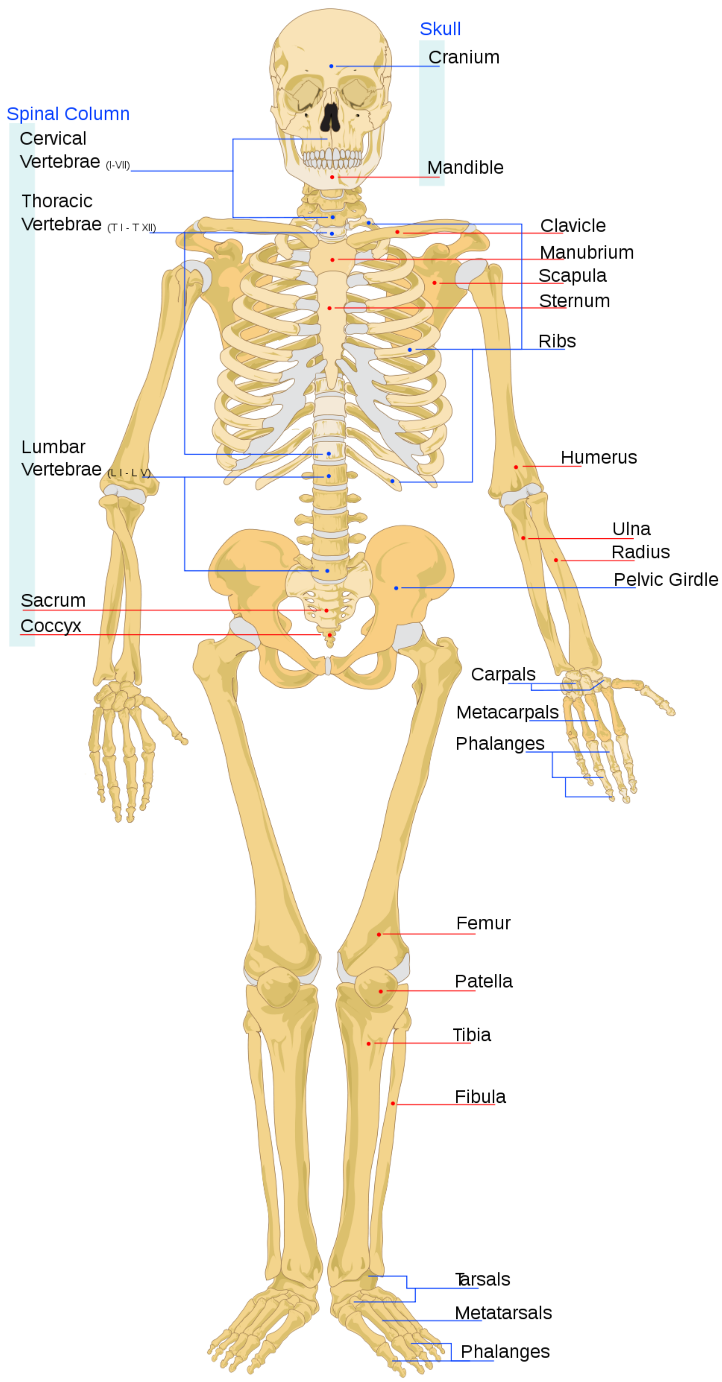


Figure 11.13: The skeletal system is made up of bones, cartilage, and ligaments. The skeletal system has many important functions in your body.

Functions of Bones

Your skeletal system gives shape and form to your body, but it is also important in maintaining homeostasis. The main functions of the skeletal system include:

- Support. The skeleton supports the body against the pull of gravity, meaning you don't fall over when you stand up. The large bones of the lower limbs support the rest of the body when standing.
- Protection. The skeleton supports and protects the soft organs of the body. For example, the skull surrounds the brain to protect it from injury. The bones of the rib cage help protect the heart and lungs.
- Movement. Bones work together with muscles to move the body.
- Making blood cells. Blood cells are mostly made inside certain types of bones.
- Storage. Bones store calcium. They contain more calcium than any other organ. Calcium is released by the bones when blood levels of calcium drop too low. The mineral phosphorus is also stored in bones.

Structure of Bones

Bones are organs. Recall that organs are made up of two or more types of tissues. Bones come in many different shapes and sizes, but they are all made of the same materials.

The two main types of bone tissue are compact bone and spongy bone.

- Compact bone makes up the dense outer layer of bones.
- Spongy bone is found at the center of the bone, and is lighter and less dense than compact bone.

Bones look tough, shiny, and white because they are covered by a layer called the periosteum. Many bones also contain a soft connective tissue called **bone marrow**. There are two types of bone marrow - red marrow and yellow marrow.

- Red marrow makes red blood cells, platelets, and most of the white blood cells for the body (discussed in the *Diseases and the Body's Defenses* chapter).
- Yellow marrow makes white blood cells.

The bones of newborn babies contain only red marrow. As children get older, some of their red marrow is replaced by yellow marrow. In adults, red marrow is found mostly in the bones of the skull, the ribs, and pelvic bones.

Bones come in four main shapes. They can be long, short, flat, or irregular. Identifying a bone as long, short, flat, or irregular is based on the shape of the bone, not the size of the bone. For example, both small and large bones can be classified as long bones. The small bones in your fingers and the largest bone in your body, the femur, are all long bones. The structure of a long bone is shown in **Figure** 11.14.

Bone Growth

Your skeleton begins growing very early in development. After only eight weeks of growth from a fertilized egg, your skeleton has been formed by cartilage and other connective tissues.

At this point your skeleton is very flexible. After a few more weeks of growth, the cells that form hard bone begin growing in the cartilage, and your skeleton begins to harden. Not all of the cartilage, however,

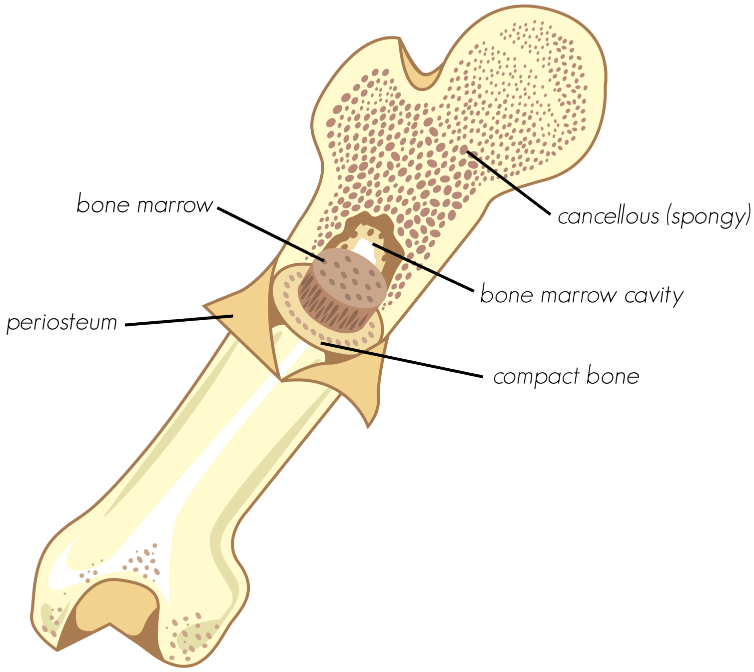


Figure 11.14: Bones are made up of different types of tissues.

is replaced by bone. Cartilage remains in many places in your body, including your joints, your rib cage, your ears, and the tip of your nose.

A baby is born with zones of cartilage in its bones that allow growth of the bones. These areas, called growth plate, allow the bones to grow longer as the child grows. By the time the child reaches an age of about 18 to 25 years, all of the cartilage in the growth plate has been replaced by bone. This stops the bone from growing any longer.

Even though bones stop growing in length in early adulthood, they can continue to increase in thickness throughout life. This thickening occurs in response to strain from increased muscle activity and from weight-lifting exercises.

Joints and How They Move

A **joint** is a point at which two or more bones meet. There are three types of joints in the body:

1. Fixed joints do not allow any bone movement. Many of the joints in your skull are fixed (**Figure** 11.15).
2. Partly movable joints allow only a little movement. Your backbone has partly movable joints between the vertebrae (**Figure** 11.16).
3. **Movable joints** allow movement.

Joints are a type of lever, which is a rigid object that is used to increase the amount of force put onto another object. Can openers and scissors are examples of levers. Joints reduce the amount of energy that is spent moving the body around. Just imagine how difficult it would be to walk about if you did not have knees!

Figure 11.15: The skull has fixed joints. Fixed joints do not allow any movement of the bones, which protects the brain from injury.

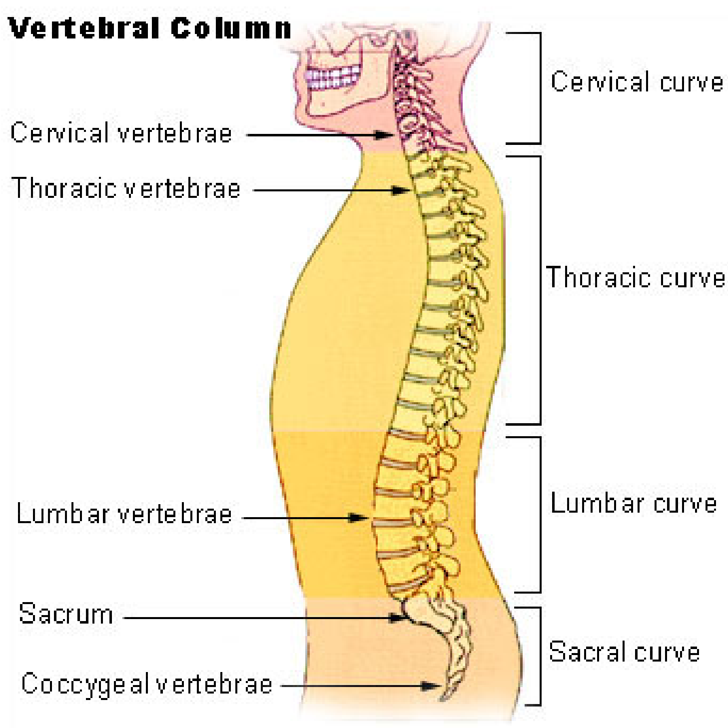


Figure 11.16: The joints between your vertebrae are partially movable.

Movable Joints

Movable joints are the most mobile joints of all. They are also the most common type of joint in your body. Your fingers, toes, hips, elbows, and knees all provide examples movable joints. The surfaces of bones at movable joints are covered with a smooth layer of cartilage. The space between the bones in a movable joint is filled with a liquid called synovial fluid. Synovial fluid is a thick, stringy fluid that looks like egg white. The fluid gives the bone a smooth cushion when they move at the joint. Four types of movable joints are shown below.

1. In a **ball and socket joint**, the ball-shaped surface of one bone fits into the cup-like shape of another. Examples of a ball and socket joint include the hip, shown in **Figure** 11.17, and the shoulder.

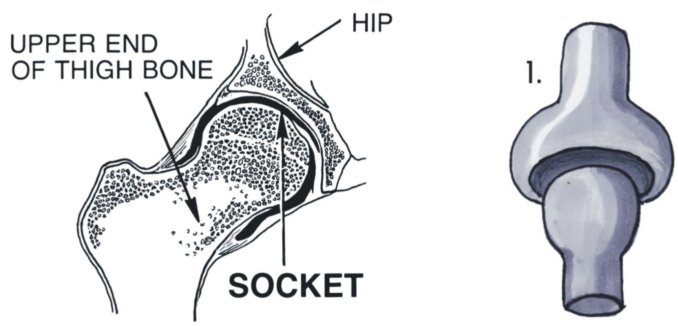


Figure 11.17: Ball and Socket Joint. Your hip joint is a ball and socket joint. The "ball" end of one bone fits into the "socket" of another bone. These joints can move in many different directions.

2. In a **hinge joint**, the ends of the bones are shaped in a way that allows motion only in two directions, forward and backward. Examples of hinge joints are the knees and elbows. A knee joint is shown in **Figure** 11.18.

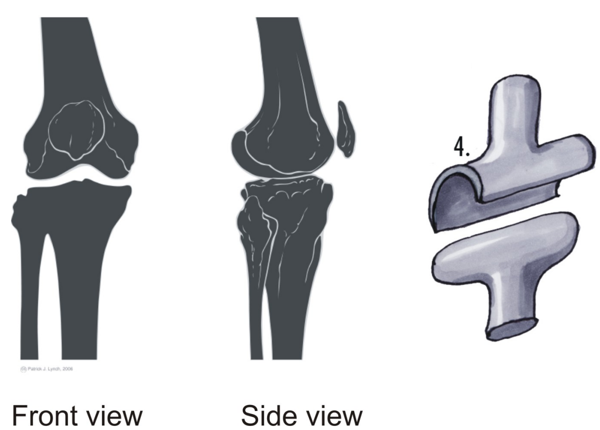


Figure 11.18: Hinge Joint. The knee joint is a hinge joint. Like a door hinge, a hinge joint allows backward and forward movement.

3. The **pivot joint** is formed by a process that rotates within a ring, the ring being formed partly of bone and partly of ligament. An example of a pivot joint is the joint between the radius and ulna that allows you to turn the palm of your hand up and down. A pivot joint is shown in **Figure** 11.19.

4. A **gliding joint** is a joint which allows only gliding movement. The gliding joint allows one bone to

slide over the other. The gliding joint in your wrist allows you to flex your wrist. It also allows you to make very small side-to-side motions. There are also gliding joints in your ankles.

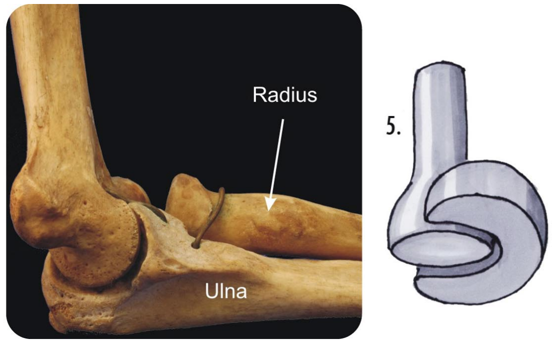


Figure 11.19: Pivot Joint. The joint at which the radius and ulna meet is a pivot joint. Movement at this joint allows you to flip your palm over without moving your elbow joint.

Keeping Bones and Joints Healthy

Your body depends on you to take care of it, just like you may take care of a plant or a dog. You can help keep your bones and skeletal system healthy by eating well and getting enough exercise. Weight-bearing exercises help keep bones strong. Weight-bearing exercises work against gravity. Such activities include basketball, tennis, gymnastics, karate, running, and walking. When the body is exercised regularly by performing weight-bearing activity, bones respond by adding more bone cells to increase their bone density.

Eating Well

Did you know that what you eat as a teenager can affect how healthy your skeletal system will be in 30, 40, and even 50 years? Calcium and vitamin D are two of the most important nutrients for a healthy skeletal system. Your bones need calcium to grow properly. If you do not get enough calcium in your diet as a teenager, your bones may become weak and break easily later in life.

Osteoporosis is a disease in which bones become lighter and more porous than they should be. Light and porous bones are more likely to break, which can cause pain and prevent a person from walking. Two of the easiest ways to prevent osteoporosis are eating a healthy diet that has the right amount of calcium and vitamin D, and to do some sort of weight-bearing exercise every day. Foods that are a good source of calcium include milk, yogurt, and cheese. Non-dairy sources of calcium include Chinese cabbage, kale, and broccoli. Many fruit juices, fruit drinks, tofu, and cereals have calcium added to them. It is recommended that teenagers get 1300 mg of calcium every day. For example, one cup of milk provides about 300 mg of calcium, or about 30% of the daily requirement. Other sources of calcium are shown in **Figure** 11.20.

Your skin makes vitamin D when exposed to sunlight. The pigment melanin in the skin acts like a filter that can prevent the skin from making vitamin D. As a result, people with darker skin need more time in the sun than people with lighter skin to make the same amount of vitamin D.

Fish is naturally rich in vitamin D. Vitamin D is added to other foods, including milk, soy milk, and breakfast cereals. Teenagers are recommended to get 5 micrograms (200 IU) of vitamin D every day. A 3½-ounce portion of cooked salmon provides 360 IU of vitamin D.

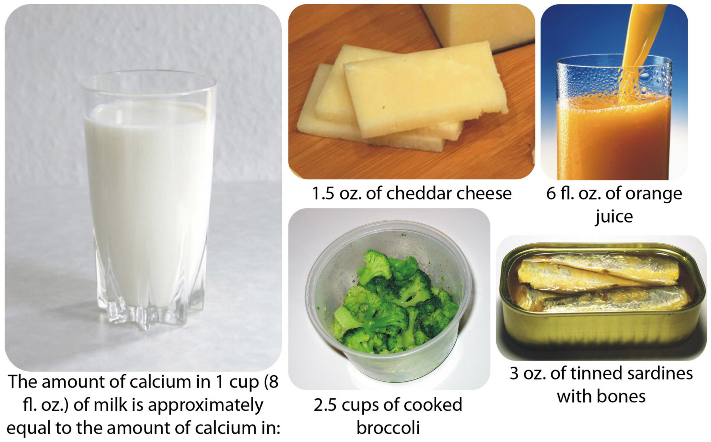


Figure 11.20: There are many different sources of calcium. Getting enough calcium in your daily diet is important for good bone health. How many ounces of cheddar cheese would provide your recommended daily intake of calcium?

Bone Fractures

Even though they are very strong, bones can **fracture**, or break. Fractures can happen at different places on a bone. They are usually caused by excess bending stress on the bone. Bending stress is what causes a pencil to break if you bend it too far.

Soon after a fracture, the body begins to repair the break. The area becomes swollen and sore. Within a few days bone cells travel to the break site and begin to rebuild the bone. It takes about two to three months before compact and spongy bone form at the break site. Sometimes the body needs extra help in repairing a broken bone. In such a case a surgeon will piece a broken bone together with metal pins. Moving the broken pieces together will help keep the bone from moving, and give the body a chance to repair the break. A broken ulna has been repaired with pins in **Figure** 11.21.

Cartilage Injuries

Osteoarthritis occurs when the cartilage at the ends of the bones breaks down. The break down of the cartilage leads to pain and stiffness in the joint. Decreased movement of the joint because of the pain may lead to weakening of the muscles that normally move the joint, and the ligaments surrounding the joint may become looser. Osteoarthritis is the most common form of arthritis. It has many causes, including aging, sport injuries, fractures, and obesity.

Ligament Injuries

Recall that a ligament is a short band of tough connective tissue that connects bones together to form a joint. Ligaments can get injured when a joint gets twisted or bends too far. The protein fibers that make up a ligament can get strained or torn, causing swelling and pain. Injuries to ligaments are called **sprains**. Ankle sprains are a common type of sprain. A sprain of the anterior cruciform ligament (ACL), a small ligament in the knee, is a common injury among athletes. Ligament injuries can take a long time to heal. Treatment of the injury includes rest and special exercises that are developed by a physical therapist.

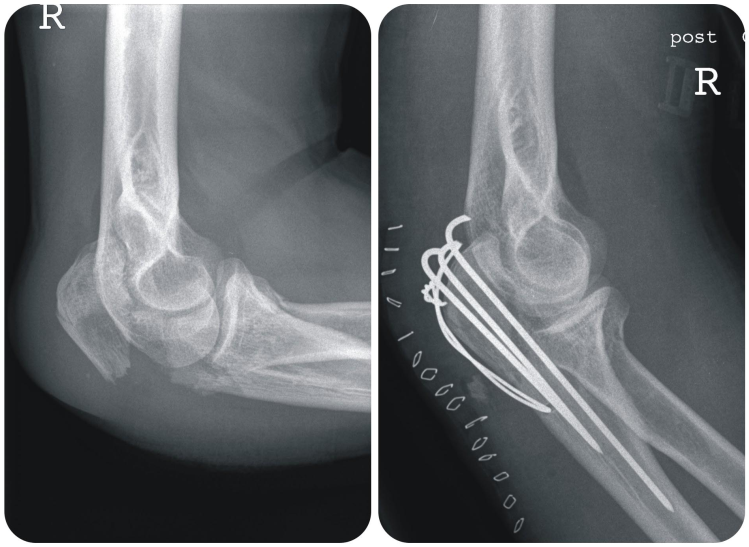


Figure 11.21: The upper part of the ulna, just above the elbow joint, is broken, as you can see in the X-ray at left. The x-ray at right was taken after a surgeon inserted a system of pins and wires across the fracture to bring the two pieces of the ulna into close proximity.

Preventing Injuries

Preventing injuries to your bones and ligaments is easier and much less painful than treating an injury. Wearing the correct safety equipment when performing activities that require such equipment can help prevent many common injuries. For example, wearing a bicycle helmet can help prevent a skull injury if you fall. Warming up and cooling down properly can help prevent ligament and muscle injuries. Stretching before and after activity also helps prevent injuries. Stretching can improve your posture, and helps prevent some aches and pains associated with tight muscles.

Lesson Summary

- Bones, cartilage, and ligaments make up the skeletal system.
- The skeleton supports the body against the pull of gravity.
- The skeleton provides a framework that supports and protects the soft organs of the body.
- Bones work together with muscles to move the body.
- Blood cells are mostly made inside the bone marrow.
- There are three types of joints in the body: fixed, partly movable, and movable.
- Calcium and vitamin D are two of the most important nutrients for a healthy skeletal system.
- The break down of the cartilage leads to pain and stiffness in the joint.
- A sprain is an injury to a ligament.
- A fracture is a break or crack in a bone.

Review Questions

Recall

1. What are the main organs of the skeletal system?

2. Name one tissue of the skeletal system.

3. List four functions of the skeletal system.

4. Name three types of movable joints.

5. Name two things you can do to keep your skeletal system healthy.

Apply Concepts

6. "All joints in the body are movable." Do you agree with this statement? Explain why or why not.

7. How are the joints in your body similar to levers?

8. Why is calcium important for a healthy skeletal system?

9. The recommended daily amount of calcium for teenagers is 1300 mg. If a person gets only 1000 mg a day, what percentage of the recommended daily amount are they getting?

10. What part of the skeletal system does osteoarthritis affect?

11. Why might a doctor need to insert pins into a broken bone?

Critical Thinking

12. You are a doctor. An athlete comes to you with a torn ACL and asks you to give him a cast. Tell him why that is not the correct treatment for his injury.

Further Reading / Supplemental Links

- http://www.girlshealth.gov/bones
- [http://www.cdc.gov/nccdphp/dnpa/nutrition/nutrition_for_everyone/basics/calcium.htm http://www.cdc.gov/nccdphp/dnpa/nutrition/nutrition_for_everyone/basics/calcium.htm
- http://en.wikipedia.org/wiki

Points to Consider

Next we discuss the muscular system.

- How do you think your skeletal system interacts with your muscular system?
- How could a broken bone affect the functioning of the muscular system?

11.4 The Muscular System

Lesson Objectives

- Identify the three muscle types in the body.
- Describe how skeletal muscles and bones work together to move the body.
- Describe how exercise affects the muscular system.
- Identify two types of injuries to the muscular system.

Check Your Understanding

- What is muscle tissue?
- What is the function of the muscular system?

Vocabulary

- aerobic exercises
- anaerobic exercises
- cardiac muscle
- contraction
- extensor
- flexor
- involuntary muscle
- muscle fibers
- muscular system
- physical fitness
- skeletal muscle
- smooth muscle
- strain
- tendon
- voluntary muscle

Types of Muscles

The **muscular system** is the body system that allows us to move. You depend on many muscles to keep you alive. Your heart, which is mostly muscle, pumps blood around your body. Muscles are always moving in your body.

Each muscle in the body is made up of cells called muscle fibers. **Muscle fibers** are long, thin cells that can do something that other cells cannot do — they are able to get shorter. Shortening of muscle fibers is called **contraction**. Nearly all movement in the body is the result of muscle contraction.

Certain muscle movements happen without you thinking about them, while you can control other muscle movements. Muscles that you can control are called **voluntary muscles**. Muscles that you cannot control are called **involuntary muscles**.

There are three different types of muscles in the body (**Figure** 11.22):

1. **Skeletal muscle** is made up of voluntary muscles, usually attached to the skeleton. Skeletal muscles move the body. They can also contract involuntarily by reflexes. For example, you can choose to move your arm, but your arm would move automatically if you were to burn your finger on a stove top.
2. **Smooth muscle** is composed of involuntary muscles found within the walls of organs and structures such as the esophagus, stomach, intestines, and blood vessels. Unlike skeletal muscle, smooth muscle can never be under your control.
3. **Cardiac muscle** is also an involuntary muscle, found only in the heart.

Figure 11.22: There are three types of muscles in the body: cardiac, skeletal, and smooth. Everyone has the same three types of muscle tissue, no matter their age.

Muscles, Bones, and Movement

Skeletal muscles are attached to the skeleton by tendons. A **tendon** is a tough band of connective tissue that connects a muscle to a bone. Tendons are similar to ligaments, except that ligaments join bones to each other.

Muscles move the body by contracting against the skeleton. When muscles contract, they get shorter. When they relax, they get longer. By contracting and relaxing, muscles pull on bones and allow the body to move. Muscles work together in pairs. Each muscle in the pair works against the other to move bones at the joints of the body. The muscle that contracts to cause a joint to bend is called the **flexor**. The muscle that contracts to cause the joint to straighten is called the **extensor**.

For example, the biceps and triceps muscles work together to allow you to bend and straighten your elbow. Your biceps muscle, shown in **Figure** 11.23, contracts, and at the same time the triceps muscle relaxes. The biceps is the flexor and the triceps is the extensor of your elbow joint. In this way the joints of your body act like levers. This lever action of your joints decreases the amount of energy you have to spend to make large body movements.

Muscles and the Nervous System

Muscles are controlled by the nervous system (see the *Controlling the Body* chapter). Nerves send messages to the muscular system from the brain. Nerves also send messages to the brain from the muscles. For example, when you want to move your foot, electrical messages called impulses move along nerve cells from your brain to the muscles of your foot. At the point at which the nerve cell and muscle cells meet, the electrical message is converted to a chemical message. The muscle cells receive the chemical message, which causes tiny protein fibers inside the muscle cells to get shorter. The muscles contract, pulling on the bones, and your foot moves.

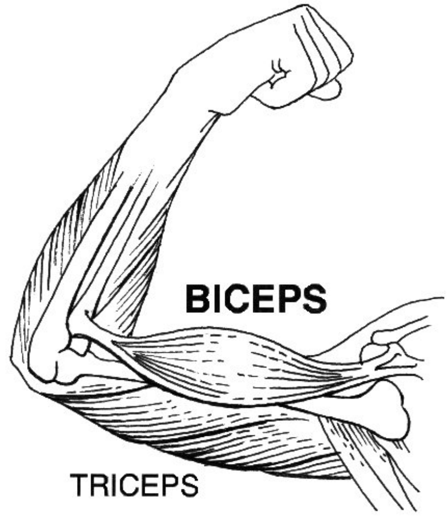


Figure 11.23: The biceps and triceps act against one another to bend and straighten the elbow joint. To bend the elbow, the biceps contract and the triceps relax. To straighten the elbow, the triceps contract and the biceps relax.

Muscles and Exercise

Your muscles are important for carrying out everyday activities. The ability of your body to carry out your daily activities without getting out of breath, sore, or overly tired is called **physical fitness**. Physical exercise is any activity that maintains or improves physical fitness and overall health. Regular physical exercise is important in preventing lifestyle diseases such as heart disease, cardiovascular disease, Type 2 diabetes, and obesity. Regular exercise improves the health of the muscular system. Muscles that are exercised are bigger and stronger than muscles that are not exercised.

Exercise improves both muscular strength and muscular endurance. Muscular strength is the ability of a muscle to use force during a contraction. Muscular endurance is the ability of a muscle to continue to contract over a long time without getting tired.

Exercises are grouped into three types depending on the effect they have on the body:

- **Aerobic exercises**, such as cycling, walking, and running, increase muscular endurance.
- **Anaerobic exercises**, such as weight training or sprinting, increase muscle strength.
- Flexibility exercises, such as stretching, improve the range of motion of muscles and joints. Regular stretching helps avoid activity-related injuries.

Anaerobic Exercise and Muscular Strength

Anaerobic exercises cause muscles to get bigger and stronger. Anaerobic exercises use a resistance against which the muscle has to work to lift or push away. The resistance can be a weight or a person's own body weight, as shown in **Figure** 11.24. After many muscle contractions, muscle fibers build up larger energy stores and the muscle tissue gets bigger. The larger a muscle is, the greater the force it can apply to lift a weight or move a body joint. The muscles of weightlifters are large and strong.

Figure 11.24: Anaerobic exercises involve the muscles working against resistance. In this case the resistance is the person's own body weight.

Aerobic Exercise and Muscular Endurance

Aerobic exercises are exercises that cause your heart to beat faster and allow your muscles to use oxygen to contract. Aerobic exercise causes many different changes in skeletal muscle. Muscle energy stores are increased and the ability to use oxygen improves. If you exercise aerobically, overtime, your muscles will not get easily tired and you will use oxygen and food more efficiently. Aerobic exercise also helps improve cardiac muscle. Overtime, the heart muscles will increase in size and be able to pump a larger volume of blood to your cells. Examples of an aerobic exercise are shown in **Figure** 11.25.

Figure 11.25: When done regularly, aerobic activities such as cycling, make the heart stronger.

Muscle Injuries

Sometimes muscles and tendons get injured when a person starts doing an activity before they have warmed up properly. A warm up is a slow increase in the intensity of a physical activity that prepares muscles for an activity. Warming up increases the blood flow to the muscles and increases the heart rate. Warmed-up muscles and tendons are less likely to get injured. For example, before running or playing soccer, a person might jog slowly to warm muscles and increase their heart rate. Even elite athletes need to warm up, as shown in **Figure** 11.26.

A **strain** happens when muscle fibers tear because the muscle contracts too much or contracts before the muscle is warmed up. Strains are also known as "pulled muscles." Some injuries are caused by overuse. An overuse injury happens if the muscle or joint is not rested enough between activities. Overuse injuries often involve tendons. Overuse of tendons can cause tiny tears within the protein fibers of the tendon. These tiny tears lead to swelling, pain, and stiffness, a condition called tendinitis. Tendinitis can affect any tendon that is overused. Strains and tendinitis are usually treated with rest, cold compresses, and stretching exercises that a physical therapist designs for each patient.

Figure 11.26: Warming up before the game helps the players avoid injuries. Some warm-ups may include stretching exercises. Some researchers believe stretching before activities may help prevent injury.

Proper rest and recovery are also as important to health as exercise is. If you do not get enough rest, your body will become injured and will not improve or react well to exercise. You can also rest by doing a different activity. For example, if you run, you can rest your running muscles and joints by swimming. This type of rest is called ”active rest.”

Steroids

Anabolic steroids are hormones that cause the body to build up more protein in its cells. Muscle cells, which contain a lot of protein, get bigger when exposed to anabolic steroids. Your body naturally makes small amounts of anabolic steroids. They help your body repair from injury, and help to build bones and muscles. Anabolic steroids are used as medicines to treat people that have illnesses that affect muscle and bone growth. But some athletes who do not need steroids take them to increase their muscle size. When taken in this way, anabolic steroids can have long-term affects other body systems. They can damage the person’s kidneys, heart, liver, and reproductive system. If taken by adolescents, anabolic steroids can cause bones to stop growing, resulting in stunted growth.

Lesson Summary

- The body has three types of muscle tissue: skeletal, smooth, and cardiac.
- Muscles move the body by contracting against the skeleton.
- Muscles are controlled by the nervous system.
- Regular exercise improves the health of the muscular system and makes muscles bigger and stronger.
- Muscular strength is the ability of a muscle to exert force during a contraction.
- Muscular endurance is the ability of a muscle to continue to contract over a long time without getting tired.
- A strain is an injury to a muscle in which the muscle fibers tear because the muscle contracts too much or contracts before the muscle is warmed up.

- Tiny tears and swelling in a tendon results in tendinitis.

Review Questions

Recall

1. Name the three types of muscle tissue in the body.
2. Which of the three types of muscles in the body is voluntary?
3. What is a tendon?
4. What is a muscle strain?

Apply Concepts

5. Describe how skeletal muscles and bones work together to move the body.
6. How does aerobic exercise affect the heart?
7. How does aerobic exercise affect skeletal muscle?
8. How does anaerobic exercise affect skeletal muscle?
9. Why is warming up before exercise a good idea?

Critical Thinking

10. A friend of yours says that taking steroids is not bad for their health because humans produce steroids in their body anyway. Can you explain to them why taking anabolic steroids is dangerous?

Further Reading / Supplemental Links

- http://www.cdc.gov/nccdphp/dnpa/physical/everyone/index.htm

Points to Consider

Next we move on to the digestive system.

- How does your muscular system depend on your digestive system?
- How does what you choose to eat affect your muscular system and your skeletal system?

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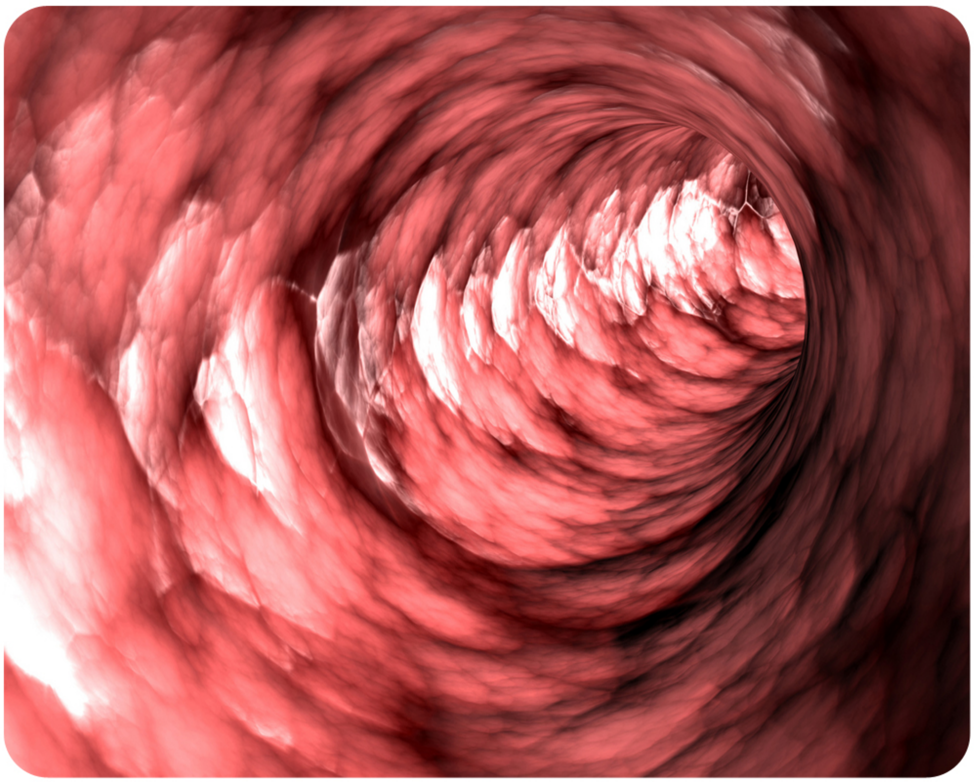
Chapter 12

MS Food and the Digestive System



The above image shows a close-up of the inside of a fleshy tunnel. Could it be an intestine? It could. Or it could be something else. But what is an intestine? It is an organ in the digestive system. The digestive system does what you think it does - it digests your food.

But does the inside of your intestine really look like a tunnel? Some would say an intestine looks more like a mountain range, with peaks and valleys. Why? The peaks and valleys would represent the villi that are inside of the intestines. They increase the surface area of the intestine so they can absorb as many nutrients as possible.

So what is another function of the digestive system? Absorption. What happens when you get sick? Does the digestive system work properly? What nutrients and vitamins do you need in order to make sure that your digestive system and your whole body works properly? What do the villi in the intestines have to do with these processes? As you read, think about the organs that help you digest and absorb the nutrients in your foods. Also, consider how healthy eating leads to healthy organ systems.

12.1 Food and Nutrients

Lesson Objectives

- Explain why the body needs food.
- Identify the roles of carbohydrates, proteins, and lipids.
- Give examples of vitamins and minerals, and state their functions.
- Explain why water is a nutrient.

Check Your Understanding

- What are the four types of organic compounds?
- What do all cells need in order to function?
- What are muscles made of?

Vocabulary

- calorie
- essential amino acid
- minerals
- nutrients
- starch
- trans fat
- vitamins

Why We Need Food

Did you ever hear the old saying "An apple a day keeps the doctor away"? Do apples really prevent you from getting sick? Probably not, but eating apples and other fresh fruits can help keep you healthy. The girl shown in **Figure** 12.1 is eating fresh vegetables as part of a healthy meal. Why do you need foods like these for good health? What role does food play in the body?

Figure 12.1: This girl is eating a salad of vegetables and leafy green vegetables. Fresh vegetables such as these are excellent food choices for good health.

Your body needs food for three reasons:

1. Food gives your body energy. You need energy for everything you do.
2. Food provides building materials for your body. Your body needs building materials so it can grow and repair itself.
3. Food contains substances that help control body processes. Your body processes must be kept in balance for good health.

For all these reasons, you must have a regular supply of nutrients. **Nutrients** are chemicals in food that your body needs. There are six types of nutrients:

1. Carbohydrates.
2. Proteins.
3. Lipids.
4. Vitamins.
5. Minerals.
6. Water.

Carbohydrates, proteins, and lipids give your body energy. Proteins provide building materials. Proteins, vitamins, and minerals help control body processes.

Nutrients that Provide Energy

Molecules of carbohydrates, proteins, and lipids contain energy. When your body digests food, it breaks down the molecules of these nutrients. This releases the energy so your body can use it. The energy in food is measured in units called **calories.**

Carbohydrates

Carbohydrates are nutrients that include sugars, starches, and fiber. How many grams of carbohydrates you need each day are shown in **Figure** 12.2. It also shows some foods that are good sources of carbohydrates.

There are two types of carbohydrates: simple and complex.

Simple Carbohydrates

Sugars are small, simple carbohydrates that are found in foods such as fruits and milk. The sugar found in fruits is called fructose. The sugar found in milk is called lactose. These sugars are broken down by the body to form glucose, the simplest sugar of all. Glucose is used by cells for energy.

Remember the discussion of cellular respiration in the *Cell Functions* chapter? Cellular respiration turns glucose into the usable form of chemical energy, ATP. One gram of sugar provides your body with four Calories of energy.

Some people cannot digest lactose, the sugar in milk. This condition is called lactose intolerance. If people with this condition drink milk, they may have cramping, bloating, and gas. To avoid these symptoms, they should not drink milk, or else they should drink special, lactose-free milk.

Complex Carbohydrates

Starch is a large, complex carbohydrate. Starches are found in foods such as vegetables and grains. Starches are broken down by the body into sugars that provide energy. Like sugar, one gram of starch provides your body with four calories of energy.

Fiber is another type of large, complex carbohydrate. Unlike sugars and starches, fiber does not provide energy. However, it has other important roles in the body. There are two types of fiber found in food: soluble fiber and insoluble fiber. Each type has a different role. Soluble fiber dissolves in water. It helps keep sugar and fat at normal levels in the blood. Insoluble fiber does not dissolve in water. As it moves

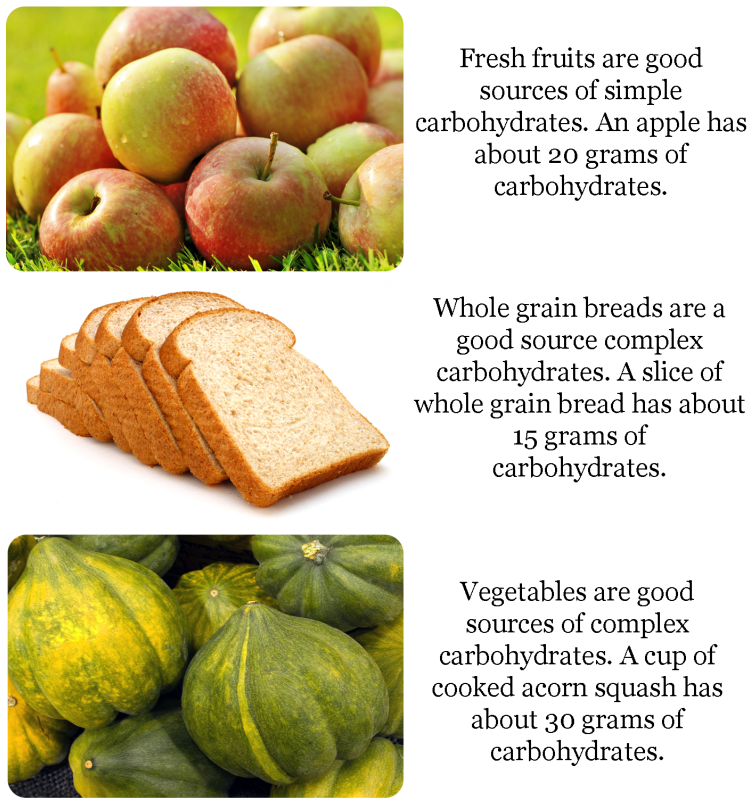


Figure 12.2: Up to the age of 13 years, you need about 130 grams of carbohydrates a day. Most of the carbohydrates should be complex. They are broken down by the body more slowly than simple carbohydrates. Therefore, they provide energy longer and more steadily. What other foods do you think are good sources of complex carbohydrates?

through the large intestine, it absorbs water. This helps keep food waste moist so it can pass easily out of the body.

Eating foods high in fiber helps fill you up without providing too many calories. Most fruits and vegetables are high in fiber. Some examples are shown in **Figure** 12.3.

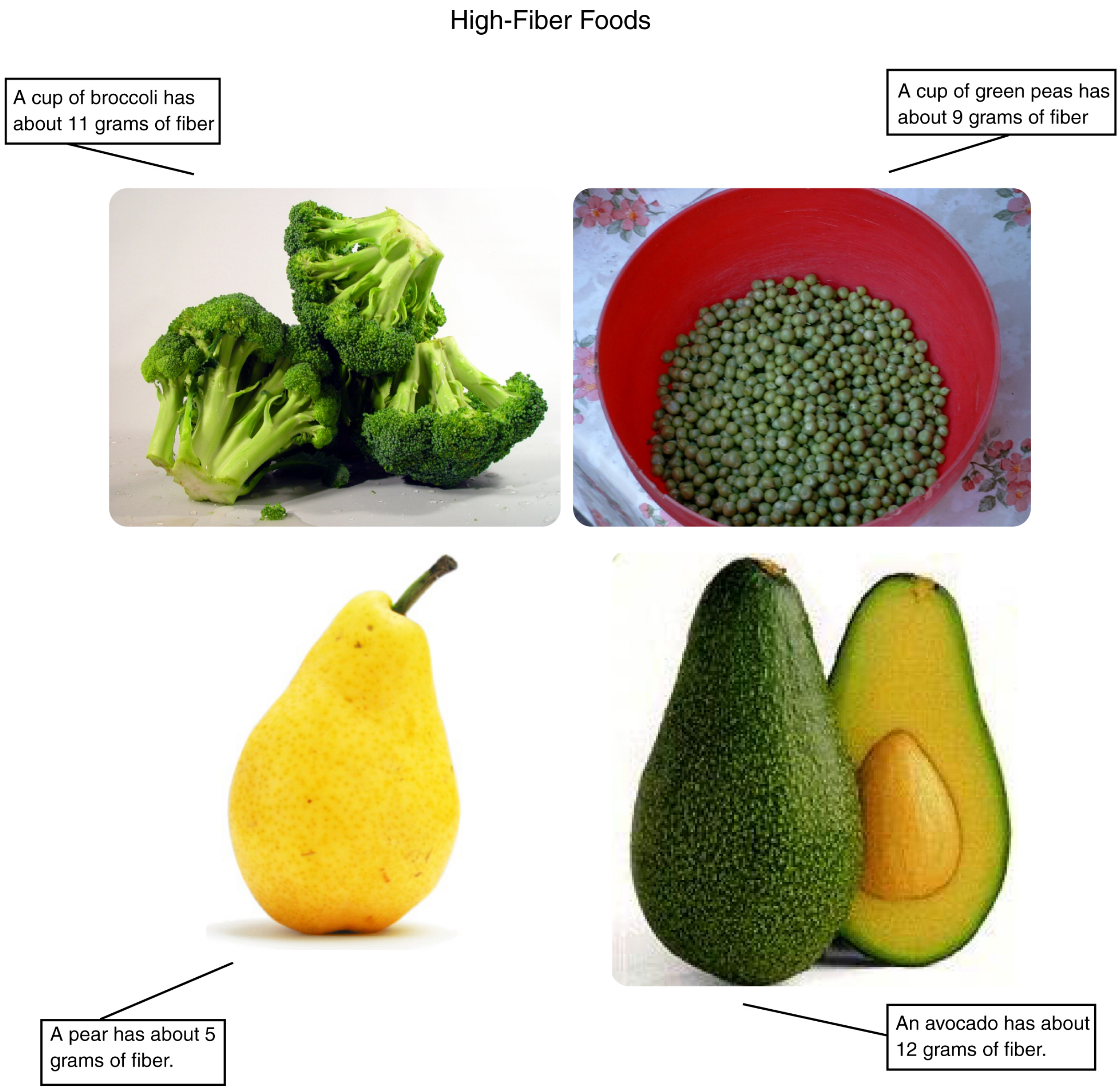


Figure 12.3: Between the ages of 9 and 13 years, girls need about 26 grams of fiber a day, and boys need about 31 grams of fiber a day. Do you know other foods that are high in fiber?

Proteins

Proteins are nutrients made up of smaller molecules called amino acids. As discussed in the *Introduction to Living Things* chapter, the amino acids are arranged like "beads on a string." These amino acid chains then fold up into a three-dimensional molecule. Proteins have several important roles in the body. For example, proteins:

- Make up muscles.
- Help control body processes.
- Help the body fight off bacteria and other "foreign invaders."
- Carry substances in the blood.

If you eat more proteins than you need for these purposes, the extra proteins are used for energy. One gram of protein provides four calories of energy. This is the same amount as one gram of sugar or starch. How many grams of proteins you need each day are shown in **Figure** 12.4. It also shows some foods that are good sources of proteins.

Figure 12.4: Between the ages of 9 and 13 years, you need about 34 grams of proteins a day. What other foods do you think are good sources of proteins?

There are many different amino acids, the building blocks of proteins, but your body needs only 20 of them. Your body can make ten of these amino acids from simpler substances. The other ten amino acids must come from the proteins in foods. These ten are called **essential amino acids**. Only animal foods, such as milk and meat, contain all ten essential amino acids in a single food. Plant foods are missing one or more essential amino acids. However, by eating a combination of plant foods, such as beans and rice, you can get all ten essential amino acids.

Lipids

Lipids are nutrients such as fats that store energy. The heart and skeletal muscles rely mainly on lipids for energy. One gram of lipids provides nine calories of energy. This is more than twice the amount provided by carbohydrates or proteins. Lipids have several other roles in the body. For example, lipids:

- Protect nerves.
- Help control blood pressure.
- Help blood to clot.
- Make up the membranes that surround cells.

Fats are one type of lipid. Stored fat gives your body energy to use for later. It's like having money in a savings account. It's there in case you need it. Stored fat also cushions and protects internal organs. In addition, it insulates the body. It helps keep you warm in cold weather.

Fats and other lipids are necessary for life. However, they can be harmful if you eat too much of them, or the wrong type of fats. Fats can build up in the blood and damage blood vessels. This increases the risk of heart disease.

There are two types of lipids, saturated and unsaturated.

1. Saturated lipids can be unhealthy, even in very small amounts. They are found mainly in animal foods, such as meats, whole milk, and eggs. Saturated lipids increase cholesterol levels in the blood. Cholesterol is a fatty substance that is found naturally in the body. Too much cholesterol in the blood can lead to heart disease. It is best to limit the amount of saturated lipids in your diet.

1. Unsaturated lipids are found mainly in plant foods, such as vegetable oil, olive oil, and nuts. Unsaturated lipids are also found in fish, such as salmon. Unsaturated lipids are needed in small amounts for good health because your body cannot make them. Most lipids in your diet should be unsaturated.

Another type of lipid is called **trans fat**. Trans fats are manufactured and added to certain foods to keep them fresher for longer. Foods that contain trans fats include cakes, cookies, fried foods, and margarine. Eating foods that contain trans fats increases the risk of heart disease. You should do your best to eat fewer foods that contain it.

Beginning in 2010, California banned trans fats from restaurant products, and, beginning in 2011, from all retail baked goods.

Vitamins and Minerals

Vitamins and minerals are also nutrients. They do not provide energy, but they are needed for good health.

Vitamins

Vitamins are substances that the body needs in small amounts to function properly. Humans need 13 different vitamins. Some of them are listed in **Table** 12.1. The table also shows how much of each vitamin you need each day. Vitamins have many roles in the body. For example, Vitamin A helps maintain good vision. Vitamin B_9 helps form red blood cells. Vitamin K is needed for blood to clot when you have a cut or other wound.

Table 12.1: **Vitamins Needed For Good Health**

Vitamin	One Reason You Need It	Some Foods that Have It	How Much of It You Need Each Day (at ages 9–13 years)
Vitamin A	Needed for good vision	Carrots, spinach, milk, eggs	600 g (1 g = 1 x 10^{-6} g)
Vitamin B_1	Needed for healthy nerves	Whole wheat, peas, meat, beans, fish, peanuts	0.9 mg (1 mg = 1 x 10^{-3} g)
Vitamin B_3	Needed for healthy skin and nerves	Beets, liver, pork, turkey, fish, peanuts	12 mg
Vitamin B_9	Needed to make red blood cells	Liver, peas, dried beans, green leafy vegetables	300 g

Table 12.1: (continued)

Vitamin	One Reason You Need It	Some Foods that Have It	How Much of It You Need Each Day (at ages 9–13 years)
Vitamin B_{12}	Needed for healthy nerves	Meat, liver, milk, shellfish, eggs	1.8 g
Vitamin C	Needed for growth and repair of tissues	Oranges, grapefruits, red peppers, broccoli	45 mg
Vitamin D	Needed for healthy bones and teeth	Milk, salmon, tuna, eggs	5 g
Vitamin K	Needed for blood to clot	Spinach, Brussels sprouts, milk, eggs	60 g

Some vitamins are produced in the body. For example, vitamin D is made in the skin when it is exposed to sunlight. Vitamins B_{12} and K are produced by bacteria that normally live inside the body. Most other vitamins must come from foods. Foods that are good sources of vitamins are listed in **Table** 12.1. They include whole grains, vegetables, fruits, and milk.

Not getting enough vitamins can cause health problems. For example, too little vitamin C causes a disease called scurvy. People with scurvy have bleeding gums, nosebleeds, and other symptoms. Getting too much of some vitamins can also cause health problems. The vitamins to watch out for are vitamins A, D, E, and K. These vitamins are stored by the body, so they can build up to high levels. Very high levels of these vitamins can even cause death, although this is very rare.

Minerals

Minerals are chemical elements that are needed for body processes. Minerals are different from vitamins because they do not contain the element carbon. Minerals that you need in relatively large amounts are listed in **Table** 12.2. Minerals that you need in smaller amounts include iodine, iron, and zinc.

Minerals have many important roles in the body. For example, calcium and phosphorus are needed for strong bones and teeth. Potassium and sodium are needed for muscles and nerves to work normally.

Table 12.2: **Minerals Needed For Good Health**

Mineral	One Reason You Need It	Some Foods that Have It	How Much of It You Need Each Day (at ages 9–13 years)
Calcium	Needed for strong bones and teeth	Milk, soy milk, green leafy vegetables	1,300 mg
Chloride	Needed for proper balance of water and salts in body	Table salt, most packaged foods	2.3 g
Magnesium	Needed for strong bones	Whole grains, green leafy vegetables, nuts	240 mg
Phosphorus	Needed for strong bones and teeth	Meat, poultry, whole grains	1,250 mg
Potassium	Needed for muscles and nerves to work normally	Meats, grains, bananas, orange juice	4.5 g

Table 12.2: (continued)

Mineral	One Reason You Need It	Some Foods that Have It	How Much of It You Need Each Day (at ages 9–13 years)
Sodium	Needed for muscles and nerves to work normally	Table salt, most packaged foods	1.5 g

Your body cannot produce any of the minerals that it needs. Instead, you must get minerals from the foods you eat. Good sources of minerals are listed in **Table** 12.2. They include milk, green leafy vegetables, and whole grains.

Not getting enough minerals can cause health problems. For example, too little calcium may cause osteoporosis. This is a disease in which bones become soft and break easily. Getting too much of some minerals can also cause health problems. Many people get too much sodium. Sodium is added to most packaged foods. People often add more sodium to their food by using table salt. Too much sodium causes high blood pressure in some people.

Water

Did you know that water is also a nutrient? By weight, your cells are about two-thirds water, so you cannot live without it. In fact, you can survive for only a few days without water.

You lose water in each breath you exhale. You also lose water in sweat and urine. If you do not take in enough water to replace the water that you lose, you may develop dehydration. Symptoms of dehydration include dry mouth, headaches, and feeling dizzy. Dehydration can be very serious. Severe dehydration can even cause death.

When you exercise, especially on a hot day, you lose more water in sweat than you usually do. You need to drink extra water before, during, and after exercise. The children in **Figure** 12.5 are drinking water while playing outside on a warm day. They need to drink water to avoid dehydration.

Figure 12.5: When you are active outside on a warm day, it's important to drink plenty of water. You need to replace the water you lose in sweat.

Getting too much water can also be dangerous. Excessive water may cause a condition called hyponatremia. In this condition, water collects in the brain and causes it to swell. Hyponatremia can cause death. It requires emergency medical care.

Lesson Summary

- The body needs food for energy, building materials, and substances that help control body processes.
- Carbohydrates, proteins, and lipids provide energy and have other important roles in the body.
- Vitamins and minerals do not provide energy but are needed in small amounts for the body to function properly.
- The body must have water to survive.

Review Questions

Recall

1. What are three reasons that your body needs food?

2. Which nutrients can be used for energy?

3. What are some foods that are good sources of vitamin C?

4. What are two minerals that are needed for strong bones and teeth?

Apply Concepts

5. Name two types of fiber and state the role of each type of fiber in the body.

6. Your body needs 20 different amino acids. Why do you need to get only ten of these amino acids from food? Name foods you can eat to get these ten amino acids.

7. Compare and contrast saturated and unsaturated lipids.

8. Identify three vitamins that are produced in the body. How are they produced?

9. Why do you need to drink extra water when you exercise on a hot day? What might happen if you did not drink extra water?

Critical Thinking

10. List some of the functions of proteins in the body. Based on your list, predict health problems people might have if they do not get enough proteins in foods.

Further Reading / Supplemental Links

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Points to Consider

Think about how you can be sure you are getting enough nutrients.

- Do you think knowing the nutrients in the foods you eat are important?
- Do you have to keep track of all the nutrients you eat, or is there an easier way to choose foods that provide the nutrients you need?

12.2 Choosing Healthy Foods

Lesson Objectives

- State how to use MyPyramid to get the proper balance of nutrients.
- Describe how to read food labels to choose foods wisely.
- Explain how to balance food with exercise.

Check Your Understanding

- What is a nutrient?
- Why do you need extra energy when you exercise?

Vocabulary

- ingredient
- main ingredient
- MyPlate
- MyPyramid
- nutrition facts label
- obesity
- serving size

Introduction

Foods such as whole grain breads, fresh fruits, and fish provide nutrients you need for good health. But different foods give you different types of nutrients. You also need different amounts of each nutrient. How can you choose the right mix of foods to get the proper balance of nutrients? Two tools can help you choose foods wisely: MyPyramid and food labels.

MyPyramid

MyPyramid is a diagram that shows how much you should eat each day of foods from six different food groups. It recommends the amount of nutrients you need based on your age, your sex, and your level of activity. MyPyramid is shown in **Figure** 12.6. The six food groups in MyPyramid are:

- Grains, such as bread, rice, pasta, and cereal.
- Vegetables, such as spinach, broccoli, carrots, and sweet potatoes.
- Fruits, such as oranges, apples, bananas, and strawberries.
- Oils, such as vegetable oil, canola oil, olive oil, and peanut oil.
- Dairy, such as milk, yogurt, cottage cheese, and other cheeses.
- Meat and beans, such as chicken, fish, soybeans, and kidney beans.

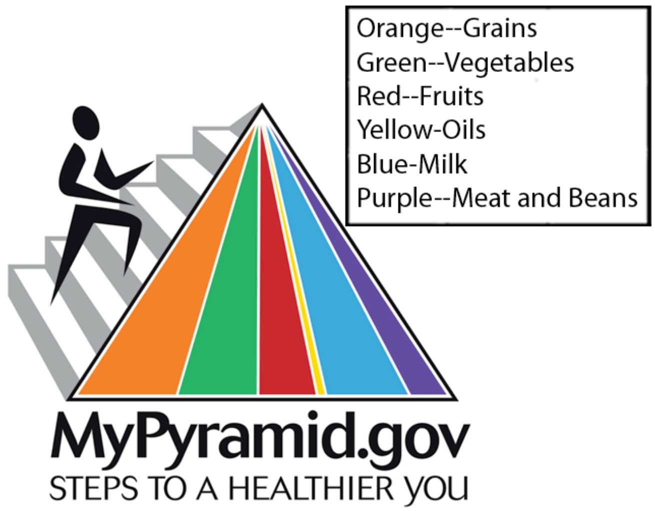

Figure 12.6: MyPyramid can help you choose foods wisely for good health. Each colored band represents a different food group. The key shows which food group each color represents. Which colored band of MyPyramid is widest? Which food group does it represent?

Using MyPyramid

In MyPyramid, each food group is represented by a band of a different color. For example, grains are represented by an orange band, and vegetables are represented by a green band. The wider the band, the more foods you should choose from that food group each day.

The orange band in MyPyramid is the widest band. This means that you should choose more foods from the grain group than from any other single food group. The green, blue, and red bands are also relatively wide. Therefore, you should choose plenty of foods from the vegetable, dairy, and fruit groups as well. You should choose the fewest foods from the food group with the narrowest band. Which band is narrowest? Which food group does it represent?

Healthy Eating Guidelines

Did you ever hear the saying, "variety is the spice of life"? Variety is also the basis of a healthy eating plan. When you choose foods based on MyPyramid, you should choose a variety of different foods. Follow these guidelines to make the wisest food choices for good health. Keep in mind that nutritional rules may change as you get older. As food provides energy and nutrients for growth and development, nutritional requirements may vary with body weight, age, sex, activity, and body functioning.

- Make at least half your daily grain choices whole grains. Examples of whole grains are whole wheat bread, whole wheat pasta, and brown rice.
- Choose a variety of different vegetables each day. Be sure to include both dark green vegetables, such as spinach and broccoli, and orange vegetables, such as carrots and sweet potatoes.
- Choose a variety of different fruits each day. Select mainly fresh fruits rather than canned fruits and whole fruits instead of fruit juices.
- When choosing oils, go for unsaturated oils, such as olive oil, canola oil, or vegetable oil.
- Choose low-fat or fat-free milk and other dairy products. For example, select fat-free yogurt and low-fat cheese.
- For meats, choose fish, chicken, and lean cuts of beef. Also, be sure to include beans, nuts, and seeds.

What about Ice Cream, Cookies, and Potato Chips?

Are you wondering where foods like ice cream, cookies, and potato chips fit into MyPyramid? The white tip of MyPyramid represents foods such as these. These are foods that should be eaten only in very small amounts and not very often. Such foods contain very few nutrients, and are called nutrient-poor. Instead, they are high in fats, sugars, and sodium, which are nutrients that you should limit in a healthy eating plan. Ice cream, cookies, and potato chips are also high in calories. Eating too much of them may lead to unhealthy weight gain.

MyPlate

In June 2011, the United States Department of Agriculture replaced My Pyramid with **MyPlate.** MyPlate depicts the relative daily portions of various food groups. See http://www.choosemyplate.gov/ for further information.

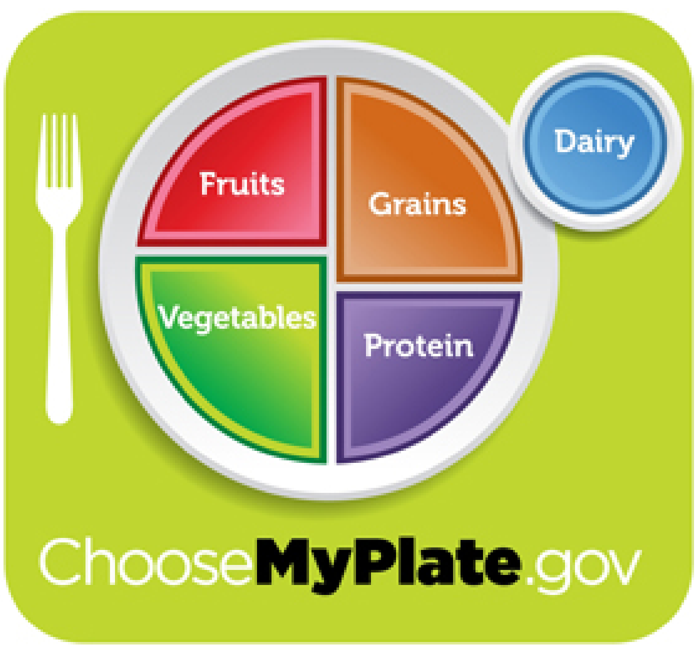

Figure 12.7: MyPlate is a visual guideline for balanced eating, replacing MyPyramid in 2011.

The following guidelines accompany MyPlate:

1. Balancing Calories
   - Enjoy your food, but eat less.
   - Avoid oversized portions.
2. Foods to Increase
   - Make half your plate fruits and vegetables.
   - Make at least half your grains whole grains.
   - Switch to fat-free or low-fat (1%) milk.
3. Foods to Reduce
   - Compare sodium in foods like soup, bread, and frozen meals and choose the foods with lower numbers.
   - Drink water instead of sugary drinks.

Food Labels

In the United States, packaged foods are required by law to have nutrition facts labels. A **nutrition facts label** shows the nutrients in a food. Packaged foods are also required to list their ingredients. An **ingredient** is a specific item that a food contains.

Using Nutrition Facts Labels

An example of a nutrition facts label is shown in **Figure** 12.8. The information listed at the right of the label tells you what to look for. At the top of the label, look for the serving size. The serving size tells you how much of the food you should eat to get the nutrients listed on the label. A cup of food from the label in **Figure** 12.8 is a serving. The calories in one serving are listed next. In this food, there are 250 calories per serving.

Next on the nutrition facts label, look for the percent daily values (% DV) of nutrients. Remember the following tips when reading a food label:

- A food is low in a nutrient if the percent daily value of the nutrient is 5% or less.
- The healthiest foods are low in nutrients such as fats and sodium.
- A food is high in a nutrient if the percent daily value of the nutrient is 20% or more.
- The healthiest foods are high in nutrients such as fiber and proteins.

Look at the percent daily values on the food label in **Figure** 12.8. Which nutrients have values of 5% or less? These are the nutrients that are low in this food. They include fiber, vitamin A, vitamin C, and iron. Which nutrients have values of 20% or more? These are the nutrients that are high in this food. They include sodium, potassium, and calcium.

Using Ingredients Lists

The food label in **Figure** 12.9 includes the list of ingredients in a different food. The ingredients on food labels are always listed from the highest amount to the lowest amount. This means that the main ingredient is listed first. The **main ingredient** is the ingredient that is present in the food in the greatest amount. As you go down the list, the ingredients are present in smaller and smaller amounts.

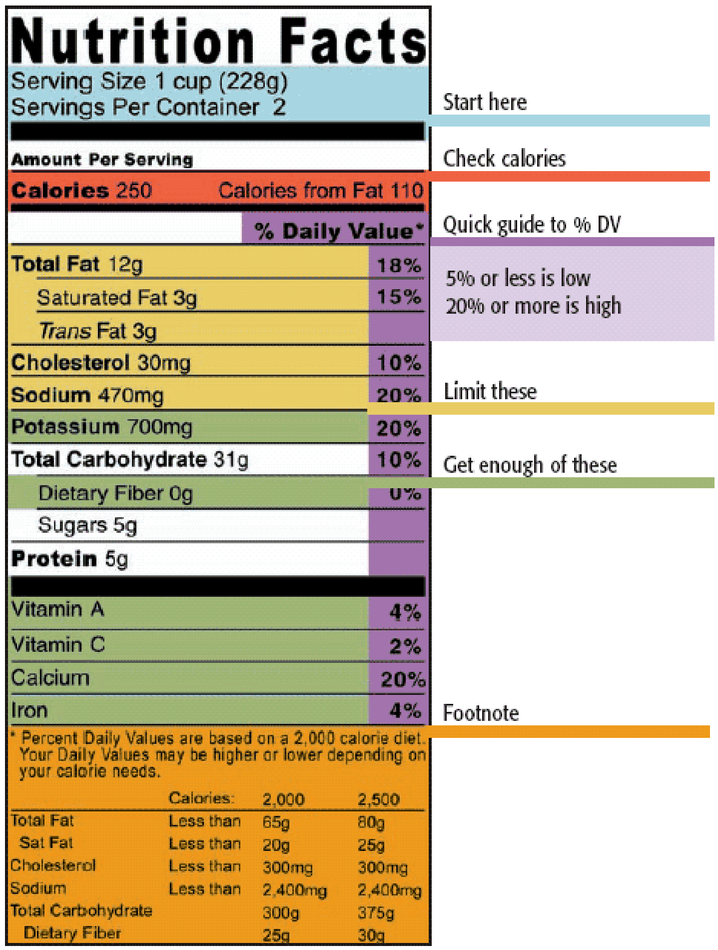

Figure 12.8: Reading nutrition facts labels can help you choose healthy foods. Look at the nutrition facts label shown here. Do you think this food is a good choice for a healthy eating plan? Why or why not?

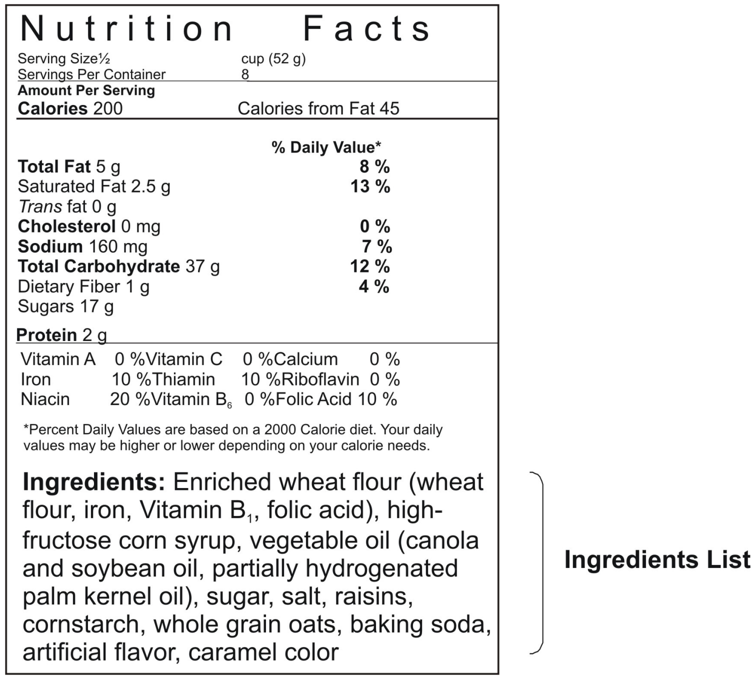

Figure 12.9: This food label includes the list of ingredients in the food. The main ingredient is enriched wheat flour, followed by high-fructose corn syrup. Why should you avoid foods with ingredients such as these at the top of the ingredients list?

Reading the ingredients lists on food labels can help you choose the healthiest foods. At the top of the list, look for ingredients such as whole grains, vegetables, milk, and fruits. These are the ingredients you need in the greatest amounts for balanced eating. Avoid foods that list fats, oils, sugar, or salt at the top of the list. For good health, you should avoid getting too much of these ingredients. Be aware that ingredients such as corn syrup are sugars.

You should also use moderation when eating foods that contain ingredients such as white flour or white rice. These ingredients have been processed, and processing removes nutrients. The word "enriched" is a clue that an ingredient has been processed. Ingredients are enriched with added nutrients to replace those lost during processing. However, enriched ingredients are still likely to have fewer nutrients than unprocessed ingredients.

Balancing Food with Exercise

Look at MyPyramid in **Figure** 12.6. Note the person walking up the side of the pyramid. This shows that exercise is important for balanced eating. Exercise helps you use any extra energy in the foods you eat. The more active you are, the more energy you use. You should try to get at least an hour of physical activity just about every day. **Figure** 12.10 shows some activities that can help you use extra energy.

How Does Fat Form?

Any unused energy in food is stored in the body as fat. This is true whether the extra energy comes from carbohydrates, proteins, or lipids. What happens if you take in more energy than you use, day after day? You will store more and more fat and become overweight.

Eventually, you may become obese. **Obesity** is having a very high percentage of body fat. Obese people

Figure 12.10: All of these activities are good ways to exercise and use extra energy. The calories given for each activity are the number of calories used in an hour by a person that weighs 100 pounds. Which of these activities uses the most calories? Which of the activities do you enjoy?

are at least 20 percent heavier than their healthy weight range. The excess body fat of obesity is linked to many diseases. Obese people often have serious health problems, such as diabetes, high blood pressure, and high cholesterol. They are also more likely to develop arthritis and some types of cancer. People that remain obese during their entire adulthood usually do not live as long as people that stay within a healthy weight range.

The current generation of children and teens is the first generation in our history that may have a shorter life than their parents. The reason is their high rate of obesity and the health problems associated with obesity. You can avoid gaining weight and becoming obese. The choice is yours. Choose healthy foods by using MyPyramid and reading food labels. Then get plenty of exercise to balance the energy in the foods you eat.

Lesson Summary

- MyPyramid shows how much you should eat each day of foods from six different food groups.
- Reading food labels can help you choose the healthiest foods.
- Regular exercise helps you use extra energy and avoid unhealthy weight gain.

Review Questions

Recall

1. List the six food groups represented by MyPyramid.

2. Which food group contains soybeans, kidney beans, and fish?

3. What guideline should you follow in choosing foods from the grains food group?

4. Which ingredient is always listed first on a food label?

5. What happens if you take in more energy than you use, day after day?

Apply Concepts

6. Explain how you can use MyPyramid to choose foods that provide the proper balance of nutrients.

7. Why should you limit foods like ice cream and potato chips in a healthy eating plan?

8. Explain how you can use food labels to choose foods that are high in fiber.

9. Why should you try to avoid foods with processed ingredients? What are some examples of processed ingredients?

Critical Thinking

10. You are trying to convince your friends that it is worth it to eat healthy and do physical activity. What will you tell them? Give examples from the chapter.

Further Reading / Supplemental Links

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Points to Consider

Next we discuss the digestive system.

- Discuss how you think foods may be broken down into nutrients that your body can use? For example, how do you think an apple becomes simple sugars that your body can use for energy? Or how might a piece of cheese become proteins that your body can use for building materials?

12.3 The Digestive System

Lesson Objectives

- List the functions of the digestive system.
- Explain the role of enzymes in digestion.
- Describe the digestive organs and their functions.
- Explain the roles of helpful bacteria in the digestive system.
- List ways to help keep your digestive system healthy.

Check Your Understanding

- What is a chemical reaction?
- What is an enzyme?
- What are bacteria?

Vocabulary

- absorption

- chemical digestion
- digestion
- digestive system
- duodenum
- esophagus
- food allergies
- ileum
- jejunum
- large intestine
- mechanical digestion
- small intestine
- stomach
- villi

What Does the Digestive System Do?

Nutrients in the foods you eat are needed by the cells of your body. How do the nutrients in foods get to your body cells? What organs and processes break down the foods and make the nutrients available to cells? The organs are those of the digestive system. The processes are digestion and absorption.

The **digestive system** is the body system that breaks down food and absorbs nutrients. It also gets rid of solid food waste. The main organs of the digestive system are shown in **Figure** 12.11.

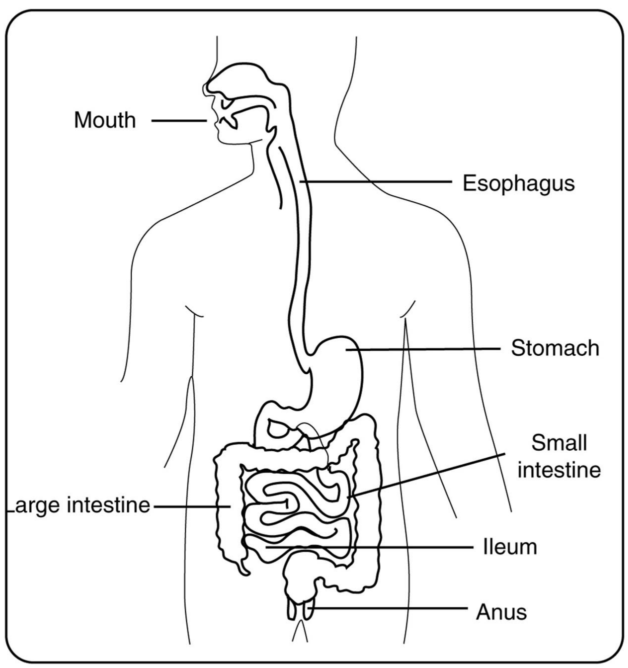

Figure 12.11: This drawing shows the major organs of the digestive system. Trace the path of food through the organs of the digestive system as you read about them in this lesson.

Digestion is the process of breaking down food into nutrients. There are two types of digestion, mechanical and chemical. In **mechanical digestion**, large chunks of food are broken down into small pieces. This is a physical process. In **chemical digestion**, large food molecules are broken down into small nutrient molecules. This is a chemical process.

Absorption is the process that allows substances you eat to be taken up by the blood. After food is broken down into small nutrient molecules, the molecules are absorbed by the blood. After absorption, the nutrient molecules travel in the bloodstream to cells throughout the body.

Some substances in food cannot be broken down into nutrients. They remain behind in the digestive system after the nutrients are absorbed. Any substances in food that cannot be digested and absorbed pass out of the body as solid waste. The process of passing solid food waste out of the body is called elimination.

The Role of Enzymes in Digestion

Chemical digestion could not take place without the help of digestive enzymes. An **enzyme** is a protein that speeds up chemical reactions in the body. Digestive enzymes speed up chemical reactions that break down large food molecules into small molecules.

Did you ever use a wrench to tighten a bolt? You could tighten a bolt with your fingers, but it would be difficult and slow. If you use a wrench, you can tighten a bolt much more easily and quickly. Enzymes are like wrenches. They make it much easier and quicker for chemical reactions to take place. Like a wrench, enzymes can also be used over and over again. But you need the appropriate size and shape of the wrench to efficiently tighten the bolt, just like each enzyme is specific for the reaction it helps.

Digestive enzymes are released, or secreted, by the organs of the digestive system. Examples of digestive enzymes are:

- Amylase, produced in the mouth. It helps break down large starches molecules into smaller sugar molecules.
- Pepsin, produced in the stomach. Pepsin helps break down proteins into amino acids.
- Trypsin, produced in the pancreas. Trypsin also breaks down proteins.
- Pancreatic lipase, produced in the pancreas. It is used to break apart fats.
- Deoxyribonuclease and ribonuclease, produced in the pancreas. They are enzymes that break bonds in nucleic acids like DNA and RNA.

Bile salts are bile acids that help to break down fat. Bile acids are made in the liver. When you eat a meal, bile is secreted into the intestine, where it breaks down the fats. Bile acids also help to remove cholesterol from the body.

Hormones and Digestion

If you are a typical teenager, you like to eat. For your body to break down, absorb and spread the nutrients throughout your body, your digestive system and endocrine system need to work together. The endocrine system sends hormones around your body to communicate between cells like chemical messengers.

Digestive hormones are made by cells lining the stomach and small intestine. These hormones cross into the blood where they can affect other parts of the digestive system. Some of these hormones are listed below.

- Gastrin, which signals the secretion of gastric acid.
- Cholecystokinin, which signals the secretion of pancreatic enzymes.
- Secretin, which signals secretion of water and bicarbonate from the pancreas.
- Ghrelin, which signals when you are hungry.

- Gastric inhibitory polypeptide, which stops or decreases gastric secretion. It also causes the release of insulin in response to high blood glucose levels.

Digestive Organs and Their Roles

The mouth and stomach are just two of the organs of the digestive system. Other digestive system organs are the esophagus, small intestine, and large intestine. From **Figure 17.10** you can see that the digestive organs form a long tube. In adults, this tube is about 30 feet long! At one end of the tube is the mouth. At the other end is the anus. Food enters the mouth and then passes through the rest of the digestive system. Food waste leaves the body through the anus.

The organs of the digestive system are lined with muscles. The muscles contract, or tighten, to push food through the system. This is shown in **Figure** 12.12. The muscles contract in waves. The waves pass through the digestive system like waves through a slinky. This movement of muscle contractions is called peristalsis. Without peristalsis, food would not be able to move through the digestive system. Peristalsis is an involuntary process, which means that it occurs without your conscious control.

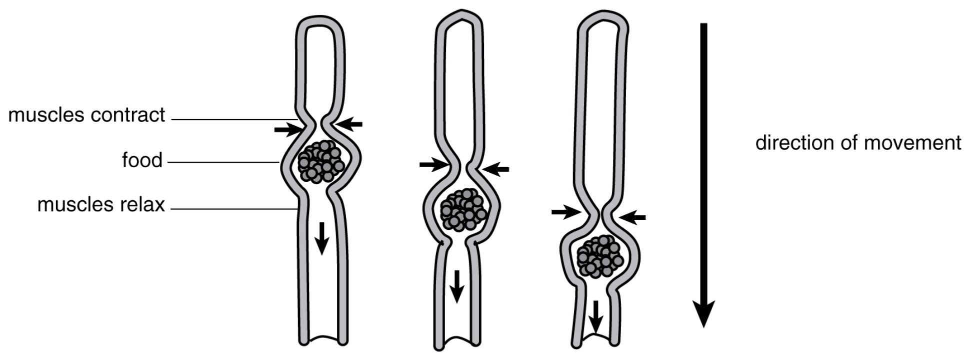

Figure 12.12: This diagram shows how muscles push food through the digestive system. Muscle contractions travel through the system in waves, pushing the food ahead of them. This is called peristalsis.

The liver, gall bladder, and pancreas are also organs of the digestive system. They are shown in **Figure** 12.13. Food does not pass through these three organs. However, these organs are important for digestion. They secrete or store enzymes or other chemicals that are needed to help digest food chemically.

Mouth, Esophagus, and Stomach

The mouth is the first organ that food enters. But digestion may start even before you put the first bite of food into your mouth. Just seeing or smelling food can cause the release of saliva and digestive enzymes in your mouth.

Once you start eating, saliva wets the food, which makes it easier to break up and swallow. Digestive enzymes, including amylase, start breaking down starches into sugars. Your tongue helps mix the food with the saliva and enzymes.

Your teeth also help digest food. Your front teeth are sharp. They cut and tear food when you bite into

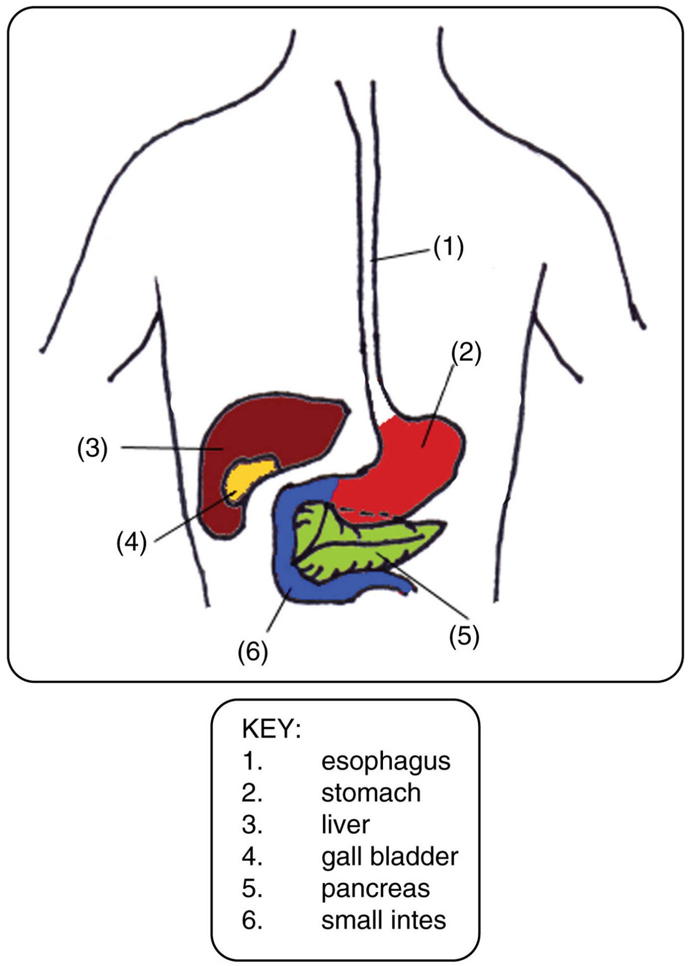

Figure 12.13: This drawing shows the liver, gall bladder, and pancreas. These organs are part of the digestive system. Food does not pass through them, but they secrete substances needed for chemical digestion.

it. Your back teeth are broad and flat. They grind food into smaller pieces when you chew. Chewing is part of mechanical digestion. Your tongue pushes the food to the back of your mouth so you can swallow it. When you swallow, the lump of chewed food passes down your throat to your esophagus.

The **esophagus** is a narrow tube that carries food from the throat to the stomach. Food moves through the esophagus because of peristalsis. At the lower end of the esophagus, a circular muscle controls the opening to the stomach. The muscle relaxes to let food pass into the stomach. Then the muscle contracts again to prevent food from passing back into the esophagus.

Some people think that gravity moves food through the esophagus. If that were true, food would move through the esophagus only when you are sitting or standing upright. In fact, because of peristalsis, food can move through the esophagus no matter what position you are in — even upside down! Just don't try to swallow food when you upside down! You could choke if you try to swallow when you are not upright.

The **stomach** is a sac-like organ at the end of the esophagus. It has thick muscular walls. The muscles contract and relax. This moves the food around and helps break it into smaller pieces. Mixing the food around with the enzyme pepsin and other chemicals helps digest proteins.

Water, salt, and simple sugars can be absorbed into the blood from the stomach. Most other substances are broken down further in the small intestine before they are absorbed. The stomach stores food until the small intestine is ready to receive it. A circular muscle controls the opening between the stomach and small intestine. When the small intestine is empty, the muscle relaxes. This lets food pass from the stomach into the small intestine.

Small Intestine

The **small intestine** is narrow tube that starts at the stomach and ends at the large intestine (see **Figure** 12.11). In adults, the small intestine is about 23 feet long. It is made up of three parts, the duodenum, the jejunum and the ileum.

1. The **duodenum** is the first part of the small intestine. This is where most chemical digestion takes place. Many enzymes and other chemicals are secreted here.
2. The **jejunum** is the second part of the small intestine. This is where most nutrients are absorbed into the blood. The jejunum is lined with tiny "fingers" called **villi**. A magnified picture of villi is shown in **Figure** 12.14. Villi contain very tiny blood vessels. Nutrients are absorbed into the blood through these tiny vessels. There are millions of villi, so altogether there is a very large area for absorption to take place. In fact, villi make the inner surface area of the small intestine 1,000 times larger than it would be without them. The entire inner surface area of the small intestine is about as big as a basketball court!
3. The **ileum** is the third part of the small intestine. Like the jejunum, the ileum is covered with villi. A few remaining nutrients are absorbed in the ileum. From the ileum, any remaining food waste passes into the large intestine.

The small intestine is much longer than the large intestine. So why is it called "small"? If you compare the small and large intestines in **Figure** 12.11, you will see why. The small intestine is smaller in width than the large intestine.

Large Intestine

The **large intestine** is a wide tube that connects the small intestine with the anus. In adults, it is about 5 feet long. Waste enters the large intestine from the small intestine in a liquid state. As the waste moves

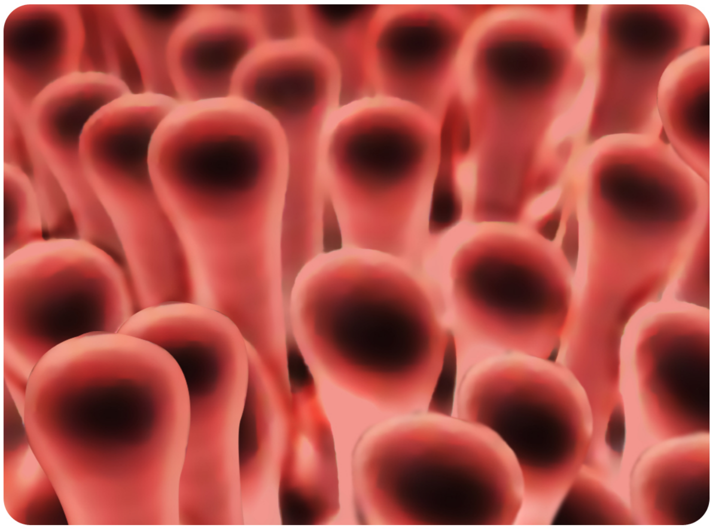

Figure 12.14: This is what the villi lining the small intestine look like when magnified. Each one is actually only about 1 millimeter long. Villi are just barely visible with the unaided eye.

through the large intestine, excess water is absorbed from it. After the excess water is absorbed, the remaining solid waste is called feces.

Circular muscles control the anus. They relax to let the feces pass out of the body through the anus. After feces pass out of the body, they are called stool. Releasing the stool from the body is referred to as a bowel movement.

Liver

The liver has a wide range of functions, a few of which are:

- Removing toxins from the blood.
- Keeping glucose levels stable.
- Creating proteins.
- Producing biochemicals for digestion.

The liver is necessary for survival. You cannot live without a liver. The liver is one of the most important organs in the body when it comes to getting rid of toxins, especially from the gut. The liver filters blood from the intestine. This filtering process can remove microorganisms such as bacteria, fungi, viruses and parasites from the blood. Almost 2 quarts of blood pass through the liver every minute. Since the liver also ensures that glucose levels remain stable, people with liver problems are at risk for diabetes.

Bacteria in the Digestive System

Your large intestine is not just made up of cells. It is also an ecosystem, home to trillions of bacteria. But don't worry. Most of these bacteria are helpful. They have several roles in the body. For example, intestinal bacteria:

- Produce vitamins B_{12} and K.

- Control the growth of harmful bacteria.
- Break down poisons in the large intestine.
- Break down some substances in food that cannot be digested, such as fiber and some starches and sugars.

Keeping Your Digestive System Healthy

Most of the time, you probably aren't aware of your digestive system. It works well without causing any problems. But most people have problems with their digestive system at least once in awhile. Did you ever eat something that didn't "agree" with you? Maybe you had a stomachache or felt sick to your stomach? Maybe you had diarrhea? These could be symptoms of foodborne illness.

Foodborne Illness

Harmful bacteria can enter your digestive system in food and make you sick. This is called foodborne illness. The bacteria, or the toxins they produce, may cause vomiting or cramping, in addition to the symptoms mentioned above. You can help prevent foodborne illness by following a few simple rules.

- Keep hot foods hot and cold foods cold. This helps prevent any bacteria in the foods from multiplying.
- Wash your hands before you prepare or eat food. This helps prevent bacteria on your hands from getting on the food.
- Wash your hands after you touch raw foods such as meats, poultry, fish, or eggs. These foods often contain bacteria that your hands could transfer to your mouth.
- Cook meats, poultry, fish, and eggs thoroughly before eating them. The heat of cooking kills any bacteria the foods may contain, so they cannot make you sick.

Food Allergies

Food allergies are like other allergies. They occur when the immune system reacts to harmless substances as though they were harmful. Almost 10 percent of children have food allergies. Some of the foods most likely to cause allergies are shown in **Figure** 12.15.

Eating foods you are allergic to may cause vomiting, diarrhea, or skin rashes. Some people are very allergic to certain foods. Eating even tiny amounts of the foods causes them to have serious symptoms, such as difficulty breathing. If they eat the foods by accident, they may need emergency medical treatment.

If you think you may have food allergies, a doctor can test you to find out for sure. The tests will identify which foods you are allergic to. Then you can avoid eating these foods. This is the best way to prevent the symptoms of food allergies. To avoid the foods you are allergic to, you may have to read food labels carefully. This is especially likely if you are allergic to common food ingredients, such as soybeans, wheat, or peanuts.

A food intolerance, or food sensitivity, is different from a food allergy. A food intolerance happens when the digestive system is unable to break down a certain type of food. This can result in stomach cramping, diarrhea, tiredness, and weight loss. Food intolerances are often mistakenly called allergies. Lactose intolerance is a food intolerance. A person who is lactose intolerant does not make enough lactase, the enzyme that breaks down the milk sugar lactose. About 75 percent of the world's population is lactose intolerant.

Figure 12.15: Some of the foods that commonly cause allergies are shown here. They include nuts, eggs, fish, milk, and shellfish. Are you allergic to any of these foods?

Lesson Summary

- The digestive system breaks down food, absorbs nutrients, and gets rid of food wastes.
- Digestive enzymes speed up the reactions of chemical digestion.
- The main organs of the digestive system are the mouth, esophagus, stomach, small intestine, and large intestine.
- Bacteria in the large intestine produce vitamins and have other roles in the body.

Review Questions

Recall

1. What are three functions of the digestive system?
2. Identify two roles of helpful bacteria in the large intestine.
3. List two rules that can help prevent foodborne illness.

Apply Concepts

4. Describe the roles of the mouth in digestion.
5. In which organs of the digestive system does absorption of nutrients take place?
6. Explain the role of enzymes in digestion. Give examples to illustrate your answer.
7. Describe peristalsis, and explain why it is necessary for digestion.
8. How can the inner surface area of the small intestine be as big as a basketball court? How does this help the small intestine absorb nutrients?

Critical Thinking

9. Assume a person has an illness that prevents the large intestine from doing its normal job. Why might the person have diarrhea?
10. Explain why eating high-fiber foods can help prevent constipation.

Further Reading / Supplemental Links

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Points to Consider

- After nutrients are absorbed into the blood, think about how the blood could carry them to all the cells of the body. How does the blood travel? What keeps the blood moving?

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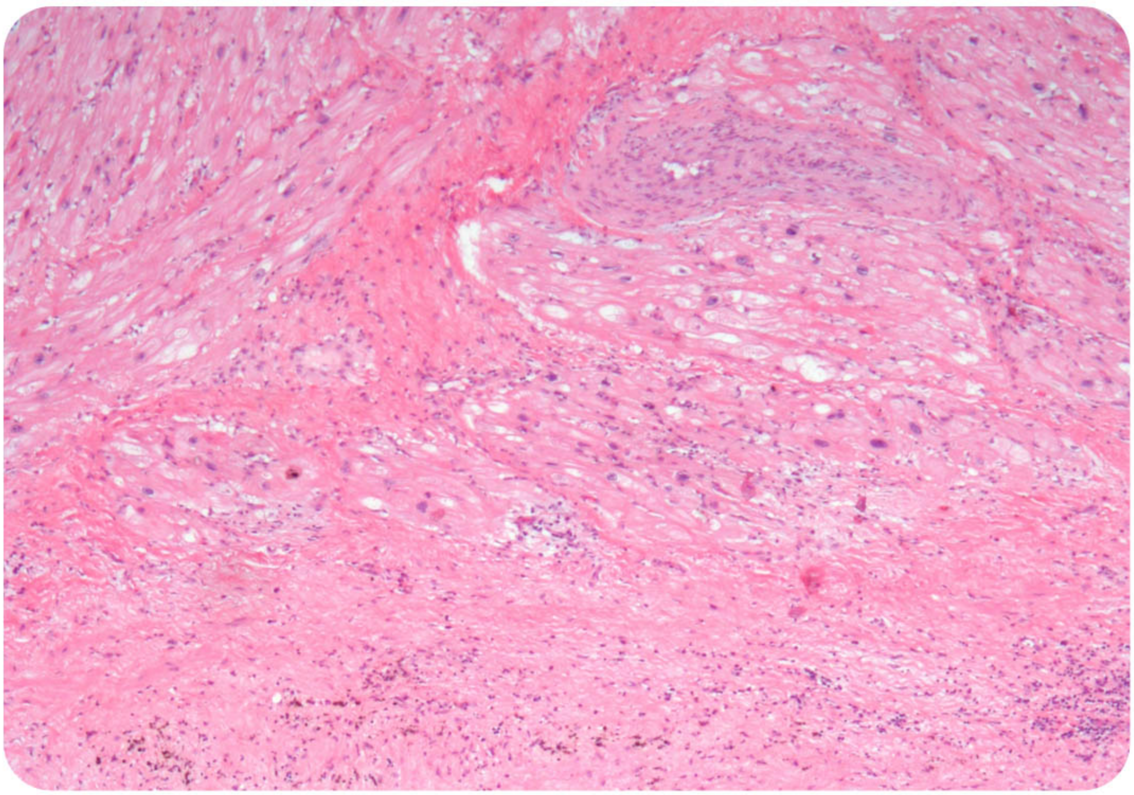
Chapter 13

MS Cardiovascular System



What does the above image show? It could be any of a number of things. A bowl of melted strawberry ice cream. Some chewed bubble gum. But the above image is actually a close-up of cardiac muscle, the muscle that makes up your heart. If you recall, cardiac muscle is one of three muscle types in the human body. Is cardiac muscle found anywhere else in the body? No. Cardiac muscle is only found in the heart!

Why is cardiac muscle only found in the heart? Why does the heart need its own special muscle? What does blood do, anyway? If a heart pumps blood, how does the heart get the blood it needs to keep pumping? What happens if the heart does not get enough blood?

You may have heard of a heart attack - but what is actually happening in the heart when that happens?

Consider these questions about the heart and cardiac muscle as you read about one of the most important and intriguing systems in the body, the cardiovascular system.

13.1 Introduction to the Cardiovascular System

Lesson Objectives

- Identify the main structures of the cardiovascular system.
- Identify three types of blood vessels.
- Describe the differences between the pulmonary and the systemic circulations.
- Identify the main structures of the lymphatic system.
- Outline how the cardiovascular and the lymphatic systems work together.

Check Your Understanding

- What is an organ system?
- What are the three types of muscles found in the human body?

Vocabulary

- arteries
- blood
- capillaries
- lymphatic system
- plasma
- pulmonary circulation
- systemic circulation
- veins

Functions of the Cardiovascular System

Your cardiovascular system has many jobs. It acts as a message delivery service, a pump, a heating system, and a protector of the body against diseases. Every cell in your body depends on your cardiovascular system. In this chapter, you will learn how your cardiovascular system works and how it helps to maintain homeostasis.

The cardiovascular system shown in **Figure** 13.1 is the organ system that is made up of the heart, the blood vessels, and the blood. It moves nutrients, hormones, gases (such as oxygen) and wastes (such as carbon dioxide) to and from your cells. It also helps to keep you warm by moving warm blood around your body. To do these tasks, your cardiovascular system works with other organ systems, such as the respiratory, endocrine, and nervous systems.

The Movement of Gases

The movement of gases, especially oxygen and carbon dioxide, is one of the most important jobs of the cardiovascular system. But the cardiovascular system cannot do this alone. It must work with other organ systems, especially the respiratory system, to move these gases throughout your body.

Oxygen is needed by every cell in your body. You breathe in oxygen and breathe out carbon dioxide through your respiratory system. Once oxygen enters your lungs, it must enter your blood stream in order to move around your body. Oxygen is moved in your blood by attaching to a protein called **hemoglobin**.

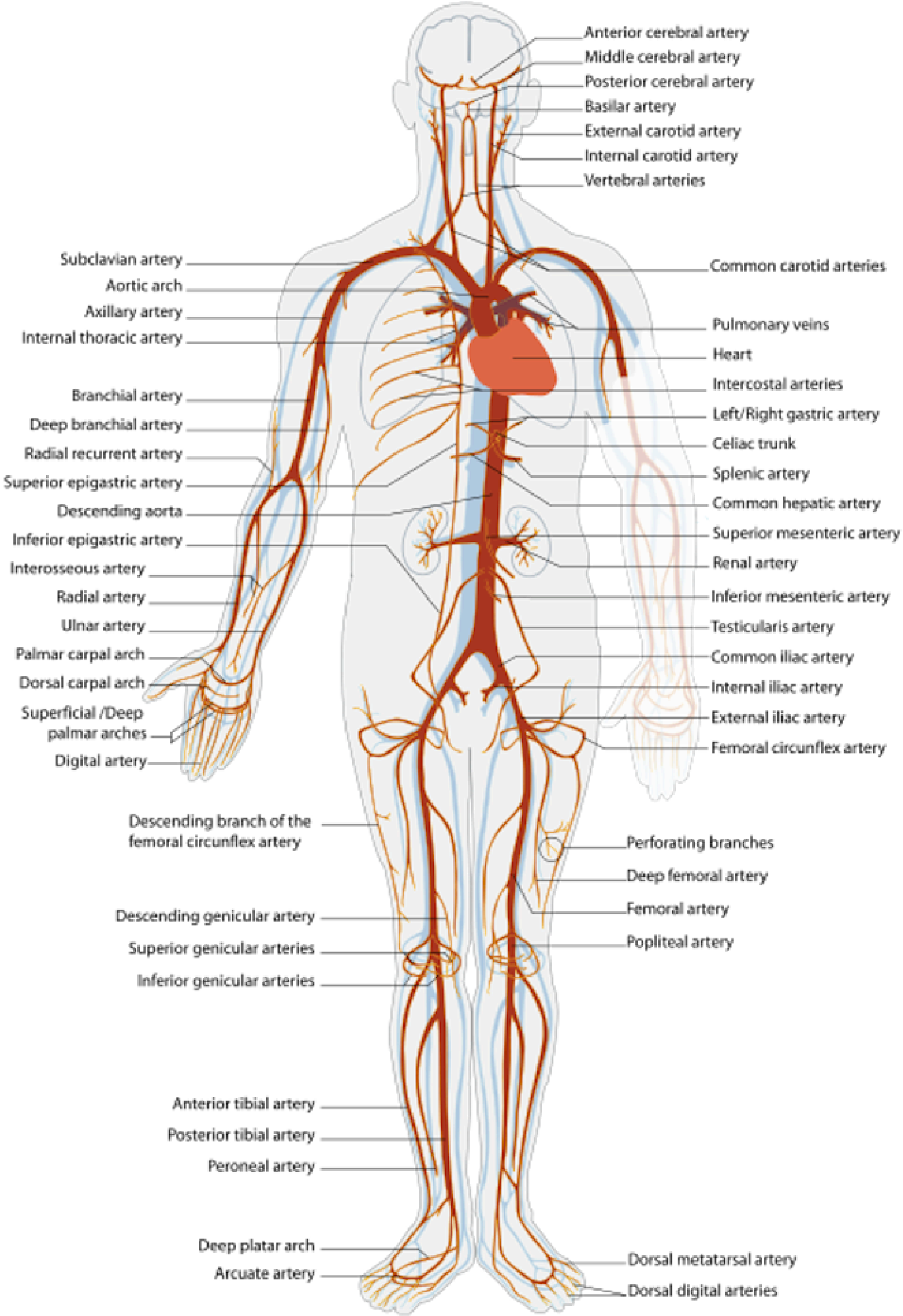


Figure 13.1: The cardiovascular system moves nutrients and other substances throughout the body.

The oxygen moves from the blood into the tissues, while carbon dioxide travels in the opposite direction. Carbon dioxide is transported back to the lungs, where it moves out of the blood and into your lungs for release from your body.

Parts of the Cardiovascular System

Your heart pushes the blood around your body through the blood vessels. The heart, shown in **Figure** 13.2, is made of cardiac muscle. The heart is connected to many blood vessels that bring blood all around the body. The cardiac muscle contracts and pumps blood through the blood vessels.

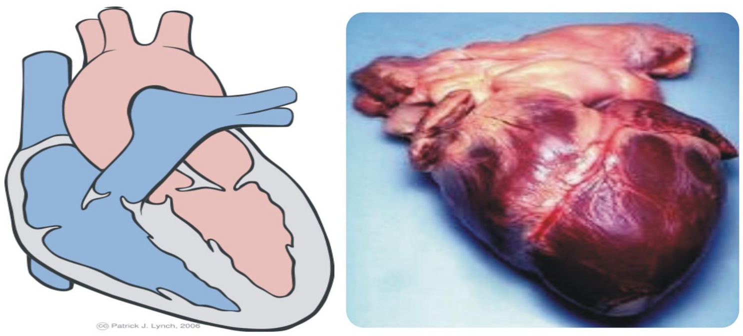


Figure 13.2: Blood is collected in the heart and pumped out to the lungs, where it releases carbon dioxide and picks up oxygen before it is pumped to the rest of the body.

Blood Vessels

The job of the blood vessels is to move the blood around the body. There are three main types of blood vessels in the body.

1. **Arteries** are blood vessels that carry blood *away* from the heart. Arteries have thick walls that have a layer of smooth muscle, as shown in **Figure** 13.3. Arteries usually carry oxygen-rich blood around the body. The blood that is in arteries is under pressure. The contractions of the heart muscle causes blood to push against the walls of the arteries. This "push" is referred to as **blood pressure**. Blood pressure is highest in the arteries and decreases as the blood moves into smaller blood vessels. Thick walls help prevent arteries from bursting under the pressure of blood.
2. **Veins** are blood vessels that carry blood back *to* the heart. Veins have thinner walls than arteries do, as you can see in **Figure** 13.4. The blood in veins is not under pressure. Veins have valves that stop blood from moving backward. Blood is moved forward in veins when the skeletal muscles squeeze the veins. Blood that is carried by veins is usually low in oxygen. The only veins that carry oxygen-rich blood are called the pulmonary veins, which carry blood to the heart from the lungs.
3. **Capillaries** these are the tiniest blood vessels in the body. Every cell in the body needs oxygen, but arteries are too large to bring oxygen and nutrients to single cells. Further from the heart, arteries form capillaries. The walls of capillaries are only as thick as a single layer of cells. Capillaries connect arteries and veins together, as shown in **Figure** 13.5. Capillaries also send water, oxygen and other substances to body cells, while they collect carbon dioxide and other wastes from cells and tissues. Capillaries are so narrow that blood cells must move in single file through them. A capillary bed is the network of capillaries that supply an organ with blood. The more active a tissue or organ is, the more capillaries it needs to get nutrients and oxygen.

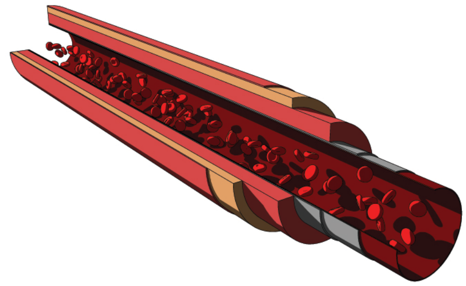


Figure 13.3: Arteries are thick-walled vessels with many layers, including a layer of smooth muscle.

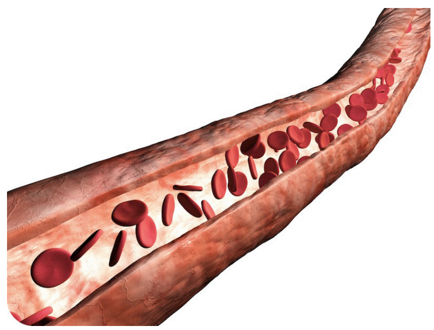


Figure 13.4: The walls of veins are not as thick as artery walls; veins have valves that stop blood from flowing backward.

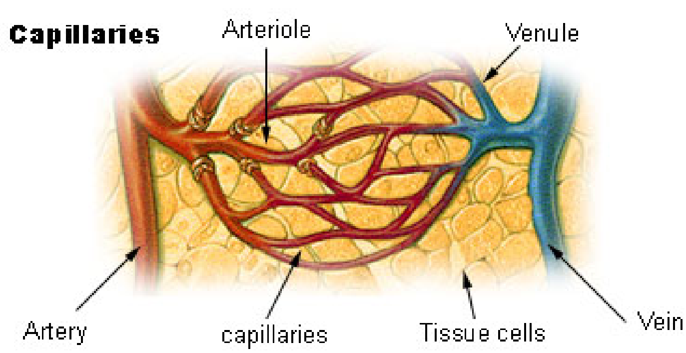


Figure 13.5: Capillaries connect arteries and veins.

Blood

Blood is a body fluid that is a type of connective tissue. Blood is made of blood cells, and a liquid called **plasma**. The main types of cells found in blood are red blood cells and white blood cells.

- **Red blood cells** carry oxygen. Oxygen-rich blood is bright red and oxygen-poor blood is dark red.
- **White blood cells** fight against infection and disease.

The cardiovascular system of humans is "closed." That means the blood never leaves the blood vessels inside of the body Other organisms have blood vessels that interact with the environment.

Two Blood Circulation Systems

The blood is pumped around in two large "loops" within the body. One loop moves blood around the body - to the head, limbs, and internal organs. The other loop moves blood to and from the lungs where carbon dioxide is released and oxygen is picked up by the blood. A simple version of these two "loops" is shown in **Figure** 13.6.

Systemic circulation is the part of the cardiovascular system that carries oxygen-rich blood away from the heart, to the body, and returns oxygen-poor blood back to the heart. **Pulmonary circulation** is the part of the cardiovascular system that carries oxygen-poor blood away from the heart to the lungs, and returns oxygen-rich blood back to the heart.

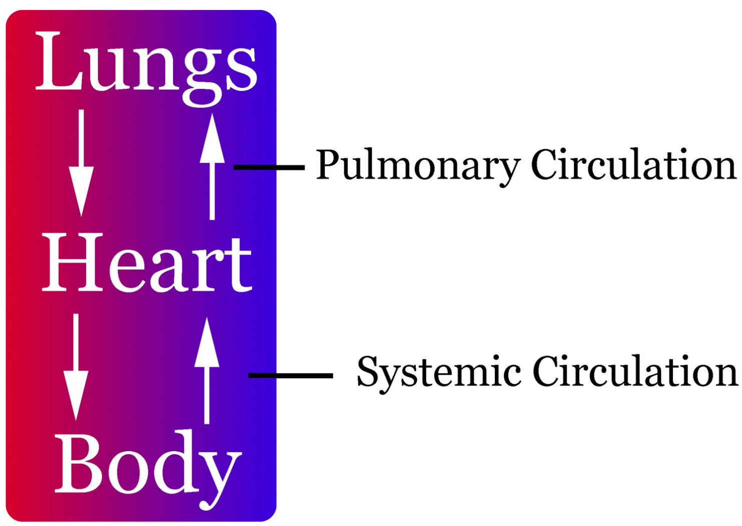


Figure 13.6: The double circulatory system. Trace the systemic circulation. Where is the path of pulmonary circulation?

The Lymphatic System

The **lymphatic system** is a network of vessels and tissues that carry a clear fluid called lymph. The lymphatic system, shown in **Figure** 13.7 spreads all around the body. **Lymph vessels** are tube-shaped, just like blood vessels. The lymphatic system works with the cardiovascular system to return body fluids to the blood. The lymphatic system and the cardiovascular system are often called the body's two "circulatory systems."

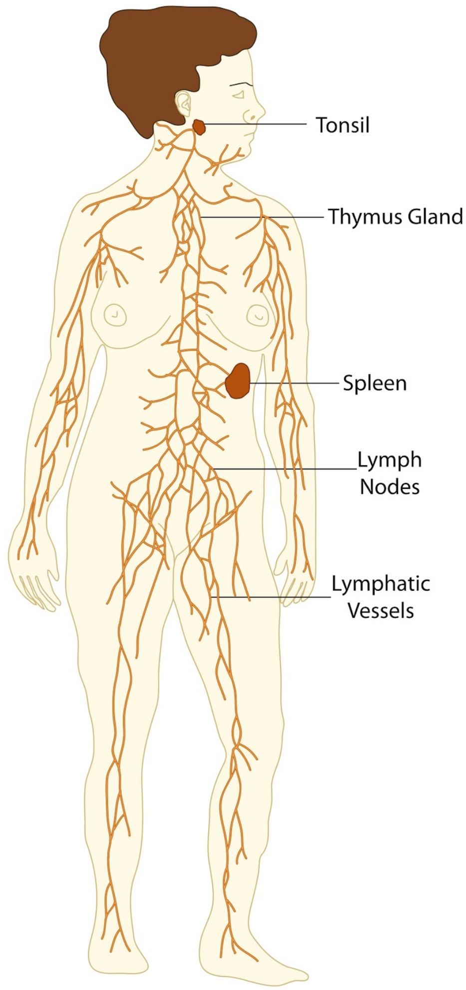


Figure 13.7: The lymphatic system helps return fluid that leaks from the blood vessels back to the cardiovascular system.

Role of the Lymphatic System in Circulation

You may think that your blood vessels have thick walls without any leaks, but it's not true! Blood vessels can leak just like any other pipe. The lymphatic system makes sure leaked blood returns back to the bloodstream.

When a small amount of fluid leaks out from the blood vessels, it collects in the spaces between cells and tissues. Some of the fluid returns to the cardiovascular system, and the rest is collected by the lymph vessels of the lymphatic system, which are shown in **Figure** 13.8. The fluid that collects in the lymph vessels is called **lymph**. The lymphatic system then returns the lymph to the cardiovascular system. Unlike the cardiovascular system, the lymphatic system is not closed and has no central pump (or heart). Lymph moves slowly in lymph vessels. It is moved along in the lymph vessels by the squeezing action of smooth muscles and skeletal muscles.

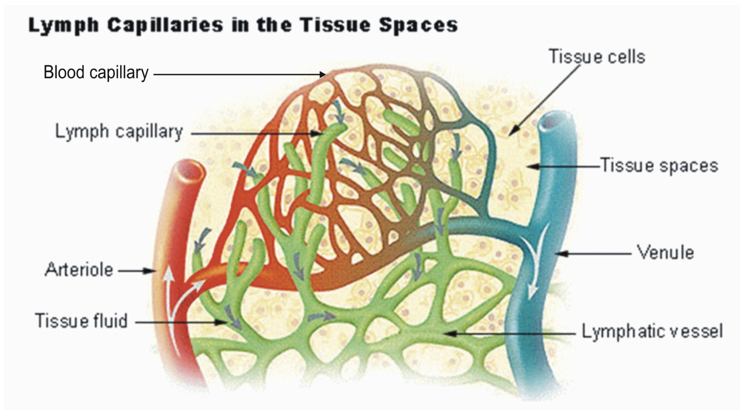


Figure 13.8: Lymph capillaries collect fluid that leaks out from blood capillaries.

Role of the Lymphatic System in the Body's Defenses

The lymphatic system also plays an important role in the immune system. The lymphatic system makes white blood cells that protect the body from diseases.

Organs of the Lymphatic System

Along with the lymph vessels, lymph ducts, and lymph nodes, the lymphatic system also includes many organs. The tonsils, thymus, and spleen, which are shown in **Figure** 13.7, also help prevent diseases. Many of these organs are also part of the immune system.

Tonsils

If you open your mouth and look at your throat in a mirror, you may see some lumps in the back of your throat. These are your tonsils. **Tonsils** are areas of lymphatic tissue on either side of the throat **Figure** 13.9. There are also tonsils in the nasal cavity and behind the tongue. Like other organs of the lymphatic system, the tonsils are also part of the immune system. The immune system helps protect the body against infection. The tonsils are believed to help fight off nose and throat, and other upper respiratory tract infections such as colds. Tonsillitis is an infection of the tonsils that can cause a sore throat and fever.

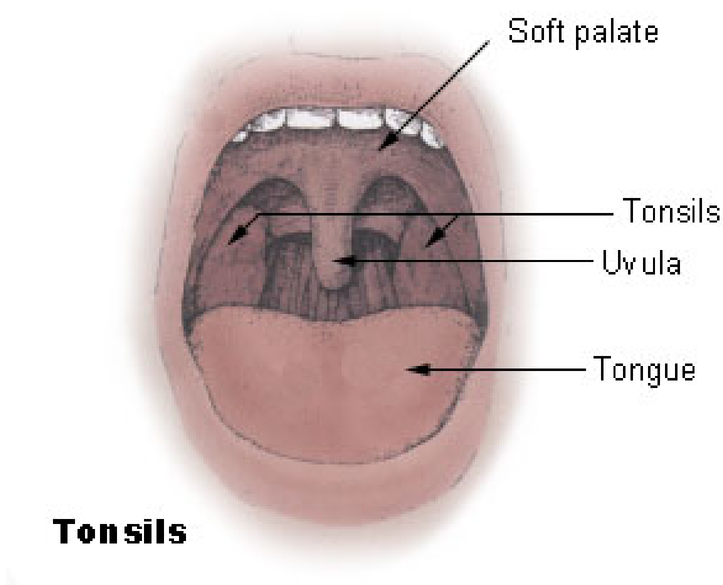


Figure 13.9: This image shows the tonsils in the back of the throat, but there are also tonsils in the nasal cavity and behind the tongue.

Bone Marrow

Bone marrow is the tissue found in the middle of bones. The marrow in the large bones of adults makes new blood cells, like white blood cells, called T-cells. Other white blood cells, called B-cells, are also created in the bone marrow.

Thymus

The **thymus** is found in the upper chest. Chemicals made by the thymus help produce cells that fight infection. White blood cells called **lymphocytes** move from the bone marrow to the thymus to finish growing. The thymus grows to its largest size near puberty, and gets smaller as a person ages. If a person's thymus is surgically removed or damaged by disease while they are young, the person will be more prone to infection.

Spleen

The spleen is in the abdomen, as shown in **Figure** 13.10. In an area of the spleen called **red pulp**, materials are filtered from the blood, including old and dead red blood cells. The spleen also makes red blood cells. Areas called **white pulp** help fight infections by making white blood cells. If a person's spleen is surgically removed, or does not work properly, the person is at risk for certain infections. You can learn more about the roles of the lymphatic system and white blood cells in the *Diseases and the Body's Defenses* chapter.

Lesson Summary

- **Table** 13.1 summarizes the structures and functions of the cardiovascular and lymphatic systems.

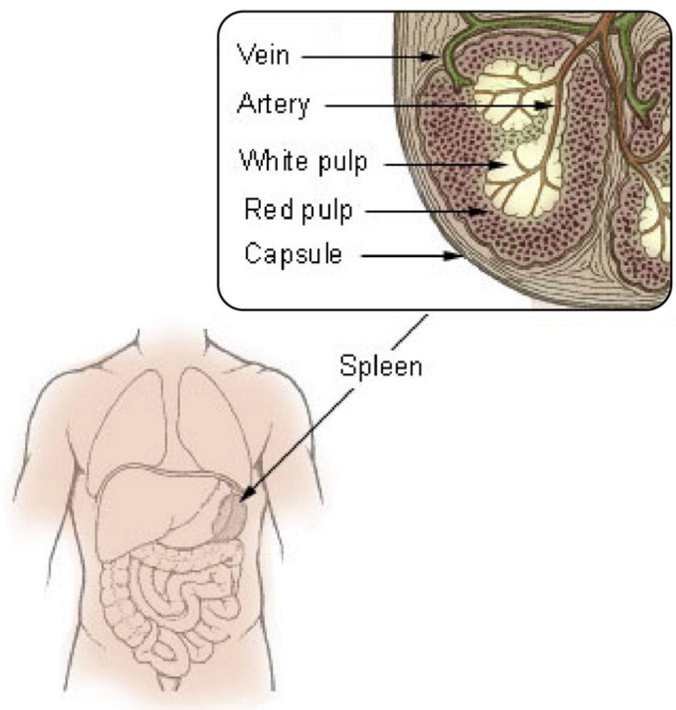


Figure 13.10: In the spleen, the white pulp makes white blood cells, while the red pulp acts like a filter and removes dead and dying cells from the blood.

Table 13.1: **Structures and Functions of the Cardiovascular and Lymphatic Systems**

System	Structure (organs and tissues)	Function
Lymphatic	Lymph vessels	Transport fluid (lymph) from between body cells back to blood
	Lymph nodes	Trap invading diseases and cells with cancer
	Spleen, tonsils, and adenoids	Trap invading diseases
	Thymus	where white blood cell (lymphocytes) grow larger
Cardiovascular	Blood vessels	Transport blood around the body
	Blood	Moves oxygen and nutrients; also carries white blood cells to sites of infection and inflammation
	Heart	Pumps blood around the body

- The cardiovascular system includes the heart, the blood vessels, and the blood.
- There are three main types of blood vessels in the body: arteries, veins, and capillaries.
- Systemic circulation is the part of the cardiovascular system that carries oxygen-rich blood away from the heart, to the body, and returns oxygen-poor blood back to the heart.
- Pulmonary circulation is the part of the cardiovascular system that carries oxygen-poor blood away from the heart to the lungs, and returns oxygen-rich blood back to the heart.
- Organs of the lymphatic system include the tonsils, thymus, and spleen.
- The lymphatic system works with the cardiovascular system to return body fluids to the blood.

Review Questions

Recall

1. Identify the three main parts of the cardiovascular system.
2. Identify three types of blood vessels found in the body.
3. Which blood vessels move blood away from the heart?
4. What are the smallest blood vessels in the body called?
5. Which blood vessels bring blood back to the heart?
6. Identify three main organs of the lymphatic system.
7. Name one function of tonsils.

Apply Concepts

8. Where does blood in the pulmonary system go after it leaves the heart?
9. Where does blood in systemic circulation go after it leaves the heart?
10. What does blood that leaves the heart in systemic circulation have that body cells need?
11. How do the cardiovascular and lymphatic systems work together?

12. What is lymph, and where does it come from?
13. What might happen if a person did not have a spleen?

Critical Thinking

14. Explain how there are actually two circulatory systems in the body.

Further Reading / Supplemental Links

- http://en.wikipedia.org/wiki/Heart

Points to Consider

Next we look further at the heart and blood vessels.

- How can the heart pump blood to the entire body?
- How do you think a hole in the heart muscle affect blood flow?

13.2 Heart and Blood Vessels

Lesson Objectives

- Describe the structure of the heart.
- Outline how blood moves through the heart.
- Describe the importance of valves in the heart.
- Describe the coronary circulation.

Check Your Understanding

- What is the role of the cardiovascular system?
- What is the main function of the heart?

Vocabulary

- atrioventricular (AV) valves
- atrium
- semilunar (SL) valves
- valves
- ventricles

The Heart

What is the heart? How does it pump blood? The heart is divided into four chambers, or spaces: the left and right atria, and the left and right ventricles. An **atrium** (singular for atria) is one of the two small, thin-walled chambers on the top of the heart where the blood first enters. A **ventricle** is one of the two muscular V-shaped chambers that pump blood out of the heart. You can remember they are called ventricles because they are shaped like a "V." The four chambers of the heart are shown in **Figure** 13.11.

The atria receive the blood, and the ventricles pump the blood out of the heart. Each of the four chambers of the heart has a specific job.

- The right atrium receives oxygen-poor blood from the body.
- The right ventricle pumps oxygen-poor blood toward the lungs.
- The left atrium receives oxygen-rich blood from the lungs.
- The left ventricle pumps oxygen-rich blood out of the heart to the rest of the body.

Where is the Heart?

The heart is closer to the center of the body than you may think. It is usually found in the left to middle of the chest, with the largest part of the heart slightly to the left. It always feels like the heart is on the left side of the body because the left ventricle is bigger and stronger than the right ventricle. The heart is also surrounded by the lungs.

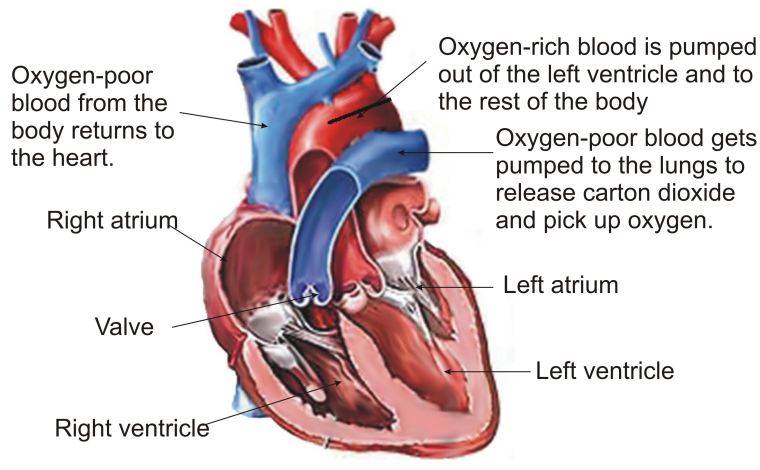


Figure 13.11: The atria receive blood and the ventricles pump blood out of the heart.

Blood Flow Through the Heart

Blood flows through the heart in two separate loops. You can think of them as a "left side loop" and a "right side loop." The right side of the heart collects oxygen-poor blood from the body and pumps it into the lungs, where it releases carbon dioxide and picks up oxygen. The left side carries the oxygen-rich blood back from the lungs into the left side of the heart, which then pumps the oxygen-rich blood to the rest of the body.

The Heartbeat

To move blood through the heart, the cardiac muscle needs to contract in an organized way. Blood first enters the atria, as shown in **Figure** 13.12. When the atria contract, blood is pushed into the ventricles. After the ventricles fill with blood, they contract, and blood is pushed out of the heart. So how is the blood kept from flowing back on itself?

Valves in the heart keep the blood flowing in one direction. You can see some of the valves in **Figure** 13.12. The valves do this by opening and closing in one direction only. Blood only moves forward through the heart. The valves stop the blood from flowing backward. There are four valves of the heart.

- The two atrioventricular (AV) valves stop blood from moving from the ventricles to the atria.
- The two semilunar (SL) valves are found in the arteries leaving the heart, and they prevent blood flowing back from the arteries into the ventricles.

Why does a heart beat? The “lub-dub” sound of the heartbeat is caused by the closing of the AV valves (”lub”) and SL valves (”dub”), after blood has passed through them.

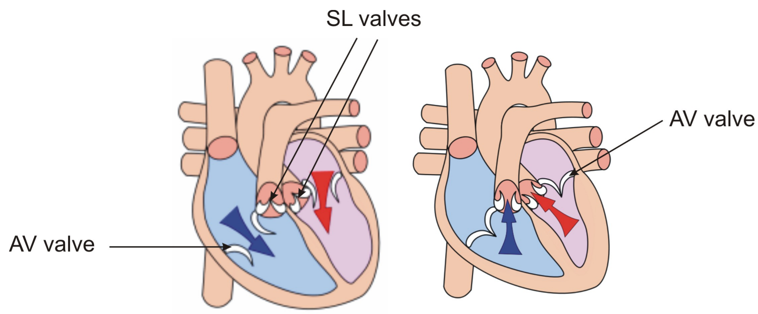


Figure 13.12: Blood flows in only one direction in the heart. Blood enters the atria, which contract and push blood into the ventricles. The atria relax and the ventricles fill with blood. Finally, the ventricles contract and push blood around the body.

Control of the Heartbeat

The heart is a made up of cardiac muscle cells. Cardiac cells are able to contract by themselves. They do not need help from the nervous system. This is different from skeletal muscle, which needs messages from nerves to contract. The number of times a heart contracts over a certain amount of time is called the **heart rate**. Exercising or getting scared can make the heart rate increase. After the exercise is over, or the fear has passed, the heart rate returns to normal.

Blood Circulation and Blood Vessels

The blood vessels are an important part of the cardiovascular system. They connect the heart to every cell in the body. Arteries carry blood away from the heart, while veins return blood to the heart. The main arteries and veins of the heart are shown in **Figure** 13.13.

Important Arteries and Veins

There are specific veins and arteries that are more significant than others. The pulmonary arteries carry oxygen-poor blood away from the heart to the lungs. These are the only arteries that carry oxygen-poor blood. The aorta is the largest artery in the body. It carries oxygen-rich blood away from the heart. Further away from the heart, the aorta branches into smaller arteries, which eventually branch into capillaries.

The veins that return oxygen-poor blood to the heart are the superior vena cava and the inferior vena cava. The **pulmonary veins** return oxygen-rich blood from the lungs to the heart. The pulmonary veins are the only veins that carry oxygen-rich blood.

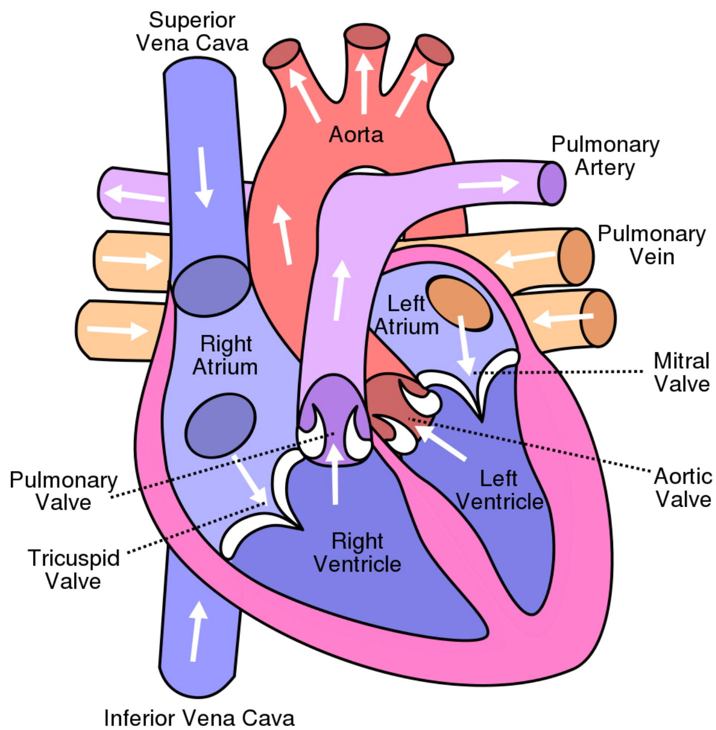


Figure 13.13: The right side of the heart pumps deoxygenated blood into pulmonary circulation, while the left side pumps oxygenated blood into systemic circulation.

Pulmonary Circulation

Pulmonary circulation is the part of the cardiovascular system that carries oxygen-poor blood away from the heart and brings it to the lungs. Oxygen-poor blood returns to the heart from the body and leaves the right ventricle through the pulmonary arteries, which carry the blood to each lung. Once at the lungs, the red blood cells release carbon dioxide and pick up oxygen when you breathe. The oxygen-rich blood then leaves the lungs through the pulmonary veins, which return it to the left side of the heart. This completes the pulmonary cycle. The oxygenated blood is then pumped to the body through systemic circulation, before returning again to pulmonary circulation.

Systemic Circulation

Systemic circulation is the part of the cardiovascular system that carries oxygen-rich blood away from the heart, to the body, and returns oxygen-poor blood back to the heart. Oxygen-rich blood leaves the left ventricle through the aorta, then it travels to the body's organs and tissues. The tissues and organs absorb the oxygen through the capillaries. Oxygen-poor blood is collected from the tissues and organs by tiny veins, which then flow into bigger veins, and eventually into the inferior vena cava and superior vena cava. This completes systemic circulation. The blood releases carbon dioxide and gets more oxygen in pulmonary circulation before returning to systemic circulation.

Lesson Summary

- The heart is divided into four chambers, the left and right atria and the left and right ventricles.

- The right side of the heart collects oxygen-poor blood from the body and pumps it into the lungs, where it releases carbon dioxide and picks up oxygen.
- The left-side carries the oxygen-poor blood back from the lungs into the left side of the heart, which then pumps the oxygen-poor blood to the rest of the body.
- The valves in the heart prevent blood from flowing backward into the heart.

Further Reading / Supplemental Links

- http://en.wikipedia.org/wiki/William_Harvey
- http://thevirtualheart.org/anatomyindex.html
- http://en.wikipedia.org/wiki/Cardiac_cycle

Review Questions

Recall

1. Name the four chambers of the heart.
2. Where does oxygen-poor blood first enter the heart?
3. Do ventricles pump blood out of the heart, or do they pump blood into the atria?
4. Do the inferior vena cava and superior vena cava carry oxygen-poor or oxygen-rich blood?
5. To what organ or organs does systemic circulation bring blood?
6. To what organ or organs does pulmonary circulation bring blood?

Apply Concepts

7. Why can the heart be considered to be two separate pumps?
8. What is the purpose of the valves in the heart?

Critical Thinking

9. How might a hole in the heart wall between the two ventricles affect the circulation of blood?

Points to Consider

A more in-depth look at blood is next.

- How do different parts of the blood impact the cardiovascular system?
- How can diet affect how blood carries oxygen?

13.3 Blood

Lesson Objectives

- List the main parts of blood.

- Identify three functions of blood.
- Name the oxygen-carrying protein found in red blood cells.
- Identify the main function of white blood cells.
- Describe the importance of the ABO blood system.
- Identify three blood disorders or diseases.

Check Your Understanding

- What is the main function of the blood?
- What is the role of oxygen in aerobic (cellular) respiration?

Vocabulary

- ABO blood type system
- antibody
- blood clotting
- fibrin
- hemoglobin
- hemophilia
- leukemia
- lymphoma
- platelets
- red blood cells
- sickle cell disease
- universal donor
- universal recipient
- white blood cells

Components of Blood

Did you know that blood is a tissue? Blood is a fluid connective tissue that is made up of red blood cells, white blood cells, platelets, and plasma. The cells that make up blood are shown in **Figure** 13.14. The different parts of blood have different roles.

Some of the roles of blood include:

- The defense of the body against diseases.
- The movement of chemical messages, such as hormones and hormone-like substances.
- The control of body temperature.
- The repair of damage to body tissues.

Plasma

If you were to filter out all the cells in blood, plasma is what would be left over. Plasma is the golden-yellow liquid part of the blood. Plasma is about 90 percent water and about 10 percent dissolved proteins, glucose, ions, hormones, and gases. Blood is made up mostly of plasma.

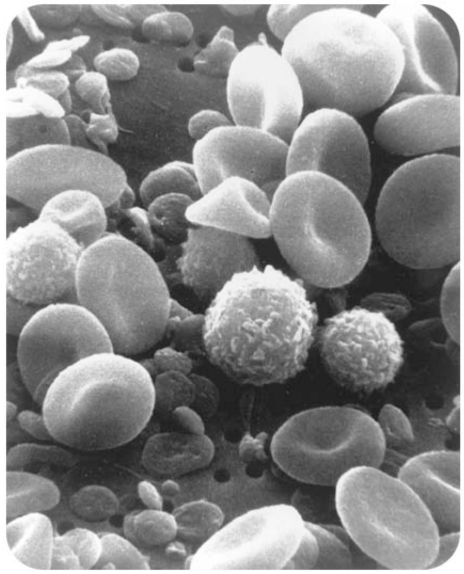


Figure 13.14: A scanning electron microscope (SEM) image of human blood cells. Red blood cells are the flat, bowl-shaped cells, the tiny disc-shaped pieces are platelets and white blood cells are the round cells shown in the center.

Red Blood Cells

Red blood cells (RBCs) are flattened, disk-shaped cells that carry oxygen. They are the most common blood cell in the blood. There are about 4 to 6 million RBCs per cubic millimeter of blood. Each RBC has 200 million molecules of hemoglobin. **Hemoglobin** is the protein that carries oxygen. Hemoglobin also gives the RBCs their red color.

Red blood cells are made in the red marrow of long bones, ribs, skull, and vertebrae. Each red blood cell lives for only 120 days (about four months). After this time, they are destroyed in the liver and spleen. Red blood cells are shown in **Figure** 13.15. Mature RBCs do not have a nucleus or other organelles.

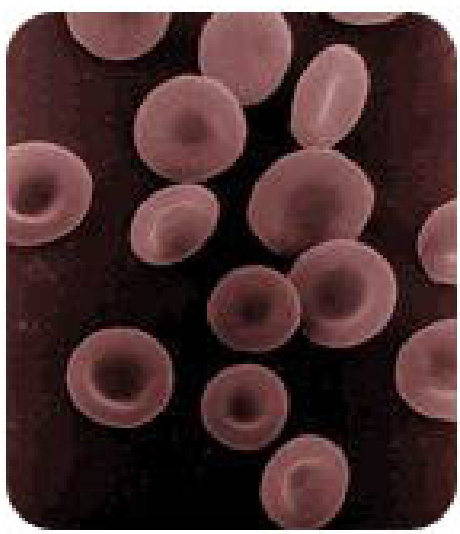


Figure 13.15: The flattened shape of RBCs helps them to carry more oxygen than if they were rounded.

White Blood Cells

White blood cells (WBCs) are usually larger than red blood cells. They have a nucleus but do not have hemoglobin. White blood cells make up less than one percent of the blood's volume. Most WBCs are made in the bone marrow, and some mature in the lymphatic system. WBCs defend the body against infection by bacteria, viruses, and other diseases. There are different WBCs with different jobs.

- Neutrophils can squeeze through capillary walls and swallow particles such as bacteria and parasites.
- Macrophages can also swallow and destroy old and dying cells, bacteria, or viruses. In **Figure** 13.16 a macrophage is attacking and swallowing two particles, possibly diseases. Macrophages also release chemical messages that cause the number of WBCs to increase.
- Lymphocytes fight infections caused by viruses and bacteria. Some lymphocytes attack and kill cancer cells. Lymphocytes called B-cells make antibodies. An **antibody** is a protein that finds harmful antigens and destroys them. To learn more about the role of WBCs in protecting the body from infection, see the *Diseases and the Body's Defenses* chapter.

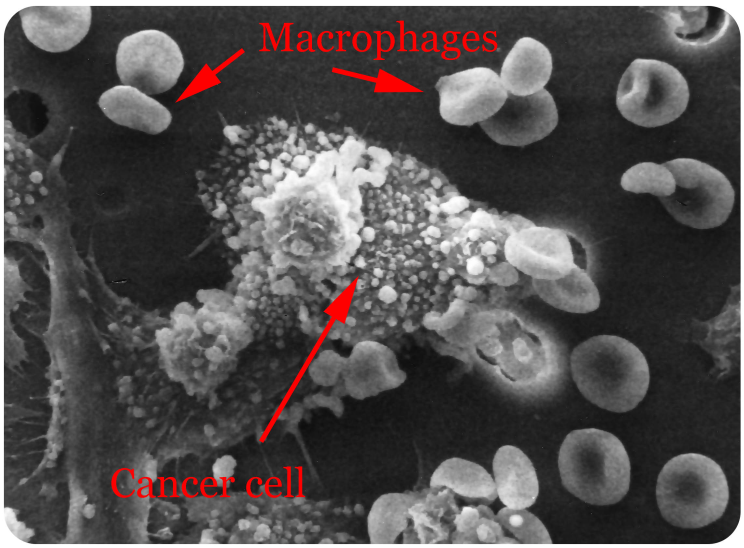


Figure 13.16: A type of WBC, called a macrophage, is attacking a cancer cell

Platelets

Platelets are very small, but they are very important in blood clotting. Platelets are not cells. They are sticky little pieces of larger cells. Platelets bud off large cells that stay in the bone marrow. A platelet sits between a RBC and a WBC in **Figure** 13.17. When a blood vessel gets cut, platelets stick to the injured areas. They release chemicals called clotting factors, which cause proteins to form over the wound. This web of proteins catches RBCs and forms a clot. This clot stops more blood from leaving the body through the cut blood vessel. The clot also stops bacteria from entering the body. Platelets survive in the blood for 10 days before they are removed by the liver and spleen.

Transport of Chemical Messages

The blood also acts as a messenge delivery service, like a post office. Chemical messengers called hormones are carried and brought to cells by the blood.

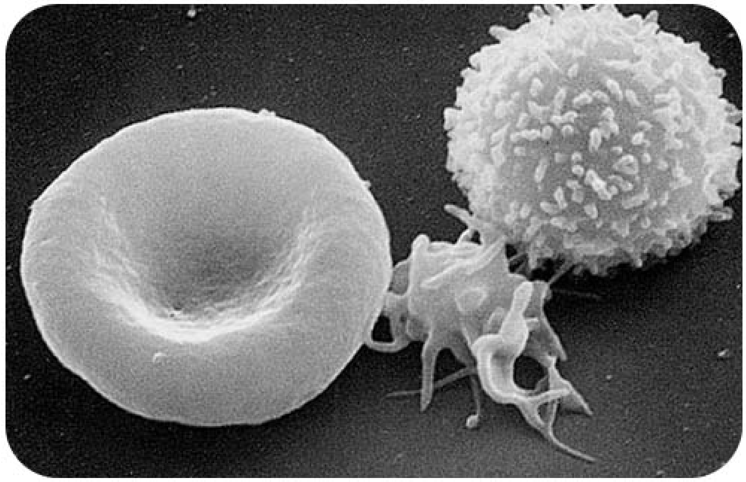


Figure 13.17: A platelet lies between a RBC, at left, and a WBC at right. Platelets are little pieces of larger cells that are found in the bone marrow.

Control of Body Temperature

How do your blood vessels control your body temperature? Your blood also moves heat around your body. When your brain senses that your body temperature is increasing, it sends messages to the blood vessels in the skin to increase in diameter. Increasing the diameter of the blood vessels increases the amount of blood and heat that moves near the skin surface. The heat is then released from the skin. What do you think your blood vessels do when your body temperature is decreasing?

Blood Clotting

Blood clotting is a complex process by which blood forms solid clots. As discussed above, clotting is important to stop bleeding and begin the repair of damaged blood vessels. Blood clotting disorders can lead to an increased risk of bleeding or clotting inside a blood vessel. Platelets are important for the proper clotting of blood.

Clotting is started almost immediately when an injury damages the inside lining of a blood vessel. The steps involved in clotting are described below:

1. Platelets clump together, forming a clot at the injury site.
2. Proteins in the plasma cause a chemical reaction that brings a protein called **fibrin** to the site.
3. The fibrin forms a web across the platelet clot, trapping red blood cells.
4. This mass of platelets, fibrin, and red blood cells forms a clot that turns into a scab.

Certain nutrients are needed for the clotting system to work properly. Two of these are calcium and vitamin K. Bacteria that live in your intestines make enough vitamin K, so you do not need to eat extra vitamin K in your food.

Blood Types

Do you know what your blood type is? Maybe you have heard someone say that they some Type A or Type O blood. Blood type is a way to describe the type of antigens, or proteins, on the surface of red blood cells (RBCs). There are four blood types; A, B, AB, and O.

1. Type A blood has type A antigens on the RBCs in the blood.
2. Type AB blood has A and B antigens on the RBCs.
3. Type B has B antigens on the RBCs.
4. Type O does not have any antigens.

The ABO blood group system is important if a person needs a blood transfusion. A blood transfusion is the process of putting blood or blood products from one person into the circulatory system of another person. Blood also has different types of antibodies, or proteins released by the blood cells that attack other strange substances or diseases in the body. Different blood types have different antibodies (see chart below). What type of antibodies do people with Type O blood produce? Anti-A and anti-B antibodies. This means that if a person with type O blood received type A blood, the anti-A antibodies in the person's blood would attack the A antigens on the RBCs in the donor blood, as shown in **Figure** 13.18. The antibodies would cause the RBCs to clump together, and the clumps could block a blood vessel. This clumping of blood cells could cause death.

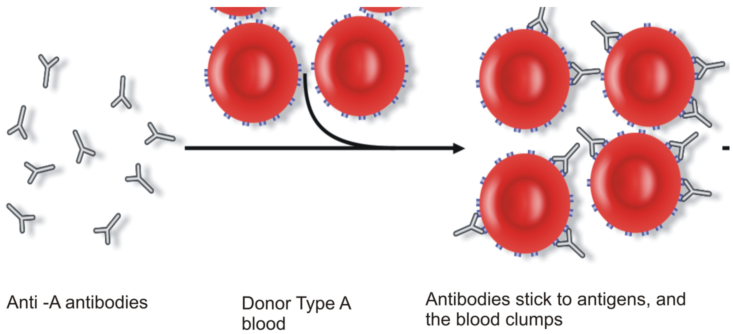


Figure 13.18: A person with type O blood has A and B antibodies in their plasma; if the person was to get type A blood instead of type O, Their A antibodies would attach to the antigens on the RBCs and cause them to clump together.

The Rhesus System

The second most important blood group system in human blood is the Rhesus (Rh) system. A person either has, or does not have, the Rh antigen on the surface of their RBCs. If they do have it, then the person is positive. If the person does not have the antigen, they are considered negative.

Blood Donors

Recall that people with type O blood do not have any antigens on their RBCs. As a result, type O blood can be given to people with blood types A, B, or AB. If there are no antigens on the RBCs, there cannot be an antibody reaction in the blood. People with type O blood are often called **universal donors.**

The blood plasma of AB blood does not contain any anti-A or anti-B antibodies. People with type AB blood can receive any ABO blood type. People with type AB positive blood are called **universal recipients** because they can receive any blood type. The antigens and antibodies that define blood type are listed in **Table** 13.2.

Table 13.2: **Blood Types, Antigens, and Antibodies**

Blood type	Antigen type	Plasma antibodies	Can receive blood from types	Can donate blood to types
A	A	anti-B	A,O	A, AB
B	B	anti-A	B,O	B, AB
AB	A and B	none	AB, A, B, O	AB
O	none	anti-A, anti-B	O	AB, A, B, O

Blood Diseases

Problems can occur with red blood cells, white blood cells, platelets, and other parts of the blood. Many blood disorders are genetic, meaning they are inherited from a parent. Some blood diseases are caused by not getting enough of a certain nutrient, while others are cancers of the blood.

Sickle-Cell Disease

Sickle-cell disease is a blood disease that is caused by abnormally-shaped blood protein hemoglobin. Many of the RBCs of a person with sickle cell disease are long and curved (sickle-shaped), as shown in **Figure** 13.19. The long, sickle-shaped RBCs can have damaged cell membranes, which can cause them to burst. The long shape of the cells can cause them to get stuck in narrow blood vessels. This clotting means that oxygen cannot reach the cells. People with sickle-cell disease are most often well, but can occasionally have painful attacks. The disease is not curable, but can be treated with medicines.

There is an advantage, however, to sickle-cell disease. People who are carriers for the sickle cell gene, or who are heterozygous, are resistant to severe malaria. See the *Genetics* chapter for further information.

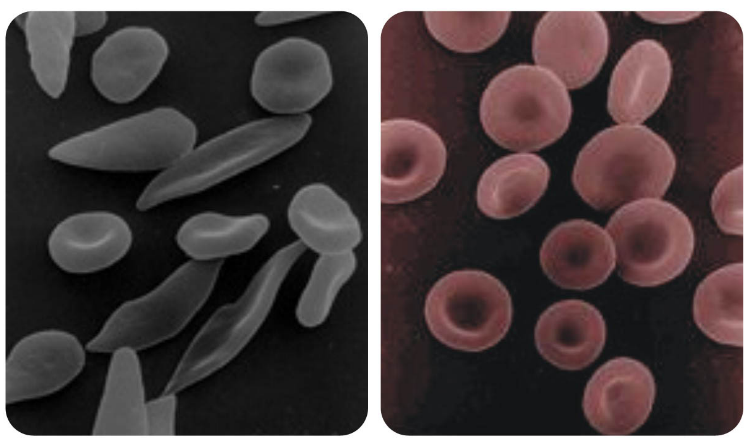


Figure 13.19: The RBCs of a person with sickle-cell disease (left) are long and pointed, rather than straight, like normal cells (right). The abnormal cells cannot carry oxygen properly and can get stuck in capillaries.

Anemia

Anemia is a disease that occurs when there is not enough hemoglobin in the blood to carry oxygen to body cells. Hemoglobin normally carries oxygen from the lungs to the tissues. Anemia leads to a lack of oxygen in organs.

Anemia is usually caused by one of the following:

- A loss of blood from a bleeding wound or a slow leak of blood.
- The destruction of RBCs.
- A lack of RBC production.

Anemia may not have any symptoms. Some people with anemia feel weak or tired in general or during exercise. They also may have poor concentration. People with more severe anemia often get short of breath during activity. Iron-deficiency anemia is the most common type of anemia. It occurs when the body does not receive enough iron. Since there is not enough iron, hemoglobin, which contains iron, cannot be made.

In the United States, 20 percent of all women of childbearing age have iron deficiency anemia, compared with only 2 percent of adult men. The most common cause of iron deficiency anemia in young women is blood lost during menstruation. Iron deficiency anemia can be avoided by getting the recommended amount of iron in one's diet. Anemia is often treated or prevented by taking iron supplements.

Boys and girls between the ages of 9 and 13 should get 9 mg of iron every day. Girls between the ages of 14 and 18 should get 15 mg of iron every day. Boys between the ages of 14 and 18 should get 11 mg of iron every day. Pregnant women need the most iron — 27 mg daily.

Good sources of iron include shellfish, such as clams and oysters. Red meats, such as beef, are also a good source of iron. Non-animal sources of iron include seeds, nuts, and legumes. Breakfast cereals often have iron added to them in a process called fortification. Some good sources of iron are listed in **Table** 13.3. Eating vitamin C along with iron-containing food increases the amount of iron that the body can absorb.

Table 13.3: **Sources of Iron**

Food	Milligrams (mg) of Iron
Canned clams, drained, 3 oz	23.8
Fortified dry cereals, about 1 oz	1.8 to 21.1
Roasted pumpkin and squash seeds, 1 oz	4.2
Cooked lentils, ½ cup	3.3
Cooked fresh spinach, ½ cup	3.2
Cooked ground beef, 3 oz	2.2
Cooked sirloin beef, 3 oz	2.0

Leukemia

Leukemia is a cancer of the blood or bone marrow. It is characterized by an abnormal production of blood cells, usually white blood cells. **Lymphoma** is a type of cancer in white blood cells called *lymphocytes.* There are many types of lymphoma.

Hemophilia

Hemophilia is the name of a group of sex-linked hereditary diseases that affect the body's ability to control blood clotting. Hemophilia is caused by a lack of clotting factors in the blood. Since people with hemophilia cannot produce clots, any cut can put a person at risk of bleeding to death. The risk of internal bleeding is also increased in hemophilia, especially into muscles and joints.

Lesson Summary

- Blood is a fluid connective tissue that contains red blood cells, white blood cells, platelets, and plasma.
- The red blood cells give blood its red color.
- Blood carries oxygen and nutrients to body cells and carries wastes away. It also helps to maintain body temperature and to carry chemical messengers called hormones around the body.
- Hemoglobin is the oxygen-carrying protein that is found in red blood cells.
- White blood cells defend the body against infection by bacteria, viruses and other pathogens.
- Blood type is determined by the presence or absence of certain molecules, called antigens, on the surface of red blood cells (RBCs).
- There are four blood types; A, B, AB, and O.
- If a person receives the wrong blood type, antibodies in the recipient's blood will attack the antigens on the RBCs in the donor blood.
- Sickle-cell disease is a blood disease that is caused by abnormally-shaped hemoglobin, and important blood protein.
- Anemia is a disorder caused by a lack of hemoglobin in the blood.

Review Questions

Recall

1. What types of cells are found in blood?
2. What is the liquid part of blood called?
3. What is the function of platelets?
4. Identify one other function of blood other than bringing oxygen to body cells.
5. What is the oxygen-carrying protein found in red blood cells?
6. Identify two ways that white blood cells defend the body from infection.
7. Identify three blood disorders or diseases.
8. Identify two good sources of iron in the diet.

Apply Concepts

9. How are the red blood cells of the different blood groups different?
10. Why are people with type O blood called "universal donors?"
11. Why are people with type AB blood called "universal recipients?"
12. What is a common cause of anemia in young people?

Critical Thinking

13. How can the shape of the hemoglobin protein in a person with sickle-cell disease affect other body systems?

Further Reading / Supplemental Links

- http://www.nhlbi.nih.gov/health/dci/Diseases/Sca/SCA_WhatIs.html
- http://www.leukemia-lymphoma.org/all_page?item_id=7026
- http://en.wikipedia.org/wiki

Points to Consider

The health of the cardiovascular system is next.

- Why do you think the blood in veins not under pressure?
- How might your diet affect your cardiovascular system?

13.4 Health of the Cardiovascular System

Lesson Objectives

- Outline the cause of blood pressure in arteries.
- Identify the healthy range for blood pressure.
- Describe three types of cardiovascular disease.
- Identify things you can do to avoid cardiovascular disease.

Check Your Understanding

- What is the role of the cardiovascular system?

Vocabulary

- angina
- atherosclerosis
- blood pressure
- cardiovascular disease (CVD)
- coronary heart disease
- heart attack
- hypertension
- plaque
- stroke

Blood Vessels and Blood Pressure

The health of your whole body depends on the good health of your cardiovascular system. **Blood pressure** occurs when circulating blood puts pressure on the walls of blood vessels. The pressure causes the walls of the arteries to move in a rhythmic fashion.

Blood in arteries is under the greatest amount of pressure. A person's pulse is the throbbing of their arteries that results from the heart beat. The pressure of the circulating blood slowly decreases as blood moves from the arteries, and into the smaller blood vessels. Blood in veins is not under pressure.

The **systolic** pressure is the highest pressure in the arteries. The **diastolic** pressure is the lowest pressure. Pressure in arteries is most commonly measured by an instrument called a **sphygmomanometer**, shown in **Figure** 13.20. The height of the column of mercury shows the pressure of the circulating blood. Many modern blood pressure devices no longer use mercury, but values are still reported in millimeters of mercury (mm Hg).

Figure 13.20: A digital sphygmomanometer is made of an inflatable cuff and a pressure meter to measure blood pressure.

Healthy Blood Pressure Ranges

Healthy ranges for blood pressure are:

- Systolic: less than 120 mm Hg
- Diastolic: less than 80 mm Hg

Blood pressure is usually written as systolic/diastolic mm Hg. For example, a reading of 120/80 mm Hg is said as "one twenty over eighty." These measures of blood pressure can change with each heartbeat and over the course of the day. Age, gender and race also influence blood pressure values. Pressure also varies with exercise, emotions, sleep, stress, nutrition, drugs, or disease.

Studies have shown that people whose systolic pressure is around 115 mm Hg rather than 120 mm Hg have fewer health problems. Clinical trials have shown that people who have blood pressures at the low end of these ranges have much better long term cardiovascular health.

Hypertension, which is also called "high blood pressure," occurs when a person's blood pressure is always high. Hypertension is said to be present when a person's systolic blood pressure is always 140 mm Hg or higher, and/or their diastolic blood pressure is always 90 mm Hg or higher. Having hypertension increases a person's chance for developing heart disease, having a stroke, and other serious cardiovascular diseases. Hypertension often does not have any symptoms, so a person may not know they have high blood pressure. For this reason, hypertension is often called the silent killer. Treatments for hypertension include diet changes, exercise, and medication.

Atherosclerosis and Other Cardiovascular Diseases

A **cardiovascular disease (CVD)** is any disease that affects the cardiovascular system. But the term is usually used to describe diseases that are linked to atherosclerosis.

Atherosclerosis is an inflammation of the walls of arteries that causes swelling and a buildup of material called plaque. **Plaque** is made of cell pieces, fatty substances, calcium, and connective tissue that builds up around the area of inflammation. As a plaque grows, it stiffens and narrows the artery, which decreases the flow of blood through the artery, shown in **Figure** 13.21.

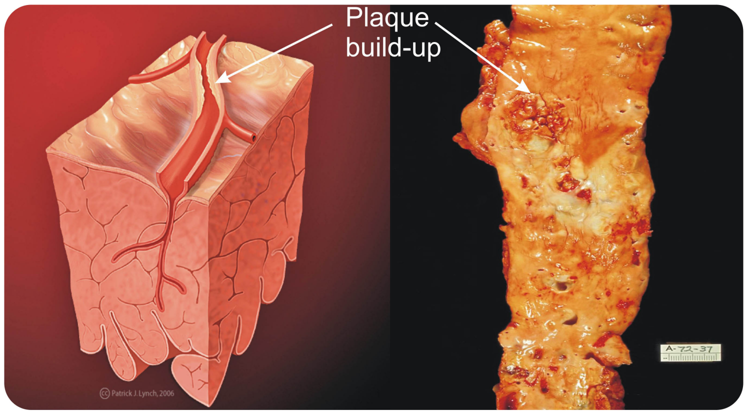


Figure 13.21: Atherosclerosis is sometimes referred to as hardening of the arteries; plaque build-up decreases the blood flow through the artery.

Atherosclerosis

Atherosclerosis normally begins in later childhood, and is usually found in most major arteries. It does not usually have any early symptoms. Causes of atherosclerosis include a high-fat diet, high cholesterol, smoking, obesity, and diabetes. Atherosclerosis becomes a threat to health when the plaque buildup prevents blood circulation in the heart or the brain. A blocked blood vessel in the heart can cause a heart attack. Blockage of the circulation in the brain can cause a stroke. According to the American Heart Association, atherosclerosis is a leading cause of CVD.

Coronary Heart Disease

Hearts have arteries that require oxygen, too. Muscle cells in the heart are given oxygen by **coronary arteries**. Blocked flow in a coronary artery can result in a lack of oxygen and the death of heart muscle. **Coronary heart disease** is the end result of the buildup of plaques within the walls of the coronary arteries.

Coronary heart disease often does not have any symptoms. A symptom of coronary heart disease is chest pain. Occasional chest pain, called **angina** can happen during times of stress or physical activity. The pain of angina means the heart muscle fibers need more oxygen than they are getting. Most people with coronary heart disease often have no symptoms for many years until they have a heart attack.

A **heart attack** happens when the blood cannot reach the heart because a blood vessel is blocked. If cardiac muscle is starved of oxygen for more than about five minutes, it will die. Cardiac muscle cells cannot be replaced, so once they die, they are dead forever. Coronary heart disease is the leading cause of death of adults in the United States. How a blocked coronary artery can cause a heart attack, and cause part of the heart muscle to die, is shown in **Figure** 13.22. If part of the cardiac muscle becomes injured, the heart will not work as well as it used to.

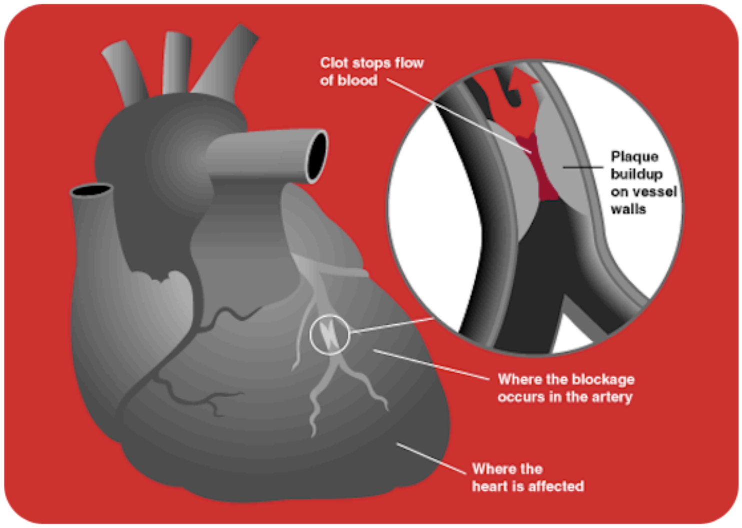


Figure 13.22: A blockage in a coronary artery stops oxygen getting to part of the heart muscle, so areas of the heart that depend on the blood flow from the blocked artery are starved of oxygen.

Stroke

Atherosclerosis in the arteries of the brain can also lead to a stroke. A **stroke** is a loss of brain function due to a blockage of the blood supply to the brain. It can be caused by a blood clot, an object that gets caught in a blood vessel, or by a bleeding blood vessel. Risk factors for stroke include old age, high blood pressure, having a previous stroke, diabetes, high cholesterol, and smoking. The best way to reduce the risk of stroke is to have low blood pressure. Many other risk factors, however, such as avoiding or quitting smoking are also important.

Keeping Your Cardiovascular System Healthy

There are many risk factors that can cause a person to develop CVD. A **risk factor** is anything that is linked to an increased chance of developing a disease or an infection. Some of the risk factors for CVD you cannot control, but there are many risk factors you can control.

Risk factors you cannot control include:

- **Age**: the older a person is, the greater their chance of developing a cardiovascular disease.
- **Gender**: men under age 64 are much more likely to die of coronary heart disease than women, although the gender difference decreases with age.
- **Genetics**: family history of cardiovascular disease increases a person's chance of developing heart disease.

Risk factors you can control include:

- **Tobacco smoking**: giving up smoking or never starting to smoke is the best way to reduce the risk of heart disease.

- **Diabetes**: diabetes can cause bodily changes, such as high cholesterol levels, which are are risk factors for CVD.
- **High cholesterol levels**: high amounts of low-density lipids in the blood, also called ”bad cholesterol,” increase the risk of CVD.
- **Obesity**: being obese, especially if the fat is mostly found in the upper body, rather than the hips and thighs, increases risk significantly.
- **High blood pressure**: hypertension can cause atherosclerosis.
- **Lack of physical activity**: aerobic activities, such as the one shown in **Figure** 13.23, help keep your heart healthy. To reduce the risk of disease, you should be active for at least 60 minutes a day, five days a week.
- **Poor eating habits**: eating mostly foods that do not have many nutrients other than fat or carbohydrate leads to high cholesterol levels, obesity and CVD (**Figure** 13.24).

Figure 13.23: Sixty minutes a day of vigorous aerobic activity, such as basketball, is enough to help keep your cardiovascular system healthy.

Lesson Summary

- Blood pressure is the force put on the walls of blood vessels by circulating blood.
- The force put on the walls of arteries is called blood pressure.
- Blood pressure is measured by an instrument called a sphygmomanometer.
- In the United States, the healthy ranges for systolic pressure is less than 120 mm Hg and a diastolic pressure of less than 80 mm Hg.
- Hypertension occurs when a person’s blood pressure is always high.
- A cardiovascular disease (CVD) is any disease that affects the cardiovascular system. Atherosclerosis, coronary heart disease, and stroke are examples of CVDs.
- Cardiovascular diseases are lifestyle diseases. Having a poor diet and not getting enough exercise are two major causes of CVD.

Figure 13.24: The USDA's MyPyramid recommends that you limit the amount of such foods in your diet to occasional treats.

Review Questions

Recall

1. What is the cause of blood pressure?

2. What is the healthy range for blood pressure?

3. When is a person considered to have hypertension?

4. What is atherosclerosis?

5. What are three risks factor for cardiovascular disease?

Apply Concepts

6. How is the pulse related to blood pressure?

7. Is the blood in veins under pressure? Explain your answer.

8. Why is hypertension called a silent killer?

9. A stroke could be thought of as a "brain attack," in a similar way to a heart attack. How are strokes and heart attacks similar?

10. What is the difference between a controllable risk factor and an uncontrollable risk factor?

11. Why are cardiovascular diseases called lifestyle diseases?

Critical Thinking

12. One of your friends says, "Heart disease is genetic and people have it in my family, so there is nothing I can do about it." Explain to your friend how cardiovascular disease can be a lifestyle choice. Also, give your friend three recommendations on things he/she can do to prevent cardiovascular disease.

Further Reading / Supplemental Links

- http://bio-alive.com/animations/cardiovascular.htm
- http://www.cdc.gov/nccdphp/dnpa/physical/everyone/recommendations/index.htm
- http://www.cdc.gov/bloodpressure http://en.wikipedia.org/wiki/Aerobic_exercise; http://www.cdc.gov/bloodpressure

Points to Consider

Next we take a look at the respiratory system.

- Do you think there is a relationship between the cardiovascular system and the respiratory system? What could it be?
- Do you think hypertension affects the ability of the blood to release carbon dioxide and pick up oxygen in the lungs? Why?

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(22) NCI. *Capillaries connect arteries and veins.*. Public Domain-gov.

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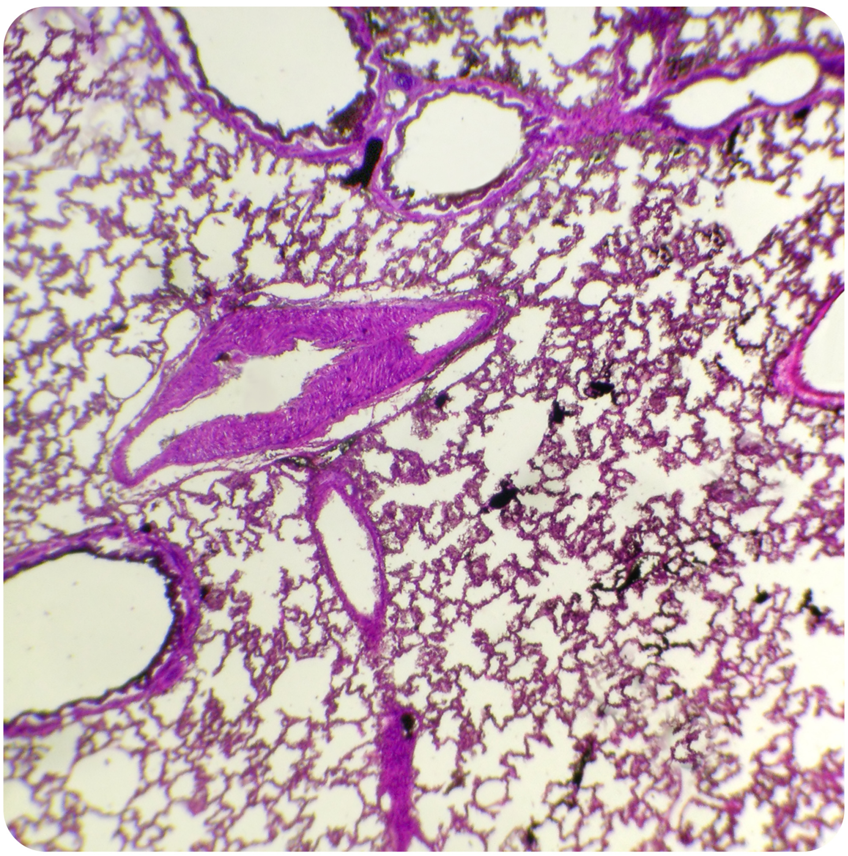
Chapter 14

MS Respiratory and Excretory Systems



The above image shows the tissue found inside of the lungs. The lungs contain alveoli. Alveoli absorb oxygen and send it to the blood vessels. They also move carbon dioxide from the blood vessels back to the lungs to be exhaled.

Alveoli look like clumps of grapes. Why do you think it is important that your body have many alveoli? What would happen if your alveoli lost their ability to function? Why do you think alveoli are shaped like spheres?

The respiratory system is important because it brings oxygen to cells in your body. But it also removes a waste, carbon dioxide. Another system in your body, the excretory system, also removes wastes. The excretory system moves waste from your digestive system and from your blood out of your body.

How do the respiratory system and excretory system work together? How does damage in one system affect the other? Consider these questions about respiration and waste removal as you read the following chapter.

14.1 The Respiratory System

Lesson Objectives

- Identify the parts of the respiratory system.
- Identify the main function of the respiratory system.
- Describe how breathing works.
- Outline how the respiratory system and the cardiovascular system work together.
- Identify how breathing and cellular respiration are connected.

Check Your Understanding

- What is an organ system?
- What is the role of the circulatory system?
- How does your blood get oxygen?

Vocabulary

- alveoli
- diaphragm
- epiglottis
- exhalation
- external respiration
- gas exchange
- inhalation
- internal respiration
- larynx
- pharynx
- respiration
- respiratory system
- trachea

Roles of the Respiratory System

You breathe mostly without thinking about it. Remember how uncomfortable you felt the last time you had a cold or a cough? You usually do not think about your respiratory system or how it works until there is a problem with it. Every cell in your body depends on your respiratory system.

Your **respiratory system** is made up of the tissues and organs that allow oxygen to enter the body and carbon dioxide to leave your body. Organs in your respiratory system include your:

- Nose.

- Mouth.
- Larynx.
- Pharynx.
- Lungs.
- Diaphragm.

These structures are shown in **Figure** 14.1.

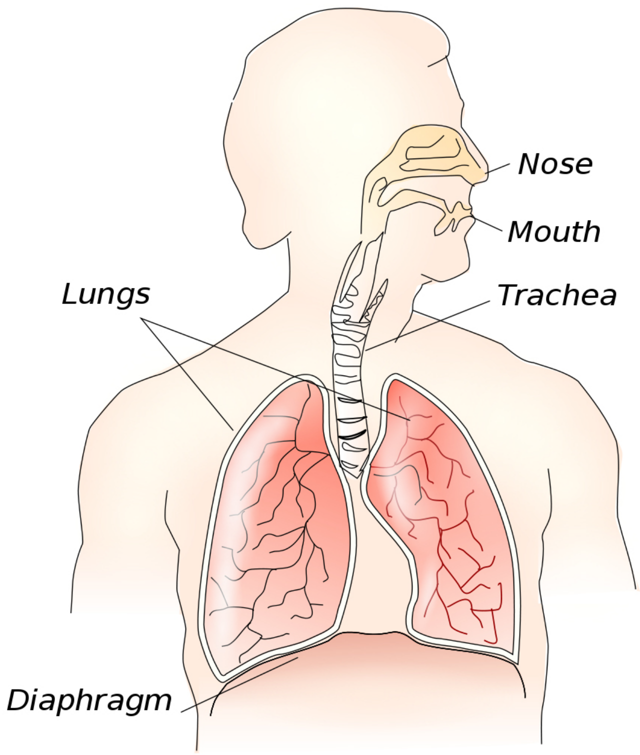


Figure 14.1: The respiratory system. Air moves in through the nose and mouth and down the trachea, which is a long, straight tube in the chest.

Parts of the Respiratory System

Figure 14.1 shows many of the structures of the respiratory system. Each of the parts has a specific job. The parts of the respiratory system include the following:

- The **diaphragm** is a sheet of muscle that spreads across the bottom of the rib cage. When the diaphragm contracts, the chest volume gets larger and the lungs take in air. When the diaphragm relaxes, the chest volume gets smaller and air is pushed out of the lungs.
- The nose and nasal cavity filter, warm, and moisten the air you breathe. The nose hairs and mucus produced by the cells in the nose catch particles in the air and keep them from entering the lungs. When particles in the air do reach the lungs, what do you think happens?
- Behind the nasal cavity, air passes through the **pharynx**, a long tube. Both food and air pass through the pharynx.
- The **larynx**, also called the "voice box," is found just below the pharynx. Your voice comes from your larynx. Air from the lungs passes across thin tissues in the larynx and produces sound.

- The **trachea**, or windpipe, is a long tube that leads down to the lungs, where it divides into the right and left **bronchi**. The bronchi branch out into smaller bronchioles in each lung.
- Since food goes down the pharynx, how is it stopped from entering the trachea? A flap of tissue called the *epiglottis* closes over the trachea when food is swallowed to prevent choking or inhaling food.
- The bronchioles lead to the alveoli. **Alveoli** are the little sacs at the end of the bronchioles. They look like little bunches of grapes, as shown in **Figure** 14.2. Oxygen is exchanged for carbon dioxide in the alveoli. **Gas exchange** is the name we give to the process that allows oxygen to enter the blood and carbon dioxide to move out of the blood - the two gases are "exchanged."

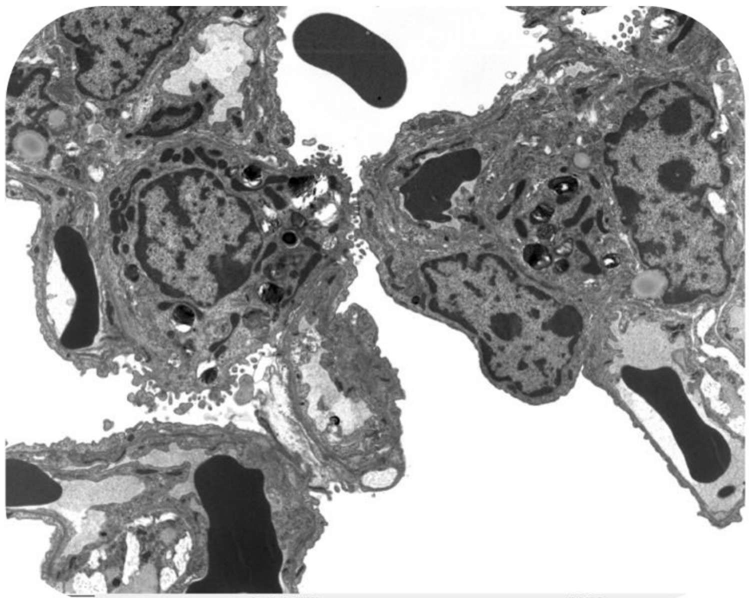


Figure 14.2: The alveoli are the tiny grape-like structures in the lungs and the sites of gas exchange.

How We Breathe

Most of the time, you breathe without thinking about it. Breathing is mostly an involuntary action that is controlled by a part of your brain that also controls your heart beat. If you swim, do yoga, or sing, you know you can also control your breathing. Taking air into the body through the nose and mouth is called **inhalation**. Pushing air out of the body through the nose or mouth is called **exhalation**. The man in **Figure** 14.3 is exhaling before he surfaces from the pool water.

How do lungs allow air in? As mentioned above, air moves into and out of the lungs by the movement of muscles. The diaphragm and rib muscles contract and relax to move air into and out of the lungs. During inhalation, the diaphragm contracts and moves downward. The rib muscles contract and cause the ribs to move outward. This causes the chest volume to increase. Because the chest volume is larger, the air pressure inside the lungs is lower than the air pressure outside. This difference in air pressures causes air to be sucked into the lungs. When the diaphragm and rib muscles relax, air is pushed out of the lungs. Exhalation is similar to letting the air out of a balloon.

The walls of the alveoli are very thin and allow gases to enter into them. The alveoli are lined with capillaries. These capillaries are shown in **Figure** 14.4. Oxygen moves from the alveoli to the blood in the capillaries that surround the alveoli. At the same time, carbon dioxide moves in the opposite direction, from capillary blood to the alveoli.

Figure 14.3: Being able to control breathing is important for many activities, such as swimming. The man in the photograph is exhaling before he surfaces from the water.

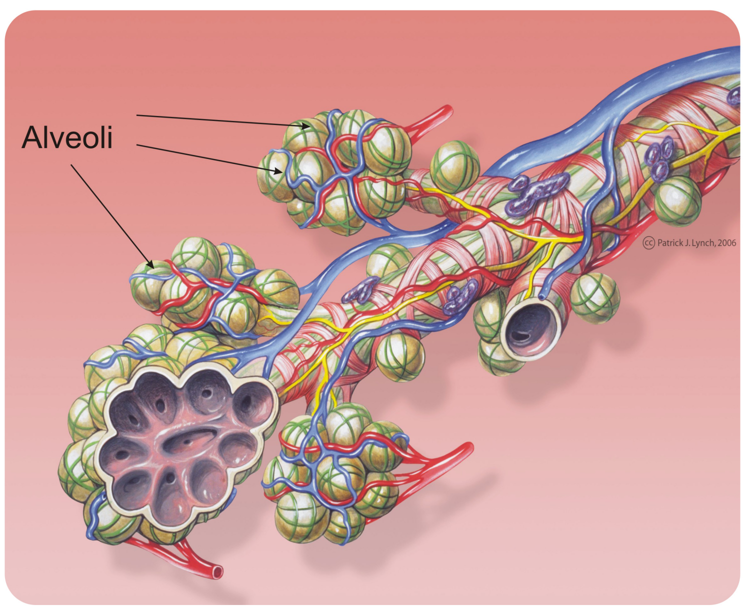


Figure 14.4: The bronchi and alveoli. During respiration, oxygen gets pulled into the lungs and enters the blood by passing across the thin alveoli membranes and into the capillaries.

Breathing and Respiration

When you breath in, oxygen is drawn in through the mouth and down into the lungs. The oxygen then passes across the thin lining of the capillaries and into the blood. The oxygen molecules are carried to the body cells by the blood. Carbon dioxide from the body cells is carried by the blood to the lungs where it is released into the air. The process of getting oxygen into the body and releasing carbon dioxide is called **respiration**.

Sometimes breathing is called respiration, but there is much more to respiration than just breathing. There are actually two parts to respiration, external respiration and internal respiration. **External respiration** is the movement of oxygen into the body and carbon dioxide out of the body. **Internal respiration** is the exchange of oxygen and carbon dioxide between the blood and the cells of the body (**Figure** 14.5).

The Journey of a Breath of Air

Breathing is only part of the process of bringing oxygen to where it is needed in the body. After oxygen enters the lungs, what happens?

1. The oxygen enters the blood stream from the alveoli. Then, the oxygen-rich blood returns to the heart.
2. Oxygen-rich blood is then pumped through the aorta.
3. From the aorta, oxygen-rich blood travels to the smaller arteries and finally to the capillaries.
4. The oxygen molecules move out of the capillaries and into the body cells.
5. While oxygen moves from the capillaries and into body cells, carbon dioxide moves from the cells into the capillaries.

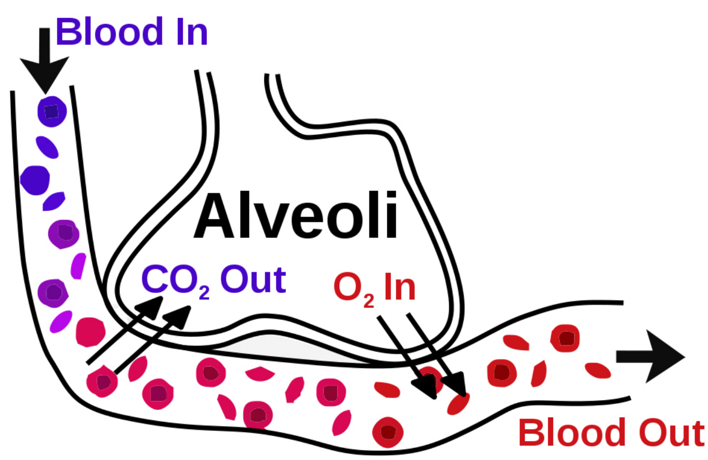


Figure 14.5: Gas exchange is the movement of oxygen into the blood and carbon dioxide out of the blood.

Breathing and Cellular Respiration

The oxygen that arrives at the cells from the lungs is used by the cells to help release the energy stored in molecules of sugar. Cellular respiration is the process of breaking down glucose to release energy (see the *Cell Functions* chapter). The waste products of cellular respiration include carbon dioxide and water. The carbon dioxide molecules move out of the cells and into the capillaries that surround the cells. As explained above, the carbon dioxide is removed from the body by the lungs.

Lesson Summary

- Your respiratory system is made up of the tissues and organs that allow oxygen to enter and carbon dioxide to leave your body.
- Respiratory system organs include your nose, mouth, larynx, pharynx, lungs, and diaphragm.
- During inhalation, the diaphragm contracts and moves downward, and brings air into the lungs.

During exhalation, the diaphragm and rib muscles relax and air is pushed out of the lungs.

- Oxygen enters the lungs, then passes through the alveoli and into the blood. The oxygen is carried around the body in blood vessels.
- Carbon dioxide, a waste gas, moves into the blood capillaries and is brought to the lungs to be released into the air during exhalation.
- The oxygen that arrives from the lungs is used by the cells during cellular respiration to release the energy stored in molecules of sugar.

Review Questions

Recall

1. Name the five main organs in the respiratory system.
2. What is the main function of the respiratory system?
3. In what part of the lung does gas exchange occur?
4. What is the important gas that is carried into the lungs during inhalation?

Apply Concepts

5. A classmate says that lung muscles cause the lungs to move during breathing. Do you agree with your classmate?
6. How do the respiratory system and the cardiovascular system work together?
7. Breathing is an involuntary action. Does this mean that you cannot control your breathing?
8. What is the difference between breathing and respiration?
9. What is the name of the waste gas that is released during exhalation?

Critical Thinking

10. If a disease caused the alveoli to collapse, how might this affect a person's health?

Further Reading / Supplemental Links

- http://en.wikipedia.org/wiki

Points to Consider

- How do you think the health of your respiratory system might affect the health of other body systems?

14.2 Health of the Respiratory System

Lesson Objectives

- Identify the organs affected by a respiratory disease.
- Identify how a respiratory disease can affect the rest of the body.
- Describe how asthma affects breathing.
- Outline how smoking affects the respiratory system.
- Identify what you can do to keep your respiratory system healthy.

Check Your Understanding

- What is the role of the respiratory system?
- What are some of the organs in the respiratory system?

Vocabulary

- allergen
- asthma
- bronchitis
- chronic disease
- chronic obstructive pulmonary disease (COPD)
- emphysema
- environmental tobacco smoke (ETS)
- lifestyle disease
- lung cancer
- pathogen
- pneumonia
- respiratory disease
- tuberculosis (TB)

Respiratory System Disease

Most of the time your respiratory system works well. But your respiratory system can sometimes be knocked out of homeostasis. Recall that homeostasis is the balancing act your body performs that keeps everything inside of your body stable. Anything that stops the respiratory system from doing its job disrupts homeostasis. When homeostasis is thrown out of balance, your respiratory system can get diseases. There are many causes of respiratory diseases, and many ways to treat such diseases.

In general, diseases that last a short time are called acute diseases. Other diseases can last for a long time, perhaps years. Diseases that last for a long time are called **chronic diseases**. Both acute and chronic diseases affect the respiratory system. **Respiratory diseases** are diseases of the lungs, bronchial tubes, trachea, nose, and throat (**Figure** 14.6). These diseases can range from a mild cold to a severe case of pneumonia. Respiratory diseases are common and may cause illness or death. Some respiratory diseases are caused by bacteria or viruses, while others are caused by environmental pollutants such as tobacco smoke. Some diseases can be genetic.

Figure 14.6: This boy is suffering from whooping cough (also known as pertussis), which gets its name from the loud whooping sound that is made when the person inhales during a coughing fit.

Bronchitis

Bronchitis is an inflammation of the bronchi, which means they become red and swollen with infection. Acute bronchitis is usually caused by viruses or bacteria, and may last several days or weeks. It is characterized by a cough that produces phlegm, or mucus. Symptoms include shortness of breath and wheezing. Acute bronchitis is usually treated with antibiotics.

Chronic bronchitis may not be caused by a bacterium or a virus. Chronic bronchitis occurs when a cough produces phlegm, for at least three months in a two-year period. Tobacco smoking is the most common cause of chronic bronchitis, but it can be caused by environmental pollution, such as smog and dust. It is generally part of a disease called chronic obstructive pulmonary disease (COPD). Treatments for bronchitis include antibiotics and steroid drugs used to reduce inflammation.

Asthma

Asthma is a chronic illness in which the bronchioles are inflamed and become narrow, as shown in **Figure** 14.7. The muscles around the bronchioles contract which narrows the airways. Large amounts of mucus are also made by the cells in the lungs. A person with asthma has difficulty breathing. Their chest feels tight and they wheeze. Asthma can be caused by different things, such as allergies. An **allergen** is any antigen that is not actually a disease, but your body responds to it as if it were a disease. Allergens can cause allergic reactions. Common allergens that cause asthma are mold, dust, or pet hair.

Asthma can also be caused by cold air, warm air, moist air, exercise, or stress. The most common asthma triggers are illnesses like the common cold. The symptoms of asthma can usually be controlled with medicine. Bronchodilators are drugs that reduce inflammation of the bronchioles and are often used to treat asthma. An inhaler is usually a bronchodilator.

Asthma is not contagious and cannot be passed on to other people. Children and adolescents who have asthma can still lead active lives if they control their asthma. Asthma can be controlled by taking medication and by avoiding contact with environmental triggers for asthma, like smoking.

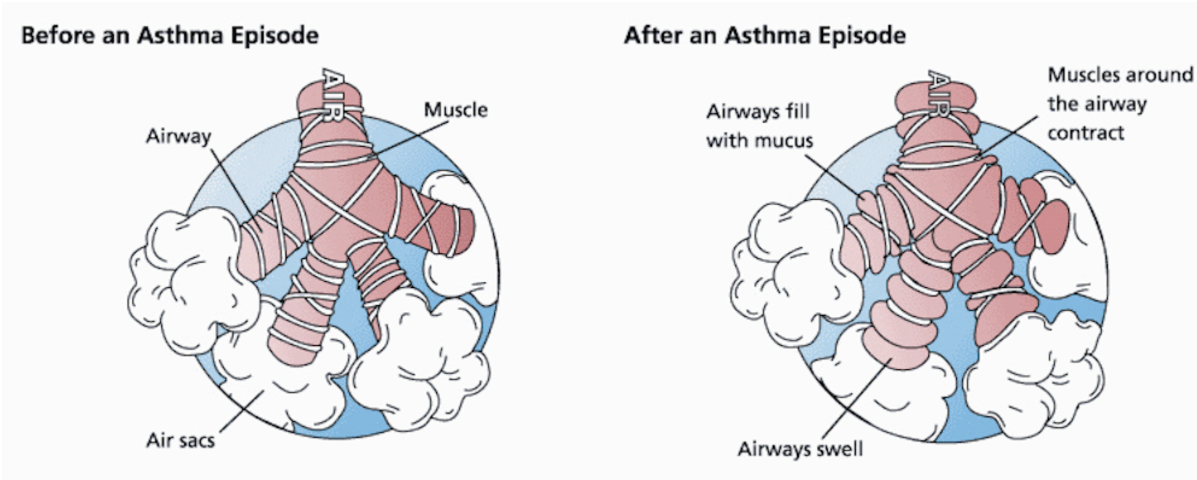


Figure 14.7: Asthma occurs when the bronchioles swell and the muscles around the bronchioles contract.

Pneumonia

Pneumonia is an illness that occurs when the alveoli become inflamed and filled with some kind of fluid. When a person has pneumonia, gas exchange cannot happen properly across the alveoli. Pneumonia can be caused by many things. Infection by bacteria, viruses, fungi, or parasites can cause pneumonia. An injury caused by chemicals or a physical injury to the lungs can also cause pneumonia. Symptoms of pneumonia include cough, chest pain, fever, and difficulty breathing. Treatment depends on the cause of pneumonia. Bacterial pneumonia is treated with antibiotics.

Pneumonia is a common illness that affects people in all age groups. It is a leading cause of death among the elderly and people who are chronically and terminally ill. Sometimes people take vaccines to prevent certain types of pneumonia.

Tuberculosis

Tuberculosis (TB) is a common and often deadly disease caused by a genus of bacterium called *Mycobacterium*. When a disease like TB can passed from person to person, it is called "infectious." Tuberculosis most commonly attacks the lungs, but can also affect other parts of the body. TB is a chronic disease, but most people who become infected do not develop the full disease.

The TB bacteria are spread in the air when people who have the disease cough, sneeze or spit, so it is very contagious. To help prevent the spread of the disease, public health notices, such as the one in **Figure** 14.8, remind people how to stop the spread of the disease.

Cancer

Lung cancer is a disease where the cells found in the lungs grow out of control. The growing mass of cells can form a tumor that pushes into nearby tissues. The tumor will affect how these tissues work. Lung

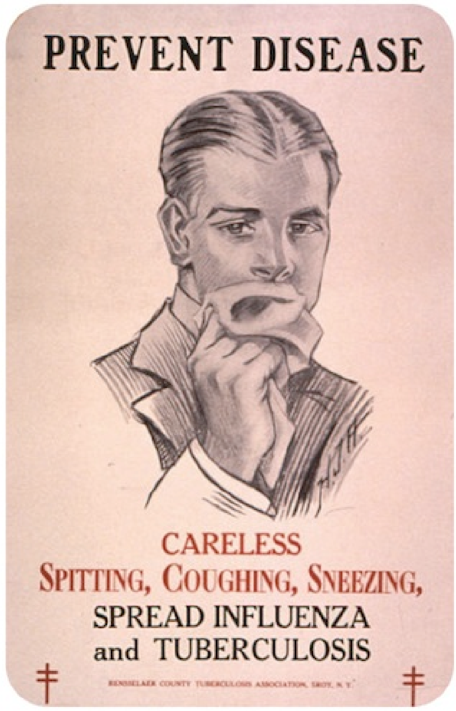


Figure 14.8: A public health notice from the early 20th century reminded people that TB could be spread very easily.

cancer, which is the most common cause of cancer-related death in men and the second most common in women, is responsible for 1.3 million deaths worldwide every year (**Figure** 14.9). The most common symptoms are shortness of breath, coughing (including coughing up blood), and weight loss. The most common cause of lung cancer is exposure to tobacco smoke.

Emphysema

Emphysema is a chronic lung disease caused by the breakdown of the lung tissue. The surfaces of healthy alveoli are springy and flexible. They stretch out a little when full of air and relax when air leaves them. But the breakdown of the tissues that support the alveoli and the capillaries that feed the alveoli cause the alveoli to become hard and stiff. Eventually, the walls of the alveoli break down and the alveoli become larger. When alveoli become larger, oxygen cannot enter the blood as it did before. Symptoms of emphysema include shortness of breath during exercise. Damage to the alveoli, which can be seen in **Figure** 14.10, is not curable. Smoking is the leading cause of emphysema.

Causes of Respiratory Diseases

Pathogens

Many respiratory diseases are caused by pathogens. A **pathogen** is an organism that causes disease in another organism. Certain bacteria, viruses, and fungi are pathogens of the respiratory system. The common cold and flu are caused by viruses. The influenza virus that causes the flu is shown in **Figure** 14.11. Tuberculosis, whooping cough, and acute bronchitis are caused by bacteria. The pathogens that cause colds, flu, and TB can be passed from person to person by coughing, sneezing, and spitting.

Figure 14.9: The inside of lung showing cancerous tissue.

Figure 14.10: The lung of a smoker who had emphysema (left). The black areas are enlarged alveoli, and tar, a sticky, black substance found in tobacco smoke is evident. Chronic obstructive pulmonary disease (right), is a tobacco-related disease that is characterized by emphysema.

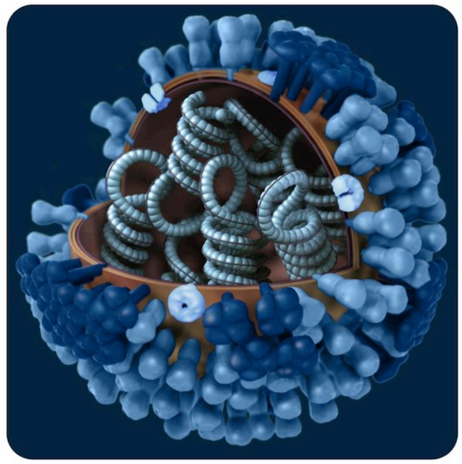


Figure 14.11: This is the influenza virus that causes the swine flu, or H1N1. The Center for Disease Control and Prevention recommends that children between the ages of 6 months and 19 years get a flu vaccination each year.

Pollution

The quality of the air can affect the health of your lungs. Asthma, heart and lung diseases, allergies, and several types of cancers are all linked to air quality. Air pollution can be either outdoor pollution or indoor pollution. Outdoor air pollution can be caused by car exhaust fumes, smoke from factories and forest fires, volcanoes, and animal feces. These pollutants contain tiny particles that can get "stuck" in the tissues of the respiratory system and irritate the lungs. Indoor air pollution can be caused by tobacco smoke, dust, mold, insects, rodents, and cleaning chemicals.

Lifestyle Choices

Smoking is the major cause of chronic respiratory disease as well as cardiovascular disease and cancer. Exposure to tobacco smoke, by smoking or by breathing air that contains tobacco smoke, is the leading cause of preventable death in the U.S. Regular smokers die about 10 years earlier than nonsmokers do. The Centers for Disease Control and Prevention (CDC) describes tobacco use as "the single most important preventable risk to human health in developed countries and an important cause of [early] death worldwide."

Dangers of Smoking

Tobacco use, particularly cigarette smoking, is a preventable cause of death in the United States. This means that people would not die if they stopped smoking. Cigarette smoking alone is directly responsible for approximately 30 percent of all yearly cancer deaths in the United States. The main health risks of using tobacco are linked to diseases of the cardiovascular system and respiratory system. Cardiovascular diseases caused by smoking include heart disease and stroke.

Diseases of the respiratory system that are caused by exposure to tobacco smoke include:

- Emphysema.
- Lung cancer.
- Cancers of the larynx and mouth.

Cigarette smoking causes 87 percent of lung cancer deaths. Smoking and using tobacco is also linked to the risk of developing other types of cancer, such as pancreatic and stomach cancer.

Indoor Air Pollution

Cigarettes, like the ones shown in **Figure** 14.12, are a major source of indoor air pollution. Cigarette smoke contains about 4,000 substances, including over 60 cancer-causing chemicals. Many of these substances, such as carbon monoxide, tar, arsenic, and lead, are toxic to the body. Non-smokers can also be affected by tobacco smoke. Exposure to secondhand smoke, also known as **environmental tobacco smoke (ETS)**, greatly increases the risk of lung cancer and heart disease in nonsmokers.

Figure 14.12: Tobacco use, particularly cigarette smoking, is the single most preventable cause of death in the United States.

Chronic Obstructive Pulmonary Disease

Chronic obstructive pulmonary disease (COPD) is a disease of the lungs that occurs when the airways narrow and air cannot enter the lungs as well as it did before. This leads to shortness of breath. The lack of air entering the lungs usually gets worse over time. COPD is most commonly caused by smoking. Gases and particles in tobacco smoke trigger an inflammatory response in the lung. The inflammatory response in the larger airways is known as chronic bronchitis. In the alveoli, the inflammatory response causes the breakdown of the tissues in the lungs, leading to emphysema.

Keeping Your Respiratory System Healthy

Many of the diseases related to smoking are called **lifestyle diseases**, diseases that are caused by choices that people make in their daily lives. For example, the choice to smoke can lead to cancer in later life. But there are many things you can do to help keep your respiratory system healthy.

Avoid Smoking

Never smoking or quitting now are the most effective ways to reduce your risk of developing chronic respiratory diseases, such as cancer.

Eat Well, Exercise Regularly, and Get Rest

Eating a healthful diet, getting enough sleep, and being active every day can help keep your immune system strong.

Wash Your Hands

Washing your hands often, and after sneezing, coughing or blowing your nose, helps to protect you and others from diseases. Washing your hands for 20 seconds with soap and warm water can help prevent colds and flu.

Some viruses and bacteria can live from 20 minutes up to 2 hours or more on surfaces like cafeteria tables, doorknobs, and desks. A public health notice that shows people how to prevent the spread of respiratory diseases is shown in **Figure** 14.13.

Avoid Contact with Others When Sick

Do not go to school or to other public places when you are sick. You risk spreading your illness to other people and getting sicker, if you catch something else.

Visit Your Doctor

Getting the recommended vaccinations can help prevent diseases such as whooping cough and flu. Seeking medical help for diseases such as asthma can help stop the disease from getting worse.

Lesson Summary

- Respiratory diseases are diseases that affect the lungs, bronchial tubes, trachea, nose, and throat.
- Respiratory diseases can reduce the amount of oxygen that gets into the blood.
- Asthma is an illness that occurs when the bronchioles are inflamed and become narrow.
- Difficulty breathing happens because of the inflammation, contraction of the muscles, and the production of mucus by the cells that line the bronchioles.
- Diseases of the respiratory system that are caused by exposure to tobacco smoke include emphysema, lung cancer and cancers of the larynx and mouth.
- Cigarette smoking causes 87 percent of lung cancer deaths.
- Avoid smoking, get enough exercise, and wash your hands in order to protect your respiratory system from illness.

Figure 14.13: Cover your Cough - Clean your Hands is a public health campaign that reminds people of the quickest and easiest ways to avoid spreading respiratory diseases such as colds and the flu.

Review Questions

Recall

1. Identify two organs that can be affected by respiratory diseases.
2. What lifestyle activity has the largest health impact on the respiratory system?
3. Identify three diseases caused by smoking.
4. Identify three things besides smoking that can cause a respiratory disease.
5. What are two things you can do to keep your respiratory system healthy?

Apply Concepts

6. How might a respiratory disease affect the rest of the body?
7. How does asthma affects the bronchioles?
8. Explain how washing your hands can help prevent you from catching a cold.

Critical Thinking

9. Pneumonia is a disease that causes the alveoli to fill up with fluid. How might this affect the lungs' ability to absorb oxygen?

10. A person who has never smoked before gets lung cancer. How might they have contracted the disease?

Further Reading / Supplemental Links

- http://www.cdc.gov/vaccines/vpd-vac/pertussis/default.htm
- http://www.cdc.gov//HealthyLiving/
- http://www.cancer.gov/cancertopics/factsheet/Tobacco/cancer http://en.wikipedia.org/wiki/Cigarette_smoking; http://www.cancer.gov/cancertopics/factsheet/Tobacco/cancer
- http://www.cancer.gov/cancertopics/factsheet/Tobacco/cancer
- http://www.cdc.gov/flu/protect/covercough.htm

Points to Consider

Next, we move on to the excretory system.

- The excretory system gets rids of a certain type of waste. What type of waste do you think is removed by this system?

14.3 The Excretory System

Lesson Objectives

- Identify the functions of the excretory system.
- List the organs of the excretory system.

- Describe the parts of urinary system.
- Outline how the kidneys filter blood.
- Identify three disorders of the urinary system.

Check Your Understanding

- What are some ”wastes” that must be removed from your body?
- Do your circulatory and respiratory systems remove ”waste?”

Vocabulary

- excretion
- excretory system
- kidney
- kidney dialysis
- kidney failure
- nephron
- urinary bladder
- urinary system
- urinary tract infection (UTI)
- urination
- urine

The Excretory System

One of the most important ways your body maintains homeostasis is by keeping the right amount of water and salts inside your body. If you have too much water in your body, your cells can swell and burst. If you have too little water in your body, your cells can shrivel up like an old apple. Either extreme can cause illness and death of cells, tissues, and organs. The organs of your **excretory system** help to keep the correct balance of water and salts within your body.

Your body also needs to remove the wastes that build up from cell activity and from digestion. These wastes include carbon dioxide, urea, and certain plant materials. If these wastes are not removed, your cells can stop working and you can get very sick. The excretory system can also help to release wastes from the body. **Excretion** is the process of removing wastes from the body.

The organs of the excretory system are also parts of other organ systems. For example, your lungs are part of the respiratory system. Your lungs remove carbon dioxide from your body, so they are also part of the excretory system. More organs of the excretory system are listed in **Table ??**.

Table 14.1: **Organs of the Excretory System**

Organ(s)	Function	Other Organ System of which it is Part
Lungs	Remove carbon dioxide	Respiratory system
Skin	Sweat glands remove water, salts, and other wastes	Integumentary system
Large intestine	Removes solid waste and some water in the form of feces	Digestive system

Table 14.1: (continued)

Organ(s)	Function	Other Organ System of which it is Part
Kidneys	Remove urea, salts, and excess water from the blood	Urinary system

Table 19.4: Organs of the Excretory System

Functions of the Excretory System

The excretory system controls the levels of water and salts in your body by removing wastes. This means the excretory system has an important role in maintaining homeostasis. Your body takes nutrients from food and uses them for energy, growth, and repair. After your body has taken what it needs from the food, waste products are left behind in the blood and in the large intestine. These waste products need to be removed from the body. The kidneys work with the lungs, skin, and intestines to keep the correct balance of nutrients, salts and water in your body.

The Urinary System

Sometimes, the urinary system is called the excretory system. But the urinary system is only one part of the excretory system. Recall that the excretory system is made up of the skin, lungs, and large intestine as well as the kidneys. The **urinary system** is the organ system that makes, stores, and gets rid of urine. It includes:

- Two kidneys.
- Two ureters.
- One bladder.
- One urethra.

The urinary system is shown in **Figure** 14.14.

Organs of the Urinary System

1. As you can see from **Figure** 14.14, the kidneys are two bean-shaped organs. **Kidneys** filter and clean the blood and form urine. They are about the size of your fists and are found near the middle of the back, just below your rib cage.
2. Ureters are tube-shaped and bring urine from the kidneys to the urinary bladder.
3. The **urinary bladder** is a hollow and muscular organ. It is shaped a little like a balloon. It is the organ that collects urine.
4. Urine leaves the body through the urethra.

What is Urine?

Urine is a liquid that is formed by the kidneys when they filter wastes from the blood. Urine contains mostly water, but also contains salts and nitrogen-containing molecules. The amount of urine released from the body depends on many things. Some of these include the amounts of fluid and food a person

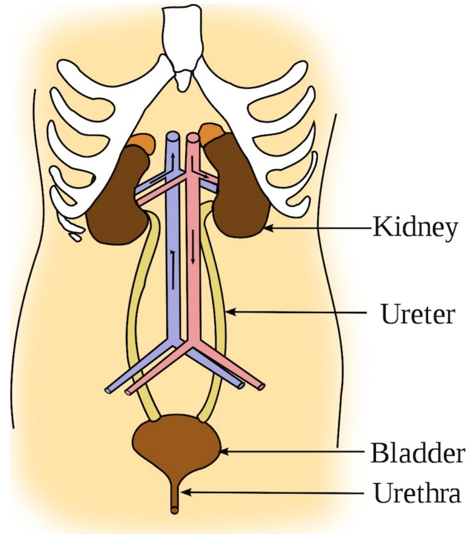


Figure 14.14: The kidneys filter the blood that passes through them and the urinary bladder stores the urine until it is released from the body.

consumes and how much fluid they have lost from sweating and breathing. Urine ranges from colorless to dark yellow, but is usually a pale yellow color. Light yellow urine contains mostly water. The darker the urine, the less water it contains.

The urinary system also removes a type of waste called *urea* from your blood. Urea is a nitrogen-containing molecule that is made when foods containing protein, such as meat, poultry, and certain vegetables, are broken down in the body. Urea and other wastes are carried in the bloodstream to the kidneys, where they are removed and form urine.

How the Kidneys Filter Wastes

The kidneys are important organs in maintaining homeostasis. Kidneys perform a number of homeostatic functions.

- They maintain the volume of body fluids.
- They maintain the balance of salt ions in body fluids.
- They excrete harmful nitrogen-containing molecules, such as urea, ammonia, and uric acid.

There are many blood vessels in the kidneys, as you can see in **Figure** 14.15. The kidneys remove urea from the blood through tiny filtering units called nephrons. **Nephrons** are tiny, tube-shaped structures found inside each kidney. A nephron is shown in **Figure** 14.16. Each kidney has up to a million nephrons. Each nephron collects a small amount of fluid and waste from a small group of capillaries.

If the body is in need of more water, water is removed from the fluid inside the nephron and is returned to the blood. The fluid within nephrons is carried out into a larger tube in the kidney called a ureter, which you can see in **Figure** 14.16. Urea, together with water and other wastes, forms the urine as it passes through the nephrons and the kidney.

Formation of Urine

The process of urine formation is as follows:

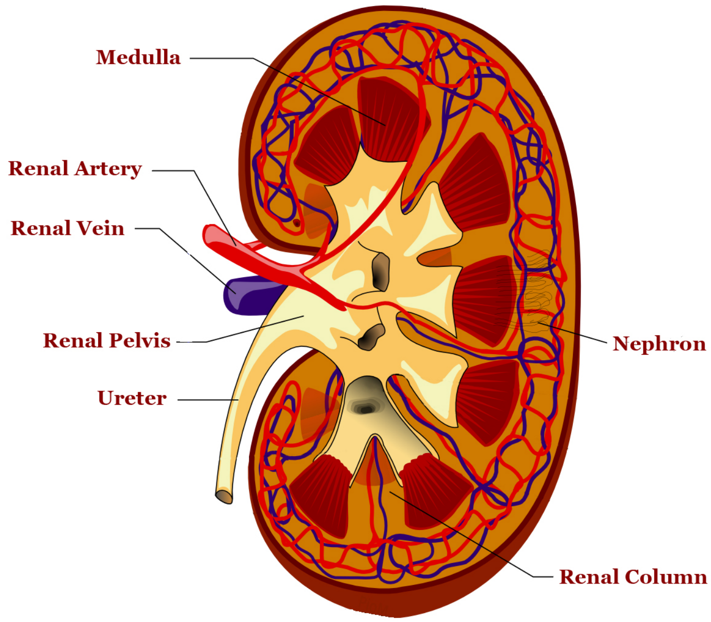


Figure 14.15: Structures of the kidney; fluid leaks from the capillaries and into the nephrons where the fluid forms urine then moves to the ureter and on to the bladder.

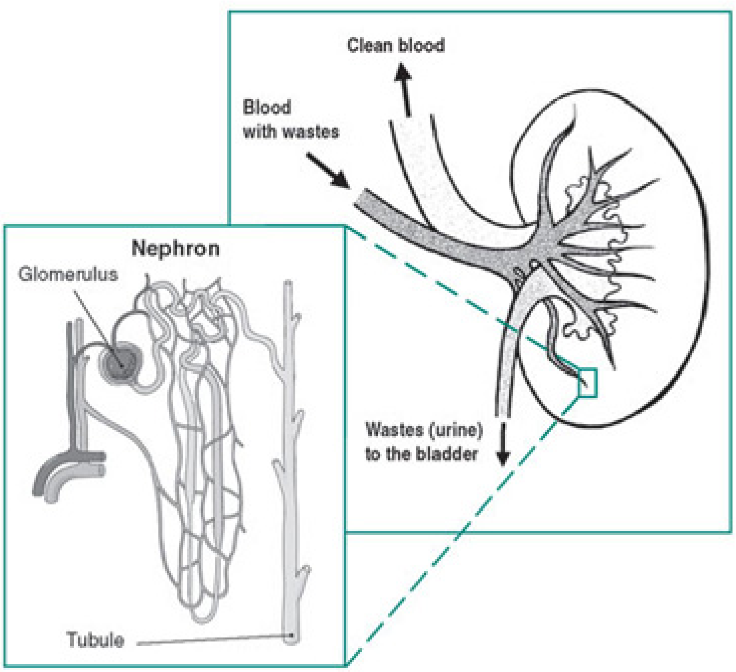


Figure 14.16: The location of nephrons in the kidney. The fluid collects in the nephron tubules, and moves to the bladder through the ureter.

1. Blood flows into the kidney through the renal artery, shown in **Figure** 14.16. The renal artery connects to capillaries inside the kidney. Capillaries and nephrons lie very close to each other in the kidney.
2. The blood pressure within the capillaries causes water, salts, sugars, and urea to leave the capillaries and move into the nephron.
3. The water and salts move along through the tube-shaped nephron to a lower part of the nephron.
4. The fluid that remains in the nephron at this point is called urine.
5. The blood that leaves the kidney in the renal vein has much less waste than the blood that entered the kidney.
6. The urine is collected in the ureters and is moved to the urinary bladder, where it is stored.

Nephrons filter about ¼ cup of body fluid per minute. In a 24-hour period, nephrons filter 180 liters of fluid, and 1.5 liters of the fluid is released as urine. Urine enters the bladder through the ureters. Similar to a balloon, the walls of the bladder are stretchy. The stretchy walls allow the bladder to hold a large amount of urine. The bladder can hold about 1½ to 2½ cups of urine, but may also hold more if the urine cannot be released immediately.

How do you know when you have to urinate? **Urination** is the process of releasing urine from the body. Urine leaves the body through the urethra. Nerves in the bladder tell you when it is time to urinate. As the bladder first fills with urine, you may notice a feeling that you need to urinate. The urge to urinate becomes stronger as the bladder continues to fill up.

Brain Control

The kidneys never stop filtering waste products from the blood, so they are always producing urine. The amount of urine your kidneys produce is dependent on the amount of fluid in your body. Your body loses water through sweating, breathing, and urination. The water and other fluids you drink every day help to replace the lost water. This water ends up circulating in the blood because blood plasma is mostly water.

The filtering action of the kidneys is controlled by the pituitary gland. The pituitary gland is about the size of a pea and is found below the brain, as shown in **Figure** 14.17. The pituitary gland is also part of the endocrine system. The pituitary gland releases hormones, which help the kidneys to filter water from the blood.

The movement of water back into blood is controlled by a hormone called antidiuretic hormone (ADH). ADH is released from the pituitary gland in the brain. One of the most important roles of ADH is to control the body's ability to hold onto water. If a person does not drink enough water, ADH is released. It causes the blood to reabsorb water from the kidneys. If the kidneys remove less water from the blood, what will the urine look like? It will look darker, because there is less water in it.

When a person drinks a lot of water, then there will be a lot of water in the blood. The pituitary gland will then release a lower amount of ADH into the blood. This means less water will be reabsorbed by the blood. The kidneys then produce a large volume of urine. What color will this urine be?

Excretory System Problems

The urinary system controls the amount of water in the body and removes wastes. Any problem with the urinary system can also affect many other body systems.

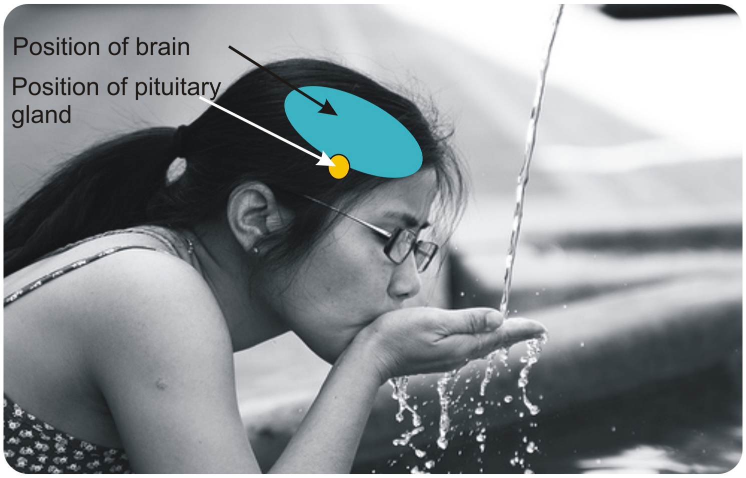


Figure 14.17: The pituitary gland is found directly below the brain and releases hormones that control how urine is produced.

Kidney Stones

In some cases, certain mineral wastes can form kidney stones, like the one shown in **Figure** 14.18. Stones form in the kidneys and may be found anywhere in the urinary system. They vary in size. Some stones cause great pain, while others cause very little pain. Some stones may need to be removed by surgery or ultrasound treatments.

Figure 14.18: A kidney stone. The stones can form anywhere in the urinary system.

Kidney failure

Kidney failure happens when the kidneys cannot remove wastes from the blood. If the kidneys are unable to filter wastes from the blood, the wastes build up in the body. Homeostasis is disrupted because the fluids in the body are out of balance. Kidney failure can be caused by an accident that injures the kidneys, the loss of a lot of blood, or by some drugs and poisons. Kidney failure may lead to permanent loss of kidney function. But if the kidneys are not seriously damaged, they may recover.

Chronic kidney disease is the slow decrease in kidney function that may lead to permanent kidney failure. A person who has lost kidney function may need to get kidney dialysis. **Kidney dialysis** is the process of filtering the blood of wastes using a machine. A dialysis machine (also called a hemodialyzer) filters the blood of waste by pumping it through a fake kidney. The filtered blood is then returned to the patient's body. A dialysis machine is shown in **Figure** 14.19.

Figure 14.19: During dialysis, a patient's blood is sent through a filter that removes waste products. The clean blood is returned to the body.

Urinary tract infections (UTIs)

Urinary tract infections (UTIs) are bacterial infections of any part of the urinary tract. When bacteria get into the bladder or kidney and produce more bacteria in the urine, they cause a UTI. The most common type of UTI is a bladder infection. Women get UTIs more often than men. UTIs are often treated with antibiotics.

Lesson Summary

- The excretory system controls the chemical make-up of liquids found in the body.
- The organs of the excretory system remove wastes. They also maintain the proper levels of water, salts, and nutrients in the body.
- The lungs, skin, kidneys, and large intestine are all organs in the excretory system.
- The urinary system is made up of the kidneys, the ureters, the bladder, and the urethra.
- The filtering parts of the kidneys are the nephrons.
- Water and waste molecules move out of the blood capillaries and into the nephrons. Most of the water returns to the blood.
- Urine collects in the nephron and moves to the urinary bladder through the ureters.
- The filtering action of the kidneys is controlled by the pituitary gland.
- ADH is the hormone released by the pituitary gland and controls the how water is reabsorbed by the blood from the kidneys.
- Disorders of the urinary system include kidney stones, kidney disease, and urinary tract infections.

Review Questions

Recall

1. What is the main function of the excretory system?

2. List the organs that make up the excretory system.

3. What is urine made of?

4. What is the purpose of the urinary bladder?

5. What connects the kidneys to the urinary bladder?

Apply Concepts

6. What is the difference between the urinary system and the excretory system?

7. How do the kidneys filter the blood?

8. The walls of the urinary bladder are stretchy. What do you think is the advantage of having these stretchy walls?

9. What does antidiuretic hormone (ADH) do?

10. What is a urinary tract infection?

11. Why is kidney failure such a serious health problem?

Critical Thinking

12. If a person's urine is dark brown, what are two organs in the body that might not be functioning properly? Explain what might be wrong with the two organs.

Further Reading / Supplemental Links

- http://kidney.niddk.nih.gov/kudiseases/pubs/yourkidneys

- http://en.wikipedia.org/wiki/Kidney_function

Points to Consider

Next we turn our attention to the nervous system.

- What do you think the nervous system is? What do you think it does?

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Chapter 15

MS Ecosystem Dynamics

This marine iguana eats algae. The algae give the iguana the energy it needs to live. But where does the algae get their energy? The algae get energy from the sun.

You may also notice that the algae are growing on rocks. How can algae grow without soil? What would happen to the iguana population if the algae could not grow on the rocks?

Marine iguanas live on the Galapagos Islands. These islands used to be covered with hot lava, but are now covered with volcanic rock. The Galapagos Islands are also are home to many different plants and animals. How can an island that used to be covered in lava now be home to new plants and animals?

This chapter discusses how energy flows in an ecosystem and also how new ecosystems form. Think about all these questions as you read this chapter.

15.1 Flow of Energy

Lesson Objectives

- Explain where all the energy in an ecosystem comes from.
- Classify organisms on the basis of how they obtain energy and describe examples of each.
- Be able to draw and interpret a food web.
- Explain the flow of energy through an ecosystem using an energy pyramid.

Check Your Understanding

- What is photosynthesis?
- What are some examples of organisms that can photosynthesize?
- What is a community?

Vocabulary

- carnivore
- consumer
- food chain
- food web
- herbivore
- omnivore
- producer
- trophic level

Energy and Producers

Energy is the ability to do work. In organisms, this work can be physical work, like walking or jumping. It can also be the work used to carry out the chemical processes in their bodies. All organisms need a supply of energy to stay alive.

Some organisms can get the energy from the sun. Other organisms get energy from other organisms. Through predator-prey relationships, the energy of one organism is passed on to another. Energy is constantly flowing through a community. With just a few exceptions, all life on Earth depends on the sun's energy for survival.

Producers

The energy of the sun is first captured by **producers** (**Figure** 15.1), organisms that can make their own food. Many producers make their own food through the process of photosynthesis. The "food" the producers make is glucose. Producers make, or produce, food for the rest of the ecosystem.

Recall that the only required ingredients needed for photosynthesis are sunlight, carbon dioxide (CO_2), and water (H_2O). From these simple inorganic ingredients, photosynthetic organisms can produce glucose ($C_6H_{12}O_6$) and other complex organic compounds.

The survival of every ecosystem is dependent on the producers. Without producers capturing the energy from the sun and turning it into glucose, an ecosystem could not exist. On land, plants are the dominant producers. Algae called phytoplankton are the most common producers in the oceans.

There are also bacteria that use chemical processes to produce food. They get their energy from sources other than the sun, but they are still called producers.

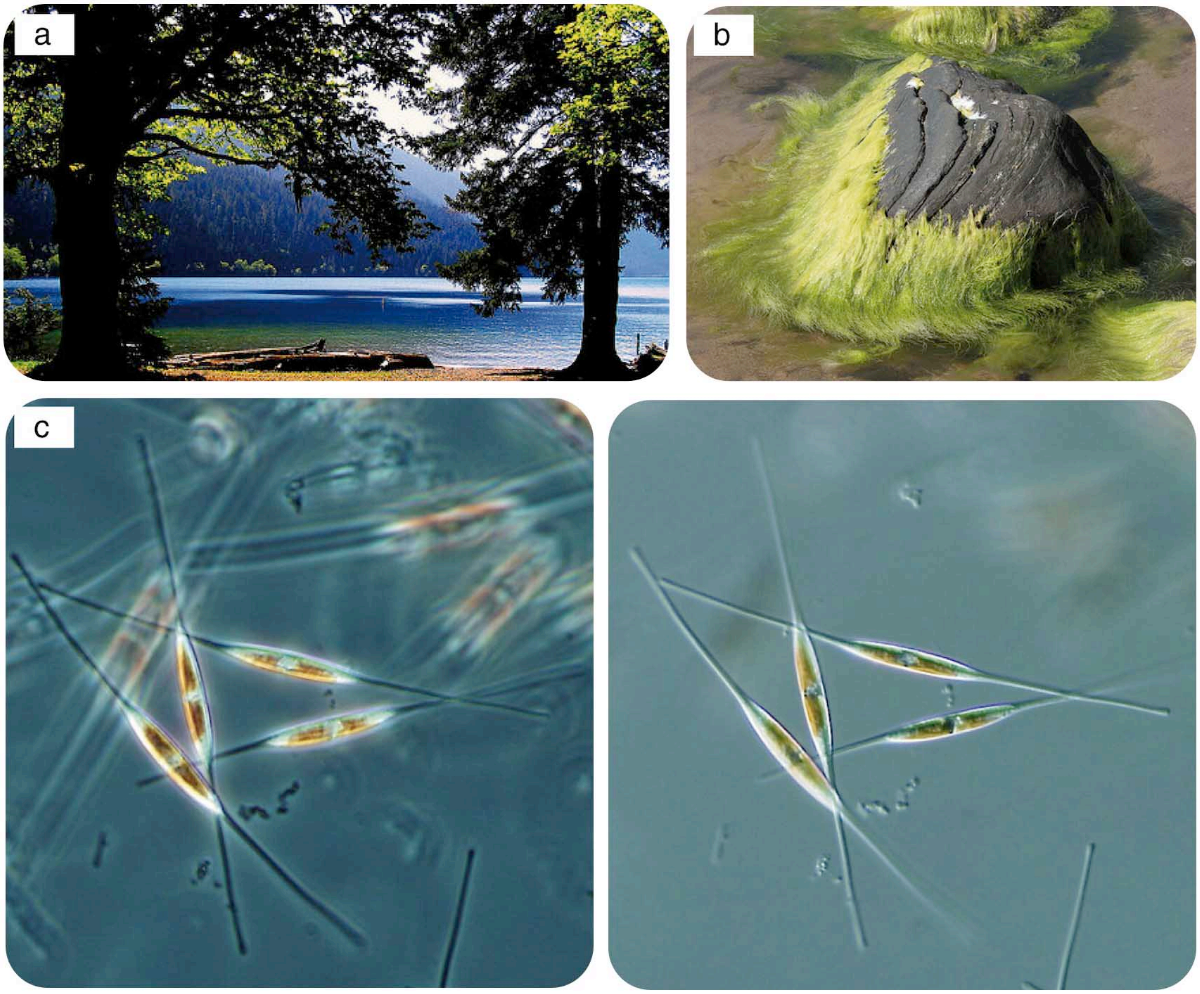

Figure 15.1: Producers include plants (a), algae (b), and diatoms, which are one-celled algae (c).

Consumers and Decomposers

Many organisms are not producers and cannot make their own food from sunlight. The organisms that must consume other organisms to get food for energy are called **consumers**. All animals are consumers.

The consumers can be placed into different groups:

- **Herbivores** are animals that eat producers to get energy. For example, rabbits and deer are herbivores that eat plants. The caterpillar in **Figure** 15.2 is an herbivore. Animals that eat phytoplankton in aquatic environments are also herbivores.
- **Carnivores** feed on animals, either herbivores or other carnivores. Snakes that eat mice are carnivores. Hawks that eat snakes are also carnivores.
- **Omnivores** eat both producers and consumers. Most people are omnivores, since they eat fruits, vegetables, and grains from plants, and also meat and dairy products from animals. Dogs, bears, and raccoons are also omnivores.

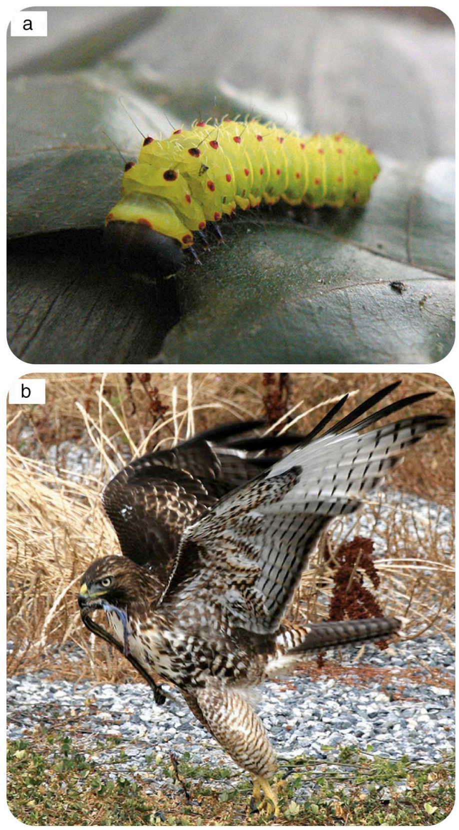

Figure 15.2: Examples of consumers are caterpillars (herbivores) and hawks (carnivore).

- Decomposers (**Figure** 15.3) get nutrients and energy by breaking down dead organisms and animal wastes. Through this process, decomposers release nutrients, such as carbon and nitrogen. These nutrients are recycled back into the ecosystem so that the producers can use them.

The stability of an ecosystem also depends on the actions of the decomposers. Examples of decomposers include mushrooms on a decaying log. Bacteria in the soil are also decomposers. Imagine what would happen if there were no decomposers. Wastes and the remains of dead organisms would pile up and the nutrients within the waste and dead organisms would never be released back into the ecosystem.

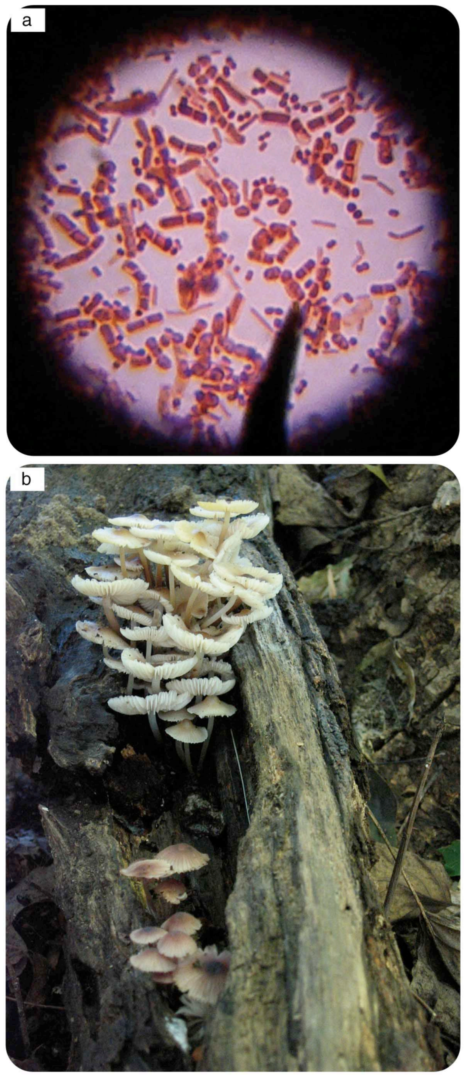

Figure 15.3: Examples of decomposers are bacteria (a) and fungi (b).

Food Chains and Food Webs

Food chains (**Figure** 15.4) show the eating patterns in an ecosystem. Food energy flows from one organism to another. Arrows are used to show the feeding relationship between the animals. The arrow points from the organism being eaten to the organism that eats it. For example, an arrow from leaves to a grasshopper shows that the grasshopper eats the leaves. Energy and nutrients are moving from the leaves to the grasshopper. Next, a mouse might prey on the grasshopper, a snake may eat the mouse, and then a hawk might eat the snake.

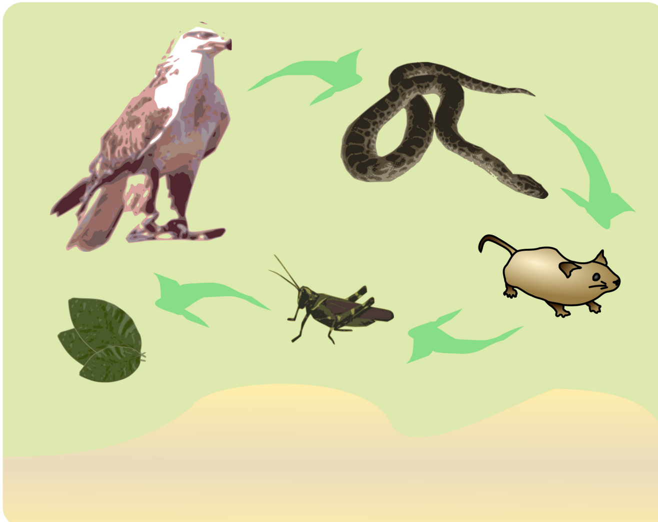

Figure 15.4: Food chain. This figure shows, for example, that the snake gets its energy from the rat, and the rat gets its energy from the insect.

In an ocean ecosystem, one possible food chain might look like this: phytoplankton -> krill -> fish -> shark.

The producers are always at the beginning of the food chain. The herbivores come next, then the carnivores. In this example, phytoplankton are eaten by krill, which are tiny, shrimp-like animals. The krill are eaten by fish, which are then eaten by sharks.

Each organism can eat and be eaten by many different types of organisms, so simple food chains are rare in nature. There are also many different species of fish and sharks. In ecosystems, there are many food chains.

Since feeding relationships are so complicated, we can combine food chains together to create a more accurate flow of energy within an ecosystem. A **food web** (**Figure** 15.5) shows the feeding relationships between many organisms in an ecosystem. If you expand our original example of a food chain, you could add deer that eat clover and foxes that hunt chipmunks. A food web shows many more arrows, but still shows the flow of energy. A complete food web may show hundreds of different feeding relationships.

Energy Pyramids

When an herbivore eats a plant, the energy in the plant tissues is used by the herbivore. The herbivore uses this energy to power its own life processes and to build more body tissues. However, only about 10% of the total energy from the plant gets stored in the herbivore's body as extra body tissue. The rest of the energy is used by the herbivore and released as heat. The next consumer on the food chain that eats the herbivore will only store about 10% of the total energy from the herbivore in its own body. This means the carnivore will store only about 1% of the total energy that was originally in the plant. In other words, only about 10% of energy of one step in a food chain is stored in the next step in the food chain. The majority of the energy is used or released to the environment.

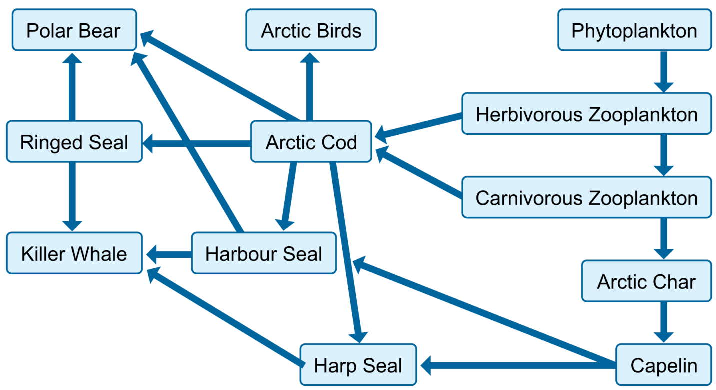

Figure 15.5: Food web in the Arctic Ocean.

Every time energy is transferred from one organism to another, there is a loss of energy. This loss of energy can be shown in an energy pyramid. An example of an energy pyramid is shown in **Figure** 15.6. Since there is energy loss in food chains, it takes many producers to support just a few carnivores in a community.

Each step of the food chain in the energy pyramid is called a **trophic level**. Plants or other photosynthetic organisms are found on the first trophic level, at the bottom of the pyramid. The next level will be the herbivores, then the carnivores that eat the herbivores. The energy pyramid in **Figure** 15.6 shows four levels of a food chain, from producers to carnivores. Because of the high rate of energy loss in food chains, there are usually only 4 or 5 trophic levels in the food chain or energy pyramid.

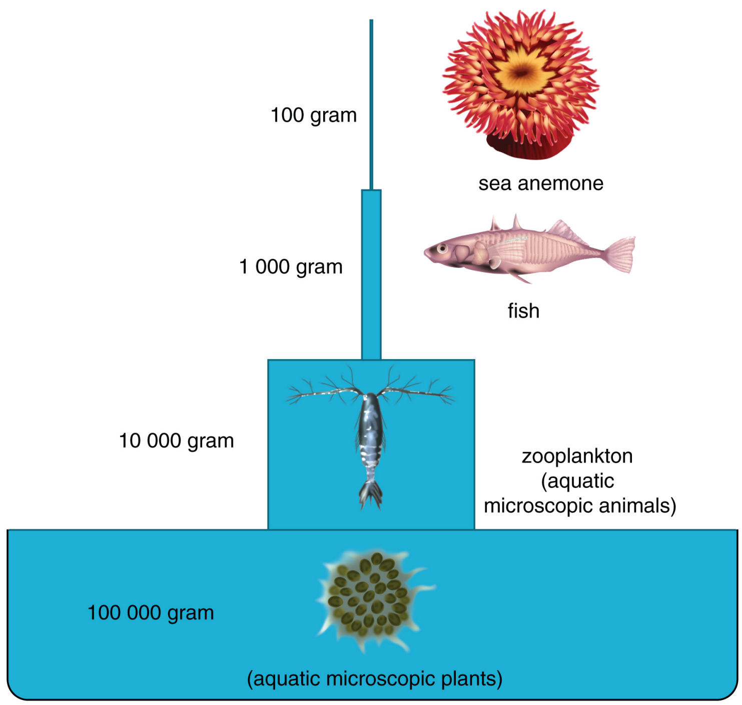

Figure 15.6: As illustrated by this ecological pyramid, it takes a lot of phytoplankton to support the carnivores of the oceans.

Lesson Summary

- Producers, such as plants and algae, can make their own food from the sun and other simple sources.
- Consumers must obtain their nutrients and energy by eating other organisms.
- Decomposers break down animal remains and wastes to get energy.
- Food chains and food webs show the feeding patterns in an ecosystem.
- As energy is transferred along a food chain, energy is lost as heat.

Review Questions

Recall

1. How do producers get energy?
2. How do decomposers obtain energy?
3. What shows the complex feeding interactions in a community?
4. What's the term for a consumer that eats both plants and animals?

Apply Concepts

5. What happens to 90% of the energy that passes from one step in the food chain to the next step?

For questions 6 - 8, Analyze the following food chain: **algae -> fish -> herons**

6. What is the producer in the food chain?
7. What is the herbivore in the food chain?
8. What is the carnivore in the food chain?

Critical Thinking

9. In a forest community, caterpillars eat leaves, and birds eat caterpillars. Draw a food chain using this information.

Further Reading / Supplemental Links

- http://science-class.net/Ecology/energy_transfer.htm
- http://en.wikipedia.org/wiki/Energy_pyramid
- http://science-class.net/Ecology/energy_transfer.htm
- http://en.wikipedia.org/wiki/Food_chain

Venus fly trap - The Private Life of Plants can be viewed at http://www.youtube.com/watch?v=ktIGVtKdgwo (3:29).

Points to Consider

- Animals are made partly of the element carbon. When animals decompose, what happens to the carbon?

Figure 15.7: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/614

- We need nitrogen to make our DNA. Where does it come from? Where does it go? What would happen to nitrogen released from decaying organisms?
- Water is necessary for photosynthesis. Water moves through both the living and non-living parts of an ecosystem. How does water move through the living parts of an ecosystem?

15.2 Cycles of Matter

Lesson Objectives

- Describe the key features of the water cycle.
- Describe the key features of the nitrogen cycle.
- Describe the key features of the carbon cycle.

Check Your Understanding

- What types of organisms break down animal remains and wastes to release nutrients?
- What are the main chemical elements that are essential for life?

Vocabulary

- biogeochemical cycles
- fossil fuels
- global warming
- groundwater
- nitrogen fixation
- precipitation
- runoff
- transpiration

The Water Cycle

Chemicals and nutrients are recycled in an ecosystem in **biogeochemical cycles**. This recycling process involves both the biotic factors and the abiotic factors of the ecosystem. Through biogeochemical cycles, nutrients are constantly being passed through living organisms to non-living matter and back again, over and over. These recycled nutrients contain the elements carbon and nitrogen.

Water is obviously an extremely important aspect of every ecosystem. Life cannot exist without water. Many organisms contain a large amount of water in their bodies, and many live in water, so the water cycle is essential to life on earth. Water is cycled through the biotic and abiotic factors of an ecosystem, moving between living things and non-living things, such as clouds, rivers, and oceans (**Figure** 15.8).

The water cycle does not have a real starting or ending point, since it is an endless recycling process, but we will start with the oceans. Here are the steps in the water cycle:

1. Water evaporates from the surface of the oceans, leaving behind salts. As the water vapor rises, it collects and is stored in clouds.
2. As water cools in the clouds, condensation occurs. Condensation is when gases turn back into liquids.
3. Condensation creates precipitation. **Precipitation** includes rain, snow, hail, and sleet. The precipitation allows the water to return again to the Earth's surface.
4. When precipitation lands on land, the water can sink into the ground to become part of our underground water reserves, also known as **groundwater**. Much of this underground water is stored in aquifers, which are porous layers of rock that can hold water.

Run-off

Most precipitation that occurs over land, however, is not absorbed by the soil and is called **runoff**. This runoff collects in streams and rivers and moves back into the ocean.

Transpiration

Water also moves through the living organisms in an ecosystem. Plants soak up large amounts of water through their roots. The water then moves up the plant and evaporates from the leaves in a process called **transpiration**. The process of transpiration, like evaporation, returns water back into the atmosphere.

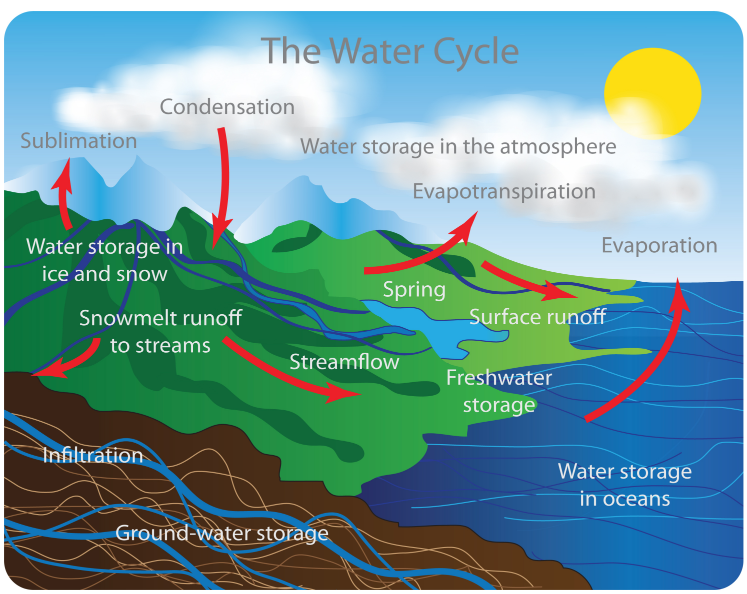

Figure 15.8: The water cycle.

See http://www.youtube.com/watch?v=4Cb3SIMRCIE&NR=1 for an animation of the water cycle (3:14).

Figure 15.9: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/615

The Carbon Cycle

Carbon is one of the most common elements found in living organisms. Chains of carbon molecules form the backbones of many molecules, such as carbohydrates, proteins, and lipids. Carbon is constantly cycling between living things and the atmosphere (**Figure** 15.10).

In the atmosphere, there is carbon dioxide. Producers capture the carbon dioxide and convert it to glucose through the process of photosynthesis. As consumers eat producers or other consumers, they gain the carbon from those organisms. Some of this carbon is lost, however, through the process of cellular respiration. That means when our cells burn food for energy, carbon dioxide is released. We, like all animals, exhale this carbon dioxide and return it back to the atmosphere. Also, carbon dioxide is released to the atmosphere as an organism dies and decomposes.

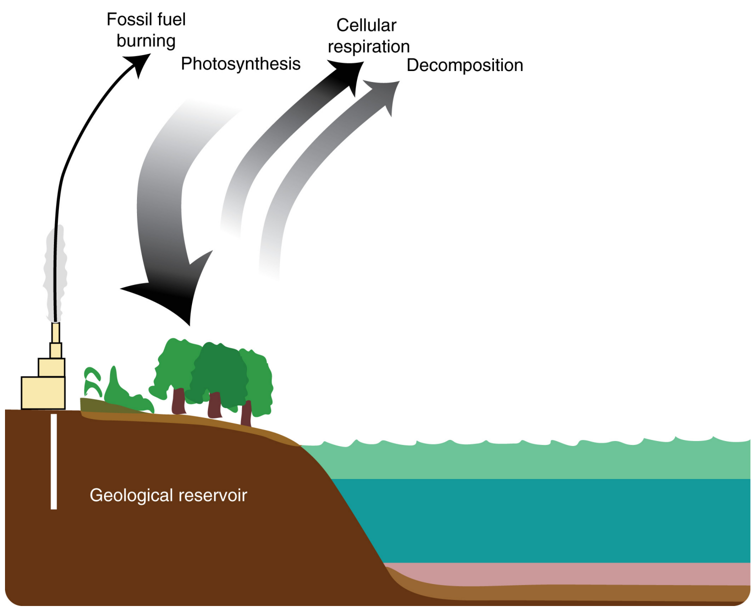

Figure 15.10: The carbon cycle.

Formation of Fossil Fuels

Millions of years ago, there were so many dead plants and animals that they could not completely decompose before they were buried. These plants and animals are organic matter, with lots of carbon. When organic matter is under pressure for millions of years, it forms **fossil fuels.** Fossil fuels are coal, oil, and natural gas.

When humans dig up and use fossil fuels, we have an impact on the carbon cycle (**Figure** 15.11). The burning of fossil fuels releases more carbon dioxide into the atmosphere than is used by photosynthesis. So, there is more carbon dioxide entering the atmosphere than is coming out of it. Carbon dioxide is known as a greenhouse gas, since it lets in light energy but does not let heat escape, much like the panes of a greenhouse. The increase of greenhouse gasses in the atmosphere is contributing to a global rise in Earth's temperature, known as **global warming** (see the *Environmental Problems* chapter for additional information).

Figure 15.11: Human activities like burning gasoline in cars are contributing to a global change in our climate.

The Nitrogen Cycle

Nitrogen is also one of the most common elements in living organisms. It is important for creating both proteins and nucleic acids, like DNA. Nitrogen gas (N_2) is in the majority of the air we breathe, but unfortunately, animals and plants cannot use it when it is a gas. In fact, plants often die from a lack of nitrogen even through they are surrounded by plenty of nitrogen gas.

In order for plants to make use of nitrogen, it must be transformed into molecules they can use. This can be accomplished several different ways (**Figure** 15.12).

- Lightning: Nitrogen gas can be transformed into nitrate (NO_3^-) that plants can use when lightning strikes.
- **Nitrogen fixation**: Special nitrogen-fixing bacteria can also transform nitrogen gas into useful forms. These bacteria live in the roots of plants in the pea family. In water environments, bacteria in the water can fix nitrogen gas into ammonium (NH_4^+). Ammonium can be used by aquatic plants as a source of nitrogen.
- Nitrogen also is released to the environment by decaying organisms or decaying wastes. These wastes release nitrogen in the form of ammonium. Ammonium in the soil can be turned into nitrate by a

two-step process completed by two different types of bacteria. In the form of nitrate, it can be used by plants through a process called assimilation.

Sending Nitrogen back to the Atmosphere

Turning nitrate back into nitrogen gas happens through the work of denitrifying bacteria. These bacteria often live in swamps and lakes. They take in the nitrate and release it as nitrogen gas.

Just like the carbon cycle, human activities impact the nitrogen cycle. These human activities include the burning of fossil fuels, which release nitrogen oxide gasses into the atmosphere. Releasing nitrogen oxide back into the atmosphere leads to problems like acid rain.

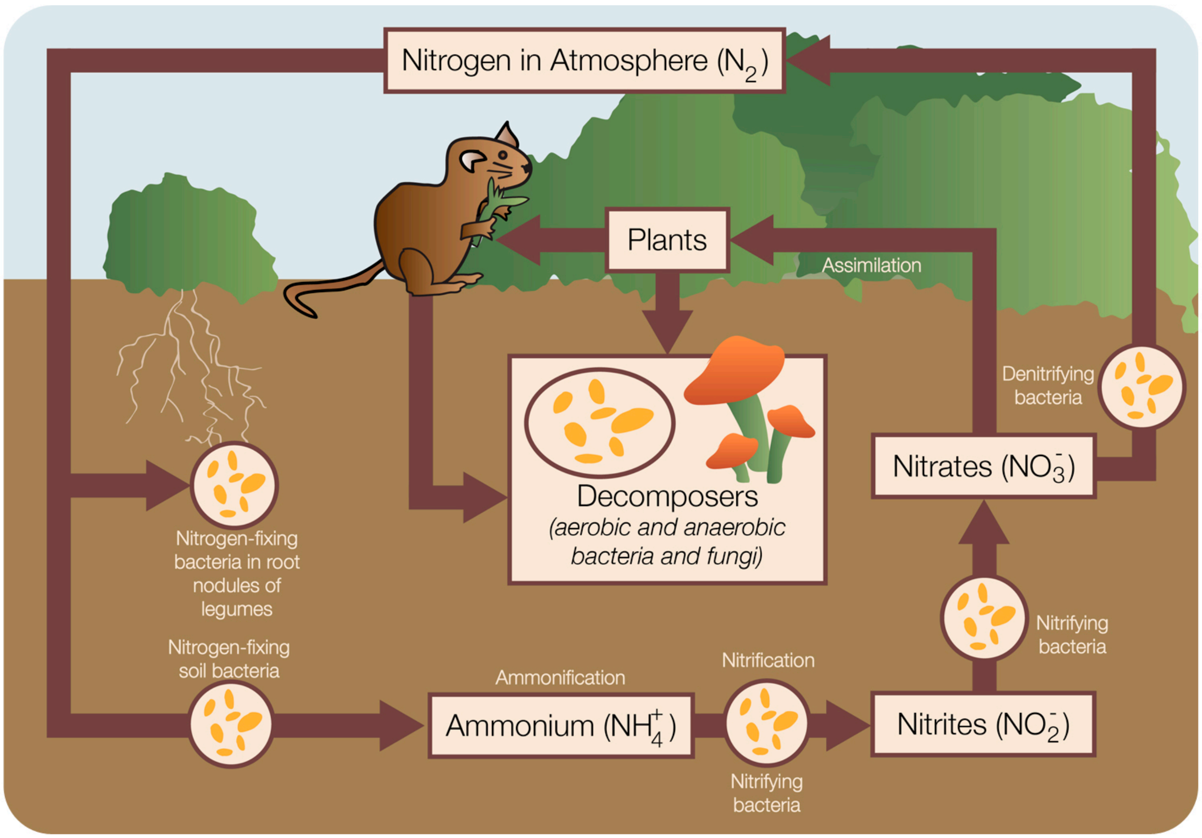

Figure 15.12: The nitrogen cycle includes assimilation, when plants absorb nitrogen; nitrogen-fixing bacteria that make the nitrogen available to plants in the form of nitrates; decomposers that transform nitrogen in dead organisms into ammonium; nitrifying bacteria that turn ammonium into nitrates; and denitrifying bacteria that turn nitrates into gaseous nitrogen.

The nitrogen cycle is described at http://www.youtube.com/watch?v=pdY4I-EaqJA (5:08).

Lesson Summary

- During the water cycle, water enters the atmosphere by evaporation, and water returns to land by precipitation.
- During the carbon cycle, animals add carbon dioxide to the atmosphere through respiration, and plants remove carbon dioxide through photosynthesis.

Figure 15.13: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/170

- During the nitrogen cycle, gaseous nitrogen is converted into water-soluble forms that can be used by plants, while denitrifying bacteria turn nitrate back into gaseous nitrogen.

Review Questions

Recall

1. What is the term for the remains of organisms that are burned for energy?
2. How does water in the atmosphere return to the ground?
3. What are some examples of fossil fuels?
4. What biological process "fixes" carbon, removing it from the atmosphere?

Apply Concepts

5. What human activities have thrown the carbon cycle off balance?
6. What is the significance of nitrogen-fixing bacteria?
7. What biological process releases carbon back into the atmosphere?
8. What must happen for plants to use nitrogen in the atmosphere?
9. What is the significance of denitrifying bacteria?

Critical Thinking

10. Why is carbon dioxide referred to as a "greenhouse gas"? Explain the effects of greenhouse gasses on the planet.

Further Reading / Supplemental Links

- http://earthobservatory.nasa.gov/Library/CarbonCycle
- http://www.cosee-ne.net/resources/documents/OceanLiteracyWorkshopIReport.pdf
- http://www.estrellamountain.edu/faculty/farabee/biobk/BioBookcycles.html
- http://earthobservatory.nasa.gov/Library/CarbonCycle
- http://earthguide.ucsd.edu/earthguide/diagrams/watercycle/index.html
- http://en.wikipedia.org/wiki

Points to Consider

- Do ecosystems change over time? Why or why not?
- Can you think of an example of a ecosystem changing over time?

15.3 Ecosystem Change

Lesson Objectives

- Explain the process of ecological succession.
- Distinguish between secondary and primary succession.
- Describe a climax community.

Check Your Understanding

- What is a biome?
- What is the most abundant element in living things?
- How do humans obtain nitrogen?

Vocabulary

- climax community
- ecological succession
- pioneer species
- primary succession
- secondary succession

Ecosystems Change

When you see an older forest, it's easy to picture that the forest has been there forever. This is not the case.

Ecosystems are "dynamic." This means that ecosystems change over time. That forest may lie on land that was once covered by an ocean millions of years ago. Or the forest may have been cut down at one point for agricultural use, then abandoned and allowed to re-grow over time. During the ice ages, glaciers once covered areas that are tropical rainforests today. Both natural forces and human actions cause ecosystems to change.

If there is a big ecosystem change caused by natural forces or human actions, the plants and animals that live there may be destroyed. Or they may be forced to leave. Over time, a new community will develop, and then that community may be replaced by another. You may see several changes in the plant and animal composition of the community over time. **Ecological succession** is the constant replacement of one community by another. It happens after a big change in the ecosystem.

Primary Succession

Primary succession is the type of ecological succession that happens on lands without plants or animal life. It can take place after a lava flow or a glacier. Since the land that results from these processes is often completely new land, soil must be produced.

Primary succession always starts with a **pioneer species**. This is the species that first lives in the disturbed area.

If life wants to begin on rocks without life, the pioneer species could be a lichen (**Figure** 15.14). A lichen is actually not one species, but two. There is a symbiotic relationship between a fungus and an algae or cyanobacteria. The fungus is able to absorb minerals and nutrients from the rock, while algae supplies the fungus with sugars. Since lichens can photosynthesize and do not rely on soil, they can live in environments where other organisms cannot. As a lichen grows, it breaks down the rock, which is the first step of soil formation.

Figure 15.14: Primary succession on a rock often begins with the growth of lichens. What do lichens help create?

The pioneer species is soon replaced by other communities. Mosses and grasses will be able to grow in the newly created soil. During early succession, plant species like grasses that grow and reproduce quickly will take over the landscape. Over time, these plants improve the soil and a few shrubs can begin to grow. Slowly, the shrubs are replaced by trees. Since trees are more successful at competing for resources than shrubs and grasses, a forest may be the end result of primary succession.

Secondary Succession

Sometimes ecological succession happens where there are already soil and organisms.

Secondary succession is the type of succession that happens after something destroys the community. Abandoning a field that was once used for agriculture can lead to secondary succession (**Figure** 15.15). In this case, the pioneer species would be the grasses that first appear. Slowly, the field would return to the natural state and look like it used to look before the humans used it for agriculture.

Another event that results in secondary succession is a forest fire (**Figure** 15.16, and **Figure** 15.17). Although the area will look devastated at first, the seeds of new plants are underground. They are waiting for their chance to grow. Just like primary succession, the burned forest will go through a series of communities, starting with small grasses, then shrubs, and finally bigger trees.

Figure 15.15: This land was once used for growing crops. Now that the field is abandoned, secondary succession has begun. Pioneer species, such as grasses, appear first, and then shrubs begin to grow.

Figure 15.16: The early stages of succession after a forest fire are shown in these pictures. Taken four years after the fire, they show the charred remains of the original forest as well as the small grasses and shrubs that are beginning to grow back in the area.

Figure 15.17: In 1988, a forest fire destroyed much of Yellowstone National Park. This photo, taken 17 years later, shows that the forest is gradually growing back. Small grasses first grew here and are now being replaced by small trees and shrubs. This is an example of the later stages of secondary succession.

Climax Communities

Climax communities (**Figure** 15.18) are the end result of ecological succession. They are a stable balance of all organisms in an ecosystem. The climax community will remain stable unless a disaster strikes. After the disaster, succession will start all over again. Depending on the climate of the area, the climax community will look different. In the tropics, the climax community might be a tropical rainforest. At the other extreme, in northern parts of the world, the climax community might be a coniferous forest.

Figure 15.18: These ancient redwood trees are part of a climax community, the end result of a series of community replacements during succession.

Lesson Summary

- Ecological succession is the continual replacement of one community by another that happens after big changes in the ecosystem.
- Primary succession happens in disturbed areas that have little or no soil.
- Secondary succession happens in disturbed areas that previously supported life.
- Climax communities develop as the last stage of succession, when the ecosystem is again stable.

Review Questions

Recall

1. What is the term for a continuous replacement of one community by another following a disturbance?
2. What type of succession occurs in areas where there is no soil?
3. What type of succession occurs in areas where soil is present?
4. What is the term for the final stage of succession, when the community becomes stable?

Apply Concepts

5. Imagine a forest fire destroyed a forest. The forest will slowly re-establish itself, which is an example of what kind of succession?

6. A glacier slowly melts, leaving bare rock behind it. As life starts establishing itself on the newly available land, what kind of succession is this?

7. Does the climax community look the same in all parts of the world?

Critical Thinking

8. An area covered with lava is going through primary succession. Explain in detail all of the stages of succession up until the climax community. Also, describe the complex community.

Further Reading / Supplemental Links

- http://www.scribd.com/doc/529104/Ecological-Succession
- http://www.biologycorner.com/worksheets/succession.html
- http://ecolibrary.cs.brandeis.edu/general_search.php?id=CS_Succession@Secondary%20succession&page=links
- http://en.wikipedia.org/wiki

Points to Consider

- Think about what would happen if dangerous toxins were illegally dumped near a river.
- Discuss why it is important to seek alternative energy sources.
- Do we have an infinite supply of fossil fuels, or will we run out some day?

Image Sources

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Chapter 16

MS Life Science Glossary

A

abiotic Physical (nonliving) properties of an organism's environment, such as sunlight, climate, soil, water and air.

ABO blood type system Blood group system that is determined by the presence or absence of certain molecules, called antigens, on the surface of red blood cells (RBCs); there are four blood types in the ABO system: A, B, AB, and O.

abscisic acid Plant hormone involved in maintaining dormancy and closing the stomata.

absorption Process in which substances are taken up by the blood; after food is broken down into small nutrient molecules, the molecules are absorbed by the blood.

acid rain Precipitation or deposits with a low (acidic) pH.

acquired trait A feature that an organism gets during its lifetime in response to the environment (not from genes); not passed on to future generations through gene

active transport The movement of a molecule from an area of lower concentration to an area of higher concentration; requires a carrier protein and energy.

adaptation A beneficial trait that helps an organism survive in its environment.

adolescence Period of life between the start of puberty and the beginning of adulthood.

aerobic exercises Types of exercises that cause the heart to beat faster and allow the muscles to obtain energy to contract by using oxygen.

aerobic respiration Cellular respiration in the presence of oxygen.

aerofoil A surface which is designed to aid in lifting or controlling by making use of the air currents through which it moves.

AIDS Acquired immune deficiency syndrome, which is a fatal condition caused by the human immunodeficiency virus (HIV).

alcoholic fermentation Fermentation in the absence of oxygen; produces ethyl alcohol (drinking alcohol) and carbon dioxide; occurs in yeasts.

algal bloom Excessive growth of aquatic vegetation or phytoplankton as a result of eutrophication.

allele An alternative form of a gene.

allergen A substance that triggers an allergy.

allergy A condition that occurs when the immune system attacks a harmless foreign substance.

allopatric speciation Speciation that occurs when groups from the same species are geographically isolated physically for long periods.

alternation of generations A lifecycle that alternates between a haploid gametophyte and a diploid sporophyte; characteristic of plants.

altricial Newborn that are helpless at birth and require much parental care.

alveoli Little *sacs* at the end of the bronchioles where most of the gas exchange occurs.

amino acid The units that combine to make proteins.

amniotes Vertebrates whose embryos are surrounded by an amniotic membrane.

amniotic sac Fluid-filled membrane that surrounds and protects a fetus within the uterus.

anaerobic exercise Types of exercises that involve short bursts of high-intensity activity; forces the muscles to obtain energy to contract without using oxygen.

anaerobic respiration Cellular respiration in the absence of oxygen; fermentation.

anaphase Third phase of mitosis and meiosis (anaphase I and anaphase II) where sister chromatids separate and move to opposite sides of the cell.

angina Chest pain caused by the lack of oxygen to the heart muscle; can happen during times of stress or physical activity.

angiosperms Plants with vascular tissue, seeds, and flowers.

animal behavior Any way that animals act, either alone or with other animals.

anther The pollen-containing structure in a flower.

antibody Protein that identifies pathogens or other substances as being harmful; can destroy pathogens by attaching to the cell membrane of the pathogen.

antidiuretic hormone (ADH) Hormone that controls the absorption of water back into blood.

antigen Any protein that triggers an immune response; usually a foreign protein, unlike any protein that the body makes.

anvil Second of three tiny bones that pass vibrations through the ear.

apical dominance Suppressing the growth of the side branches of a plant.

applied science The application of science to practical problems.

aquaculture The raising of aquatic plants and animals, especially seaweed, shellfish and other fish.

aquatic biomes Biomes divided into freshwater and marine biomes and defined according to different physical and ecological factors.

Archaea Microscopic one-celled organisms with no nucleus that tend to live in extreme environments.

arteries Blood vessels that carry blood away from the heart.

artificial selection Occurs when humans select which plants or animals to breed to pass specific traits on to the next generation.

asexual reproduction A form of reproduction in which a new individual is created by only one parent.

asthma A chronic illness in which the bronchioles are inflamed and become narrow.

atherosclerosis A chronic inflammation of the walls of arteries that causes swelling and a buildup of material called plaque.

atom The simplest and smallest particle of matter that still retains the physical and chemical properties of the element; the building block of all matter.

atomic number The number of protons in an element.

ATP A usable form of energy inside the cell; adenosine triphosphate.

atrioventricular (AV) valves Valves that stop blood from moving from the ventricles back into the atria.

atrium One of the two small, thin-walled chambers on the top of the heart that blood first enters.

autoimmune disease A disease that occurs when the immune system attacks the body's own cells.

autonomic nervous system Part of the motor division that carries nerve impulses to internal organs and glands.

autosomes The chromosomes other than the sex chromosomes.

autotroph Organism that produces complex organic compounds from simple inorganic molecules using a source of energy such as sunlight.

auxin Plant hormone involved in tropisms and apical dominance.

axon Part of a neuron that receives nerve impulses from the cell body and passes them on to other cells.

B

bacilli Rod-shaped bacteria or archaea.

bacteria Microscopic one-celled prokaryotic organisms (without a nucleus).

ball and socket joint Joint structure in which the ball-shaped surface of one bone fits into the cuplike depression in another bone; examples include the shoulder and hip joints.

barbel A thin fleshy structure on the external part of the head, such as the jaw, mouth or nostrils, of certain fishes.

basic science Research whose goal is just to find out how the world works, not to solve an urgent problem. Basic research is the source of most new scientific information and nearly all new theories.

behavioral isolation The separation of a population from the rest of its species due to some behavioral barrier, such as having different mating seasons.

bilateral symmetry Body plan in which the left and right side are mirror images.

binary fission An asexual form of reproduction where a cell splits into two daughter cells.

binomial nomenclature The system for naming species in which the first word is the genus and the second word is the species.

biodiversity The number of different species or organisms in an ecological unit (i.e. biome or ecosystem).

biogeochemical cycles The pathway of elements like carbon and nitrogen through the non-living and living parts of the ecosystem.

biohazard Any biological material, such as infectious material that poses a potential to human health, animal health, or the environment.

biological clock Tiny structure in the brain that controls circadian rhythms.

biome A large community of plants and animals that live in the same place.

biosphere The part of the planet and atmosphere with living organisms.

biotic Biological (living) properties of an environment, i.e., the living organisms in a habitat.

birth rate Number of births per individual within the population per unit time.

blood A body fluid that is a type of connective tissue; moves oxygen and other compounds throughout the body.

blood clotting The complex process by which blood forms solid clots.

blood pressure The force exerted by circulating blood on the walls of blood vessels.

bone marrow Soft connective tissue found inside many bones; site of blood cell formation.

brain Control center of the nervous system that is located inside the skull.

brain stem Part of the brain that controls basic body functions, such as breathing, heartbeat, and digestion.

breast cancer Most common type of cancer in females; occurs when cells of the breast grow out of control and form a tumor.

bronchitis An inflammation of the bronchi.

budding Asexual reproduction in which part of the body of a fungus, for example, grows and breaks off, eventually becoming a new organism.

C

calorie Unit used to measure the energy in food.

calyx The sepals collectively; outermost layer of the flower.

Cambrian explosion A sudden burst of evolution that may have been triggered by an environmental change(s); made the environment more suitable for a wider variety of life forms; occurred during the Cambrian Period.

camouflage An appearance which helps a species blend into the background.

cancer A disease in which abnormal cells divide out of control.

capillaries The smallest and narrowest blood vessels in the body.

carapace The thick dorsal shield seen in many crustaceans; often forms a protective chamber for the gills.

carbohydrate Nutrient that include sugars, starches, and fiber; give your body energy; class of organic compound.

carcinogen Anything that can cause cancer.

cardiac muscle An involuntary and specialized kind of muscle found only in the heart.

cardiovascular disease (CVD) Any disease that affects the cardiovascular system, although the term is usually used to describe diseases that are linked to atherosclerosis.

cardiovascular system The organ system that is made up of the heart, the blood vessels, and the blood.

carnivore An organism that eats other animals.

carpel *Female* portion of the flower; consists of stigma, style, and ovary.

carrying capacity Maximum population size that can be supported in a particular area without degradation of the habitat.

cartilage Smooth covering found at the end of bones; made of tough collagen protein fibers; creates smooth surfaces for the easy movement of bones against each other.

cartilaginous skeleton A skeleton made of bone-like material called cartilage.

cell The smallest living unit of life; the smallest unit of structure and function of living organisms.

cell body Part of a neuron that contains the nucleus and other organelles.

cell cycle Phases in the "life" of eukaryotic cells that leads to cell division.

cell theory All organisms are composed of cells; cells are the basic units of structure and function in an organism; cells only come from preexisting cells.

cellular respiration The process in which the energy in food is converted into energy that can be used by the body's cells; in other words, glucose is converted into ATP.

cell wall Provides strength and protection for the cell; found around plant, fungal, and bacterial cells.

central nervous system Part of the nervous system that includes the brain and spinal cord.

central vacuole Large organelle containing water, nutrients, and wastes; can take up to 90% of a plant cell's volume.

cephalization Having a head region with a concentration of sensory organs and central nervous system.

cephalothorax The anterior part of the arachnid body, derived from the fusion of the head and thorax.

cerebellum Part of the brain that controls body position, coordination, and balance.

cerebrum Part of the brain that controls awareness and voluntary movements.

cervix Narrow part of the uterus where it connects with the vagina.

character displacement Occurs when two or more species within the same area develop different specializations in order to coexist.

chemical digestion Digestion in which large food molecules are broken down into small nutrient molecules.

chemical reaction A process that breaks or forms the bonds between atoms.

chemotroph Organism that obtains energy by oxidizing compounds in their environment.

childbirth Process through which a baby passes from the uterus, through the vagina, and out of the mother's body.

childhood Period between a baby's first birthday and puberty.

chitin A nitrogen-containing material found in the cell wall of fungi; also found in the shells of animals such as beetles and lobsters.

chlamydia Most common bacteria causing sexually transmitted disease (STD) in the United States.

chlorophyll Green pigment in leaves; helps to capture solar energy.

chloroplast The organelle in which photosynthesis takes place.

chromatin Complex of DNA and proteins; visible when a cell is not dividing.

chromosome DNA wound around proteins; forms during prophase of mitosis and meiosis.

chronic disease A disease that lasts for a long time, perhaps a few years or longer.

chronic obstructive pulmonary disease (COPD) A disease of the lungs in which the airways become narrowed; leads to a limitation of the flow of air to and from the lungs causing shortness of breath.

cilia Finger-like projects from the cells; can be found from the cells of mucous membranes.

circadian rhythms An organism's daily cycles of behavior.

classify To organize into groups or categories; scientists classify organisms by their physical features and how closely related they are.

climax community A stable community that is the end product of succession.

cloning Creating an identical copy of a gene, or an an individual with the same genes.

club mosses Seedless vascular plants that resemble mosses.

cnidarians Invertebrates that have radial symmetry; includes the jellyfish.

cocci Sphere-shaped bacteria or archaea.

cochlea Liquid-filled structure in the ear that senses vibrations and generates nerve impulses in response.

codominance A pattern of inheritance where both alleles are equally expressed.

commensalism type of symbiosis in which one species benefits while the other is not affected.

communication Any way that animals share information.

community Populations of different species that occupy the same area and interact with each other.

competition Organisms of the same or different species compete for a limited supply of at least one resource, thereby lowering the fitness of one organism by the presence of the other.

competitive exclusion principle Species less suited to compete for resources will either adapt, be excluded from the area, or die out.

complete digestive tract A digestive tract with two openings, a mouth and anus.

complete flowers Flowers that contain all four structures: sepals, petals, stamens, and one or more carpels.

compound Any combination of two or more elements.

concentration The amount of a substance in relation to the volume.

concussion Bruise on the surface of the brain; the mildest and most common type of brain injury.

conditioning Way of learning that involves a reward or punishment.

conifers Group of gymnosperms that bear cones; includes spruces, pine, and fir trees.

conjugation The transfer of genetic material between two bacteria.

connective tissue Tissue that is made up of different types of cells that are involved in structure and support of the body; includes blood, bone, tendons, ligaments, and cartilage.

consumer An organism that must eat other organisms to obtain energy and nutrients.

contraction Shortening of muscle fibers.

convergent adaptation The appearance of similar traits in groups of animals that are evolutionarily unrelated to each other.

cooperation Working together with others for the common good.

corals Cnidarians that live on ocean reefs in colonies.

cornea Clear, protective covering on the outside of the eye that helps focus light.

corolla The petals of a flower collectively are known as the corolla.

coronary heart disease The end result of the buildup of plaques within the walls of the coronary arteries.

courtship behaviors Special behaviors that help attract a mate.

cranium a braincase

crossing-over Exchange of DNA segments between homologous chromosomes; occurs during prophase I of meiosis.

cross-pollination Sexual reproduction in plants where sperm from the pollen of one flower is received by the ovary of another flower.

cuticle Waxy layer that aids water retention in plants.

cyanobacteria Photosynthetic bacteria.

cytokinesis Division of the cytoplasm after mitosis or meiosis.

cytokinins Plant hormone involved in cell division.

cytoplasm All the contents of the cell besides the nucleus, including the cytosol and the organelles.

cytoskeleton The internal scaffolding of the cell; maintains the cell shape and aids in moving the parts of the cell.

cytosol A fluid-like substance inside the cell; organelles are embedded in the cytosol.

D

daughter cell Cells that divide from the parent cell after mitosis or meiosis.

death rate Number of deaths within the population per unit time.

decomposer Organism that break down wastes and dead organisms and recycle their nutrients back into the environment.

dendrite Part of a neuron that receives nerve impulses from other cells and passes them on to the cell body.

dermis The layer of skin directly under the epidermis; made of a tough connective tissue that contains the protein collagen.

desertification A process leading to production of a desert of formerly productive land.

diabetes A disease in which the pancreas cannot make enough insulin.

diaphragm A sheet of muscle that extends across the bottom of the rib cage.

digestion Process of breaking down food into nutrients.

digestive system Body system that breaks down food, absorbs nutrients, and gets rid of solid food waste.

diffusion Movement of molecules from an area of high concentration to an area of low concentration; does not require energy.

diploid When a cell has two sets of chromosomes.

dispersion The spacing of individuals within a population.

display behavior Fixed set of actions that carries a specific message.

DNA Deoxyribonucleic acid; a nucleic acid that is the genetic material of all organisms.

DNA replication The synthesis of new DNA; occurs during the S phase of the cell cycle.

domain The least specific category of classification.

dominant Masks the expression of the recessive trait.

dormant Halting growth and development temporarily.

double helix The shape of DNA; a double spiral, similar to a spiral staircase.

drug Any chemical substance that affects the body or brain.

drug abuse Use of a drug without the advice of a doctor or for reasons other than those for which the drug was intended.

drug addiction Condition in which a drug takes over people's lives and they cannot stop using the drug even if they want to.

drug overdose Taking so much of a drug that it causes serious illness or death.

duodenum The first part of the small intestine; where most chemical digestion takes place.

E

ear Sense organ that detects sound.

ear canal Tube-shaped opening in the ear that carries sound waves to the eardrum.

eardrum Membrane in the ear that vibrates when sound waves hit it.

ecdysis The ability to regenerate lost limbs, as well as other body parts.

ecological succession The continual replacement of one community by another; occurs after some disturbance of the ecosystem.

ecology The scientific study of how living organisms interact with each other and with their environment.

ecosystem A natural unit composed of all the living forms in an area, functioning together with all the abiotic components of the environment.

ectothermic cold-blooded; temperature depends on the temperature of their environment.

eggs female gametes or sex cells

electron A negatively charged particle in the atom, found outside of the nucleus.

electron microscope Microscope used to create high magnification (magnified many times) and high resolution (very clear) images.

element A substance that cannot break down into a simpler substance with different properties.

elevation Measures how high land is above sea level.

embryo An animal or plant in its earliest stages of development, before it is born or hatched.

embryology The study of how organisms develop.

emigration Movement of individuals out of a population.

emphysema A chronic lung disease caused by loss of elasticity of the lung tissue.

endoplasmic reticulum (ER) A folded membrane organelle; rough ER modifies proteins and smooth ER makes lipids.

endostyle Used to gather food particles and move them along the digestive tract.

environmental tobacco smoke (ETS) Secondhand smoke, which greatly increases the risk of lung cancer and heart disease in nonsmokers.

enzyme A substance, usually a protein, that speeds up a biochemical reaction.

epidermis The outermost layer of the skin; forms the waterproof, protective wrap over the body's surface; made up of many layers of epithelial cells.

epididymis Male reproductive organ where sperm mature and are stored until they leave the body.

epiglottis A flap of connective tissue that closes over the trachea when food is swallowed; prevents choking or inhaling food.

epithelial tissue A tissue that is composed of layers of tightly packed cells that line the surfaces of the body; examples of epithelial tissue include the skin, the lining of the mouth and nose, and the lining of the digestive system.

erosion Process by which the surface of the Earth is worn away by the action of winds, water, waves, glaciers, etc.

esophagus The narrow tube that carries food from the throat to the stomach.

essential amino acids Amino acids that must come from the proteins in foods; you cannot make these amino acids.

estrogen The main sex hormone in females.

ethylene Plant hormone involved in fruit ripening and abscission.

Eukarya Domain in which cells have a nucleus; includes plants, animals, fungi, and protists.

eukaryote Cell belonging to the domain Eukarya (fungi, animals, protists, and plants); has membrane-enclosed nucleus and organelles.

evidence Something that gives us grounds for knowing of the existence or presence of something else.

evolution The process in which something passes to a different stage, such as a living organism turning into a more advanced or mature organism; the change of the inherited traits of a group of organisms over many generations.

evolutionary tree Diagram used to represent the relationships between different species and their common ancestors.

excretion The process of removing wastes from the body.

excretory system The organ system that maintains homeostasis by keeping the correct balance of water and salts in your body; also helps to release wastes from the body.

exhalation Pushing air out of the body through the nose or mouth.

exocuticle The thin and waxy water resistant outer layer of the cuticle.

experiment A test to see if a hypothesis is right or wrong; a test to obtain new data.

extensor The muscle that contracts to cause a joint to straighten.

external fertilization Reproduction where the eggs are fertilized outside the body.

external respiration The movement of oxygen into the body and carbon dioxide out of the body.

extinct Something that does not exist anymore; a group of organisms that has died out without leaving any living representatives.

extinction The cessation of existence of a species or group of taxa.

F

F1 generation The first filial generation; offspring of the P or parental generation.

F2 generation The second filial generation; offspring from the self-pollination of the F1 generation.

fallopian tubes Female reproductive organs through which eggs pass to reach the uterus, and where an egg may unite with a sperm.

feedback regulation Control of a biological process based on the effect of a stimulus.

fermentation Anaerobic respiration in which NAD^+ is recycled so that is can be reused in the glycolysis (the breakdown of glucose) process.

ferns Seedless vascular plants that have large, divided fronds.

fertilization Union of a sperm and egg; occurs in a fallopian tube.

fetus Stage of a developing baby between the end of the 8th week after fertilization and birth.

fever Higher than normal body temperature.

fibrin A tough protein that forms strands during the blood clotting process.

field scientist Scientists who work outdoors.

filter-feeder An organism that feeds by filtering organic matter out of water.

flagellum (plural flagella) A tail-like structure that projects from the cell body of certain prokaryotic and eukaryotic cells, and it usually functions in helping the cell move.

flexor The muscle that contracts to cause a joint to bend.

follicle Nest of cells in an ovary that enclose an egg; protects egg during maturation prior to ovulation.

food allergies A condition in which the immune system reacts to harmless substances in food as though they were harmful.

food chain A visual representation of the flow of energy from producers to consumers in a community.

food web A visual representation of the complex eating relationships in a community; a cross-linking of food chains.

fossil The preserved remains or traces of animals, plants, and other organisms from the distant past; examples include bones, teeth, impressions, and leaves.

fossil fuels Fuels made from partially decomposed organic matter that has been compressed underground for millions of years; examples are: coal, natural gas, and oil.

fossil record Fossils and the order in which fossils appear; provides important records of how species have evolved, divided and gone extinct.

fracture Bone injury, often called a *break*; usually caused by excess bending stress on bone.

fruiting body Specialized structure used in sexual reproduction; part of the fungus that produces the spores.

G

GAIA hypothesis The concept that the biosphere is itself a living organism.

Galápagos Islands A group of islands in the Pacific Ocean off South America; known for unusual animal life. Many scientists, including Charles Darwin, made many discoveries that led to and support the theory of evolution by natural selection, while studying the plants and animals on these islands.

gamete Haploid sex cell; egg or sperm.

ganglia A compact group of nerve cells having a specific function.

gas exchange The movement of oxygen across a membrane and into the blood and the movement of carbon dioxide out of the blood.

gastric mill A gizzard-like structure for grinding food.

gastrovascular cavity A large cavity having both digestive and circulatory functions.

gene The inherited unit of DNA that encodes for one protein (or one polypeptide).

gene therapy The insertion of genes into a person's cells to cure a genetic disorder.

genetics The study of inheritance.

genital herpes Common sexually transmitted disease (STD) that is caused by the herpes virus.

genome All of the genes in an organism.

genotype The genetic makeup of a cell or organism, defined by certain alleles for a particular trait.

genus The first word in the two word name given to every organism.

geographic isolation The separation of a population from the rest of its species due to some physical barrier, such as a mountain range, an ocean, or great distance.

geologic time scale A time scale used to describe when events happened in the history of Earth.

gibberellins Plant hormone involved in seed germination and stem elongation.

ginkgo Tree known as the *living fossil* because it is the only species left in the phylum Ginkgophyta.

gliding joint Joint structure that allows one bone to slide over the other; examples includes the joints in the wrists and ankles.

global warming Global increase in the Earth's temperature due to human activities that release greenhouse gasses into the atmosphere.

golgi apparatus The organelle where proteins are modified, labeled, packaged into vesicles, and shipped.

gonad Organ that produces gametes, such as the ovaries and testes.

gonorrhea Common sexually transmitted disease (STD); caused by bacteria.

gravitropism Plant growth towards or away from the pull of gravity.

greenhouse gases The cause of global warming by certain gases via the greenhouse effect.

groundwater Underground water reserves.

gymnosperms Seed plant where seeds are not enclosed by a fruit.

H

habitat Ecological or environmental area where a particular species live.

habituation Learning to get used to something that is not dangerous, after being exposed to it for awhile.

hallucinogenic drug Psychoactive drug that can cause strange sensations, perceptions, and thoughts.

halophiles Organisms that live and thrive in very salty environments.

hammer First of three tiny bones that pass vibrations through the ear.

haploid When a cell has only one set of chromosomes, typical of a gamete.

harem A group of females followed or accompanied by a fertile male; this male excludes other males access to the group.

hearing The ability to sense sound.

heart attack Event that occurs when the blood supply to a part of the heart is blocked.

hemoglobin Protein that moves oxygen throughout the blood.

hemophilia A group of hereditary diseases that affect the body's ability to control blood clotting.

hepatitis B Sexually transmitted disease (STD) that damages the liver and is caused by a virus called hepatitis B.

herbivore A consumer of producers in a community; often organisms that eat plants.

heterozygous Having two different alleles for a particular trait.

heterotroph Organism which obtains carbon from outside sources.

hibernation State in which an animal's body processes are slower than usual.

hinge joint Joint structure in which the ends of bones are shaped in a way that allows motion in two directions only (forward and backward); examples include the knees and elbows.

HIV The human immunodeficiency virus, which causes AIDS.

homeostasis Maintaining a stable internal environment despite changes in the environment.

homing The ability of an insect to return to a single hole among many other apparently identical holes, after a long trip or after a long time

homozygous Having identical alleles for a particular trait.

hormones Chemical messengers that signal responses to stimuli.

hornworts Seedless nonvascular plants with hornlike sporophytes.

horsetails Seedless vascular plants with hollow, rigid stems.

Human Genome Project International effort to sequence all the base pairs in human DNA; completed in 2003.

humidity The amount of water in the air.

hybrid The offspring of different species, genera, varieties or breeds.

hydropower Use of power from falling water or other water movement to generate and distribute electricity; also known as hydroelectric power.

hydroskeleton Fluid-filled body cavity that provides support for muscle contraction.

hyoid bone A U-shaped bone at the root of the tongue; in salamanders it is used to help catch prey.

hypertension Also called high blood pressure; a condition in which a person's blood pressure is always high; the systolic blood pressure is always 140 mm Hg or higher, and/or their diastolic blood pressure is always 90 mm Hg or higher.

hypertonic solution Having a higher solute concentration than the cell; cell will lose water by osmosis.

hyphae Thread-like structures which interconnect and bunch up into mycelium; helps bring food, such as a worm, inside the fungus.

hypothesis A proposed explanation for something that is testable.

hypotonic solution Having a lower solute concentration than the cell; cell will gain water by osmosis.

I

ileum The third part of the small intestine; covered with villi; the few remaining nutrients are absorbed in the ileum.

immigration Movement of individuals into a population from other areas.

immune response The specific third line of defense against pathogens; involves the immune system.

immune system System that protects the body from pathogens and other causes of disease.

immunity Ability to resist a pathogen because cells of the immune system remember the pathogen from a previous infection or vaccination.

incomplete digestive tract A digestive tract with only one opening.

incomplete dominance A pattern of inheritance where the offspring has a phenotype that is halfway between the two parents' phenotypes.

incomplete flowers Flowers that are missing one or more structures: sepals, petals, stamens, or carpels.

infancy The first year of life after birth.

infectious disease A disease that spreads from person to person.

inflammation Reaction causing redness, warmth, and pain that occurs at the site of an infection or injury.

ingredient A specific item that a food contains.

inhalation Taking air into the body through the nose and mouth.

inherited traits Features that are passed from one generation to the next.

innate behavior Any behavior that occurs naturally in all animals of a given species.

insight learning Learning from past experiences and reasoning.

instinct Any behavior that occurs naturally in all animals of a given species; another term for an innate behavior.

integumentary system The outer covering of the body; made up of the skin, hair, and nails.

internal fertilization Reproduction that occurs through the internal deposit of gametes.

internal respiration The exchange of gases between the blood and the cells of the body.

interphase Stage of the cell cycle when DNA is synthesized and the cell grows; composed of the first three phases of the cell cycle.

invasive species Exotic species, introduced into habitats, which then eliminate or expel the native species.

invertebrate Animal without a backbone.

involuntary muscle A muscle that a person cannot consciously control; cardiac muscle and smooth muscle are involuntary.

iris Colored structure at the front of the eye.

isotonic solution A solution in which the amount of dissolved material is equal both inside and outside the cell; no net gain or loss of water.

J

jejunum The second part of the small intestine; where most nutrients are absorbed into the blood; lined with tiny "fingers" called villi.

joint Point at which two or more bones meet.

K

keratin Tough, waterproof protein that is found in epidermal skin cells, nail, and hair.

keystone species A predator species that plays an important role in the community by controlling the prey population.

kidney Organ that filters and cleans the blood and forms urine; also maintains the volume of body fluids, maintains the balance of salt ions in body fluids, and excretes harmful metabolic by-products such as urea, ammonia, and uric acid.

kidney dialysis The process of artificially filtering the blood of wastes; a patient's blood is sent through a filter that removes waste products and the clean blood is returned to the body.

kidney failure When the kidneys are not able to regulate water and chemicals in the body or remove waste products from the blood.

L

lactic acid fermentation Anaerobic respiration that recycles NAD^+ for glycolysis (the breakdown of glucose); occurs in animals and some bacteria and fungi.

language Use of symbols or sounds to communicate.

large intestine The relatively wide tube between the small intestine and anus where excess water is absorbed from food waste.

larvae Young or non-adult insects.

larynx Found just below the point at which the pharynx splits into the trachea and the esophagus. Your voice comes from your larynx; air from the lungs passes across thin membranes in the larynx and produces sound; also called the voicebox.

latitude How far a biome is from the equator.

learned behavior Behavior that occurs only after experience or practice.

lens Clear, curved structure in the eye that focuses light on the retina.

leukemia Cancer of the blood or bone marrow; characterized by an abnormal production of blood cells, usually white blood cells.

life science The study of living organisms, and how they interact with each other and their environment.

lifestyle disease A disease that is caused by choices that people make in their daily lives.

ligament Fibrous tissue that connects bones to other bones; made of tough collagen fibers.

limiting factor A living or nonliving property of a population's environment, which regulates population growth.

lipid Class of organic compound that includes fats, oils, waxes and phospholipids; nutrients, such as fats, that are rich in energy.

liverworts Seedless nonvascular plants that can have flattened bodies resembling a liver.

lung cancer A disease where the cells that line the lungs grow out of control; the growing mass of cells pushes into nearby tissues and can affect how these tissues work.

lymph Yellowish fluid that leaks out of tiny vessels into spaces between cells in tissues.

lymphatic system A network of vessels and tissues that carry a clear fluid called lymph; includes lymph nodes, lymph ducts, and lymph vessels.

lymph nodes Small, oval structures located along lymphatic vessels that filter pathogens from lymph.

lymphocytes Type of white blood cells involved in an immune response.

lymphoma Cancer of white blood cells called lymphocytes.

lysosome Organelle which contains degradative enzymes; breaks down unneeded materials.

M

macroevolution Big evolutionary changes that result in new species.

macromolecule Very large molecules that make living organisms; includes carbohydrates, lipids, proteins, and nucleic acids.

main ingredient The ingredient that is present in the food in the greatest amount.

mammary glands Specialized sweat glands that produce milk.

mantle A fold of outer skin lining the shell of mollusks; releases calcium carbonate that is used to create the external shell.

marsupial A type of mammal where the female has an abdominal pouch or skin fold within which are mammary glands and a place for raising the young.

mass extinction An extinction when many species go extinct during a relatively short period of time.

mating Pairing of an adult male and female to produce young.

matter Anything that takes up space and has mass.

mechanical digestion Digestion in which large chunks of food are broken down into small pieces.

medusa Cnidarian with a bell-shaped body, with the mouth and tentacles facing downward, such as a jellyfish.

meiosis Nuclear division that results in haploid gametes.

melanin The brownish pigment that gives skin and hair their color.

menstrual cycle The monthly cycle of changes that occur in the uterus and ovaries.

menstruation Monthly shedding of the lining of the uterus through the vagina; also called a menstrual period.

metamorphosis The process by which insects transform from an immature or young insect into an adult insect.

metaphase Second phase of mitosis and meiosis (metaphase I and metaphase II) where the chromosomes are aligned in the center of the cell.

methanogens Organisms that live in swamps or in the guts of cows and termites and release methane gas.

microevolution Small changes in inherited traits; does not lead to the creation of a new species.

microscope A set of lenses used to look at things too small to be seen by the unaided eye.

microscopy All the methods for studying things using microscopes.

migration Movement of animals from one place to another; often seasonal.

minerals Chemical elements that are needed for body processes.

mitochondria Organelle where cellular respiration occurs; known as the "powerhouse" of the cell because this is the organelle where the ATP that powers the cell is produced.

mitosis Sequence of steps in which a nucleus is divided into two daughter nuclei, each with an identical set of chromosomes.

molecule Any combination of two or more atoms.

molting The process by which arthropods shed their hard exoskeleton in order to grow.

monogamous A mating system where the couple pair for the duration of the breeding season, or sometimes for a few years or until one mate dies.

monotremes A group of mammals that lays eggs and feeds their young by "sweating" milk from patches on their bellies.

mosses Seedless nonvascular plants with tiny stem-like and stem-like structures.

motor division Division of the peripheral nervous system that carries messages from the central nervous system to internal organs, glands, and muscles.

motor neuron Neuron that carries nerve impulses from the central nervous system to internal organs, glands, or muscles.

movable joint Most mobile type of joint; the most common type of joint in the body.

mucus Sticky, moist substance that coats mucous membranes.

muscle fibers Long, thin cells that can contract; also called muscle cells.

muscular system The body system that allows movement.

muscular tissue Tissue that is composed of cells that have filaments that move past each other and change the size of the cell. There are three types of muscle tissue: smooth muscle, skeletal muscle, and cardiac muscle.

mutagen A chemical or physical agent that can cause changes to accumulate in DNA.

mutation A change in the nucleotide sequence of DNA.

mutualism A type of symbiosis in which both species benefit.

mycelial fragmentation Asexual reproduction involving splitting off of the mycelia; a fragmented piece of mycelia can eventually produce a new colony of fungi.

mycelium Help the fungi absorb nutrients from living hosts; composed of hyphae.

mycorrhizal symbiosis A relationship between fungi and the roots of plants where both benefit; the plant provides sugar to the fungus; the fungi provides minerals and water to the roots of the plant.

myopia Vision problem in which nearby objects are clear but distant objects look blurry; also called nearsightedness.

MyPlate Visual representation of the relative daily portions of various food groups; replaced MyPyramid in 2011.

MyPyramid Diagram that shows how much you should eat each day of foods from six different food groups.

N

nacre The iridescent inner shell layer produced by some bivalves, some gastropods, and some cephalopods; also known as mother of pearl.

natural resources Naturally occurring substances necessary for the support of life.

natural selection Causes beneficial heritable traits to become more common in a population, and unfavorable heritable traits become less common.

negative feedback loop When the response to a stimulus decreases the effect of the original stimulus.

nematocysts Specialized cells in cnidarians that can release a small thread-like structure and toxins to capture prey.

neocortex Site of the cerebral cortex where most of higher brain functions occur.

nephron Tiny, tube-shaped filtering unit found inside each kidney.

nerve Bundle of individual nerve cells.

nerve impulse Electrical signal that is transmitted by neurons.

nerve net Interconnected neurons that send signals in all directions.

nervous system Body system that controls all the other systems of the body.

nervous tissue Tissue composed of nerve cells (neurons) and related cells.

neuron Nerve cell that carries electrical messages.

neurotransmitter Chemical that carries nerve impulses from the axon of one neuron to the dendrite of the next neuron.

neutron The non-charged particle of the atom; located in nucleus of the atom.

niche A specific role that an organism occupies within an ecosystem.

nictitating membrane A third transparent eyelid.

nitrogen fixation Process by which gaseous nitrogen is converted into chemical forms that can be used by plants.

noninfectious disease Disease that does not spread from person to person.

nonrenewable resource A natural resource that exists in fixed amounts and can be consumed or used up faster than it can be made by nature.

nonvascular plants Plants that do not have vascular tissue to conduct food and water.

notochord A hollow nerve cord along the back.

nuclear envelope A double membrane that surrounds the nucleus; helps regulate the passage of molecules in and out of the nucleus.

nuclear power A nonrenewable resource, where nuclear fission is used to generate energy.

nucleic acid Class of organic compound that includes DNA and RNA.

nucleoid The prokaryotic DNA consisting of a condensed single chromosome.

nucleotide The units that make up DNA; consists of a 5-carbon sugar, a phosphate group, and a nitrogen-containing base.

nucleus Membrane enclosed organelle in eukaryotic cells that contains the DNA; primary distinguishing feature between a eukaryotic and prokaryotic cell; the information center, containing instructions for making all the proteins in a cell, as well as how much of each one.

nutrients Chemicals in food that your body needs.

nutrition facts label The label on packaged food that shows the nutrients in the food.

nymphs A developmental stage of insects, where the young is usually similar to the adult.

O

obesity Having a very high percentage of body fat; obese people are at least 20 percent heavier than their healthy weight range.

observational learning Learning by watching and copying the behavior of someone else.

ocean acidification Process whereby the oceans' uptake of anthropogenic carbon dioxide from the atmosphere causes an ongoing decrease in ocean pH.

oil gland Skin organ that secretes an oily substance, called sebum, into the hair follicle.

omnivore A consumer in a community that eat both producers and consumers; usually eaters of both plants and animals.

omnivorous Eating both plant and animal material.

optical (light) microscope A microscope that focuses light, usually through a glass lens; used by biologists to visualize small details of biological specimens.

organ A group of tissues that work together to perform a common function.

organelle Small structure found in cells; has specialized functions; many are membrane-bound, such as mitochondria, plastids, and vacuoles. Membrane-bound organelles are found only in eukaryotic cells.

organic compound Compounds made up of a carbon backbone and associated with living things.

organism A living thing.

organ system A group of organs that work together to perform a common function.

osmosis Diffusion of water across a membrane.

outdoor air pollution Chemical, physical, or biological agents that modify the natural characteristics of the atmosphere, and cause unwanted changes to the environment and to human health.

oval window Membrane in the ear that passes vibrations from the stirrup to the cochlea.

ovaries Female reproductive organs that produce eggs and secrete estrogen.

ovary Enlarged part of the carpel where the ovules are contained.

ovulation Release of an egg by an ovary.

P

paleontologists Scientists who study fossils to learn about life in the past.

paralysis Inability to feel or move parts of the body.

parasite The organism that benefits in a relationship between two organisms in which one is harmed.

parasitism A type of symbiosis in which the parasite species benefits, while the host species is harmed.

parasympathetic division Division of the autonomic nervous system that controls body processes under nonemergency conditions.

parent cell Cell that divides into daughter cells after mitosis or meiosis.

parthenogenesis Reproduction where an unfertilized egg develops into a new individual.

passive transport Movement of molecules from an area of higher concentration to an area of lower concentration; does not require energy.

pathogen A disease causing agent.

pearl The hard, round object produced within the mantle of a living shelled mollusk.

pedigree A chart which shows the inheritance of a trait over several generations.

pedipalps The second pair of arachnid appendages used for feeding, locomotion, and/or reproductive functions.

pentadactyl Having five fingers or toes.

peptidoglycan Complex molecule consisting of sugars and amino acids that makes up the bacterial cell wall.

Periodic Table Table that organizes elements according to their unique characteristics, like atomic number, density, boiling point, and other values.

peripheral nervous system All the nerves of the body that lie outside the central nervous system.

phagocytes A type of white blood cells that travel to sites of inflammation and destroy pathogens and debris.

phagocytosis The process by which phagocytes engulf and destroy pathogens or debris.

pharynx A long tube that is shared with the digestive system; both food and air pass through the pharynx.

phenotype The physical appearance that is a result of the genotype.

pheromones Chemicals secreted by animals, especially insects, that influence the behavior or development of others within the same species.

phloem Vascular tissue that carries the sugars made during photosynthesis (in the leaves) to other parts of the plant.

phospholipid A lipid molecule with a hydrophilic head and two hydrophobic tails; makes up the cell membrane.

photosynthesis The process by which specific organisms (including all plants) use the sun's energy to make their own *food* from carbon dioxide and water; process that converts the energy of the sun, or solar energy, into carbohydrates, a type of chemical energy.

phototropism Plant growth towards or away from light.

physical dependence Condition in which drug abusers need a drug to feel well physically.

physical fitness The ability of your body to carry out your daily activities without getting out of breath, sore, or overly tired.

pineal eye An eye-like structure that develops in some cold-blooded vertebrates.

pinna Outer part of the ear that gathers sound waves.

pioneer species The species that first inhabit a disturbed area.

pivot joint Joint structure in which the end on one bone rotates within a ring-type structure which can be made partly of bone and partly of ligament.

placenta Spongy mass of blood vessels from the mother and fetus that allows substances to pass back and forth between the mother's blood and the fetus's blood.

placental A type of mammal that has a placenta that nourishes the fetus and removes waste products.

placoid Plate-like, as in the scales of sharks.

plaque Cell pieces made up of fatty substances, calcium, and connective tissue that build up around the area of inflammation; builds up on the lining of blood vessels.

plasma The straw-colored fluid in blood; about 90 percent water and about 10 percent dissolved proteins, glucose, ions, hormones, and gases.

plasma membrane Surrounds the cell; made of a double layer of specialized lipids, known as phospholipids, with embedded proteins; regulates the movement of substances into and out of the cell; also called the cell membrane.

plasmid Small circular piece of DNA; found in prokaryotic cells.

platelets Fragments of larger cells that are important in blood clotting.

pneumonia An illness in which the alveoli become inflamed and flooded with fluid.

poikilothermic Cold-blooded; without the ability to independently warm the blood.

polygamous A mating system in which where there is more than one mate.

polygenic inheritance A pattern of inheritance where the trait is controlled by many genes and each dominant allele has an additive effect.

polyp Cnidarian with a cup-shaped body directed upward.

population A group of organisms belonging to the same species, that live in the same area, and interact with one another.

population growth rate How the population size changes per unit of time.

positive feedback loop When the response to a stimulus increases the original stimulus.

precipitation Water that falls to the earth in the form of rain, snow, sleet, hail.

precocial Newborn that are independent at birth or hatching and require little parental care.

predation An interaction where a predator organism feeds on another living organism or organisms, known as prey.

primary pollutants Substances released directly into the atmosphere by processes such as fire or combustion of fossil fuels.

primary succession Ecological succession that occurs in disturbed areas that have no or little soil, i.e. after a glacier retreats.

producer An organism that can absorb the energy of the sun and convert it into food through the process of photosynthesis; i.e. plants and algae.

product The end result of a reaction.

prokaryote A microscopic single-celled organism, including bacteria and cyanobacteria; does not have a nucleus with a membrane or other specialized organelles.

prophase Initial phase of mitosis and meiosis (prophase I and prophase II) where chromosomes condense, the nuclear envelope dissolves and the spindle begins to form.

protein Organic compound made up of smaller molecules called amino acids; performs many functions in the cell.

protist Eukaryotic organism that belongs to the kingdom Protista; not a plant, animal or fung

proton The positively charged particle of the atom; located in nucleus of the atom.

protozoa Animal-like protists.

pseudopodia A moving fake foot; the cell surface extends out a membrane and the force of this membrane propels the cell forward.

puberty Stage of life when a child becomes sexually mature.

pulmonary circulation The part of the cardiovascular system which carries oxygen-poor blood away from the heart to the lungs, and returns oxygen-rich blood back to the heart.

Punnett square Visual representation of a genetic cross that helps predict the expected ratios in the offspring, first described by Reginald C. Punnett in the early 20th century.

pupa Insect metamorphosis stage in which wing development begins.

pupil Black opening in the iris that lets light enter the eye.

Q

quadrupedal four-footed

R

radial symmetry A body plan in which any cut through the center results in two identical halves.

radiometric dating A method to determine the age of rocks and fossils in each layer of rock; measures the decay rate of radioactive materials in each rock layer.

radula A molluscan feeding structure, composed mostly of chitin.

reactant The raw ingredients in a chemical reaction.

recessive Expression is masked by the dominant factor (allele); only expressed if both factors are recessive.

recombinant DNA DNA formed by the combination of DNA from two different sources, such as placing a human gene into a bacterial plasmid.

recycling The breaking down of an item into raw materials to make new items.

red blood cells Flattened disk-shaped cells that carry oxygen, the most common blood cell in the blood. Mature red blood cells do not have a nucleus.

reducing Minimizing the use of resources.

reflex arc Path of nerve impulses that bypass the brain for a quicker response.

reflex behaviors The only truly innate behaviors in humans, occurring mainly in babies.

renewable resources Resources that are replenished by natural processes at about the same rate at which they are used.

reproductive isolation Allopatric and sympatric speciation; isolation due to geography or behavior, resulting in the inability to reproduce.

respiration The process of getting oxygen into the body and releasing carbon dioxide.

respiratory disease A disease of the lungs, bronchial tubes, trachea, nose, and/or throat.

respiratory system The organ system that allows oxygen to enter the body and carbon dioxide to leave your body.

retina Layer of light-sensing cells that covers the back of the eye.

ribosome The cell structure on which proteins are made; not surrounded by a membrane; found in both prokaryotic and eukaryotic cells.

RNA The nucleic acid that carries the information stored in DNA to the ribosome.

rough endoplasmic reticulum The part of the ER with ribosomes attached; proteins can be modified in the rough ER before they are packed into vesicles for transport to the golgi apparatus.

runoff Water that is not absorbed by the soil that eventually returns to streams and rivers.

S

scanning acoustic microscope A microscope that focuses sound waves instead of light.

scanning electron microscope (SEM) A microscope that scans the surfaces of objects with a beam of electrons to produce detailed images of the surfaces of tiny things.

scientific method A careful way of asking and answering questions to learn about the physical world that is based on reason and observable evidence.

scientific theory A well-established set of explanations that explain a large amount of scientific information.

secondary pollutants Substances formed when primary pollutants interact with sunlight, air, or each other.

secondary succession Ecological succession that occurs in disturbed areas that have soil to begin with, i.e. after a forest fire.

seedless vascular plants Plants with vascular tissue but no seeds.

segmentation A body plan that has repeated units or segments.

selectively permeable Semipermeable; property of allowing only certain molecules to pass through the cell membrane.

semen "Milky" liquid that contains sperm and secretions of glands; passes through the urethra and out of body.

semicircular canals Liquid-filled part of the ear that senses changes in position and generates nerve impulses in response.

semiconservative replication Describes how the replication of DNA results in two molecules of DNA, each with one original strand and one new strand.

semilunar (SL) valves Found in the arteries leaving the heart; prevents blood flowing back from the arteries into the ventricles.

semipermeable Allowing only certain materials to pass through; characteristic of the cell membrane.

sensory division Division of the peripheral nervous system that carries messages from the sense organs and internal organs to the central nervous system.

sensory neuron Neuron that carries nerve impulses from sense organs or internal organs to the central nervous system.

sepals Outermost layer of the flower that is usually leaf-like and green.

serving size Tells you how much of the food you should eat to get the nutrients listed on the label.

sessile Permanently attached and not freely moving.

sex-linked inheritance The inheritance of traits that are located on genes on the sex chromosomes.

sex-linked trait A trait that is due to a gene located on a sex chromosome, usually the X-chromosome.

sexual dimorphism Extreme difference between the sexes.

sexually transmitted disease (STD) Disease that spreads through sexual contact and is caused by a pathogen.

sexual reproduction Reproduction where gametes from two parents combine to make an individual with an unique set of genes.

sickle cell disease A blood disease that is caused by abnormally-shaped blood protein hemoglobin.

silk A thin, strong, protein strand extruded from the spinnerets; most commonly found on the end of the abdomen of spiders.

sister chromatids The two identical molecules of DNA in a chromosome after the DNA is replicated.

skeletal muscle The muscle that is usually attached to the skeleton.

skeletal system Body system that is made up of bones, cartilage, and ligaments.

skeleton Sturdy scaffolding of bones and cartilage that is found inside vertebrates.

slash-and-burn agriculture A method of agriculture in the tropics in which the forest vegetation is cut down and burned, then crops are grown for a few years, and then the forest is allowed to grow back.

small intestine The narrow tube between the stomach and large intestine where most chemical digestion and absorption of nutrients take place.

smooth endoplasmic reticulum Part of the ER that does not have ribosomes attached; where lipids are synthesized.

smooth muscle Involuntary muscle found within the walls of organs and structures such as the esophagus, stomach, intestines, and blood vessels.

social animals Animals that live in groups with other members of their species.

solar power The use of solar cells to convert sunlight into electricity.

somatic cell A body cell; not a gamete.

somatic nervous system Part of the motor division that carries nerve impulses to muscles that control voluntary body movements.

speciation The creation of a new species; either by natural or artificial selection.

species A group of individuals that are genetically related and can breed to produce fertile young; the second word in the two word name given to every organism is the species name.

sperm male gametes or sex cells

spinal cord Long, tube-shaped bundle of neurons that carry nerve impulses back and forth between the body and brain.

spindle Fibers that move chromosomes during mitosis and meiosis.

spiracles Openings on the sides of the insect abdomen, through which air is taken in.

spirilli Spiral-shaped bacteria or archaea.

sponging The ability of an insect mouthpart to absorb liquid food.

sporangium Capsule, formed by the sporophyte, which releases spores.

spore The basic reproductive unit of fungi.

sprain A ligament injury; usually caused by the sudden overstretching of a joint which causes tearing.

stamen The part of the flower consisting of a filament and an anther that produces pollen.

starch Large, complex carbohydrate; found in foods such as vegetables and grains; broken down by the body into sugars that provide energy.

stigma The knoblike section of the carpel where the pollen must land for fertilization to occur.

stimulant drug Psychoactive drug that speeds up the nervous system.

stirrup Last of three tiny bones that pass vibrations through the ear.

stomach The sac-like organ at the end of the esophagus where proteins are digested.

stomata Special pores in leaves; carbon dioxide enters the leaf and oxygen exits the leaf through these pores.

strain An injury to a muscle in which the muscle fibers tear because the muscle contracts too much or contracts before the muscle is warmed up.

stroke A loss of brain function due to a blockage of the blood supply to the brain.

stroma Fluid in the chloroplast interior space; surrounds the thylakoids.

stromolites Fossils made of algae and a kind of bacteria; some of the oldest fossils on Earth.

sunburn A burn to the skin that is caused by overexposure to UV radiation from the sun's rays or tanning beds.

sweat gland Gland that opens to the skin surface through skin pores; found all over the body; secretes sweat.

symbiosis Close and often long-term interactions between different species, in which at least one species benefits.

sympathetic division Division of the autonomic nervous system that prepares the body for fight or flight in emergencies.

sympatric speciation Speciation that occurs when groups from the same species stop interbreeding, because of something other than physical separation, such as behavior.

synapse Place where the axon of one neuron meets the dendrite of another neuron.

syphilis Very serious STD that is caused by bacteria.

systemic circulation The portion of the cardiovascular system which carries oxygen-rich blood away from the heart to the body, and returns oxygen-poor blood back to the heart.

T

tapeworms Intestinal parasites in the phylum Platyhelminthes.

taste buds Tiny bumps on the tongue that contain taste neurons.

taxonomy The science of naming and classifying organisms.

telophase Final phase of mitosis and meiosis (telophase I and telophase II) where a nuclear envelop forms around each of the two sets of chromosomes.

tendon A tough band of connective tissue that connects a muscle to a bone.

teratogen A chemical that causes deformities.

terrestrial biomes Biomes defined based on plant and climatic factors.

testes Male reproductive organs that produce sperm and secrete testosterone.

testosterone The main sex hormone in males.

theory of evolution Theory developed by Charles Darwin that explains how populations of organisms can change over time.

thermophiles Organisms that live in very hot environments, such as near volcanoes and in geysers.

thigmotropism Differential plant growth in response to contact with an object.

thylakoid Flattened sacs within the chloroplast; formed by the inner membranes.

tissue A group of specialized cells that function together.

tolerance Condition in which people need to take more of a drug to feel the same effects as when they first started using the drug.

touch The sense of pain, pressure, or temperature.

trachea A long tube that leads down to the chest where it divides into the right and left bronchi in the lungs; also called the windpipe.

trait A feature or characteristic of an organism; for example, your height, hair color, and eye shape are physical traits.

transcription The synthesis of a RNA that carries the information encoded in the DNA.

transduction Transfer of DNA between two bacteria; occurs with the aid of a virus (bacteriophage).

trans fat Manufactured fat that is added to certain foods to keep them fresher for longer.

transformation The process by which bacteria pick up foreign DNA and incorporate it in their genome.

translation The synthesis of proteins as the ribosome reads each codon in RNA, which code for a specific amino acid.

transmission electron microscope (TEM) A microscope that focuses a beam of electrons through an object and can make an image up to two million times bigger, with a very clear image ("high resolution").

transpiration Process by which water leaves a plant by evaporating from the leaves.

trophic level A level of the food chain reflected in the ecological pyramid.

tropism Plant growth response towards or away from a stimulus.

tuberculosis (TB) A common and often deadly infectious disease caused by a type of bacterium called mycobacterium.

tumor Mass of cells that grow out of control; associated with cancer.

tympanum Equivalent to the middle ear; used in hearing.

type 1 diabetes The type of diabetes that occurs when the immune system attacks normal cells of the pancreas.

type 2 diabetes Type of diabetes that occurs when body cells no longer respond to insulin.

U

umbilical cord Tube containing blood vessels that connects a fetus to the placenta.

universal donor A person with type O positive blood; type O red blood cells do not have any antigens on their membranes and so would not cause an immune reaction in the body of a recipient.

universal recipient A person with type AB positive blood; the blood plasma of AB blood does not contain any anti-A or anti-B antibodies. People with type AB blood can receive any ABO blood type.

urinary bladder Organ that collects the urine which comes from the kidneys.

urinary system The organ system that makes, stores, and gets rid of urine.

urinary tract infection (UTI) Bacterial infections of any part of the urinary tract.

urination The process of releasing urine from the body.

urine A liquid that is formed by the kidneys when they filter wastes from the blood; contains mostly water and also dissolved salts and nitrogen-containing molecules.

uterus Female reproductive organ where a baby develops until birth.

V

vaccination Deliberate exposure to a pathogen in order to bring about immunity without causing disease.

valarian respiration Respiration in which the capillary beds are spread throughout the epidermis, so that gases can be exchanged through the skin.

valves In the heart; keep the blood flowing in one direction.

vascular tissue Tissues that conduct food, water, and nutrients in plants.

vector An organism that carries pathogens from one person or animal to another.

veins Blood vessels that carry blood back to the heart.

ventricle One of the two muscular V-shaped chambers that pump blood out of the heart.

vesicle Small membrane-enclosed sac; transports proteins around a cell or out of a cell.

vestigial structure Body part that, through evolution, has lost its use, such as a whale's pelvic bones.

villi Contain microscopic blood vessels; nutrients are absorbed into the blood through these tiny vessels; located on the jejunum and the ileum.

visible light Electromagnetic radiation that humans can detect with their eyes.

vision The ability to see light.

vitamins Substances that the body needs in small amounts to function properly.

vivipary A reproductive system in most mammals and some reptiles and fish, in which living young are produced rather than eggs laid.

voluntary muscle A muscle that a person can consciously control; skeletal muscle is voluntary.

W

waterborne diseases Diseases caused by organisms transmitted via contaminated water.

water pollution The contamination of water bodies by substances, mostly anthropogenic, which cause a harmful effect on living organisms.

water vascular system A network of fluid-filled canals; functions in gas exchange, feeding, and also in locomotion.

wavelength The distance from any point on one wave to the same point on the next wave.

whisk ferns Seedless nonvascular plants with tiny stem-like and stem-like structures.

white blood cells Nucleated blood cells that are usually larger than red blood cells; defend the body against infection by bacteria, viruses, and other pathogens.

wind power The conversion of wind energy into electricity via wind turbines.

withdrawal Symptoms like vomiting, diarrhea, or depression that can occur when people stop using a drug.

X

xylem Vascular tissue responsible for the transport of water and nutrients from the roots to the rest of the plant.

Y

Z

zygote Cell that forms when a sperm and egg unite; the first cell of a new organism.