

7: Cells and Heredity



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Laura Enama
Jean Brainard, Ph.D.

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CHAPTER 1

Introduction to Cells

Chapter Outline

- 1.1 CHARACTERISTICS OF LIFE
- 1.2 CLASSIFICATION OF LIFE
- 1.3 LIFE'S BUILDING BLOCKS
- 1.4 CELL STRUCTURES
- 1.5 REFERENCES

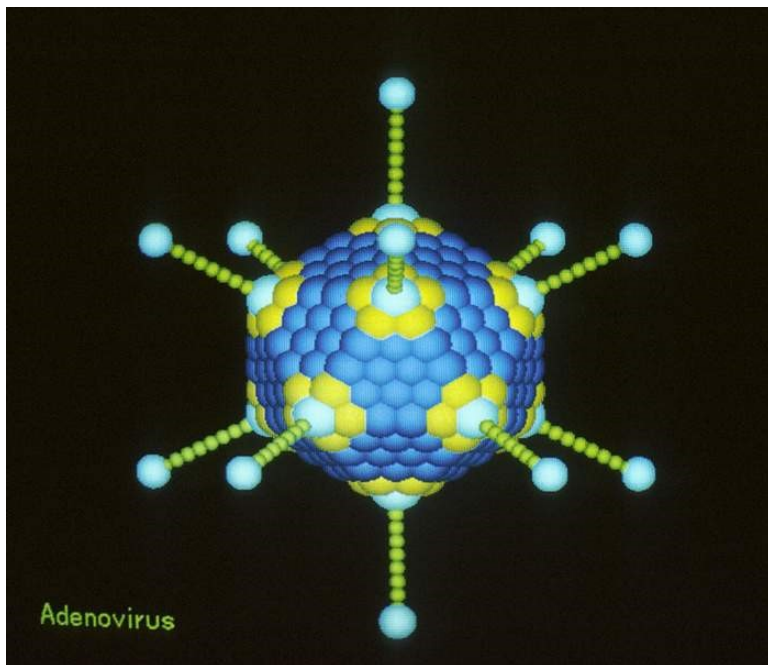


FIGURE 1.1

This colorful image represents a virus that commonly causes respiratory infections in people. Living organisms called bacteria are also common causes of human infections. Are viruses living organisms as well?

Actually, this is one of the great unanswered questions of life science. Some scientists think viruses should be considered living organisms. Other scientists disagree. In this chapter, you'll learn the basic characteristics of living things and the characteristics of viruses. At the end of the chapter, you can decide for yourself whether you think viruses are living organisms.

1.1 Characteristics of Life

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Lesson Objectives

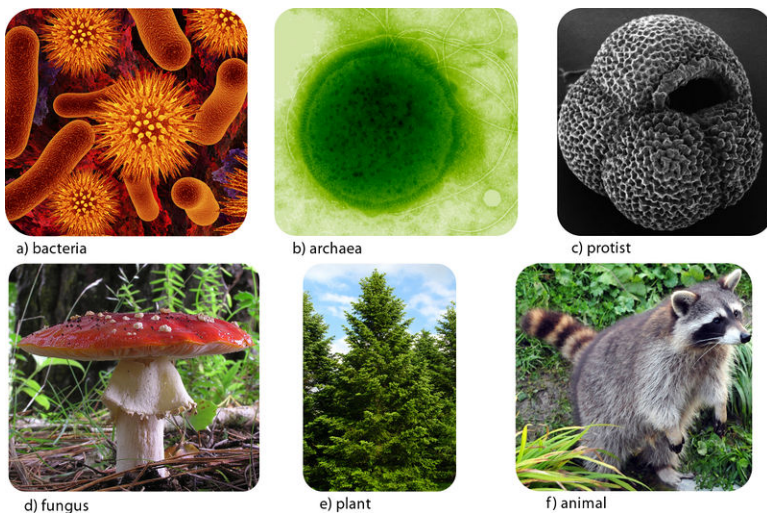
- Identify characteristics of living organisms.
- Describe cells.
- Explain why living things need energy.
- Give an example of a stimulus and response.
- Compare sexual and asexual reproduction.
- Define homeostasis.

Lesson Vocabulary

- cell
- energy
- homeostasis
- reproduction
- response
- stimulus (stimuli, plural)

Introduction

Look at the photos in **Figure 1.2**. How are they similar? All of them show living organisms. Observe how different the organisms are from each other. Clearly, living things are very diverse. Yet all of the organisms in the pictures share the same basic characteristics of life. Can you guess what these characteristics are?

**FIGURE 1.2**

These pictures represent the diversity of living organisms. Organisms in the top row (a–c) are microscopic.

Defining Life

Five characteristics are used to define life. All living things share these characteristics. All living things:

1. are made of one or more cells.
2. need energy to stay alive.
3. respond to stimuli in their environment.
4. grow and reproduce.
5. maintain a stable internal environment.

Living Things Are Made of Cells

Cells are the basic building blocks of life. They are like tiny factories where virtually all life processes take place. Some living things, like the bacteria in **Figure 1.2**, consist of just one cell. They are called single-celled organisms. You can see other single-celled organisms in Figure below. Some living things are composed of a few to many trillions of cells. They are called multicellular organisms. Your body is composed of trillions of cells.



FIGURE 1.3

The green scum in this canal consists of billions of single-celled green algae. Algae are plant-like microorganisms that produce food by photosynthesis.

Regardless of the type of organism, all living cells share certain basic structures. For example, all cells are enclosed by a membrane. The cell membrane separates the cell from its environment. It also controls what enters or leaves

the cell.

Living Things Need Energy

Everything you do takes energy. **Energy** is the ability to change or move matter. Whether it's reading these words or running a sprint, it requires energy. In fact, it takes energy just to stay alive. Where do you get energy? You probably know the answer. You get energy from food. **Figure** below shows some healthy foods that can provide you with energy.



FIGURE 1.4

Fruits, vegetables, and nuts are healthy sources of food energy.

Just like you, other living things need a source of energy. But they may use a different source. Organisms may be grouped on the basis of the source of energy they use. In which group do you belong?

- Producers such as the tree in **Figure 1.2** use sunlight for energy to produce their own “food.” The process is called photosynthesis, and the “food” is sugar. Plants and other organisms use this food for energy.

- Consumers such as the raccoon in **Figure 1.2** eat plants—or other consumers that eat plants—as a source of energy.
- Some consumers such as the mushroom in **Figure 1.2** get their energy from dead organic matter. For example, they might consume dead leaves on a forest floor.

Living Things Respond to their Environment

When a living thing responds to its environment, it is responding to a stimulus. A **stimulus** (**stimuli**, plural) is something in the environment that causes a reaction in an organism. The reaction a stimulus produces is called a **response**.

Imagine how you would respond to the following stimuli:

- You're about to cross a street when the walk light turns red.
- You hear a smoke alarm go off in the kitchen.
- You step on an upturned tack with a bare foot.
- You smell the aroma of your favorite food.
- You taste something really sour.

It doesn't take much imagination to realize that responding appropriately to such stimuli might help keep you safe. It might even help you survive.

Like you, all other living things sense and respond to stimuli in their environment. In general, their responses help them survive or reproduce. Watch this amazing time-lapse video to see how a plant responds to the stimuli of light and gravity as it grows. Why do you think it is important for a plant to respond appropriately to these stimuli for proper growth?

<http://www.youtube.com/watch?v=RzD4skFeJ7Y>



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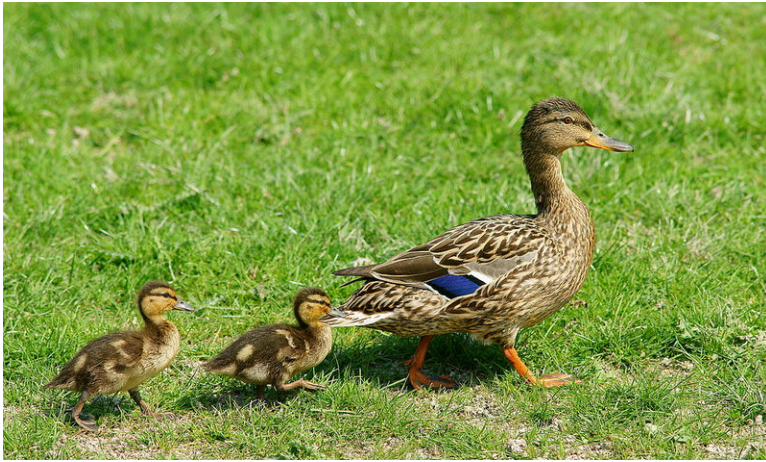
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Like plants, all living things have the capacity for growth. The ducklings in **Figure 1.5** have a lot of growing to do to catch up in size to their mother. Multicellular organisms like ducks grow by increasing the size and number of their cells. Single-celled organisms just grow in size.

As the ducklings grow, they will develop and mature into adults. By adulthood, they will be able to reproduce. **Reproduction** is the production of offspring. The ability to reproduce is another characteristic of living things.

Many organisms reproduce sexually. In sexual reproduction, parents of different sexes mate to produce offspring. The offspring have some combination of the traits of the two parents. Ducks are examples of sexually reproducing organisms. Other organisms reproduce asexually. In asexual reproduction, a single parent can produce offspring alone. For example, a bacterial cell reproduces by dividing into two daughter cells. The daughter cells are identical to each other and to the parent cell.

**FIGURE 1.5**

These ducklings will grow to become as big as their mother by the time they are about a year old.

Living Things Maintain a Stable Internal Environment

The tennis player in **Figure 1.6** has really worked up a sweat. Do you know why we sweat? Sweating helps to keep us cool. When sweat evaporates from the skin, it uses up some of the body's heat energy. Sweating is one of the ways that the body maintains a stable internal environment. It helps keep the body's internal temperature constant. When the body's internal environment is stable, the condition is called **homeostasis**.

**FIGURE 1.6**

Sweating is one way the body maintains homeostasis.

All living organisms have ways of maintaining homeostasis. They have mechanisms for controlling such factors as their internal temperature, water balance, and acidity. Homeostasis is necessary for normal life processes that take place inside cells. If an organism can't maintain homeostasis, normal life processes are disrupted. Disease or even death may result.

Lesson Summary

- All living things are made of cells, use energy, respond to stimuli, grow and reproduce, and maintain homeostasis.

- All living things consist of one or more cells. Cells are the basic units of structure and function of living organisms.
- Energy is the ability to change or move matter. All life processes require energy, so all living things need energy.
- All living things can sense and respond to stimuli in their environment. Stimuli might include temperature, light, or gravity.
- All living things grow and reproduce. Multicellular organisms grow by increasing in cell size and number. Single-celled organisms increase in cell size. All organisms can normally reproduce, or produce offspring. Reproduction can be sexual or asexual.
- All living things have ways of maintaining a stable internal environment. This stable condition is called homeostasis.

Lesson Review Questions

Recall

1. List five characteristics of living things.
2. Describe cells.
3. What is energy? How do organisms use energy?

Apply Concepts

4. Describe a response to an environmental stimulus that might save your life.

Think Critically

5. Discuss the role of reproduction in life.
6. Explain why having a fever when you are sick disrupts your body's homeostasis.

Points to Consider

In this lesson, you read that all living things consist of one or more cells.

- What are cells made of?
- Is there any matter that is smaller than a cell?

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1.2 Classification of Life

Lesson Objectives

- Define taxonomy.
- Outline Linnaeus' contributions to taxonomy.
- Describe the three-domain system of classification.
- Decide how viruses should be classified.

Lesson Vocabulary

- binomial nomenclature
- class
- domain
- family
- genus (genera, plural)
- kingdom
- Linnaeus
- order
- phylum (phyla, plural)
- species (singular and plural)
- taxon (taxa, plural)
- taxonomy
- virus

Introduction

When you see an organism that you have never seen before, you probably group it with other, similar organisms without even thinking about it. You would probably classify it on the basis of obvious physical characteristics. For example, if an organism is green and has leaves, no doubt you would classify it as a plant.

How would you classify the organisms in **Figure 1.7**? They look quite similar, but scientists place them in very different categories. The organism on the left is a type of fungus. The organism on the right is an animal called a sponge. In many ways, a sponge is no more like a fungus than you are.



FIGURE 1.7

A fungus (left) and sponge (right) are placed in two different kingdoms of living things.

Taxonomy

Like you, scientists also group together similar organisms. The science of classifying living things is called taxonomy. Scientists classify living things in order to organize and make sense of the incredible diversity of life. Modern scientists base their classifications mainly on molecular similarities. They group together organisms that have similar proteins and DNA. Molecular similarities show that organisms are related. In other words, they are descendants of a common ancestor in the past.

Contributions of Linnaeus

Carl **Linnaeus** (1707-1778) is called the “father of taxonomy.” You may already be familiar with the classification system Linnaeus introduced.

Linnaean Classification System

You can see the main categories, or **taxa (taxon, singular)**, of the Linnaean system in **Figure** below. As an example, the figure applies the Linnaean system to classify a Cardinal. The broadest category in the Linnaean system is the **kingdom**. **Figure** below shows the Animal Kingdom because cardinals belong to that kingdom. Other kingdoms include the Plant Kingdom, Fungus Kingdom, and Protist Kingdom.

Kingdoms are divided, in turn, into **phyla (phylum, singular)**. Each phylum is divided into **classes**, each class into **orders**, each order into **families**, and each family into **genera (genus, singular)**. Each genus is divided into one or more species. The **species** is the narrowest category in the Linnaean system. A species is defined as a group of organisms that can breed and produce fertile offspring together.

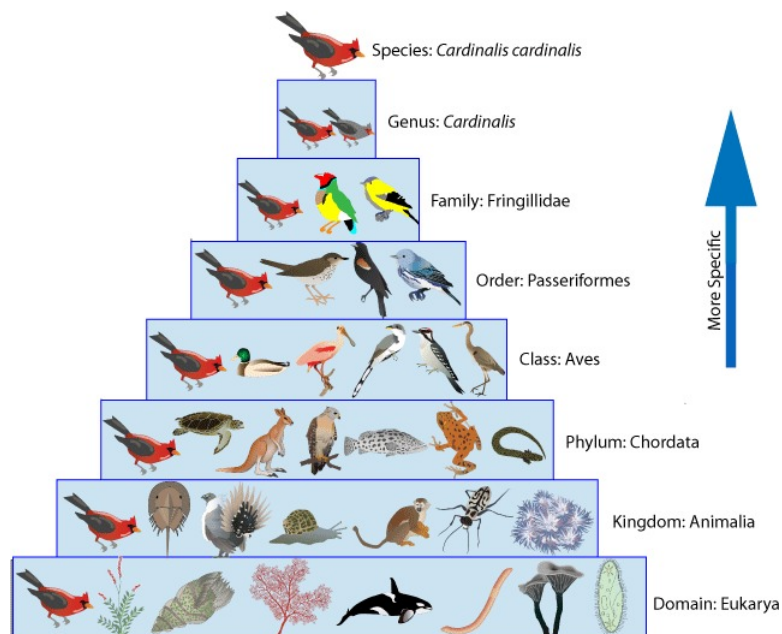


FIGURE 1.8
Modern Taxonomy

You will notice the broadest category in the figure above is not actually the kingdom, as Linnaeus stated, but instead the **domain**. When Linnaeus was naming and classifying organisms in the 1700s, almost nothing was known of microorganisms. With the development of powerful microscopes, scientists discovered many single-celled organisms that didn't fit into any of Linnaeus' kingdoms. As a result, a new taxon, called the **domain**, was added to

the classification system. The domain is even broader than the kingdom. To review the classification system watch this brief tutorial: <https://www.youtube.com/watch?v=kKwOIAqQoLk>



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Domains

Most scientists think that all living things can be classified in three domains: Archaea, Bacteria, and Eukarya. The figure below shows these three domains and six kingdoms of life they are broken into from an evolutionary framework. Based on the diagram, do you think humans are more closely related to organisms in the Archaea or Bacteria domain?

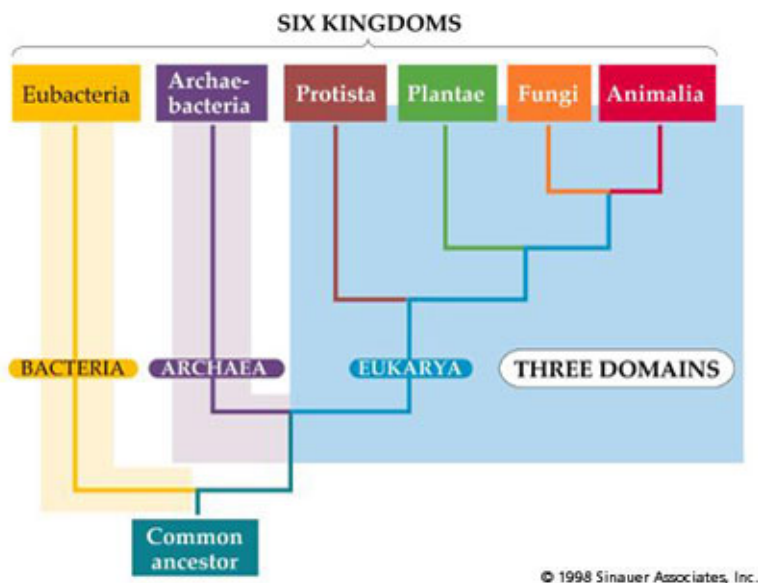


FIGURE 1.9

The 3 domains and 6 kingdoms of modern biology.

The answer to that question is Archaea. Thanks to modern technology, we know that the DNA in organisms from the Archaea domain is more similar to Eukaryota than Bacteria. To further explore these domains, review the table below. It gives a brief overview of the characteristics of the organisms in the three domains.

The Archaea and Bacteria Domains are very different from Eukarya. All of the organisms within these domains are unicellular, or composed of only one cell. They are comprised of prokaryotic cells. You will learn more about prokaryotic cells in the next section. These cells lack a nucleus. A nucleus is membrane-enclosed structure for holding a cell's DNA.

The organisms in the Eukarya Domain are comprised of eukaryotic cells. Again you will learn more about these types of cells in the next section. All Eukarya have a nucleus and other organelles. These organisms can be single-celled or multicellular.








Domains and Kingdoms 						
Domain	Bacteria	Archaea	Eukarya			
Kingdom	Bacteria	Archaea	Protista	Fungi	Plantae	Animalia
Example						
Characteristics	Bacteria are simple unicellular organisms.	Archaea are simple unicellular organisms that often live in extreme environments.	Protists are unicellular and are more complex than bacteria or archaea.	Fungi are unicellular or multicellular and absorb food.	Plants are multicellular and make their own food.	Animals are multicellular and take in their food.

FIGURE 1.10

The characteristics of organisms within the three domains and six kingdoms.

Binomial Nomenclature

Linnaeus is also famous for his method of naming species, which is still used today. The method is called **binomial nomenclature**. Every species is given a unique two-word name. Usually written in Latin, it includes the genus name followed by the species name. Both names are always written in italics, and the genus name is always capitalized. For example, the human species is named *Homo sapiens*. The species of the family dog is named *Canis familiaris*.

Coming up with a scientific naming method may not seem like a big deal, but it really is. Prior to Linnaeus, there was no consistent way to name species. Names given to organisms by scientists were long and cumbersome. Often, different scientists came up with different names for the same species. Common names also differed, generally from one place to another. A single, short scientific name for each species avoided a lot of mistakes and confusion.

How Should Viruses Be Classified?

This question was posed at the beginning of the chapter. Should viruses be placed in one of the three domains of life? Are viruses living things? Before considering these questions, you need to know the characteristics of viruses.

- A **virus** is nothing more than some DNA or RNA surrounded by a coat of proteins.
- A virus is not a cell.
- A virus cannot use energy, respond to stimuli, grow, or maintain homeostasis.
- A virus cannot reproduce on its own. However, a virus can reproduce by infecting the cell of a living host. Inside the host cell, the virus uses the cell's structures, materials, and energy to make copies of itself.
- Because they have genetic material and can reproduce, viruses can evolve. Their DNA or RNA can change through time. The ability to evolve is a very lifelike attribute.

Many scientists think that viruses should not be classified as living things because they lack most of the defining traits of living things. Other scientists aren't so sure. They think that the ability of viruses to evolve and interact with living cells earns them special consideration. Perhaps a new category of life should be created for viruses. What do you think?

Lesson Summary

- Scientists classify living things to make sense of biodiversity and how living things are related. The science of classifying living things is called taxonomy.

- Linnaeus introduced the classification system that forms the basis of modern classification. Taxa in the Linnaean system include the kingdom, phylum, class, order, family, genus, and species. Linnaeus also developed binomial nomenclature for naming species.
- More recently, scientists have added the domain to the Linnaean system of classification. The domain is a broader taxon than the kingdom. There are three widely recognized domains: Archaea, Bacteria, and Eukarya.
- Viruses lack many traits of living things so the majority of scientists do not classify them as living organisms.

Lesson Review Questions

Recall

1. What is taxonomy, and why is it important?
2. List the taxa in Linnaeus' system of classification, from the broadest taxon to the narrowest taxon.
3. Describe binomial nomenclature.

Apply Concepts

4. Apply the Linnaean classification system to the human species.

Think Critically

5. What is a domain? Explain why scientists added the domain to the Linnaean classification system.
6. Identify and compare the three domains of life.
7. How do you think viruses should be classified? Support your answer.

Points to Consider

Cells are the basic units of living things. Some cells have a nucleus.

- Besides a nucleus, what are some other structures that cells may contain?
- How do plant and animal cells differ?

1.3 Life's Building Blocks

Lesson Objectives

- Review the discovery of cells and the cell theory.
- Identify the basic parts of all cells.
- Compare and contrast prokaryotic and eukaryotic cells.
- Relate cell shape and cell function.
- Outline the levels of organization in living things.
- Explain why cells must be very small.

Lesson Vocabulary

- cell membrane
- cell theory
- cytoplasm
- eukaryote
- eukaryotic cell
- nucleus
- organ
- organelle
- organ system
- prokaryote
- prokaryotic cell
- ribosome
- tissue

Introduction

Cells are the building blocks of life. This is clear from the photo in **Figure 1.11**. It shows stacks upon stacks of cells in an onion plant. Cells are also the basic functional units of living things. They are the smallest units that can carry out the biochemical reactions of life. No matter how different organisms may be from one another, they all consist of cells. Moreover, all cells have the same basic parts and processes. Knowing about cells and how they function is necessary to understanding life itself.

Discovery of Cells and the Cell Theory

Cells were first discovered in the mid-1600s. The cell theory came about some 200 years later. Watch 'The Wacky History of the Cell Theory' to learn more about this theory and how it came to be. <http://ed.ted.com/on/TJNEB5Zv>

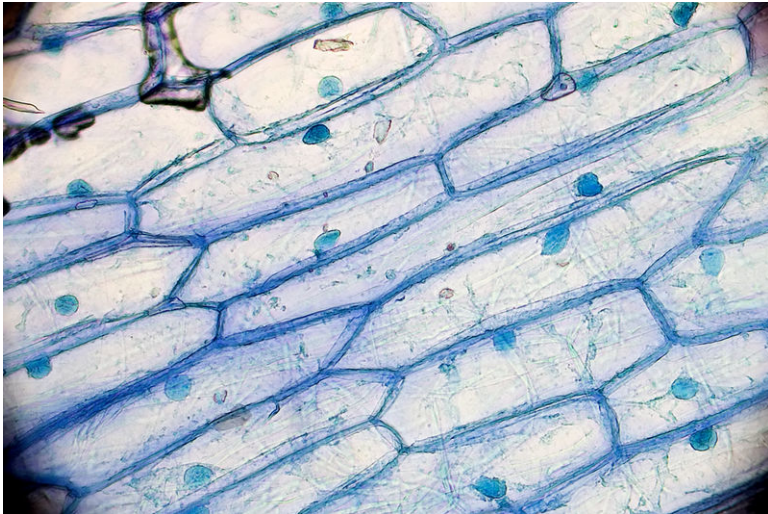


FIGURE 1.11

**MEDIA**

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British scientist Robert Hooke first discovered cells in 1665. He was one of the earliest scientists to study living things under a microscope. He saw that cork was divided into many tiny compartments, like little rooms. (Do the cells in **Figure 1.11** look like little rooms to you too?) Hooke called these little rooms cells. Cork comes from trees, so what Hooke observed was dead plant cells.

In the late 1600s, Dutch scientist Anton van Leeuwenhoek made more powerful microscopes. He used them to observe cells of other organisms. For example, he saw human blood cells and bacterial cells. Over the next century, microscopes were improved and more cells were observed.

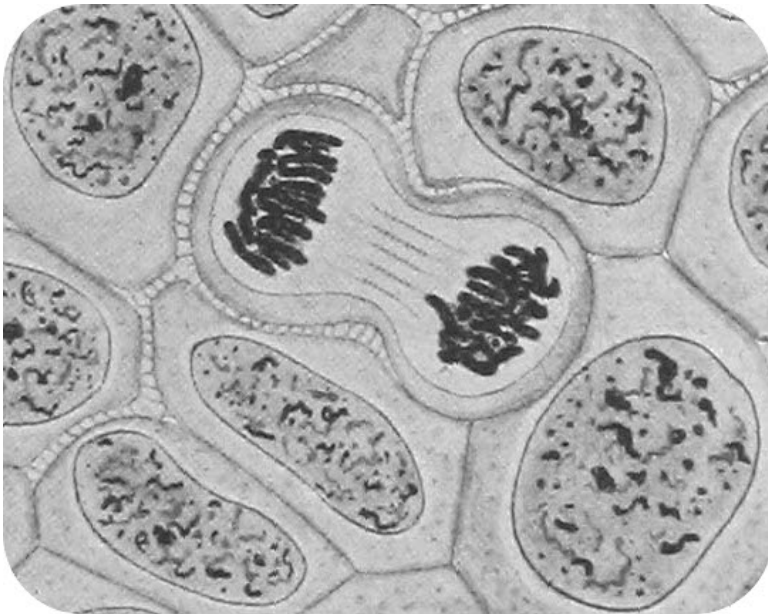
Development of the Cell Theory

By the early 1800s, scientists had seen cells in many different types of organisms. Every organism that was examined was found to consist of cells. From all these observations, German scientists Theodor Schwann and Matthias Schleiden drew two major conclusions about cells. They concluded that:

- cells are alive.
- all living things are made of cells.

Around 1850, a German doctor named Rudolf Virchow was observing living cells under a microscope. As he was watching, one of the cells happened to divide. **Figure 1.12** shows a cell dividing, like the cell observed by Virchow. This was an “aha” moment for Virchow. He realized that living cells produce new cells by dividing. This was evidence that cells arise from other cells.

The work of Schwann, Schleiden, and Virchow led to the cell theory. This is one of the most important theories in life science. The **cell theory** can be summed up as follows:

**FIGURE 1.12**

The cell in the middle of this clump of cells is dividing. It will produce two identical daughter cells.

- All organisms consist of one or more cells.
- Cells are the basic unit of structure and function in organisms.
- All cells come from pre-existing cells.

Structures Found in All Cells

All cells have certain parts in common. These parts include the cell membrane, cytoplasm, DNA, and ribosomes.

- The **cell membrane** is a thin coat of phospholipids that surrounds the cell. It's like the "skin" of the cell. It forms a physical boundary between the contents of the cell and the environment outside the cell. It also controls what enters and leaves the cell. The cell membrane is sometimes called the plasma membrane.
- **Cytoplasm** is the material inside the cell membrane. It includes a watery substance called cytosol. Besides water, cytosol contains enzymes and other substances. Cytoplasm also includes other cell structures suspended in the cytosol.
- **DNA** is a nucleic acid found in cells. It contains genetic instructions that cells need to make proteins.
- **Ribosomes** are structures in the cytoplasm where proteins are made. They consist of RNA and proteins.

These four components are found in all cells. They are found in the cells of organisms as different as bacteria and people. How did all known organisms come to have such similar cells? The answer is evolution. The similarities show that all life on Earth evolved from a common ancestor.

Prokaryotic and Eukaryotic Cells

Besides the four parts listed above, many cells also have a nucleus. The **nucleus** of a cell is a structure enclosed by a membrane that contains most of the cell's DNA. Cells are classified in two major groups based on whether or not they have a nucleus. The two groups are prokaryotic cells and eukaryotic cells.

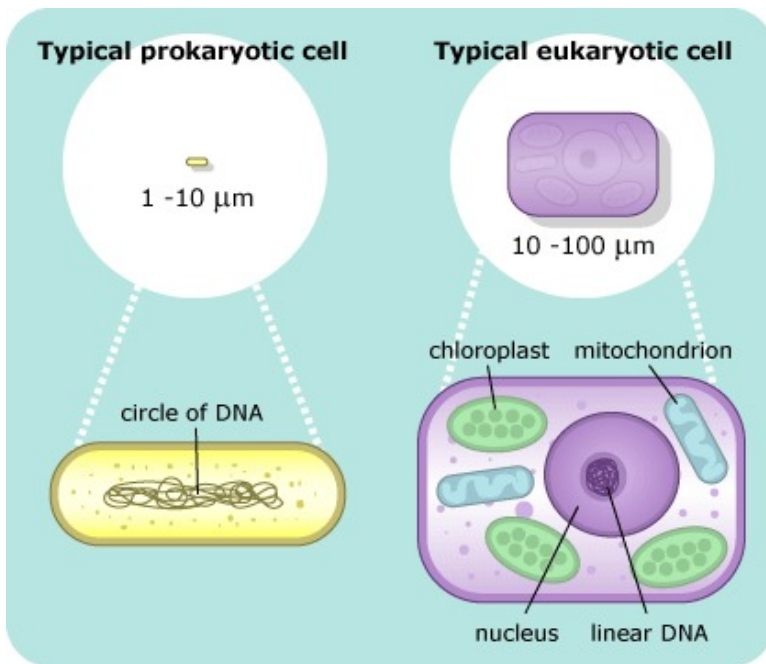


FIGURE 1.13

Prokaryotic and Eukaryotic Cells

Prokaryotic Cells

Prokaryotic cells are cells that lack a nucleus. The DNA in prokaryotic cells is in the cytoplasm, rather than enclosed within a nuclear membrane. All the organisms in the Bacteria and Archaea Domains have prokaryotic cells. No other organisms have this type of cell. Organisms with prokaryotic cells are called **prokaryotes**. They are all single-celled organisms. They were the first type of organisms to evolve. They are still the most numerous organisms today.

You can see a model of a prokaryotic cell in **Figure 1.14**. The cell in the figure is a bacterium. Notice how it contains a cell membrane, cytoplasm, ribosomes, and several other structures. However, the cell lacks a nucleus. The cell's DNA is circular. It coils up in a mass called a nucleoid that floats in the cytoplasm.

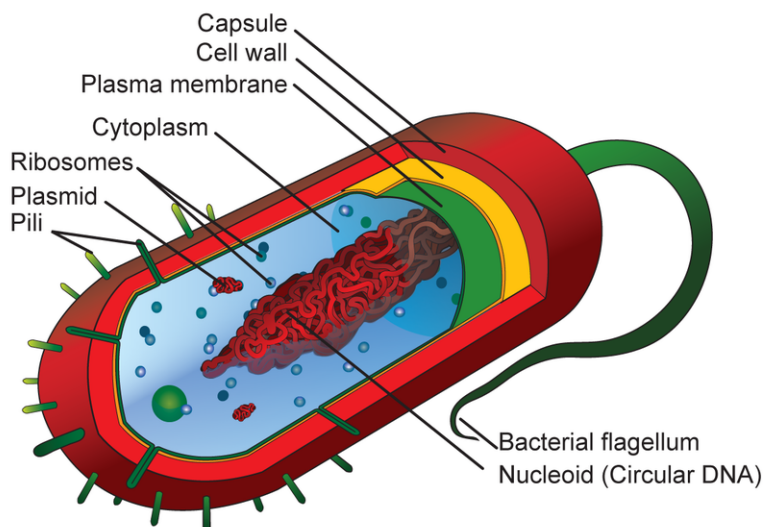


FIGURE 1.14

Prokaryotic Cell. This diagram shows the structure of a typical prokaryotic cell, a bacterium. Like other prokaryotic cells, this bacterial cell lacks a nucleus but has other cell parts, including a plasma membrane, cytoplasm, ribosomes, and DNA. Identify each of these parts in the diagram.

Eukaryotic Cells

Eukaryotic cells are cells that contain a nucleus. They are larger than prokaryotic cells. They are also more complex. Living things with eukaryotic cells are called **eukaryotes**. All of them belong to the Eukarya Domain. This domain includes protists, fungi, plants, and animals. Many protists consist of a single cell. However, most eukaryotes have more than one cell. You can see a model of a eukaryotic cell in **Figure 1.15**. The cell in the figure is an animal cell.

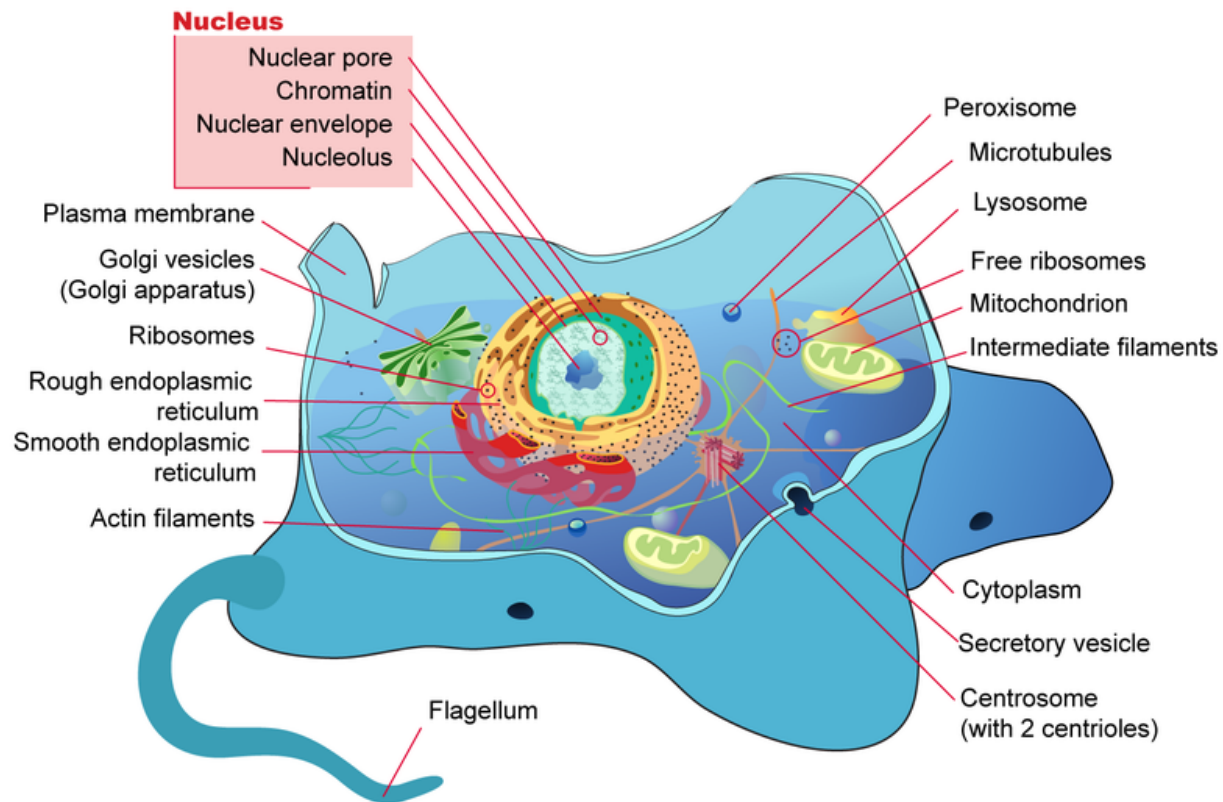


FIGURE 1.15

Model of a eukaryotic cell: animal cell

The nucleus is an example of an **organelle**. An organelle is any structure inside a cell that is enclosed by a membrane. Eukaryotic cells may contain many different organelles. Each does a special job. For example, the mitochondrion is an organelle that provides energy to the cell. You can see a mitochondrion and several other organelles in the animal cell in **Figure 1.15**. Organelles allow eukaryotic cells to carry out more functions than prokaryotic cells can.

Levels of Organization

As you can see in **Figure** below, living things can have levels of organization higher than the cell. These higher levels are found only in multicellular organisms with specialized cells.

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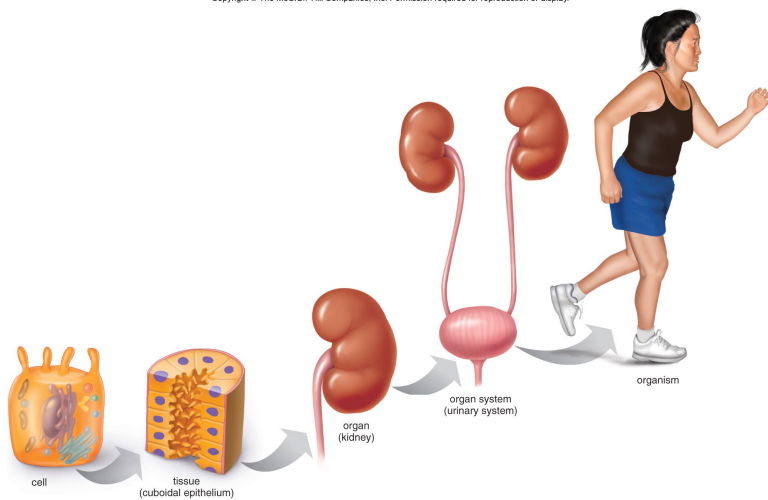


FIGURE 1.16

Levels of Multicellular Organization

Specialized Cells

All living cells have certain things in common. For example, all cells can use energy, respond to their environment, and reproduce. However, cells may also have special functions. Multicellular organisms such as you have many different types of specialized cells. Each specialized cell has a particular job. Cells with special functions generally have a shape that suits them for that job.

Figure 1.17 shows four examples of specialized cells. Each type of cell in the figure has a different function. It also has a shape that helps it perform that function.

- The function of a nerve cell is to carry messages to other cells. It has many long “arms” that extend outward from the cell. The "arms" let the cell pass messages to many other cells at once.
- The function of a red blood cell is to carry oxygen to other cells. A red blood cell is small and smooth. This helps it slip through small blood vessels. A red blood cell is also shaped like a fattened disc. This gives it a lot of surface area for transferring oxygen.
- The function of a sperm cell is to swim through fluid to an egg cell. A sperm cell has a long tail that helps it swim.
- The function of a pollen cell is to pollinate flowers. The pollen cells in the figure have tiny spikes that help them stick to insects such as bees. The bees then carry the pollen cells to other flowers for pollination.

Multicellular Organization

As mentioned, specialized cells allow multicellular organism to have higher levels of organization. The figure below allows you to see another example of the levels of multicellular organization.

- Specialized cells are organized into tissues. A **tissue** is a group of cells of the same kind that performs the same function. For example, muscle cells are organized into muscle tissue. The function of muscle tissue is to contract in order to move the body or its parts. In this example, muscle tissue allows the stomach to churn.
- Tissues may be organized into organs. An **organ** is a structure composed of two or more types of tissue that work together to do a specific task. For example, the stomach is an organ. It consists of muscle, nerve, and other types of tissues. Its task is digest food.
- Organs may be organized into organ systems. An **organ system** is a group of organs that work together to do the same job. For example, the stomach is part of the digestive system. This system also includes the small and large intestines, gall bladder and other organs.

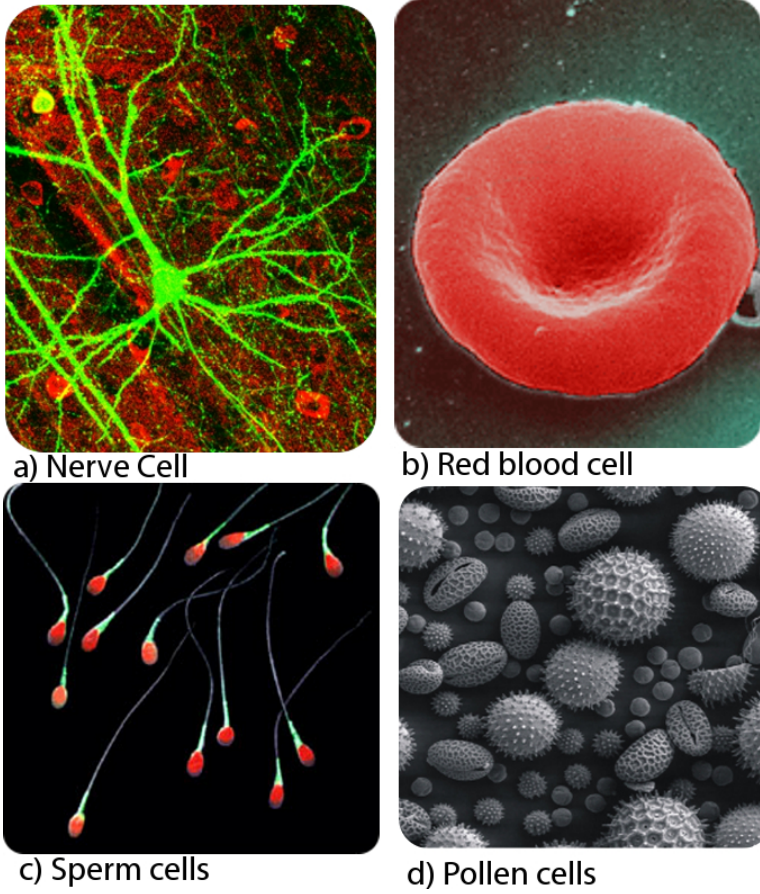


FIGURE 1.17

Examples of specialized cells include (a) nerve cells, (b) red blood cells, (c) sperm cells, and (d) pollen cells

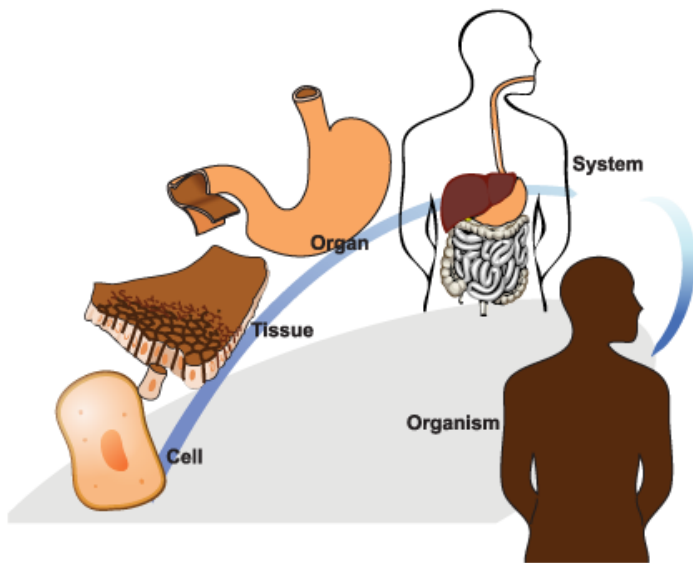


FIGURE 1.18

- Organ systems are organized into the organism. The different organ systems work together to carry out all the life functions of the individual.

Why Cells Are So Small

Cells with different functions often vary in shape. They may also vary in size. However, all cells are very small. Even the largest organisms have microscopic cells. Cells are so small that their diameter is measured in micrometers. A micrometer is just one-millionth of a meter. Use the sliding scale at the following link to see how small cells and cell parts are compared with other objects.

<http://learn.genetics.utah.edu/content/cells/scale/>

Why are cells so small? The answer has to do with the surface area and volume of cells.

- To carry out life processes, a cell must be able to pass substances into and out of the cell. For example, it must be able to pass nutrients into the cell and waste products out of the cell. Anything that enters or leaves a cell has to go through the cell membrane on the surface of the cell.
- A bigger cell needs more nutrients and creates more wastes. As the size of a cell increases, its volume increases more quickly than its surface area. If the volume of a cell becomes too great, it won't have enough surface area to transfer all of its nutrients and wastes.

Lesson Summary

- The cell theory states that all organisms consist of one or more cells; cells are alive and the site of all life processes; and all cells come from pre-existing cells.
- All cells have a cell membrane, cytoplasm, DNA, and ribosomes.
- Cells are either prokaryotic cells, which lack a nucleus, or eukaryotic cells, which have a nucleus.
- Cells may be specialized for different functions. They generally have a shape that suits their function.
- In multicellular organisms, specialized cells may be organized into tissues. Tissues may be organized into organs, and organs may be organized into organ systems. Organ systems work together to carry out all the functions of the whole organism.

Lesson Review Questions

Recall

1. Identify discoveries that led to the cell theory.
2. What are the four basic parts found in all cells?

Apply Concepts

3. Apply the levels of organization of an organism to a human being. List the levels of organization in order from the atom to the organism, and give an example at each level.

Think Critically

4. Compare and contrast prokaryotic and eukaryotic cells.
5. Use examples to show how cell shape relates to cell function.
6. Explain what limits the size of cells.

Points to Consider

All eukaryotic cells have a nucleus and other organelles. Each organelle has a special job to do.

1. What do you think some of the special jobs of organelles might be?
2. Do you think that plant and animal cells might have different organelles?

1.4 Cell Structures

Lesson Objectives

- Describe the structure and functions of the cell membrane.
- Identify the parts and roles of the cytoplasm and cytoskeleton.
- List organelles in eukaryotic cells and their special jobs.
- Describe structures found in plant cells but not animal cells.

Lesson Vocabulary

- ATP (adenosine triphosphate)
- cell wall
- central vacuole
- centriole
- cytoskeleton
- endoplasmic reticulum (ER)
- Golgi apparatus
- lysosome
- mitochondrion (mitochondria, plural)
- vacuole
- vesicle

Introduction

In some ways, a cell resembles a plastic bag full of Jell-O. Its basic structure is a cell membrane filled with cytoplasm. The cytoplasm of a eukaryotic cell is like Jell-O containing mixed fruit. It also contains a nucleus and other organelles.

Figure 1.19 shows the structures inside a typical eukaryotic cell. The model cell in the figure represents an animal cell. Refer to the model as you read about the structures below. You can also explore the structures in the interactive animal cell at this link:

Cell Membrane

The cell membrane is like the bag holding the Jell-O. It encloses the cytoplasm of the cell. It forms a barrier between the cytoplasm and the environment outside the cell. The function of the cell membrane is to protect and support the cell. It also controls what enters or leaves the cell. It allows only certain substances to pass through. It keeps other substances inside or outside the cell.

Cytoplasm and Cytoskeleton

Cytoplasm is everything inside the cell membrane (except the nucleus if there is one). It includes the watery, gel-like cytosol. It also includes other structures. The water in the cytoplasm makes up about two-thirds of the cell's weight. It gives the cell many of its properties.

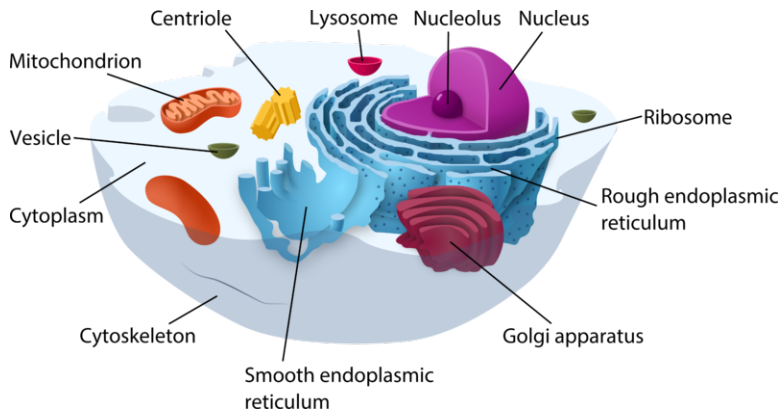


FIGURE 1.19

Model of an animal cell

Cytoplasm has several important functions. These include:

- suspending cell organelles.
- pushing against the cell membrane to help the cell keep its shape.
- providing a site for many of the biochemical reactions of the cell.

Crisscrossing the cytoplasm is a structure called the **cytoskeleton**. It consists of thread-like filaments and tubules. The cytoskeleton is like a cellular “skeleton.” It helps the cell keep its shape. It also holds cell organelles in place within the cytoplasm.

Figure 1.20 shows several cells. In the figure, the filaments of their cytoskeletons are colored green. The tubules are colored red. The blue dots are the cell nuclei.

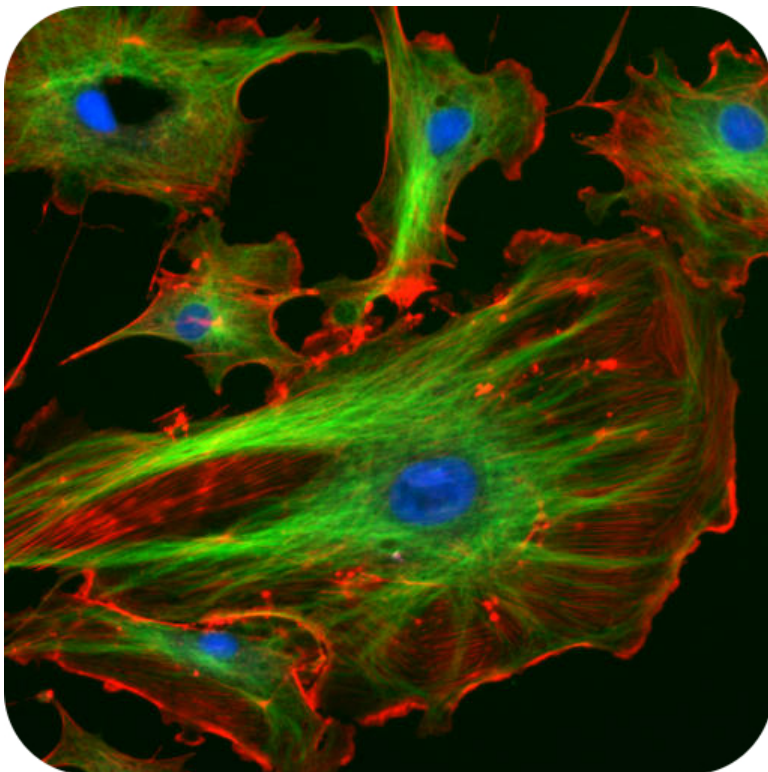


FIGURE 1.20

Cytoskeleton and nuclei of cells

Organelles

Eukaryotic cells contain a nucleus and several other types of organelles. These structures carry out many vital cell functions.

Nucleus

The nucleus is the largest organelle in a eukaryotic cell. It contains most of the cell's DNA. DNA, in turn, contains the genetic code. This code "tells" the cell which proteins to make and when to make them. You can see a diagram of a cell nucleus in Figure 1.21. Besides DNA, the nucleus contains a structure called a nucleolus. Its function is to form ribosomes. The membrane enclosing the nucleus is called the nuclear envelope. The envelope has tiny holes, or pores, in it. The pores allow substances to move into and out of the nucleus.

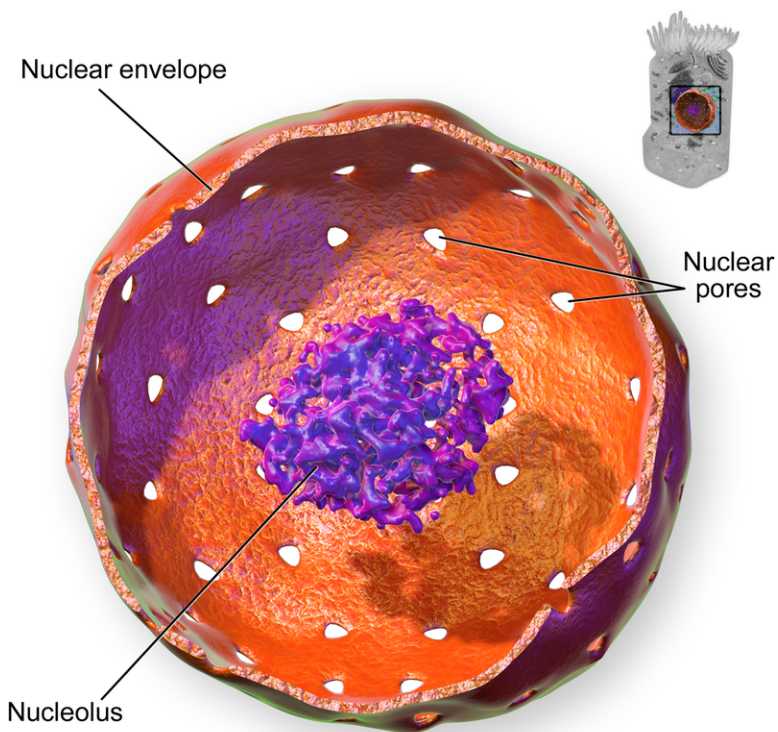


FIGURE 1.21

Nucleus of a eukaryotic cell

Mitochondrion

The **mitochondrion (mitochondria, plural)** is an organelle that makes energy available to the cell. It's like the power plant of a cell. It uses energy in glucose to make smaller molecules called **ATP (adenosine triphosphate)**. ATP packages energy in smaller amounts that cells can use.

Think about buying a bottle of water from a vending machine. The machine takes only quarters, and you have only dollar bills. The dollar bills won't work in the vending machine. Glucose is like a dollar bill. It contains too much energy for cells to use. ATP is like a quarter. It contains just the right amount of energy for use by cells.

Ribosomes

A ribosome is a small organelle where proteins are made. It's like a factory in the cell. It gathers amino acids and joins them together into proteins. Unlike other organelles, the ribosome is not surrounded by a membrane. As a result, some scientists do not classify it as an organelle. Ribosomes may be found floating in the cytoplasm. Some ribosomes are located on the surface of another organelle, the endoplasmic reticulum.

Endoplasmic Reticulum

The **endoplasmic reticulum (ER)** is an organelle that helps make and transport proteins and lipids. It's made of folded membranes. Bits of membrane can pinch off to form tiny sacs called vesicles. The vesicles carry proteins or lipids away from the ER.

There are two types of endoplasmic reticulum. They are called rough endoplasmic reticulum (RER) and smooth endoplasmic reticulum (SER). Both types are shown in **Figure 1.22**.

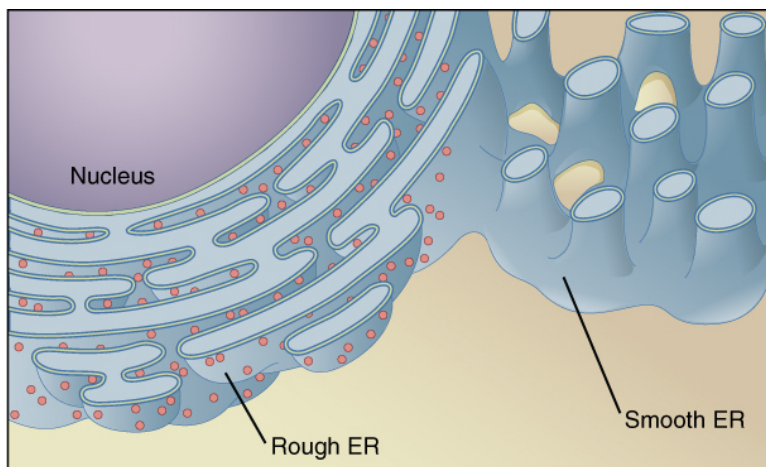


FIGURE 1.22

RER and SER are located outside the cell nucleus. The red dots on the RER are ribosomes.

Golgi Apparatus

The **Golgi apparatus** is a large organelle that sends proteins and lipids where they need to go. It's like a post office. It receives molecules from the endoplasmic reticulum. It packages and labels the molecules. Then it sends them where they are needed. Some molecules are sent to different parts of the cell. Others are sent to the cell membrane for transport out of the cell. Small bits of membrane pinch off the Golgi apparatus to enclose and transport the proteins and lipids.

Vesicles and Vacuoles

Both **vesicles** and **vacuoles** are sac-like organelles. They store and transport materials in the cell. They are like movable storage containers.

- Some vacuoles are used to isolate materials that are harmful to the cell. Other vacuoles are used to store needed substances such as water.
- Vesicles are much smaller than vacuoles and have a variety of functions. Some vesicles pinch off from the membranes of the endoplasmic reticulum and Golgi apparatus. These vesicles store and transport proteins and lipids. Other vesicles are used as chambers for biochemical reactions.

Lysosomes

A **lysosome** is an organelle that recycles unneeded molecules. It uses enzymes to break down the molecules into their components. Then the components can be reused to make new molecules. Lysosomes are like recycling centers.

Centrioles

Centrioles are organelles that are found only in animal cells. They are located near the nucleus. They help organize the DNA in the nucleus before cell division takes place. They ensure that the DNA divides correctly when the cell divides.

Special Structures in Plant Cells

All but one of the structures described above are found in plant cells as well as animal cells. The only exception is centrioles, which are not found in plant cells. Plant cells have three additional structures that are not found in animals cells. These include a cell wall, large central vacuole, and organelles called plastids. You can see these structures in the model of a plant cell in **Figure 1.23**.

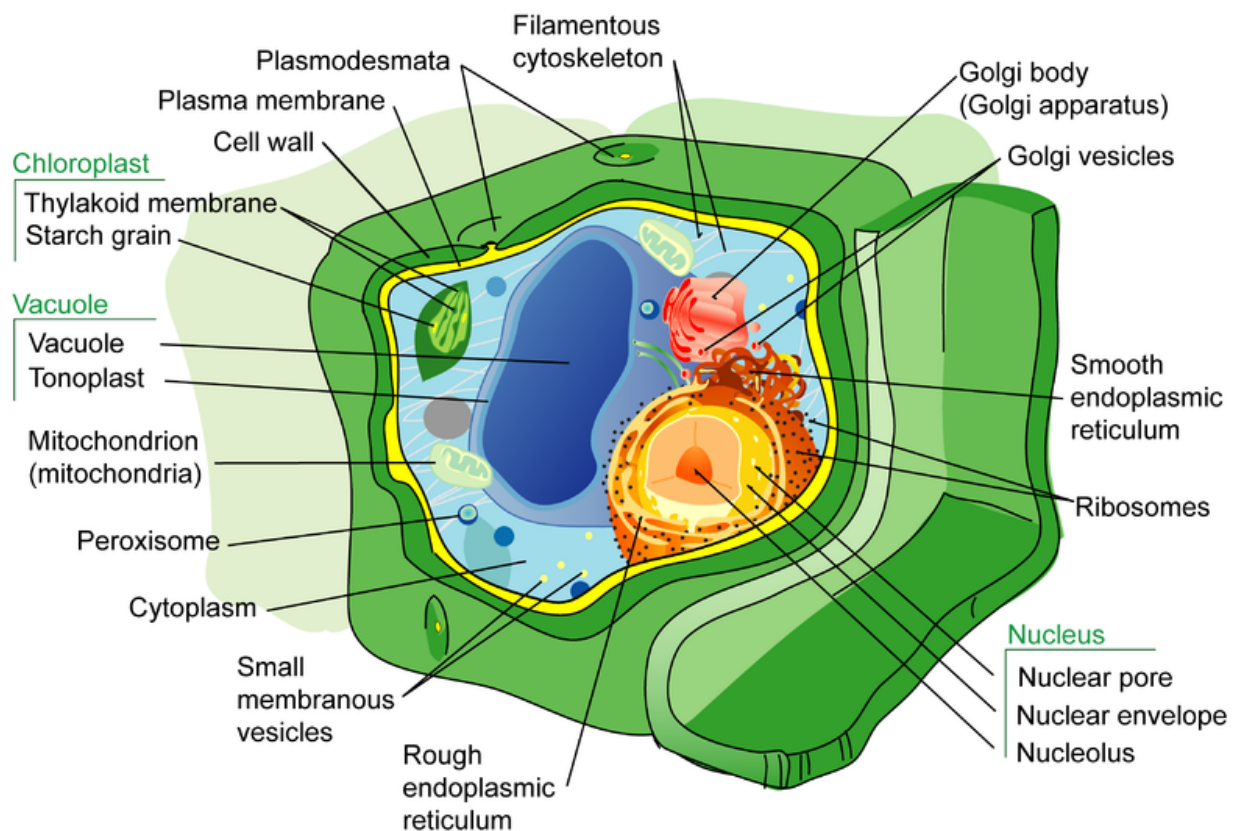


FIGURE 1.23

Model of a plant cell

Cell Wall

The **cell wall** is a rigid layer that surrounds the cell membrane of a plant cell. It's made mainly of the complex carbohydrate called cellulose. The cell wall supports and protects the cell. The cell wall isn't solid like a brick wall. It has tiny holes in it called pores. The pores let water, nutrients, and other substances move into and out of the cell.

Central Vacuole

Most plant cells have a large **central vacuole**. It can make up as much as 90 percent of a plant cell's total volume. The central vacuole is like a large storage container. It may store substances such as water, enzymes, and salts. It may have other roles as well. For example, the central vacuole helps stems and leaves hold their shape. It may also contain pigments that give flowers their colors.

Chloroplasts

Chloroplasts are organelles that contain chlorophyll. Chlorophyll is a green pigment. It gives plants their green color. Photosynthesis takes place in chloroplasts. They capture sunlight and use its energy to make glucose.

Summary of Organelles

The figure below summarizes some of the organelles found in eukaryotic cells.









 <p>Nucleus the organelle that contains the cell's DNA and is the control center of the cell</p>	 <p>Chloroplast the organelle that uses the energy of sunlight to make food</p>
 <p>Ribosome the organelle in which amino acids are hooked together to make proteins</p>	 <p>Golgi complex the organelle that processes and transports proteins and other materials out of cell</p>
 <p>Endoplasmic reticulum the organelle that makes lipids, breaks down drugs and other substances, and packages proteins for Golgi complex</p>	 <p>Large central vacuole the organelle that stores water and other materials</p>
 <p>Mitochondrion the organelle that breaks down food molecules to make ATP</p>	 <p>Lysosome the organelle that digests food particles, wastes, cell parts, and foreign invaders</p>

FIGURE 1.24

Common organelles. Can you identify the two on this diagram that are only found in plant cells?

Lesson Summary

- The cell membrane consists of two layers of phospholipids. It encloses the cytoplasm and controls what enters and leaves the cell.
- The cytoplasm consists of watery cytosol and cell structures. It has several functions. The cytoskeleton is the “skeleton” of the cell. It helps the cell keep its shape.
- Eukaryotic cells contain a nucleus and other organelles. They include the mitochondrion, endoplasmic reticulum, Golgi apparatus, vesicles, vacuoles, lysosomes, and—in animal cells—centrioles. Each type of organelle has a special function.

- Plant cells have several structures not found in animal cells. They include a cell wall, large central vacuole, and plastids such as chloroplasts.

Lesson Review Questions

Recall

1. Describe the composition of the cytoplasm and list its functions.
2. What is the cytoskeleton? What does it do?
3. Identify three organelles in eukaryotic cells and state their roles.

Apply Concepts

4. Why is the nucleus like the control center of a cell?

Think Critically

5. Explain how the structure of the cell membrane controls what enters and leaves the cell.
6. Compare and contrast plant and animal cells.

Points to Consider

The cell theory states that all cells come from pre-existing cells. Based on what you have learned about the structure of cells:

1. What cellular components will be passed from one cell to the next?
2. How do you think new cells are 'born'?

1.5 References

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CHAPTER 2**Cell Division and Reproduction****Chapter Outline**

- 2.1 CELL DIVISION**
 - 2.2 REPRODUCTION**
 - 2.3 REFERENCES**
-



FIGURE 2.1

This baby boy is just a few days old, but his body already consists of billions of cells. By the time he's as big as his father, his body will contain trillions of cells. Like all other organisms, the baby actually started out in life as a single cell. How do we develop from a single cell into an organism with trillions of cells? The answer is cell division.

2.1 Cell Division

Lesson Objectives

- Outline the process of DNA replication.
- Compare and contrast cell division in prokaryotic and eukaryotic cells.
- Describe the four phases of mitosis in eukaryotic cells.
- Identify the stages of the cell cycle in prokaryotic and eukaryotic cells.

Lesson Vocabulary

- anaphase
- binary fission
- cell cycle
- cell division
- chromosome
- cytokinesis
- DNA (deoxyribonucleic acid)
- DNA replication
- interphase
- metaphase
- mitosis
- prophase
- telophase

Introduction

Cell division is the process in which a cell divides to form two new cells. The original cell is called the parent cell. The two new cells are called daughter cells. All cells contain DNA. DNA is the nucleic acid that stores genetic information. Before a cell divides its DNA must be copied. That way, each daughter cell gets a complete copy of the parent cell's genetic material.

Copying DNA

DNA stands for deoxyribonucleic acid. It is a very large molecule. It consists of two strands of smaller molecules called nucleotides. Before learning how DNA is copied, it's a good idea to review its structure.

DNA Structure

As you can see in **Figure 2.2**, each nucleotide includes a sugar, a phosphate, and a nitrogen base. The sugar in DNA is called deoxyribose. There are four different nitrogen bases in DNA: adenine (A), thymine (T), cytosine (C), and guanine (G). Chemical bonds between the bases hold the two strands of DNA together. Adenine always bonds with thymine, and cytosine always bonds with guanine. These pairs of bases are called complementary base pairs.

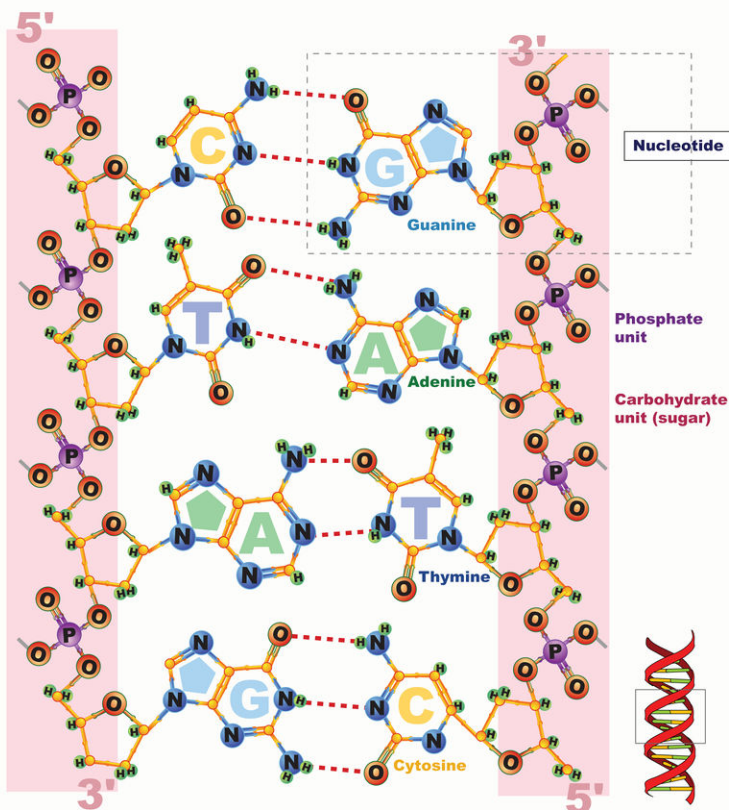


FIGURE 2.2

Structure of DNA

Chromosomes

As a cell prepares to divide, its DNA first forms one or more structures called chromosomes. A **chromosome** consists of DNA and protein molecules coiled into a definite shape. Chromosomes are circular in prokaryotes and rodlike in eukaryotes. You can see an example of the 46 human chromosomes in **Figure 2.3**. The rest of the time, DNA looks like a tangled mass of strings. In this form, it would be very difficult to copy and divide.

DNA Replication

The process in which DNA is copied is called **DNA replication**. You can see how it happens in **Figure 2.4**. An enzyme breaks the bonds between the two DNA strands. Another enzyme pairs new, complementary nucleotides with those in the original chains. Two daughter DNA molecules form. Each contains one new chain and one original chain.

Cell Division in Prokaryotic and Eukaryotic Cells

How cell division proceeds depends on whether a cell has a nucleus. Prokaryotic cells lack a nucleus. Their DNA is in the cytoplasm. It forms just one circular chromosome. Eukaryotic cells have a nucleus holding their DNA. Their DNA forms multiple rodlike chromosomes, like the one in **Figure 2.3**. Eukaryotic cells also have other organelles. For these reasons, cell division is more complex in eukaryotic cells.



FIGURE 2.3

Human Chromosomes are organized into 23 pairs. The 23rd pair determines sex. Females have two X chromosomes, while males have an X and a Y chromosome.

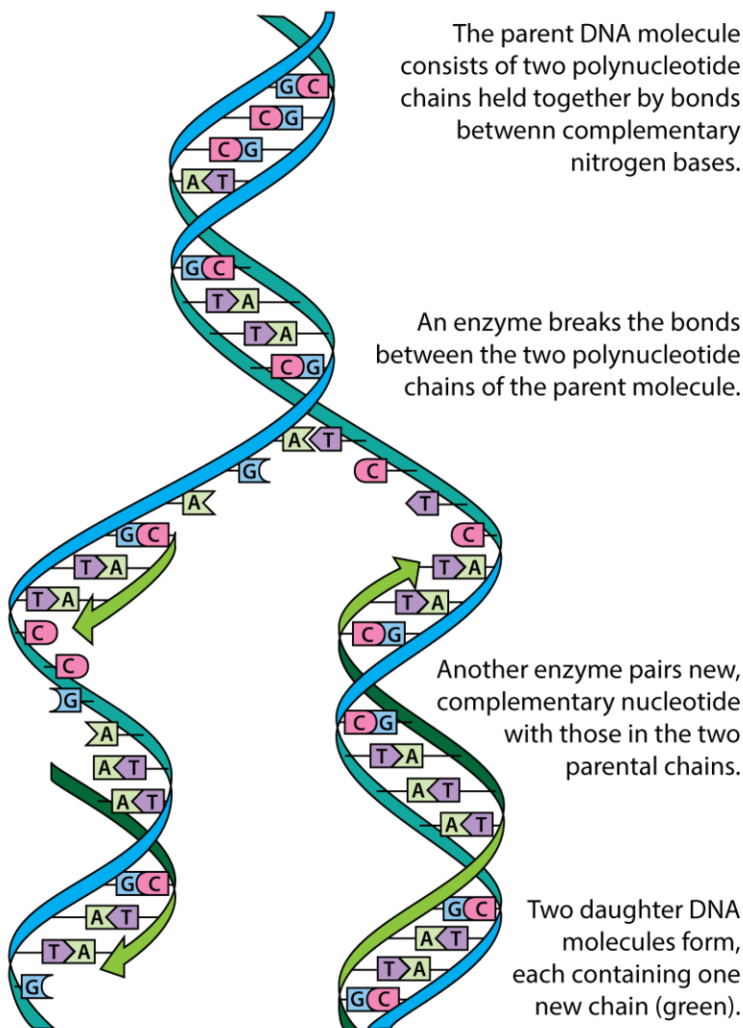


FIGURE 2.4

DNA replication

Prokaryotic Cell Division

You can see how a prokaryotic cell divides in **Figure 2.5**. This type of cell division is called binary fission. The cell simply splits into two equal halves. Binary fission occurs in bacteria and other prokaryotes. It takes place in three continuous steps:

1. The cell's chromosome is copied to form two identical chromosomes. This is DNA replication.
2. The copies of the chromosome separate from each other. They move to opposite poles, or ends, of the cell. This is called chromosome segregation.
3. The cell wall grows toward the center of the cell. The cytoplasm splits apart, and the cell pinches in two. This is called **cytokinesis**.

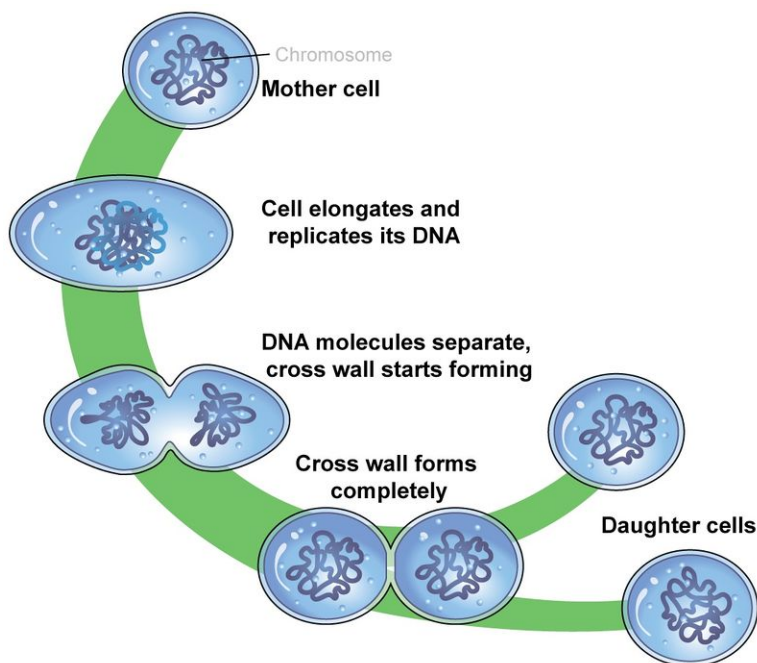


FIGURE 2.5

Binary fission in a prokaryotic cell

Eukaryotic Cell Division

You can see how a eukaryotic cell divides in **Figure below** . This type of cell division also takes place in three continuous steps:

1. The first step in eukaryotic cell division, as it is in prokaryotic cell division, is DNA replication. This process occurs during Interphase, a stage that will be explained in greater detail later in this section. As you can see in **Figure 2.6**, each chromosome then consists of two identical copies. The two copies are called sister chromatids. They are attached to each other at a point called the centromere.
2. The second step in eukaryotic cell division is division of the cell's nucleus. This includes division of the chromosomes. This step is called mitosis. It is a complex process that occurs in four phases. The phases of mitosis are described below.
3. The third step is the division of the rest of the cell. This is called cytokinesis, as it is in a prokaryotic cell. During this step, the cytoplasm divides, and two daughter cells form.

These three steps are shown in **Figure below**.

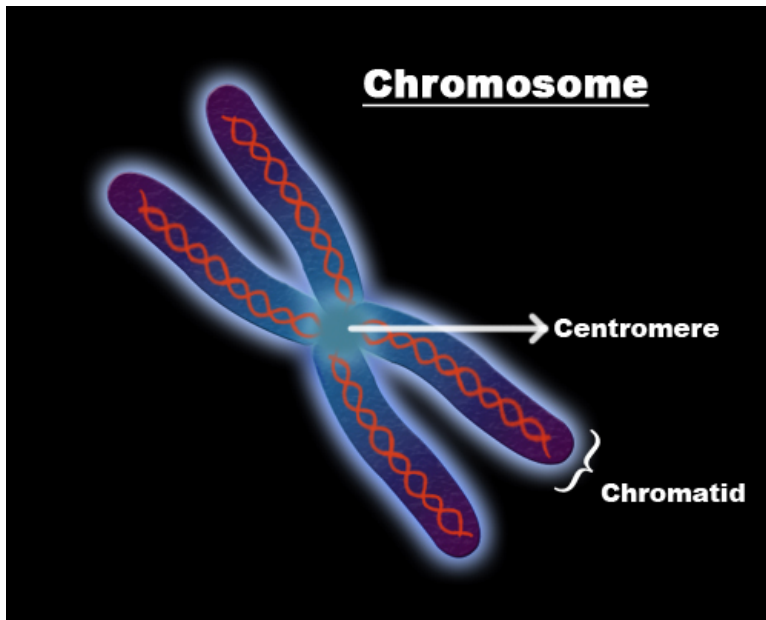


FIGURE 2.6

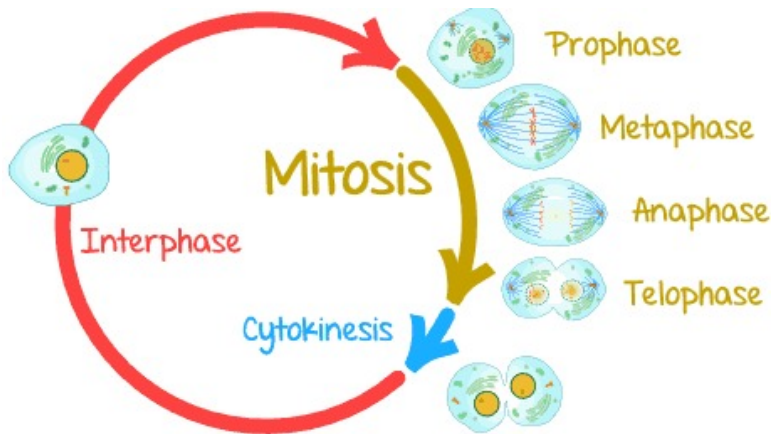


FIGURE 2.7

Cell division includes three important steps. First, the DNA is replicated during interphase. Second, the nucleus divides during the 4 phases of mitosis. Third, the cytoplasm splits and the cell divides in cytokinesis.

Mitosis

Mitosis, or division of the nucleus, occurs only in eukaryotic cells. By the time mitosis occurs, the cell's DNA has already replicated. Mitosis occurs in four phases, called prophase, metaphase, anaphase, and telophase. You can see what happens in each phase in **Figure** below.

1. **Prophase:** Chromosomes form, and the nuclear membrane breaks down. In animal cells, the centrioles near the nucleus move to opposite poles of the cell. Fibers called spindles form between the centrioles.
2. **Metaphase:** Spindle fibers attach to the centromeres of the sister chromatids. The sister chromatids line up at the center of the cell.
3. **Anaphase:** Spindle fibers shorten, pulling the sister chromatids toward the opposite poles of the cell. This gives each pole a complete set of chromosomes.
4. **Telophase:** The chromosomes uncoil, and the spindle fibers break down. New nuclear membranes form.

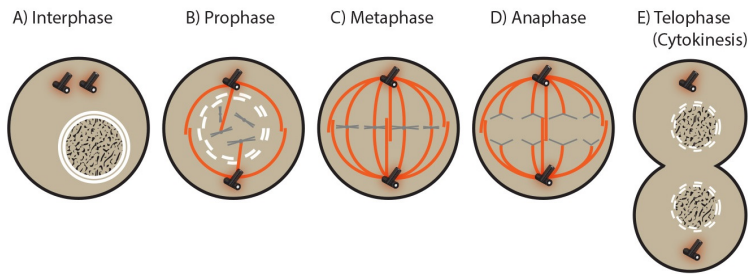
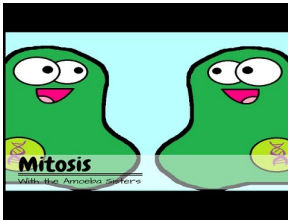


FIGURE 2.8

The phases of mitosis.

You can also learn more about the phases of mitosis by watching this video: <https://www.youtube.com/watch?v=gwewSZifKIM> .



MEDIA

Click image to the left or use the URL below.

URL: <http://www.ck12.org/flx/render/embeddedobject/149616>

The Cell Cycle

Cell division is just one of the stages that a cell goes through during its lifetime. All of the stages that a cell goes through make up the **cell cycle**.

Prokaryotic Cell Cycle

The cell cycle of a prokaryotic cell is simple. The cell grows in size, its DNA replicates, and the cell divides.

Eukaryotic Cell Cycle

In eukaryotes, the cell cycle is more complicated. The diagram in **Figure** below shows the stages that a eukaryotic cell goes through in its lifetime. There are three main stages: interphase, the mitotic phase and cytokinesis.

Interphase is the longest phase. Interphase, in turn, is divided into three phases:

1. Growth phase 1 (G1): The cell grows rapidly. It also carries out basic cell functions. It makes proteins needed for DNA replication and copies some of its organelles. A cell usually spends most of its lifetime in this phase.
2. Synthesis phase (S): The cell copies its DNA. This is DNA replication.
3. Growth phase 2 (G2): The cell gets ready to divide. It makes more proteins and copies the rest of its organelles.

Mitotic phase is when the cell nucleus divides. It includes the four steps in mitosis.

Cytokinesis is when the cell divides. This stage overlaps with the last step in mitosis, telophase.

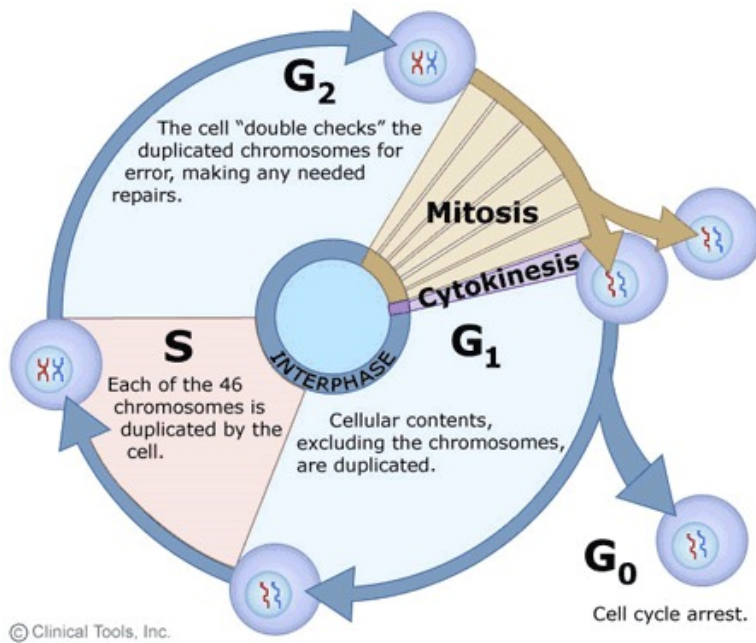


FIGURE 2.9

Eukaryotic Cell Cycle

Lesson Summary

- DNA is the nucleic acid that stores genetic information. It must be copied before a cell divides. DNA replication is the process in which DNA is copied.
- Cell division is the process in which a parent cell divides to form two daughter cells. It occurs by binary fusion in most prokaryotic cells. It is more complex in eukaryotic cells.
- Mitosis is the process by which the nucleus of a eukaryotic cell divides. It happens in four phases: prophase, metaphase, anaphase, and telophase.
- Cell division is just one stage of the cell cycle. The cell cycle includes all of the stages in the life of a cell. The cell cycle is more complex in eukaryotic than prokaryotic cells.

Lesson Review Questions

Recall

1. What is DNA replication? When and why does it occur?
2. What are chromosomes? When do chromosomes form?
3. Identify the steps of cell division in a prokaryotic cell.
4. List the phases of mitosis and what happens during each phase.

Apply Concepts

5. A single-celled organism belongs to the Eukarya Domain. Apply lesson concepts to describe how the organism's cells divide.

Think Critically

6. Explain why cell division is more complicated in eukaryotic than prokaryotic cells.
7. Compare and contrast the cell cycles of prokaryotic and eukaryotic cells.

Points to Consider

Cell division is how organisms grow and replace worn out or damaged cells. It's also how they produce offspring. Producing offspring is known as reproduction.

- How do you think prokaryotes reproduce?
- How do you think multicellular eukaryotes reproduce?

2.2 Reproduction

Lesson Objectives

- Identify three methods of asexual reproduction.
- Give an overview of sexual reproduction.
- Explain how meiosis produces haploid gametes.
- State advantages of asexual and sexual reproduction.

Lesson Vocabulary

- asexual reproduction
- diploid
- egg
- fertilization
- gamete
- haploid
- homologous chromosomes
- meiosis
- sexual reproduction
- sperm
- zygote

Introduction

Reproduction is how organisms produce offspring. The ability to reproduce is a characteristic of all living things. In some species, all the offspring are genetically identical to the parent. In other species, each offspring is genetically unique. Look at the kittens in **Figure 2.10**. They are brothers and sisters, but they are all different from each other. Why does this happen in some species but not others? It's because there are two types of reproduction. Reproduction can be sexual or asexual.

Asexual Reproduction

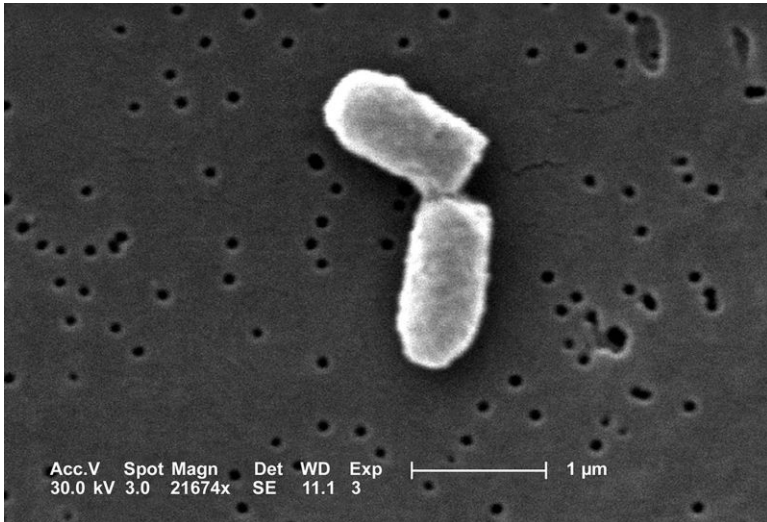
Asexual reproduction is simpler than sexual reproduction. It involves just one parent. The offspring are genetically identical to each other and to the parent. All prokaryotes and some eukaryotes reproduce this way. There are several different methods of asexual reproduction. They include binary fission, fragmentation, and budding.

Binary Fission

Binary fission occurs when a parent cell simply splits into two daughter cells. This method was described in our last chapter on 'Cell Division.' Bacteria reproduce this way. You can see a bacterial cell reproducing by binary fission in **Figure 2.11**.

**FIGURE 2.10**

These kittens have the same parents, but each kitten is unique.

**FIGURE 2.11**

Binary fission in a bacterium

Fragmentation

Fragmentation occurs when a piece breaks off from a parent organism. Then the piece develops into a new organism. Sea stars, like the one in **Figure 2.12**, can reproduce this way. In fact, a new sea star can form from a single “arm.”

Budding

Budding occurs when a parent cell forms a bubble-like bud. The bud stays attached to the parent while it grows and develops. It breaks away from the parent only after it is fully formed. Yeasts can reproduce this way. You can see two yeast cells budding in **Figure 2.13**.



FIGURE 2.12

A sea star can reproduce by asexually by fragmentation. It can also reproduce sexually.

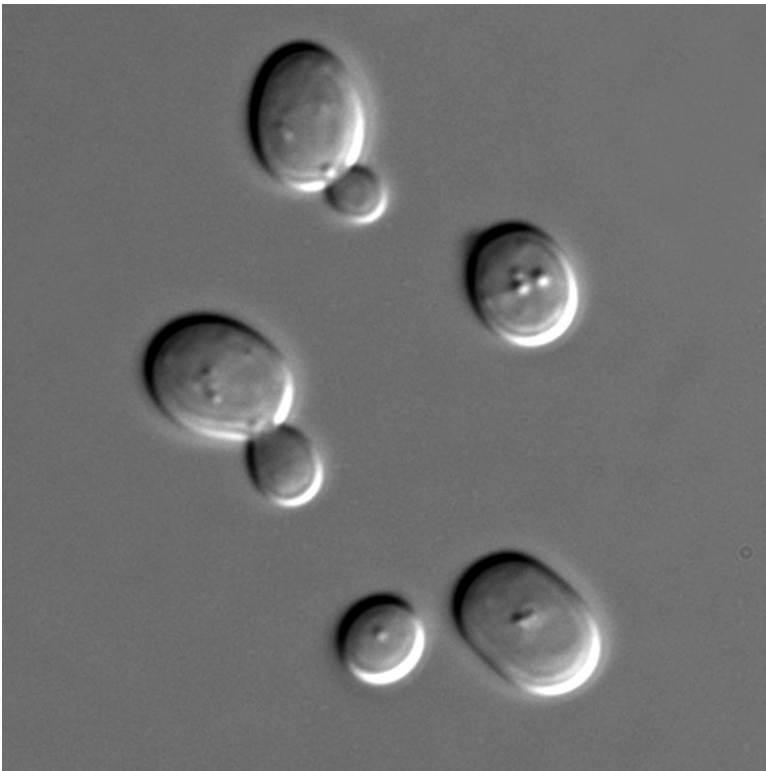


FIGURE 2.13

Budding in yeast cells

Sexual Reproduction

Sexual reproduction is more complicated. It involves two parents. Special cells called **gametes** are produced by the parents. In humans, a gamete produced by a female parent is called an **egg**, while a gamete produced by a male parent is called a **sperm**. An offspring forms when two gametes unite. The union of the two gametes is called **fertilization**. You can see a human sperm and egg uniting in **Figure 2.14**. The initial cell that forms when two gametes unite is called a **zygote**.

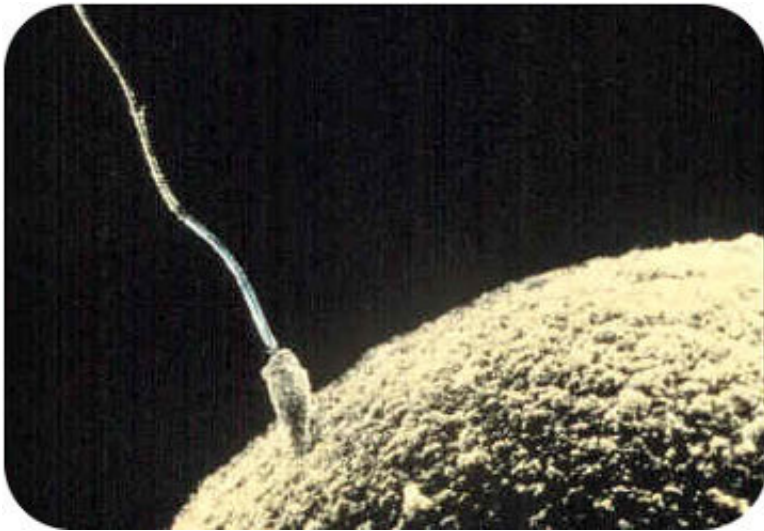


FIGURE 2.14

Fertilization: human sperm and egg

Chromosome Numbers

In species with sexual reproduction, each cell of the body has two copies of each chromosome. For example, human beings have 23 different chromosomes. Each body cell contains two of each chromosome, for a total of 46 chromosomes. You can see the 23 pairs of human chromosomes in **Figure 2.15**. The number of different types of chromosomes is called the haploid number. In humans, the haploid number is 23. The number of chromosomes in normal body cells is called the diploid number. The diploid number is twice the haploid number. In humans, the diploid number is two times 23, or 46.

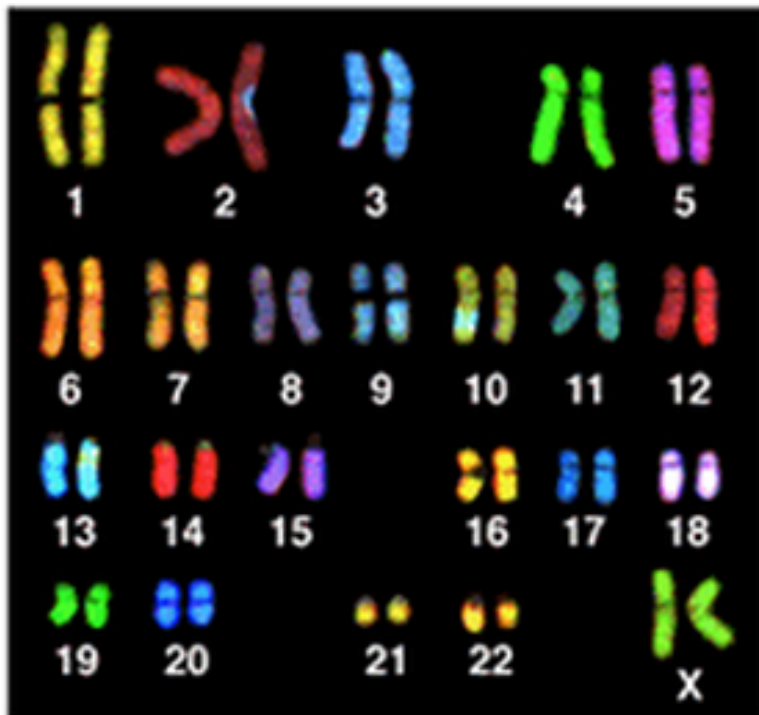


FIGURE 2.15

Humans have 23 pairs of chromosomes in each body cell

Homologous Chromosomes

The two members of a given pair of chromosomes are called **homologous chromosomes**. We get one of each homologous pair, or 23 chromosomes, from our father. We get the other one of each pair, or 23 chromosomes, from our mother. A gamete must have the haploid number of chromosomes. That way, when two gametes unite, the zygote will have the diploid number. How are haploid cells produced? The answer is meiosis.

Meiosis

Meiosis is a special type of cell division. It produces haploid daughter cells. It occurs when an organism makes gametes. Essentially cells preparing for meiosis begin by replicating their DNA. Next they go through two divisions, meiosis I and meiosis II. This results in four haploid daughter cells. Meiosis I and meiosis II each have four phases: prophase, metaphase, anaphase, and telophase. Sound familiar? While the phases of meiosis are similar to mitosis, there are important differences that allow for the cell to divide evenly with the appropriate DNA content. **Figure below** is a simple model of meiosis. It shows both meiosis I and II.

Following meiosis the four daughter cells continue to develop before they become gametes. For example, in males, the cells must develop tails, among other changes, in order to become sperm.

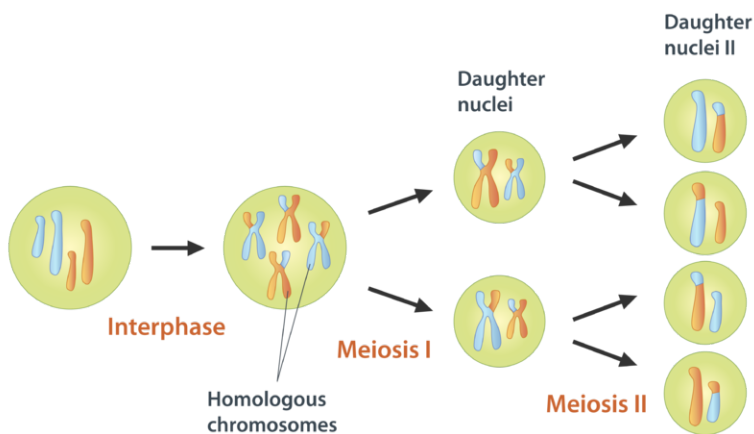
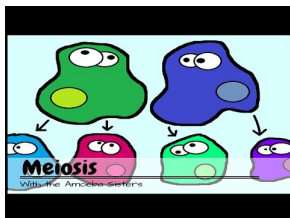


FIGURE 2.16

Meiosis occurs in two stages: meiosis I and meiosis II

You can also learn more about them by watching this video: <http://www.youtube.com/watch?v=toWK0fYfIY> .



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Advantages of Sexual and Asexual Reproduction

Both types of reproduction have certain advantages.

Advantage of Asexual Reproduction

Asexual reproduction can happen very quickly. It doesn't require two parents to meet and mate. Under ideal conditions, 100 bacteria can divide to produce millions of bacteria in just a few hours! Most bacteria don't live under ideal conditions. Even so, rapid reproduction may allow asexual organisms to be very successful. They may crowd out other species that reproduce more slowly.

Advantage of Sexual Reproduction

Sexual reproduction is typically slower. However, it also has an advantage. Sexual reproduction results in offspring that are all genetically different. This can be a big plus for a species. The variation may help it adapt to changes in the environment.

How does genetic variation arise during sexual reproduction? It happens in three ways: crossing over, independent assortment, and the random union of gametes.

- Crossing over occurs during prophase of meiosis I. The paired chromosomes exchange bits of DNA. This recombines their genetic material.
- Independent assortment occurs during metaphase of meiosis I. Chromosomes line up randomly and which ones end up together at each pole is a matter of chance.
- In sexual reproduction, two gametes unite to produce an offspring. Which two gametes is a matter of chance. The union of gametes occurs randomly.

Due to these sources of variation, each human couple has the potential to produce more than 64 trillion unique offspring. No wonder we are all different!

Lesson Summary

- Asexual reproduction involves just one parent. It produces offspring that are genetically identical to the parent. Methods of asexual reproduction include binary fission, fragmentation, and budding.
- Sexual reproduction involves two parents. It produces offspring that are all genetically unique. It requires the production of haploid gametes. The union of gametes is called fertilization. It results in a diploid zygote.
- Haploid gametes are produced through meiosis. This is a special type of cell division. The cell divides twice, called meiosis I and meiosis II. However, the DNA replicates just once. Homologous chromosomes separate. The outcome is four haploid cells.
- Asexual reproduction has the advantage of occurring quickly. Sexual reproduction has the advantage of creating genetic variation. This can help a species adapt to environmental change. The genetic variation arises due to crossing over, independent assortment, and the random union of gametes.

Lesson Review Questions

Recall

1. What are three methods of asexual reproduction? For each method, give an example of an organism that can reproduce that way.
2. Briefly describe sexual reproduction.
3. Define haploid and diploid numbers. Which cells are haploid and which are diploid?

Apply Concepts

4. If you don't have an identical twin, how likely is it that a brother or sister would be just like you?

Think Critically

5. A single-celled organism belongs to the Eukarya Domain. Apply lesson concepts to describe how the organism divides.”
6. Some organisms can reproduce sexually or asexually. Under what conditions might each type of reproduction be an advantage?

Points to Consider

All of our cells contain DNA. Meiosis ensures that each gamete receives a copy of each chromosome.

- Why do cells need DNA?
- What specific role does DNA play?

2.3 References

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CHAPTER **3**

Genetics

Chapter Outline

- 3.1 MENDEL'S DISCOVERIES**
 - 3.2 PROBABILITY AND HEREDITY**
 - 3.3 PATTERNS OF INHERITANCE**
 - 3.4 ADVANCES IN GENETICS**
 - 3.5 REFERENCES**
-

3.1 Mendel's Discoveries

Lesson Objectives

- Identify Mendel, and explain why peas were good plants for him to study.
- Outline Mendel's experiments, and state his laws of heredity.
- Summarize Mendel's scientific legacy.

Lesson Vocabulary

- selective breeding
- dominant
- genetics
- law of independent assortment
- law of segregation
- Mendel
- pollination
- recessive

Introduction

People have long known that offspring are similar to their parents. Whether it's puppies or people, offspring and parents usually share many traits. However, before Gregor Mendel's research, people didn't know how parents pass traits to their offspring. Watch this brief video to give you an overview of Gregor Mendel's life and work: <https://www.youtube.com/watch?v=QmSJGhPTB5E>



MEDIA

Click image to the left or use the URL below.

URL: <http://www.ck12.org/flx/render/embeddedobject/157612>

A Monk and His Peas

Mendel was an Austrian Monk who lived in the 1800s. You can see his picture in **Figure 3.1**.

Mendel the Scientist

Mendel didn't call himself a scientist. But he had all the traits of good scientist. He was observant and curious, and he asked a lot of questions. He also tried to find answers to his questions by doing experiments. Working alone in his garden in the mid-1800s, he grew thousands of pea plants over many years. He used a technique called **selective breeding**, when humans breed organisms for particular traits. Over time he observed specific patterns of when and what traits appeared in the offspring. He repeated each experiment many times.



FIGURE 3.1

Gregor Mendel

Why Study Peas?

Pea plants were a good choice to study for several reasons. One reason is that they are easy to grow. They also grow quickly. In addition, peas have many traits that are easy to observe, and each trait exists in two different forms.

Figure 3.2 shows the traits that Mendel studied in pea plants. For example, one trait is flower color. Flowers may be either white or violet. Another trait is stem length. Plants may be either tall or short.















Seed		Flower	Pod		Stem	
Form	Cotyledon	Color	Form	Color	Place	Size
						
Round	Yellow	White	Full	Green	Axial pods	Tall
						
Wrinkled	Green	Violet	Constricted	Yellow	Terminal pods	Short
1	2	3	4	5	6	7

FIGURE 3.2

Traits Mendel studied in peas

Pea plants reproduce sexually. The male gametes are released by tiny grains of pollen. The female gametes lie deep within the flowers. Fertilization occurs when pollen from one flower reaches the female gametes in the same or a different flower. This is called **pollination**. Mendel was able to control which plants pollinated each other. He transferred pollen by hand from flower to flower.

Mendel's Experiments and Laws of Heredity

Mendel performed two experiments. The first, studied one trait and led to his law of segregation. The second studied two traits at a time and led to his law of independent assortment.

Mendel's First Set of Experiments

An example of Mendel's first set of experiments is his research on flower color. He transferred pollen from a plant with white flowers to a plant with violet flowers. This is called cross-pollination. Then Mendel observed flower

color in their offspring. The offspring formed the first generation (F₁). You can see the outcome of this experiment in **Figure 3.3**.

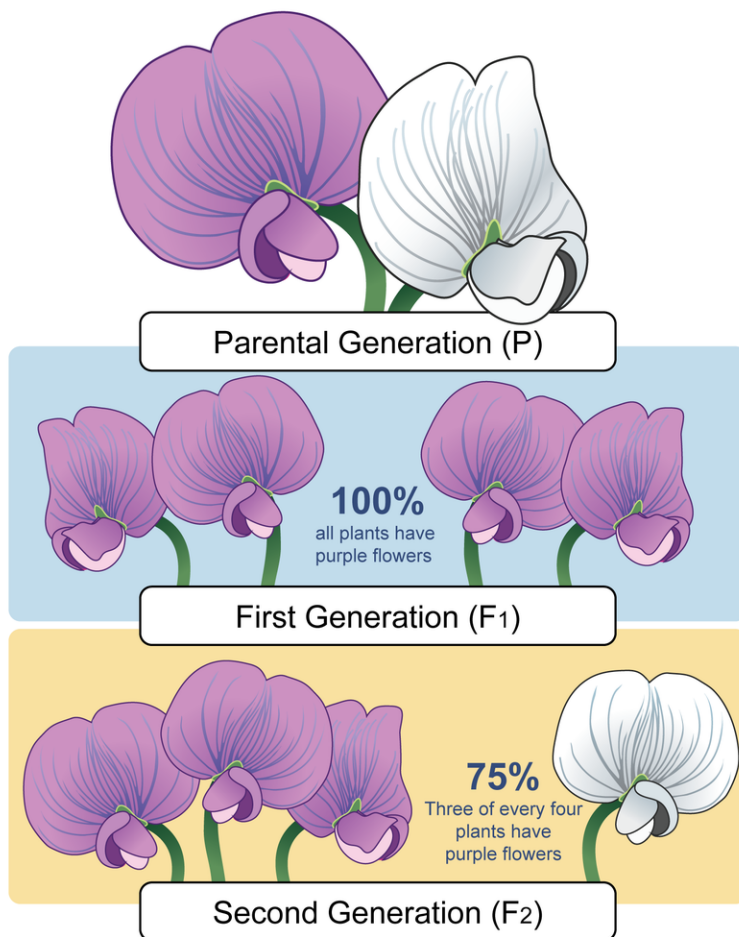


FIGURE 3.3

Mendel's flower color experiment

All of the F₁ plants had violet flowers. Mendel wondered, "What happened to the white form of the trait?" "Did it disappear?" If so, the F₁ plants should have only violet-flowered offspring. Mendel let the F₁ plants pollinate themselves. This is called self-pollination. Then he observed flower color in their offspring. These offspring formed the second generation (F₂). Surprisingly, the trait of white flowers showed up in the F₂ plants. One out of every four F₂ plants had white flowers. The other three out of four had violet flowers. In other words, F₂ plants with violet flowers and F₂ plants with white flowers had a 3:1 ratio.

Mendel repeated this experiment with each of the other traits. For each trait, he got the same results. One form of the trait seemed to disappear in the F₁ plants. Then it showed up again in the F₂ plants. Moreover, the two forms of the trait always showed up in the F₂ plants in the same 3:1 ratio.

Law of Segregation

Based on these results, Mendel concluded that each trait is controlled by two factors. He also concluded that one of the factors for each trait dominates the other. He described the dominating factor as **dominant**. He used the term **recessive** to describe the other factor. If both factors are present in an individual, only the dominant factor is expressed. This explains why one form of a trait always seems to disappear in the F₁ plants. These plants inherit both factors for the trait, but only the dominant factor shows up. The recessive factor is hidden.

When F1 plants reproduce, the two factors separate and go to different gametes. This is Mendel's first law, the **law of segregation**. It explains why both forms of the trait show up again in the F2 plants. One out of four F2 plants inherits two of the recessive factors for the trait. In these plants, the recessive form of the trait is expressed.

Second Set of Experiments

Mendel wondered whether different traits are inherited together. For example, are seed form and seed color passed together from parents to offspring? Or do the two traits split up in the offspring? To answer these questions, Mendel studied two traits at a time. For example, he crossed plants that had round, yellow seeds with plants that had wrinkled, green seeds. Then he observed how the two traits showed up in their offspring (F1). You can see the results of this cross in **Figure 3.4**. All of the F1 plants had round, yellow seeds. The wrinkled and green forms of the traits seemed to disappear in the F1 plants.

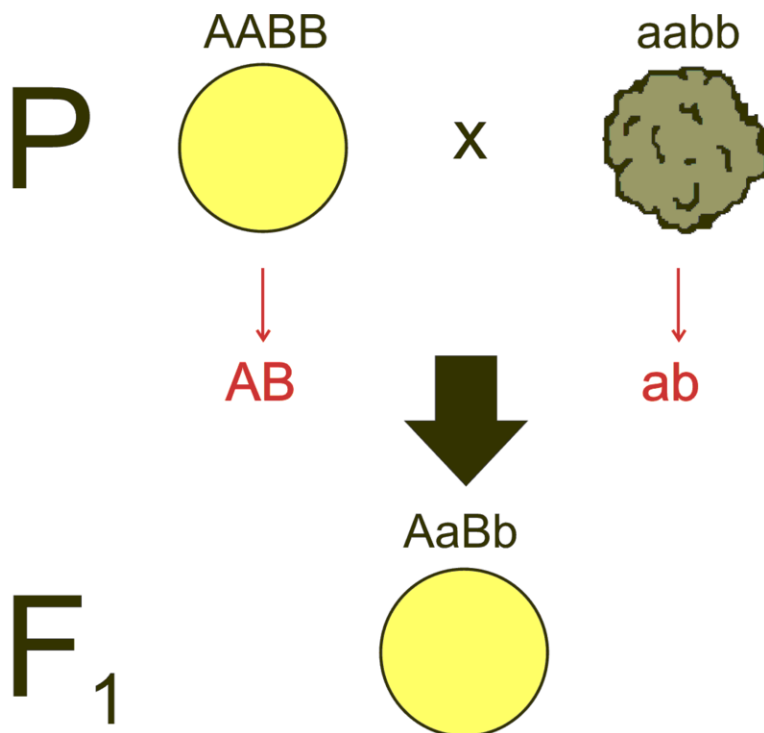


FIGURE 3.4

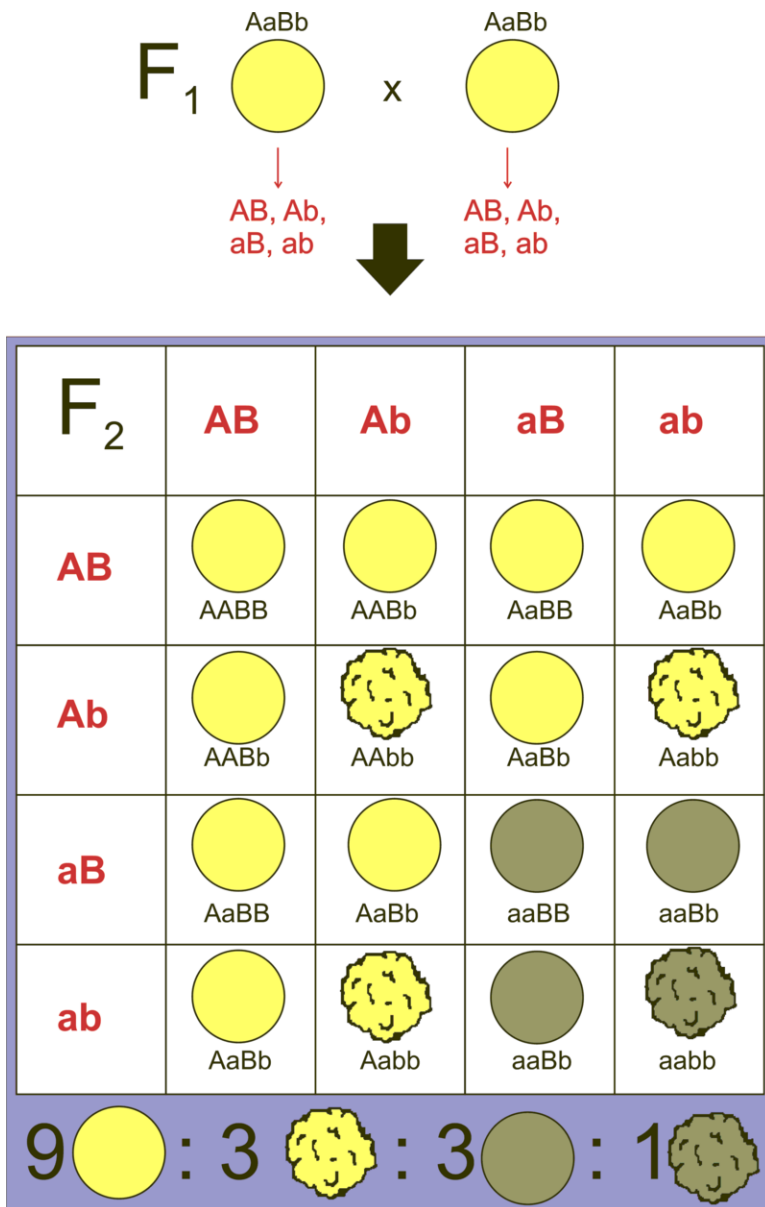
Seed color: B = yellow (dominant); b = green (recessive)

Then Mendel let the F1 plants self-pollinate. Their offspring, the F2 plants, had all possible combinations of the two traits. You can see this in **Figure 3.5**. For example there were plants that had round, green seeds, as well as plants that had wrinkled, yellow seeds. In this case the ratios were 9:3:3:1. The ratios are shown across the bottom of **Figure 3.5**.

Mendel repeated this experiment with other combinations of two traits. In each case, he got the same results. One form of each trait seemed to disappear in the F1 plants. Then these forms reappeared in the F2 plants in all possible combinations. Moreover, the different combinations of traits always occurred in the same 9:3:3:1 ratio.

Law of Independent Assortment

The results of Mendel's two-trait experiments led to the **law of independent assortment**. This law states that factors controlling different traits go to gametes independently of each other. This explains why F2 plants have all possible combinations of the two traits.


FIGURE 3.5

F₂ plants produced when F₁ plants self-pollinate

Mendel's Legacy

You might think that Mendel's discoveries would have made him an instant science rock star. He'd found the answers to age-old questions about heredity. In fact, Mendel's work was largely ignored until 1900. That's when three other scientists independently arrived at Mendel's laws. Only then did people appreciate what a great contribution to science Mendel had made. Mendel's discoveries form the basis of the modern science of genetics. **Genetics** is the science of heredity. For his discoveries, Mendel is now called the "father of genetics."

Lesson Summary

- Gregor Mendel was an Austrian monk who studied heredity in pea plants in the mid-1800s. Peas were a good choice for this purpose for several reasons.
- Mendel first experimented with one trait at a time. This led to his law of segregation. According to this law, the two factors that control a trait separate and go to different gametes.

- Mendel then experimented with two traits at a time. This led to his law of independent assortment. According to this law, the factors that control different traits go to gametes independently of each other.
- Mendel's discoveries were not appreciated until 1900. Now Mendel is called the "father of genetics." Genetics is the science of heredity.

Lesson Review Questions

Recall

1. Who was Gregor Mendel?
2. Why were peas a good choice of plants for Mendel to study?
3. State Mendel's laws.

Apply Concepts

4. Some plants reproduce asexually. What results would Mendel have obtained if he had chosen to study these plants instead of peas?

Think Critically

5. Why did Mendel need to grow two offspring generations (F1 and F2) to develop his law of segregation?
6. Explain how the results of Mendel's second set of experiments led to his law of independent assortment.

Points to Consider

Mendel's research revealed that traits are controlled by "factors" that parents pass to their offspring. Today, we know that Mendel's "factors" are genes.

1. What are genes?
2. How do genes control traits?

3.2 Probability and Heredity

Lesson Objectives

- Define gene and allele.
- Describe the relationship between genotype and phenotype.
- Show how to predict genotype and phenotype ratios in offspring for simple traits.

Lesson Vocabulary

- allele
- genotype
- heterozygote
- homozygote
- phenotype
- Punnett square

Introduction

When Mendel's laws were rediscovered in 1900, scientists were starting to learn about the molecules of heredity. They had already observed chromosomes and seen cells undergoing meiosis. Within a few decades they would learn the structure of DNA and how proteins are made. They would also learn that Mendel's "factors" consist of DNA. We now call these factors genes. For a great review of Mendel's work and an excellent introduction to this lesson, watch this entertaining video:<https://www.youtube.com/watch?v=Mehz7tCxjSE>



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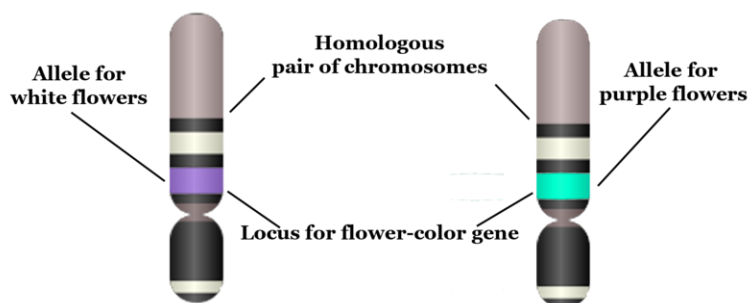
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Genes and Alleles

Today we know that the traits of organisms are controlled by genes on chromosomes. A gene can be defined as a section of a chromosome that contains the genetic code for a particular protein. The position of a gene on a chromosome is called its locus. Each gene may have different versions. The different versions are called **alleles**. **Figure 3.6** shows an example in pea plants. It shows the gene for flower color. The gene has two alleles. There is a purple-flower allele and a white-flower allele. Different alleles account for most of the variation in the traits of organisms within a species.

In sexually reproducing species, chromosomes are present in cells in pairs. Chromosomes in the same pair are called homologous chromosomes. They have the same genes at the same loci. These may be the same or different alleles.

**FIGURE 3.6**

This diagram shows how genes and alleles are related.

During meiosis, when gametes are produced, homologous chromosomes separate. They go to different gametes. Thus, the alleles for each gene also go to different gametes.

Genotype and Phenotype

When gametes unite during fertilization, the resulting zygote inherits two alleles for each gene. One allele comes from each parent.

Genotype

The two alleles that an individual inherits make up the individual's **genotype**. The two alleles may be the same or different. Look at **Table 3.1**. It shows alleles for the flower-color gene in peas. The alleles are represented by the letters B (purple flowers) and b (white flowers). A plant with two alleles of the same type (BB or bb) is called a **homozygote**. A plant with two different alleles (Bb) is called a **heterozygote**.

TABLE 3.1: Genotypes and phenotypes for alleles B and b, with B dominant to b

Genotypes	Phenotypes
BB (homozygote)	purple flowers
Bb (heterozygote)	purple flowers
bb (homozygote)	white flowers

Phenotype

The expression of an organism's genotype is called its **phenotype**. The phenotype refers to the organism's traits, such as purple or white flowers. Different genotypes may produce the same phenotype. This will be the case if one allele is dominant to the other. Both BB and Bb genotypes in Table 6.1 have purple flowers. That's because the B allele is dominant to the b allele, which is recessive. The terms *dominant* and *recessive* are the terms Mendel used to describe his "factors." Today we use them to describe alleles. In a Bb heterozygote, only the dominant B allele is expressed. The recessive b allele is expressed only in the bb genotype.

Mendelian Inheritance

Each trait Mendel studied was controlled by one gene with two alleles. In each case, one of the alleles was dominant to the other. This resulted in just two possible phenotypes for each trait. Each trait Mendel studied was also controlled by a gene on a different chromosome. As a result, each trait was inherited independently of the others. With traits like these, it's easy to predict which forms of a trait will show up in the offspring of a given set of parents.

Predicting Alleles in Gametes

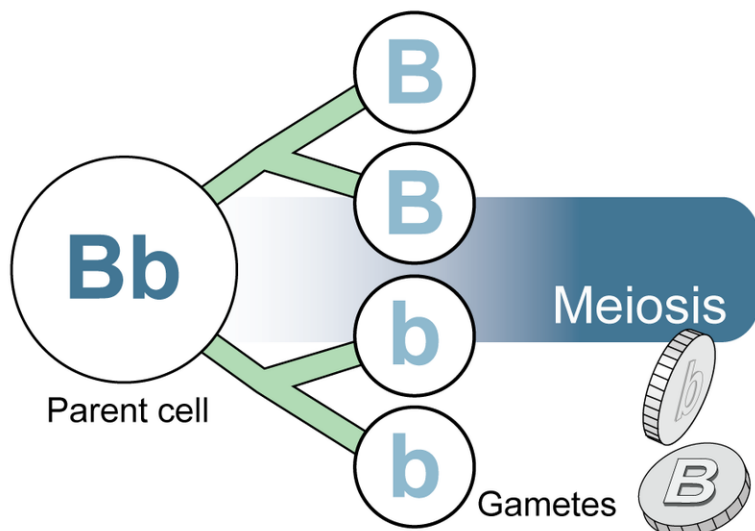


FIGURE 3.7

Gametes from a heterozygote parent (Bb)

Predicting Genotype Ratios

Now let's see what happens if two parent pea plants have the Bb genotype. What genotypes are possible for their offspring? And what ratio of genotypes would you expect? The easiest way to find the answer to these questions is with a Punnett square.

A **Punnett square** is a chart that makes it easy to find the possible genotypes in offspring of two parents. **Figure 3.8** shows a Punnett square for the two parent pea plants. The gametes produced by the male parent are at the top of the chart. The gametes produced by the female parent are along the left side of the chart. The different possible combinations of alleles in their offspring can be found by filling in the cells of the chart.

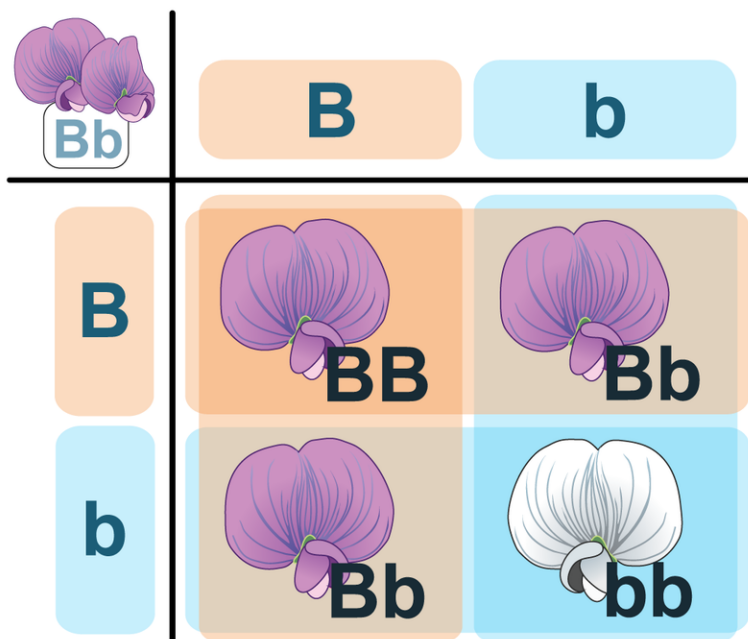


FIGURE 3.8

Punnett square for two Bb parents

If the parents had four offspring, their most likely genotypes would be one BB, two Bb, and one bb. But the genotype ratios of their actual offspring may differ. That's because which gametes happen to unite is a matter of chance, like a coin toss. The Punnett square just shows the possible genotypes and their most likely ratios.

Predicting Phenotype Ratios

You know that the B allele is dominant to the b allele. Therefore, you can also use the Punnett square in **Figure 3.8** to predict the most likely offspring phenotypes. If the parents had four offspring, their most likely phenotypes would be three with purple flowers (1 BB + 2 Bb) and one with white flowers (1 bb).

Lesson Summary

- Traits are controlled by genes on chromosomes. A gene may have different versions called alleles.
- The two alleles for a gene that an individual inherits make up the individual's genotype. The expression of the genotype as a trait is the individual's phenotype.
- Mendel studied simple traits controlled by one gene with two alleles and dominance. For traits like these, Punnett squares can be used to predict possible genotypes and phenotypes and their likely ratios in offspring.

Lesson Review Questions

Recall

1. Write a short paragraph in which you correctly use the concepts chromosome, gene, allele, locus, and trait.

Apply Concepts

2. Use a Punnett square to determine the possible offspring genotypes of parents with the genotypes Bb and bb. Assume that B is the dominant allele for violet flower color in peas and b is the recessive allele for white flower color. What is the expected ratio of violet-flowered to white-flowered offspring based on your Punnett square?

Think Critically

3. Compare and contrast genotype and phenotype.

Points to Consider

Mendel chose wisely when he decided to study garden peas. Today we know that not all organisms follow the basic patterns that he observed.

4. Can you think of a trait that has more than two phenotypes?

3.3 Patterns of Inheritance

Lesson Objectives

- Identify ways traits may be more complex than those studied by Mendel.
- Explain how sex-linked traits are inherited.
- Explain that mutations can alter a gene and are the original source of new variations.

Lesson Vocabulary

- autosome
- mutation
- sex chromosome
- sex-linked trait

Introduction

Inheritance is often more complex than it is for traits like those Mendel studied. Several factors can complicate it.



FIGURE 3.9

Tigers have different color variants due to genetic conditions. Here is a 'normal' tiger pictured with three color variants: a golden tiger whose stripes are a darker orange, not black; a white tiger with black stripes; and a stripeless white tiger.

Non-Medelian Genetics

Codominance and Incomplete Dominance

If a gene has two alleles, one may not be dominant to the other. There are other possibilities. One possibility is called codominance. Another is called incomplete dominance.

- With codominance, both alleles are expressed equally in heterozygotes. The red and white flower in **Figure 3.10** has codominant alleles for red petals and white petals.

- With incomplete dominance, a dominant allele is not completely dominant. Instead, it is influenced by the recessive allele in heterozygotes. The pink flower in **Figure 3.10** is an example. It has an incompletely dominant allele for red petals. It also has a recessive allele for white petals. This results in a flower with pink petals.

**FIGURE 3.10**

Codominance (left) and incomplete dominance (right)

Multiple Alleles

Many genes have more than two alleles. An example is ABO blood type in people. There are three common alleles for the gene that controls this trait. The allele for type A is codominant with the allele for type B. Both of these alleles are dominant to the allele for type O. The possible genotypes and phenotypes for this trait are shown in **Table** below

TABLE 3.2: ABO genotypes and phenotypes

Genotype	Phenotype
AA	Type A
AO	Type A
BB	Type B
BO	Type B
AB	Type AB
OO	Type O

Polygenic Traits

Some traits are controlled by more than one gene. They are called polygenic traits. Each gene for a polygenic trait may have two or more alleles. The genes may be on the same or different chromosomes. Polygenic traits may have many possible phenotypes. Skin color and adult height are examples of polygenic traits in humans. Think about all the variation in the heights of adults you know. Normal adults may range from less than 5 feet tall to more than 7 feet tall. There are people at every gradation of height in between these extremes.

Environmental Influences

Genes play an important role in determining an organism's traits. However, for many traits, phenotype is influenced by the environment as well. For example, skin color is controlled by genes but also influenced by exposure to sunlight. You can see the effect of sunlight on skin in **Figure 3.11**.

**FIGURE 3.11**

Skin color darkens when exposed to the sun.

Sex Chromosomes and Sex-Linked Traits

Animals and most plants have two special chromosomes. They are called **sex chromosomes**. These are chromosomes that determine the sex of the organism. All of the other chromosomes are called **autosomes**. Genes on sex chromosomes may be inherited differently than genes on autosomes.

Human Sex Chromosomes

In people, the sex chromosomes are called X and Y chromosomes. Individuals with two X chromosomes are normally females. Individuals with one X and one Y chromosome are normally males. As you can see in **Figure 3.12**, mothers pass an X chromosome to each of their children. Fathers pass an X to their daughters and a Y to their sons.

Sex-Linked Traits

Traits controlled by genes on the sex chromosomes are called **sex-linked traits**. One gene on the Y chromosome determines male sex. There are very few other genes on the Y chromosome, which is the smallest human chromosome. There are hundreds of genes on the much larger X chromosome. None is related to sex. Traits controlled by genes on the X chromosome are called X-linked traits.

X-linked traits have a different pattern of inheritance than traits controlled by genes on autosomes. With just one X chromosome, males have only one allele for any X-linked trait. Therefore, a recessive X-linked allele is always expressed in males. With two X chromosomes, females have two alleles for any X-linked trait, just as they do for autosomal traits. Therefore, a recessive X-linked allele is expressed in females only when they inherit two copies of it. This explains why X-linked recessive traits show up less often in females than males.

Figure 3.13 shows an example of how red-green color blindness, an x-linked trait can be passed down. In this example, both parents are able to see red and green colors. However, because the mother has one allele for color blindness she is called a carrier for the trait. She passes the allele to half of her children. One daughter is a carrier, and one son has the color blindness trait. No matter how many children this couple has, none of the daughters will have color blindness, but half of the sons, on average, will have the trait. Can you explain why?

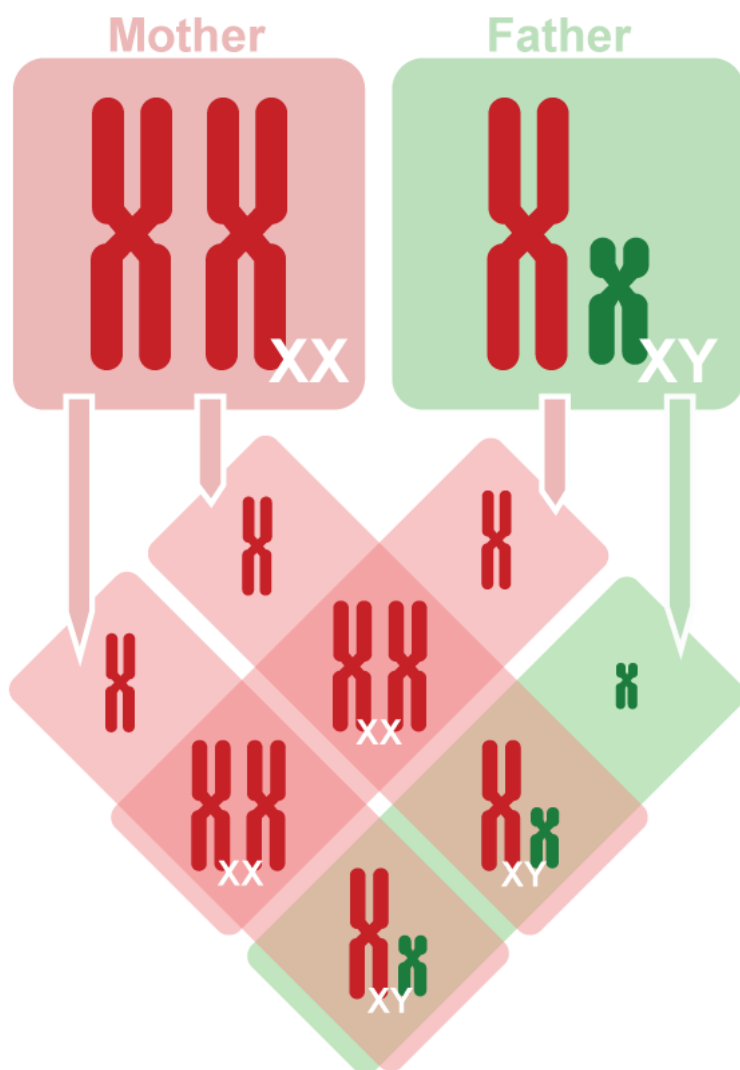


FIGURE 3.12

Inheritance of sex chromosomes

Mutations

When discussing the inheritance patterns of traits, it is important to discuss mutations. Mutations are changes to an organism's DNA. They occur naturally as the cell progresses through the cell cycle or as a result of environmental factors. It is difficult to predict when and where they will first appear. Mutations are an important part of the study of heredity, as they are the ultimate source of **variation** in a population.

Mutations can be harmful, beneficial or silent. Silent mutations have no effect on an organism's phenotype. Whether or not a mutation is considered harmful or beneficial is determined by whether it helps an organism survive and reproduce. Mutations that are harmful will often be eliminated over time, as organisms do not survive or successfully reproduce. Beneficial mutations, on the other hand, will often spread through a population.

Mutations are an important driver of diversity in organisms. They are the source of variation in our world and play a key role in the evolution of species.

X-linked Recessive, Carrier Mother

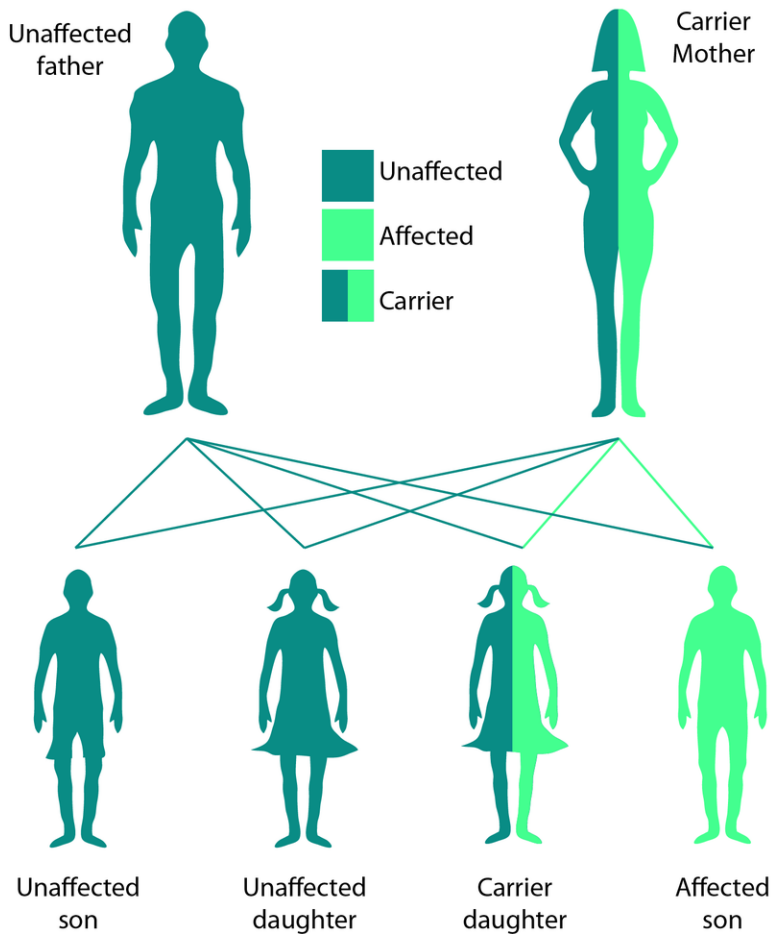


FIGURE 3.13

Pedigree for color blindness

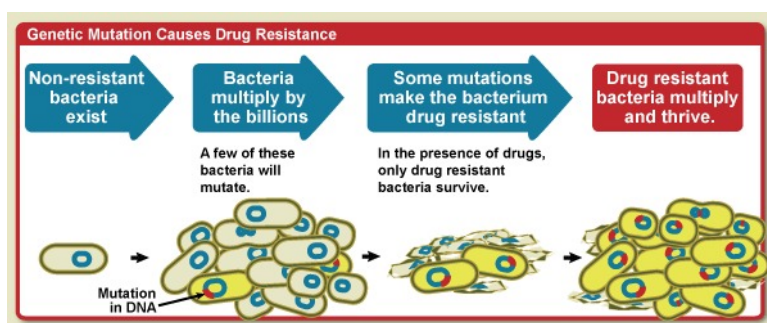


FIGURE 3.14

Bacteria evolve when a random mutation turns out to be beneficial. In this scenario, this mutation prevents the bacteria from being killed by an antibiotic. The mutation is passed on from generation to generation and becomes more common over time.

Lesson Summary

- Inheritance is more complex for traits in which there is codominance or incomplete dominance. Traits may also be controlled by multiple alleles or multiple genes. Many traits are influenced by the environment as well.
- Sex chromosomes determine sex in animals and many plants. Other chromosomes are called autosomes. Sex-linked traits are controlled by genes on sex chromosomes. They may be inherited differently than autosomal traits.

- Mutations can alter a gene and are the original source of new variations.

Lesson Review Questions

Recall

1. What are codominance and incomplete dominance? Give an example of each.
2. What is the difference between a multiple allele trait and a polygenic trait?

Apply Concepts

4. In Japanese four o'clock plants red (R) color is incompletely dominant over white (r) flowers, and the heterozygous condition (Rr) results in plants with pink flowers. Use a Punnett square to determine the possible offspring genotypes for a cross between a red plant and a white plant.

Think Critically

5. Explain why it is the father rather than the mother who determines the sex of their offspring.

Points to Consider

Genetics began with the rediscovery of Mendel's laws in 1900. There have been many advances in genetics since then.

1. What are some recent advances in genetics?
2. What do we now know about human genes?

f I

3.4 Advances in Genetics

Lesson Objectives

- Describe three ways of producing organisms with desired traits.
- Explain the significance of the Human Genome Project.

Lesson Vocabulary

- cloning
- genetic engineering
- gene therapy
- genetically modified organism (GMO)
- genetic disorder
- genome
- Human Genome Project
- selective breeding

Introduction

Humans have been manipulating the inheritance of traits since well before Mendel's times. However, advances in technology have allowed us to go further than ever before.

Selective Breeding

Selective breeding, also called artificial selection, is the process of humans breeding organisms to produce desired results. The image below shows how over time the selective breeding of wild mustard has resulted in a variety of vegetables we eat today.

Selective breeding is still used today by farmers to select for certain characteristics in the food they grow, to increase the productivity of their crops, and to design new fruits and vegetables. Can you think of another organism humans breed in this manner?

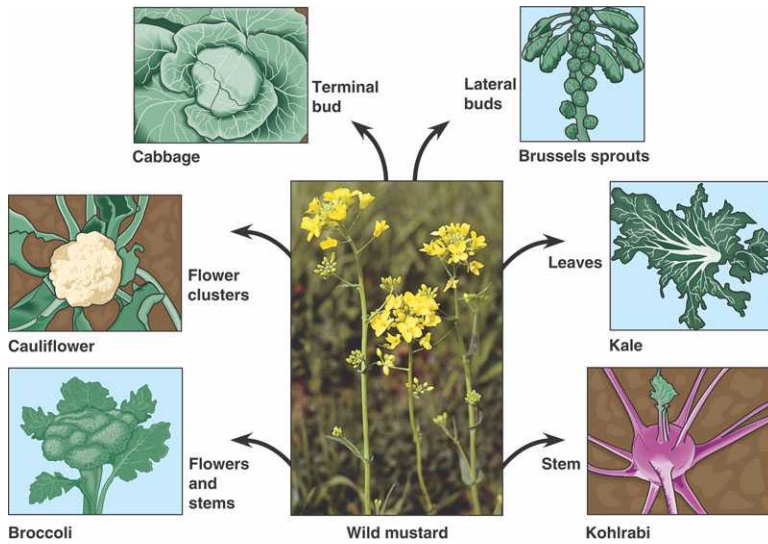
Cloning

A clone is an organism that has exactly the same genes as another organism. They can happen naturally or can be made in the lab.

In nature, some plants and bacteria produce genetically identical offspring through asexual reproduction. Think back to the section on asexual reproduction, can you see how budding or fragmentation results in clones?

Shown below, identical twins, which are another example of naturally occurring clones, occur in humans and other mammals.

Though cloning techniques have been used in the lab for quite some time, most people really started to take notice in 1997 when a sheep, Dolly, was born. She was the first successful animal clone to be created using modern technology.

**FIGURE 3.15**

Broccoli, cauliflower, several kinds of cabbage, kale, brussel sprouts and kohlrabi are all descendants of this wild mustard plant. Farmers selectively bred the plant for particular traits to create these varieties. For instance, wild mustard plants with larger leaves were selectively bred for generations resulting in the large leaved Kale we have today.

**FIGURE 3.16**

Identical twins are a great example of naturally occurring clones.

There are three different types of artificial cloning, that is cloning that does not occur naturally. The types are gene cloning, reproductive cloning and therapeutic cloning.

- **Gene cloning** produces copies of genes or segments of DNA.
- **Reproductive cloning** produces copies of whole animals.
- **Therapeutic cloning** produces stem cells that can be used for experiments. The purpose of most therapeutic cloning is to create tissues to replace injured or diseased tissues.

Genetic Engineering

Genetic engineering is the use of technology to change the genetic makeup of living things for human purposes. It has many uses. It is especially useful in medicine and agriculture. Genetic engineering is used to

- treat genetic disorders. For example, copies of a normal gene might be inserted into a patient with a defective



FIGURE 3.17

Dolly

gene. This is called **gene therapy**. Ideally, it can cure a genetic disorder.

- create **genetically modified organisms (GMOs)**. Many GMOs are food crops such as corn. Genes are inserted into plants to give them desirable traits. This might be the ability to get by with little water. Or it might be the ability to resist insect pests. The modified plants are likely to be healthier and produce more food. They may also need less pesticide.
- produce human proteins. Insulin is one example. This protein is needed to treat diabetes. The human insulin gene is inserted into bacteria. The bacteria reproduce rapidly. They can produce large quantities of the human protein.

Sequencing the Human Genome

A species' **genome** consists of all of its genetic information. The human genome consists of the complete set of genes in the human organism. It's all the DNA of a human being.

The Human Genome Project

The **Human Genome Project** was launched in 1990. It was an international effort to sequence all 3 billion bases in human DNA. Another aim of the project was to identify the more than 20,000 human genes and map their locations on chromosomes. The logo of the Human Genome Project in **Figure 3.18** shows that the project brought together experts in many fields.

The Human Genome Project was completed in 2003. It was one of the greatest feats of modern science. It provides a complete blueprint for a human being. It's like having a very detailed manual for making a human organism.

Applications of the Sequence

Knowing the sequence of the human genome is very useful. For example, it helps us understand how humans evolved. Another use is in medicine. It is helping researchers identify and understand genetic disorders. You can learn more about the Human Genome Project and its applications by watching this funny, fast-paced video: <http://www.youtube.com/watch?v=F5LzKupeHtw> .

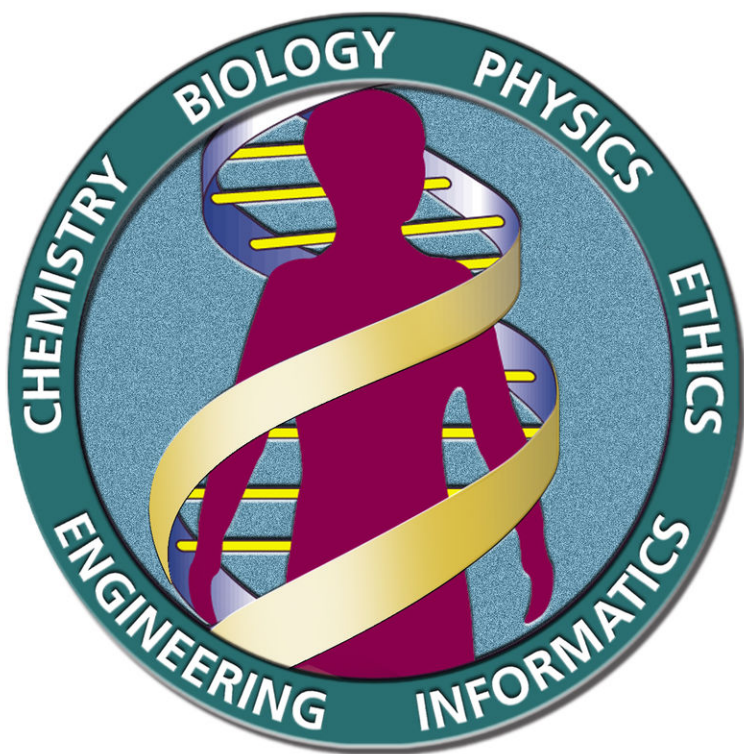
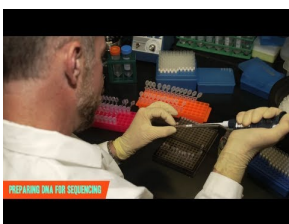


FIGURE 3.18

Human Genome Project logo



MEDIA

Click image to the left or use the URL below.

URL: <http://www.ck12.org/flx/render/embeddedobject/149621>

Sequencing the human genome has increased our knowledge of genetic disorders. **Genetic disorders** are diseases caused by mutations. A mutation is a change in the DNA sequence within an organism's genome. Many genetic disorders are caused by mutations in a single gene. Others are caused by abnormal numbers of chromosomes.

Disorders Caused by Single Gene Mutations

Table 3.3 lists some genetic disorders caused by mutations in just one gene. It include autosomal and X-linked disorders. It also includes dominant and recessive disorders.

TABLE 3.3: Examples of human genetic disorders caused by single gene mutations

Genetic Disorder	Effect of Mutation	Signs of the Disorder	Type of Trait
Marfan syndrome	Defective protein in tissues such as cartilage and bone	Heart and bone defects; unusually long limbs	Autosomal dominant

TABLE 3.3: (continued)

Genetic Disorder	Effect of Mutation	Signs of the Disorder	Type of Trait
Cystic fibrosis	Defective protein needed to make mucus	Unusually thick mucus that clogs airways in lungs and ducts in other organs	Autosomal recessive
Sickle Cell Anemia	Defective hemoglobin protein that is needed to transport oxygen in red blood cells	Sickle-shaped red blood cells that block blood vessels and interrupt blood flow	Autosomal recessive
Hemophilia A	Reduced activity of a protein needed for blood to clot	Excessive bleeding that is difficult to control	X-linked recessive

Relatively few genetic disorders are caused by dominant alleles. A dominant allele is expressed in everybody who inherits even one copy of it. If it causes a serious disorder, affected people may die young and fail to reproduce. They won't pass the allele to the next generation. As a result, the allele may die out of the population. One of the exceptions is Marfan syndrome. It is thought to have affected Abraham Lincoln. He's pictured in **Figure 3.19**. His very long limbs are one reason for the suspicion of Marfan syndrome in this former U.S. president.

Recessive disorders are more common than dominant ones. Why? A recessive allele is not expressed in heterozygotes. These people are called carriers. They don't have the genetic disorder but they carry the recessive allele. They can also pass this allele to their offspring. A recessive allele is more likely than a dominant allele to pass to the next generation rather than die out.

It is important to note that not all mutations result in disorders. Mutations are simply changes in the DNA sequence. As discussed in the previous section, they can have no impact or even benefit an individual's traits.

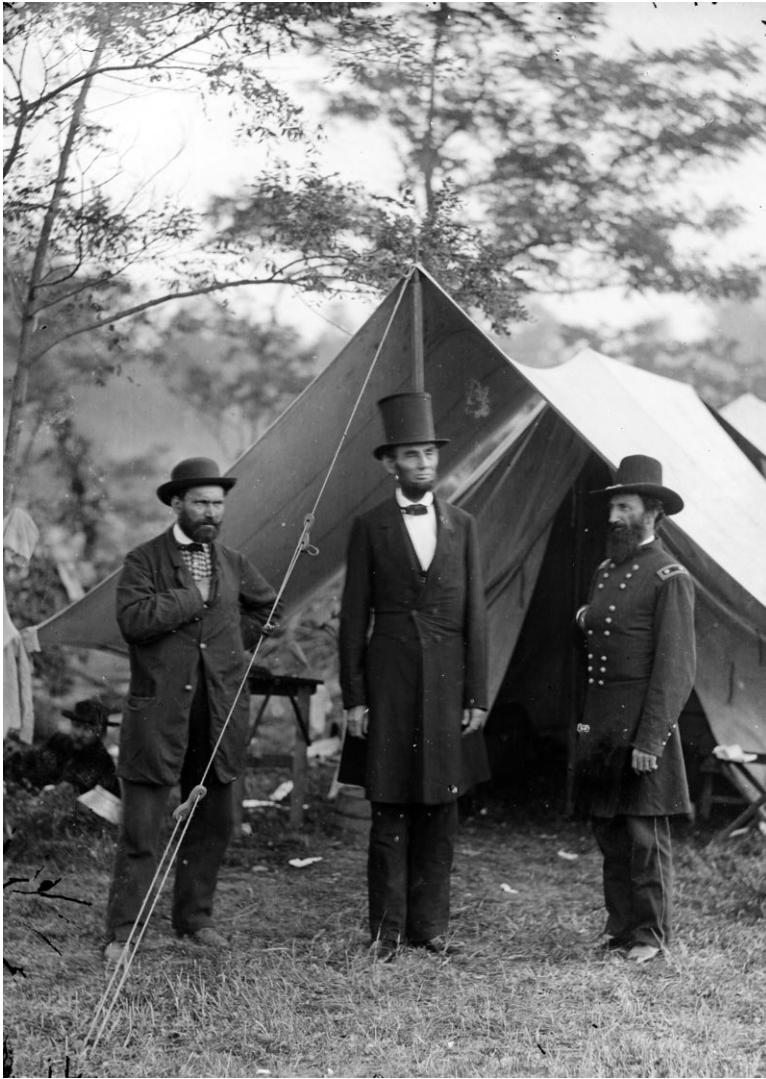
Concerns about Genetic Advancements

Modern technology has allowed us to explore and manipulate genetics in new and exciting ways. It is clear that our genetic advancements have many benefits. They help solve human problems. However, these advancements also raise many concerns. For example, some people worry about eating foods that contain GMOs. They wonder if GMOs might cause health problems. The person in **Figure 3.20** favors the labeling of foods that contain GMOs. That way, consumers can know which foods contain them and decide for themselves whether to eat them.

Another concern about these advancements is how they may affect the environment. Negative effects on the environment have already occurred because of some GMOs. For example, corn has been created that has a gene for a pesticide. The corn plants have accidentally cross-pollinated nearby milkweeds. Monarch butterfly larvae depend on milkweeds for food. When they eat milkweeds with the pesticide gene, they are poisoned. This may threaten the survival of the monarch species as well as other species that eat monarchs. Do the benefits of the genetically modified corn outweigh the risks? What do you think?

Lesson Summary

- Selective breeding, cloning and genetic engineering are three different methods used to change organisms so they are more useful to people or treat genetic illness.
- A species' genome consists of all of its genetic information. One of the greatest advances in modern genetics was sequencing the human genome. This was achieved in 2003 by the Human Genome Project.
- Sequencing the human genome has increased our knowledge of genetic disorders. These are diseases caused by mutations.

**FIGURE 3.19**

Abraham Lincoln (center) may have had the genetic disorder Marfan syndrome

Lesson Review Questions

Recall

1. Define genetic engineering and discuss one of its applications.
2. Define genome.
3. What was the Human Genome Project? What had it accomplished by 2003?
4. Identify and describe one genetic disorder caused by a single gene mutation.

Apply Concepts

4. Which type of cloning do you feel has the greatest potential to change our world?

Think Critically

5. Weigh the pros and cons of using biotechnology to produce genetically modified organisms.



FIGURE 3.20

Chances are that some of the foods you eat contain GMOs. However, they may not be labeled that way.

Points to Consider

Biotechnology can be used to artificially change the genetic makeup of organisms in a species.

1. How can the genetic makeup of a species change naturally?
2. What might be the outcome of this type of change?

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