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CK-12 Biology

AP Biology Summer 18

Jean Brainard, Ph.D.

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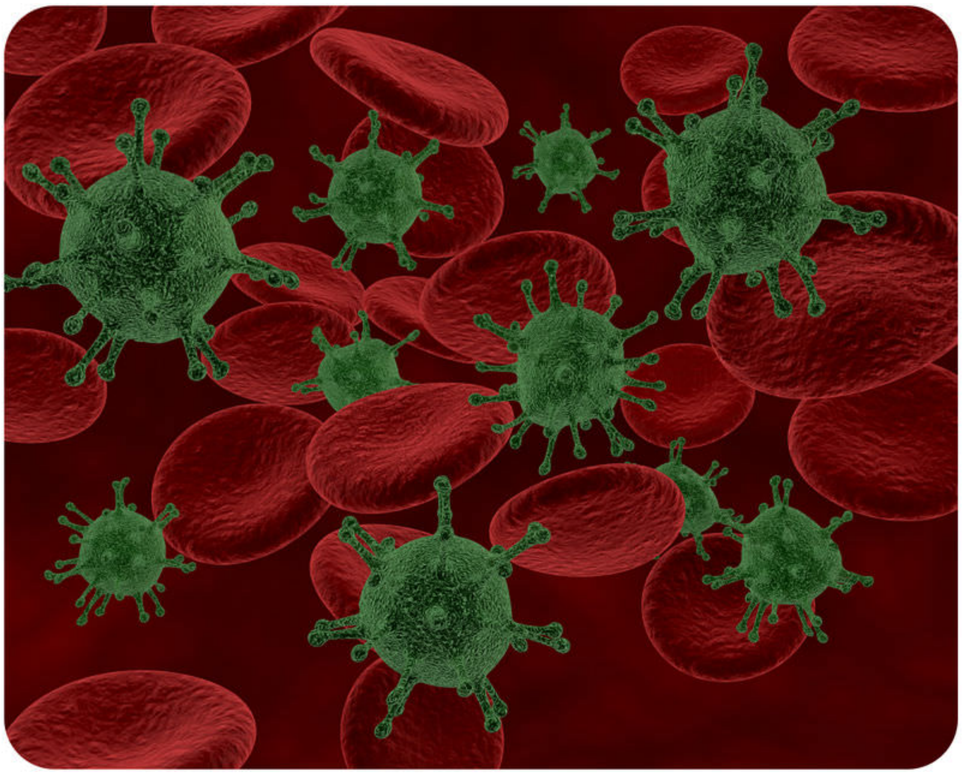

Is this picture a colorful work of abstract art, or is it something else? Imagine shrinking down to a tiny size, so small you could enter a blood vessel. This illustration shows what you might see rushing toward you. Do you know what the red objects are? If you guessed red blood cells, you are right. What about the knobby green objects? Watch out for these! They are viruses that have invaded the blood. However, this image is not scale, in reality viruses are much smaller in relationship to the red blood cells pictured here.

When you read this book, you will take an exciting journey into the realm of blood cells, viruses, and just about everything else that is related to life. You will learn how your own body works, what makes living things unique, and what you and viruses have in common. This first chapter explains how scientists learn about the natural world and introduces you to biology, the science of life.

1.1 Science and the Natural World

Lesson Objectives

- Identify the goal of science.
- Describe how scientists study the natural world.
- Explain how and why scientists do experiments.
- Describe types of scientific investigations.
- Explain what a scientific theory is.

Vocabulary

- dependent variable
- evidence
- experiment
- hypothesis
- independent variable
- model
- observation
- prediction
- science
- scientific investigation
- scientific law
- scientific method
- scientific theory

Introduction

Did you ever wonder why giraffes have such long necks or how birds learn to sing their special songs? If you ever asked questions such as these about the natural world, then you were thinking like a scientist. The word *science* comes from a Latin word that means "knowledge." **Science** is a distinctive way of gaining knowledge about the natural world that starts with a question and then tries to answer the question with evidence and logic. Science is an exciting exploration of all the whys and hows that any curious person might have about the world. You can be part of that exploration. Besides your curiosity, all you need is a basic understanding of how scientists think and how science is done, starting with the goal of science.

The Goal of Science

The goal of science is to understand the natural world. To achieve this goal, scientists make certain assumptions. They assume that:

- Nature can be understood through systematic study.
- Scientific ideas are open to revision.
- Sound scientific ideas withstand the test of time.
- Science cannot provide answers to all questions.

Nature Can Be Understood

Scientists think of nature as a single system controlled by natural laws. By discovering natural laws, scientists strive to increase their understanding of the natural world. Laws of nature are expressed as scientific laws. A **scientific law** is a statement that describes what always happens under certain conditions in nature.

An example of a scientific law is the law of gravity, which was discovered by Sir Isaac Newton (see **Figure** 1.1). The law of gravity states that objects always fall towards Earth because of the pull of gravity. Based on this law, Newton could explain many natural events. He could explain not only why objects such as apples always fall to the ground, but he could also explain why the moon orbits Earth. Isaac Newton discovered laws of motion as well as the law of gravity. His laws of motion allowed him to explain why objects move as they do.

FIGURE 1.1
Did Newton discover the law of gravity when an apple fell from a tree and hit him on the head? Probably not, but observations of nature are often the starting point for new ideas about the natural world.

Scientific Ideas Can Change

Science is more of a process than a set body of knowledge. Scientists are always testing and revising their ideas, and as new observations are made, existing ideas may be challenged. Ideas may be replaced with new ideas that better fit the facts, but more often existing ideas are simply revised. For example, when Albert Einstein developed his theory of relativity, he didn't throw out Newton's laws of motion. Instead, he showed that Newton's laws are a part of a bigger picture. In this way, scientists gradually build an increasingly accurate and detailed understanding of the natural world.

Scientific Knowledge Can Withstand the Test of Time

Many scientific ideas have withstood the test of time. For example, about 200 years ago, the scientist John Dalton proposed atomic theory—the theory that all matter is made of tiny particles called atoms. This theory is still valid today. There are many other examples of basic science ideas that have been tested repeatedly and found to be true. You will learn about many of them as you study biology.

Science Cannot Answer All Questions

Science rests on evidence and logic, so it deals only with things that can be observed. An **observation** is anything that is detected either through human senses or with instruments and measuring devices that extend human senses. Things that cannot be observed or measured by current means—such as supernatural beings or events—are outside the bounds of science. Consider these two questions about life on Earth:

- Did life on Earth evolve over time?
- Was life on Earth created through another method?

The first question can be answered by science on the basis of scientific evidence and logic. The second question could be a matter of belief. Therefore, it is outside the realm of science.

Why I Do Science

Dan Costa, Ph.D. is a professor of Biology at the University of California, Santa Cruz, and has been studying marine life for well over 40 years. He is a leader in using satellite tags, time and depth recorders and other sophisticated electronic tags to gather information about the amazing depths to which elephant seals dive, their migration routes and how they use oceanographic features to hunt for prey as far as the international dateline and the Alaskan Aleutian Islands. In the following KQED video, Dr. Costa discusses why he is a scientist:

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The Scientific Method

"We also discovered that science is cool and fun because you get to do stuff that no one has ever done before." In the article *Blackawton bees,* published by eight to ten year old students: Biology Letters (2010) http://rsbl.royalsocietypublishing.org/content/early/2010/12/18/rsbl.2010.1056.abstract .

There are basic methods of gaining knowledge that are common to all of science. At the heart of science is the scientific investigation, which is done by following the **scientific method**. A **scientific investigation** is a plan for asking questions and testing possible answers. It generally follows the steps listed in **Figure** 1.2. See http://www.youtube.com/watch?v=KZaCy5Z87FA for an overview of the scientific method.

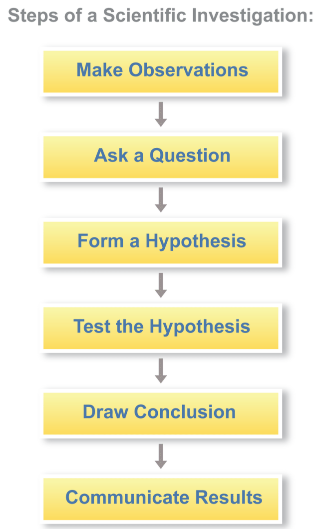


FIGURE 1.2
Steps of a Scientific Investigation. A scientific investigation typically has these steps.

Making Observations

A scientific investigation typically begins with observations. You make observations all the time. Let's say you take a walk in the woods and observe a moth, like the one in **Figure** 1.3, resting on a tree trunk. You notice that the moth has spots on its wings that look like eyes. You think the eye spots make the moth look like the face of an owl.

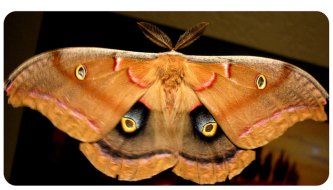


FIGURE 1.3
Does this moth remind you of an owl?

Asking a Question

Observations often lead to questions. For example, you might ask yourself why the moth has eye spots that make it look like an owl's face. What reason might there be for this observation?

Forming a Hypothesis

The next step in a scientific investigation is forming a hypothesis. A **hypothesis** is a possible answer to a scientific question, but it isn't just any answer. A hypothesis must be based on scientific knowledge, and it must be logical. A hypothesis also must be falsifiable. In other words, it must be possible to make observations that would disprove the hypothesis if it really is false. Assume you know that some birds eat moths and that owls prey on other birds. From this knowledge, you reason that eye spots scare away birds that might eat the moth. This is your hypothesis.

Testing the Hypothesis

To test a hypothesis, you first need to make a prediction based on the hypothesis. A **prediction** is a statement that tells what will happen under certain conditions. It can be expressed in the form: If A occurs, then B will happen. Based on your hypothesis, you might make this prediction: If a moth has eye spots on its wings, then birds will avoid eating it.

Next, you must gather evidence to test your prediction. **Evidence** is any type of data that may either agree or disagree with a prediction, so it may either support or disprove a hypothesis. Assume that you gather evidence by making more observations of moths with eye spots. Perhaps you observe that birds really do avoid eating the moths. This evidence agrees with your prediction.

Drawing Conclusions

Evidence that agrees with your prediction supports your hypothesis. Does such evidence prove that your hypothesis is true? No; a hypothesis cannot be proven conclusively to be true. This is because you can never examine all of the possible evidence, and someday evidence might be found that disproves the hypothesis. Nonetheless, the more evidence that supports a hypothesis, the more likely the hypothesis is to be true.

Communicating Results

The last step in a scientific investigation is communicating what you have learned with others. This is a very important step because it allows others to test your hypothesis. If other researchers get the same results as yours, they add support to the hypothesis. However, if they get different results, they may disprove the hypothesis.

When scientists share their results, they should describe their methods and point out any possible problems with the investigation. For example, while you were observing moths, perhaps your presence scared birds away. This introduces an error into your investigation. You got the results you predicted (the birds avoided the moths while you were observing them), but not for the reason you hypothesized. Other researchers might be able to think of ways to avoid this error in future studies.

Experiments

Figure 1.4 shows a laboratory experiment involving plants. An **experiment** is a special type of scientific investigation that is performed under controlled conditions, usually in a laboratory. Some experiments can be very simple, but even the simplest contributed important evidence that helped scientists better understand the natural world. An example experiment can be seen here http://www.youtube.com/watch?v=dVRBDRAsP6U or here http://www.youtube.com/watch?v=F10EyGwd57M .

FIGURE 1.4

A laboratory experiment studying plant growth. What might this experiment involve?

Variables

An experiment generally tests how one variable is affected by another. The affected variable is called the **dependent variable**. In the plant experiment shown in the **Figure** 1.4, the dependent variable is plant growth. The variable that affects the dependent variable is called the **independent variable**. In the plant experiment, the independent variable is fertilizer—some plants will get fertilizer, others will not. In any experiment, other factors that might affect the dependent variable must be controlled. In the plant experiment, what factors do you think should be controlled? (*Hint:* What other factors might affect plant growth?)

Sample Size and Repetition

The sample in an experiment or other investigation consists of the individuals or events that are studied. Typically, the sample is much smaller than all such individuals or events that exist in the world. Whether the results based on the sample are true in general cannot be known for certain. However, the larger the sample is, the more likely it is that the results are generally true. Similarly, the more times that an experiment is repeated and the same results obtained, the more likely the results are valid. This is why scientific experiments should always be repeated.

Other Types of Scientific Investigations

Experiments are sometimes hard or even impossible to do. For example, a scientist who is studying an extinct animal cannot experiment with the animal because it no longer exists. The scientist must rely instead on evidence in the natural world, such as fossils that the extinct animal left behind.

Natural Studies

When scientists do studies in nature, they usually cannot control factors that might affect the variables they are investigating. This is a drawback, because it may make the observations difficult to interpret. Without controls, it may not be possible to determine which of many factors explain the observations. For example, assume you are studying how plants grow in a forest or field. You cannot control the amount of sunlight or rain water the plants receive, so it will be difficult to determine which factors most influence plant growth. On the other hand, a natural study shows what actually occurs in nature. Therefore, it may provide a truer picture of what happens in the real world than an experiment does.

Modeling

Another way to gain scientific knowledge without experiments is by making and manipulating models. A **model** is a representation of part of the real world. Did you ever build a model car? Scientific models are something like model cars; they represent the real world but are simpler than the real world. This is one reason that models are especially useful for investigating complex systems. By using a model, scientists can better understand how the real system works. An example of a scientific model is shown in **Figure** 1.5. Do you know what systems these two models represent?

Like a hypothesis, a model must be evaluated. It is assessed by criteria such as how well it represents the real world, what limitations it has, and how useful it is. The usefulness of a model depends on how well its predictions match

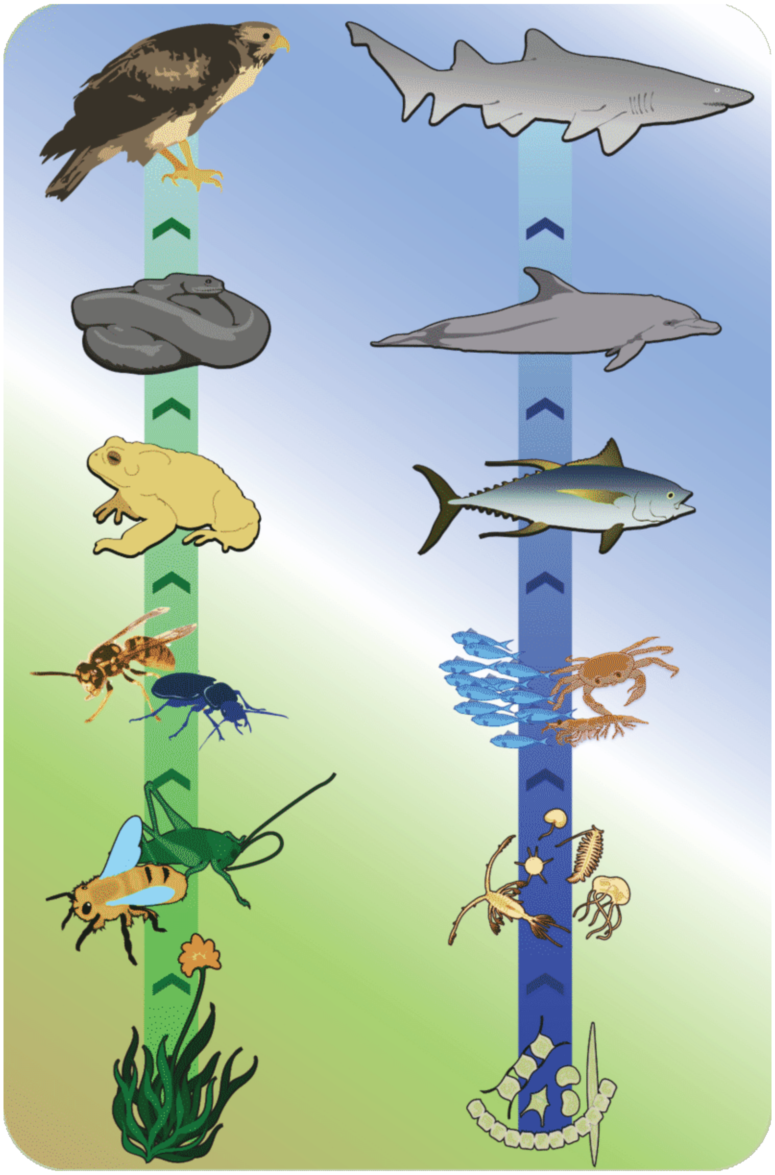


FIGURE 1.5
Food Chains. These two food chains represent complex systems in nature. They make the systems easier to understand. These are simple conceptual models. Models of very complex systems are often based on mathematical equations or computer simulations.

observations of the real world. Even when a model's predictions match real-world observations, however, it doesn't prove that the model is true or that it is the only model that works.

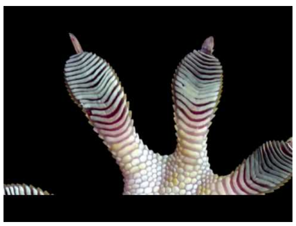
Scientific Theories

With repeated testing, some hypotheses may eventually become scientific theories. A **scientific theory** is a broad explanation for events that is widely accepted as true. To become a theory, a hypothesis must be tested over and over again, and it must be supported by a great deal of evidence.

People commonly use the word *theory* to describe a guess about how or why something happens. For example, you might say, "I think a woodchuck dug this hole in the ground, but it's just a theory." Using the word *theory* in this way is different from the way it is used in science. A scientific theory is more like a fact than a guess because it is so well-supported. There are several well-known theories in biology, including the theory of evolution, cell theory, and germ theory. You will read about all three of these theories in the next lesson "Biology: The Study of Life." A video explaining scientific theories can be seen at http://www.youtube.com/watch?v=S5YGhprR6KE .

KQED: Bio-Inspiration: Nature as Muse

For hundreds of years, scientists have been using design ideas from structures in nature. Now, biologists and engineers at the University of California, Berkeley are working together to design a broad range of new products, such as life-saving milli-robots modeled on the way cockroaches run and adhesives based on the amazing design of a gecko's foot. This process starts with making observations of nature, which lead to asking questions and to the additional aspects of the scientific process. *Bio-Inspiration: Nature as Muse* can be observed at :



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Lesson Summary

- The goal of science is to understand the natural world through systematic study. Scientific knowledge is based on evidence and logic.
- Scientists gain knowledge through scientific investigations. A scientific investigation is a plan for asking questions and testing possible answers.
- Scientists use experiments to test hypotheses under controlled conditions. Experiments are often done in a lab.
- Other types of scientific investigations include natural studies and modeling. They can be used when experiments are difficult to do.
- Scientific theories are broad explanations that are widely accepted as true. This is because they are supported by a great deal of evidence.

Lesson Review Questions

Recall

1. What is science? What is the goal of science?

2. Outline the steps of a scientific investigation.

3. What is a scientific hypothesis? What characteristics must a hypothesis have to be useful in science?

4. Give an example of a scientific question that could be investigated with an experiment. Then give an example of scientific question that could not be investigated in this way.

5. What might be an advantage of collecting evidence in a natural setting rather than in a lab?

Apply Concepts

6. Identify the independent and dependent variables in the following experiment:

A scientist grew bacteria on gel in her lab. She wanted to find out if the bacteria would grow faster on gel A or gel B. She placed a few bacteria on gel A and a few on gel B. After 24 hours, she observed how many bacteria were present on each type of gel.

Think Critically

7. Explain why science cannot provide answers to all questions.

8. Contrast how the term *theory* is used in science and in everyday language.

9. Explain how a hypothesis could become a theory.

Points to Consider

The Points to Consider at the end of each lesson in this book will help you relate what you just learned to what is coming next. The questions will help guide you to the next lesson or chapter. Before reading the next lesson of this chapter, consider these points:

- Remember the opening photo of red blood cells and green viruses? The blood cells are cells of a living thing. Do you think that the viruses are living things? Why or why not?
- Lab experiments are the main method of gathering evidence in some branches of science. Why might lab experiments not be the best way to study living things, such as wild animals?

1.2 Biology: The Study of Life

Lesson Objectives

- List the characteristics of all living things.
- State four unifying principles of biology.
- Describe how living things interact.
- Explain how life on Earth evolves.

Vocabulary

- adaptation
- biodiversity
- biology
- biome
- biosphere
- cell
- cell theory
- community
- competition
- ecosystem
- evolution
- gene theory
- homeostasis
- natural selection
- organ
- organ system
- organism
- population
- reproduction
- symbiosis
- tissue

Introduction

In this book, you will learn about one particular branch of science, the branch called biology. **Biology** is the science of life. Do you know what life is? Can you define it? Watch http://vimeo.com/15407847 to begin your journey into the study of life.

Characteristics of Life

Look at the duck decoy in **Figure** 1.6. It looks very similar to a real duck. Of course, real ducks are living things. What about the decoy duck? It looks like a duck, but it is actually made of wood. The decoy duck doesn't have all the characteristics of a living thing. What characteristics set the real ducks apart from the decoy duck? What are the characteristics of living things?

FIGURE 1.6
This duck decoy looks like it's alive. It even fools real ducks. Why isn't it a living thing?

To be classified as a living thing, an object must have all six of the following characteristics:

1. It responds to the environment.
2. It grows and develops.
3. It produces offspring.
4. It maintains homeostasis.
5. It has complex chemistry.
6. It consists of cells.

Response to the Environment

All living things detect changes in their environment and respond to them. What happens if you step on a rock? Nothing; the rock doesn't respond because it isn't alive. But what if you think you are stepping on a rock and actually step on a turtle shell? The turtle is likely to respond by moving—it may even snap at you!

Growth and Development

All living things grow and develop. For example, a plant seed may look like a lifeless pebble, but under the right conditions it will grow and develop into a plant. Animals also grow and develop. Look at the animals in **Figure** 1.7. How will the tadpoles change as they grow and develop into adult frogs?

Reproduction

All living things are capable of reproduction. **Reproduction** is the process by which living things give rise to offspring. Reproducing may be as simple as a single cell dividing to form two daughter cells. Generally, however, it is much more complicated. Nonetheless, whether a living thing is a huge whale or a microscopic bacterium, it is capable of reproduction.

FIGURE 1.7
Tadpoles go through many changes to become adult frogs.

Keeping Things Constant

All living things are able to maintain a more-or-less constant internal environment. They keep things relatively stable on the inside regardless of the conditions around them. The process of maintaining a stable internal environment is called **homeostasis**. Human beings, for example, maintain a stable internal body temperature. If you go outside when the air temperature is below freezing, your body doesn't freeze. Instead, by shivering and other means, it maintains a stable internal temperature.

Complex Chemistry

All living things—even the simplest life forms—have complex chemistry. Living things consist of large, complex molecules, and they also undergo many complicated chemical changes to stay alive. Complex chemistry is needed to carry out all the functions of life.

Cells

All forms of life are built of cells. A **cell** is the basic unit of the structure and function of living things. Living things may appear very different from one another on the outside, but their cells are very similar. Compare the human cells and onion cells in **Figure** 1.8. How are they similar? If you click on the animation titled *Inside a Cell* at the link below, you can look inside a cell and see its internal structures. http://bio-alive.com/animations/cell-biology.htm

Unifying Principles of Biology

Four unifying principles form the basis of biology. Whether biologists are interested in ancient life, the life of bacteria, or how humans could live on the moon, they base their overall understanding of biology on these four principles:

1. cell theory

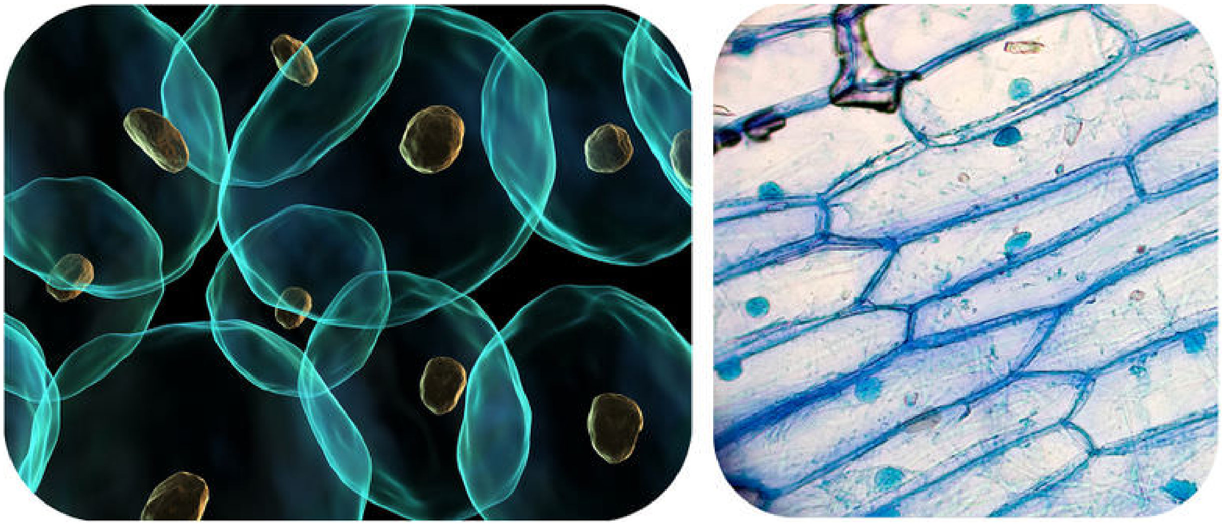

FIGURE 1.8
A representation of human cells (left) and onion cells (right). If you looked at human and onion cells under a microscope, this is what you might see.

2. gene theory
3. homeostasis
4. evolution

The Cell Theory

According to the **cell theory**, all living things are made up of cells, and living cells always come from other living cells. In fact, each living thing begins life as a single cell. Some living things, such as bacteria, remain single-celled. Other living things, including plants and animals, grow and develop into many cells. Your own body is made up of an amazing 100 trillion cells! But even you—like all other living things—began life as a single cell. More of the cell theory will be discussed in a later chapter.

The Gene Theory

The **gene theory** is the idea that the characteristics of living things are controlled by genes, which are passed from parents to their offspring. Genes are located on larger structures, called chromosomes, that are found inside every cell. Chromosomes, in turn, contain large molecules known as DNA (deoxyribonucleic acid). Molecules of DNA are encoded with instructions that tell cells what to do. To see how this happens, click on the animation titled *Journey into DNA* at the link below. http://www.pbs.org/wgbh/nova/genome/dna.html

Homeostasis

Homeostasis, or keeping things constant, is not just a characteristic of living things. It also applies to nature as a whole. Consider the concentration of oxygen in Earth's atmosphere. Oxygen makes up 21% of the atmosphere, and this concentration is fairly constant. What keeps the concentration of oxygen constant? The answer is living things.

Most living things need oxygen to survive, and when they breathe, they remove oxygen from the atmosphere. On the other hand, many living things, including plants, give off oxygen when they make food, and this adds oxygen to the atmosphere. The concentration of oxygen in the atmosphere is maintained mainly by the balance between these two processes. A quick overview of homeostasis can be viewed at http://www.youtube.com/watch?v=DFyt7FJn-UM .

Evolution

Evolution is a change in the characteristics of living things over time. Evolution occurs by a process called natural selection. In **natural selection**, some living things produce more offspring than others, so they pass more genes to the next generation than others do. Over many generations, this can lead to major changes in the characteristics of living things. Evolution explains how living things are changing today and how modern living things have descended from ancient life forms that no longer exist on Earth.

As living things evolve, they generally become better suited for their environment. This is because they evolve adaptations. An **adaptation** is a characteristic that helps a living thing survive and reproduce in a given environment. Look at the mole in **Figure** 1.9. It has tentacles around its nose that it uses to sense things by touch. The mole lives underground in the soil where it is always dark. However, by using its touch organ, it can detect even tiny food items in the soil in total darkness. The touch organ is an adaptation because it helps the mole survive in its dark, underground environment.

FIGURE 1.9
This mole uses its star-shaped nose organ to sense food by touch in the dark. The mole's very large front claws are also an adaptation for its life in the soil. Can you explain why?

Interdependence of Living Things

All living things depend on their environment to supply them with what they need, including food, water, and shelter. Their environment consists of physical factors—such as soil, air, and temperature—and also of other organisms. An **organism** is an individual living thing. Many living things interact with other organisms in their environment. In fact, they may need other organisms in order to survive. For example, living things that cannot make their own food must eat other organisms for food. Other interactions between living things include symbiosis and competition.

Symbiosis

Symbiosis is a close relationship between organisms of different species in which at least one of the organisms benefits. The other organism may also benefit, or it may be unaffected or harmed by the relationship. **Figure** 1.10 shows an example of symbiosis. The birds in the picture are able to pick out food from the fur of the deer. The deer won't eat the birds. In fact, the deer knowingly lets the birds rest on it. What, if anything, do you think the deer gets out of the relationship?

FIGURE 1.10
A flock of starlings looks out, before searching for parasites on a red deer stag.

Competition

Competition is a relationship between living things that depend on the same resources. The resources may be food, water, or anything else they both need. Competition occurs whenever they both try to get the same resources in the same place and at the same time. The two organisms are likely to come into conflict, and the organism with better adaptations may win out over the other organism.

Levels of Organization

The living world can be organized into different levels. For example, many individual organisms can be organized into the following levels:

- Cell: basic unit of all living things
- **Tissue**: group of cells of the same kind
- **Organ**: structure composed of one or more types of tissues
- **Organ system**: group of organs that work together to do a certain job
- Organism: individual living thing that may be made up of one or more organ systems

Examples of these levels of organization are shown in **Figure** 1.11.

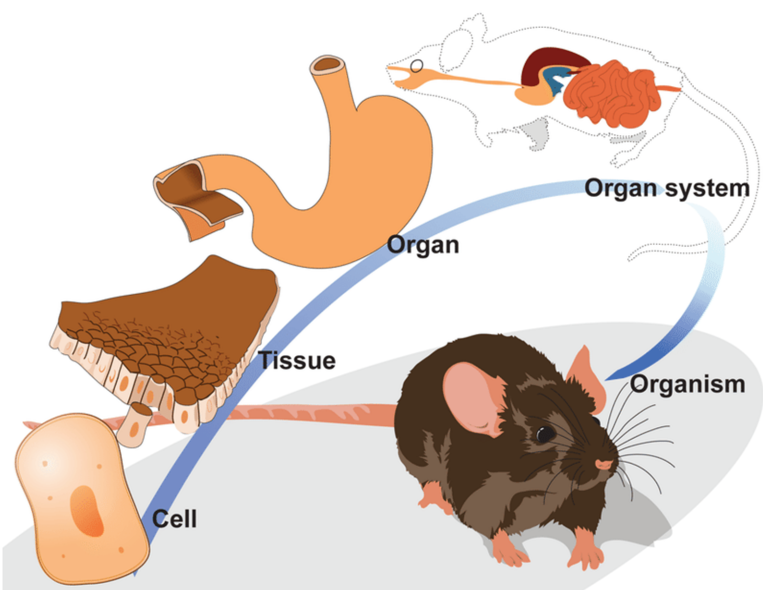

FIGURE 1.11
An individual mouse is made up of several organ systems. The system shown here is the digestive system, which breaks down food to a form that cells can use. One of the organs of the digestive system is the stomach. The stomach, in turn, consists of different types of tissues. Each type of tissue is made up of cells of the same type.

There are also levels of organization above the individual organism. These levels are illustrated in **Figure** 1.12.

- Organisms of the same species that live in the same area make up a **population**. For example, all of the goldfish living in the same area make up a goldfish population.
- All of the populations that live in the same area make up a **community**. The community that includes the goldfish population also includes the populations of other fish, coral and other organisms.
- An **ecosystem** consists of all the living things in a given area, together with the nonliving environment. The nonliving environment includes water, sunlight, and other physical factors.
- A group of similar ecosystems with the same general type of physical environment is called a **biome**.
- The **biosphere** is the part of Earth where all life exists, including all the land, water, and air where living things can be found. The biosphere consists of many different biomes.

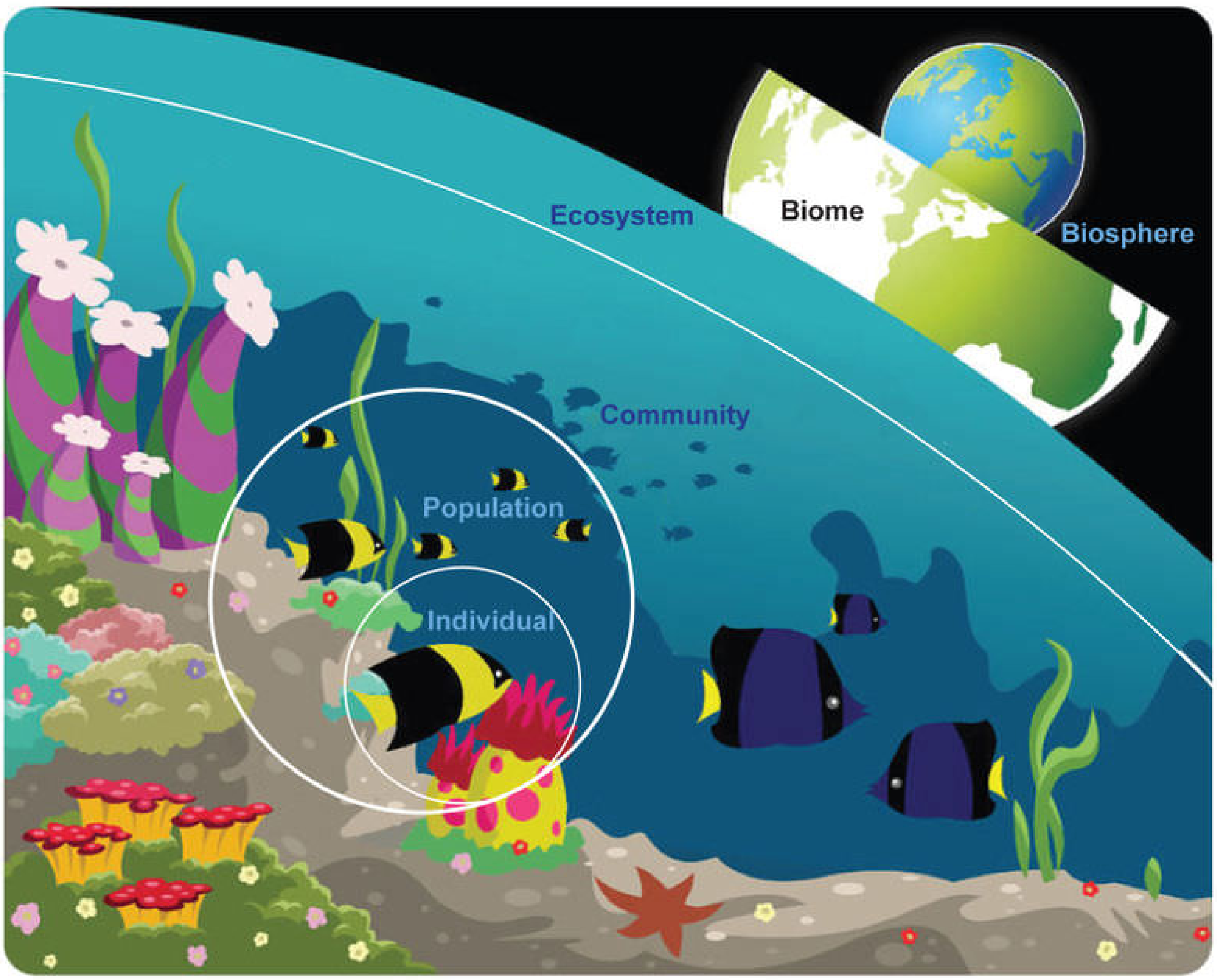

FIGURE 1.12
This picture shows the levels of organization in nature, from the individual organism to the biosphere.

Diversity of Life

Life on Earth is very diverse. The diversity of living things is called **biodiversity**. A measure of Earth's biodiversity is the number of different species of organisms that live on Earth. At least 10 million different species live on Earth today. They are commonly grouped into six different kingdoms. Examples of organisms within each kingdom are shown in **Figure** 1.13.

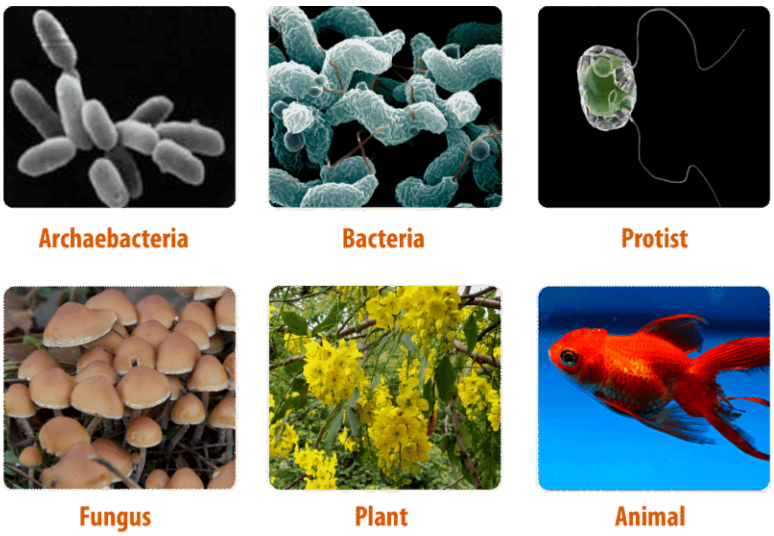

FIGURE 1.13
Diversity of life from Archaebacteria to Plants and Animals.

Evolution of Life

The diversity of life on Earth today is the result of evolution. Life began on Earth at least 4 billion years ago, and it has been evolving ever since. At first, all living things on Earth were simple, single-celled organisms. Much later, the first multicellular organisms evolved, and after that, Earth's biodiversity greatly increased. **Figure** 1.14 shows a timeline of the history of life on Earth. You can also find an interactive timeline of the history of life at the link below. http://www.johnkyrk.com/evolution.html

Today, scientists accept the evolution of life on Earth as a fact. There is too much evidence supporting evolution to doubt it. However, that wasn't always the case. An introduction to evolution and natural selection can be viewed at http://www.youtube.com/watch?v=GcjgWov7mTM .

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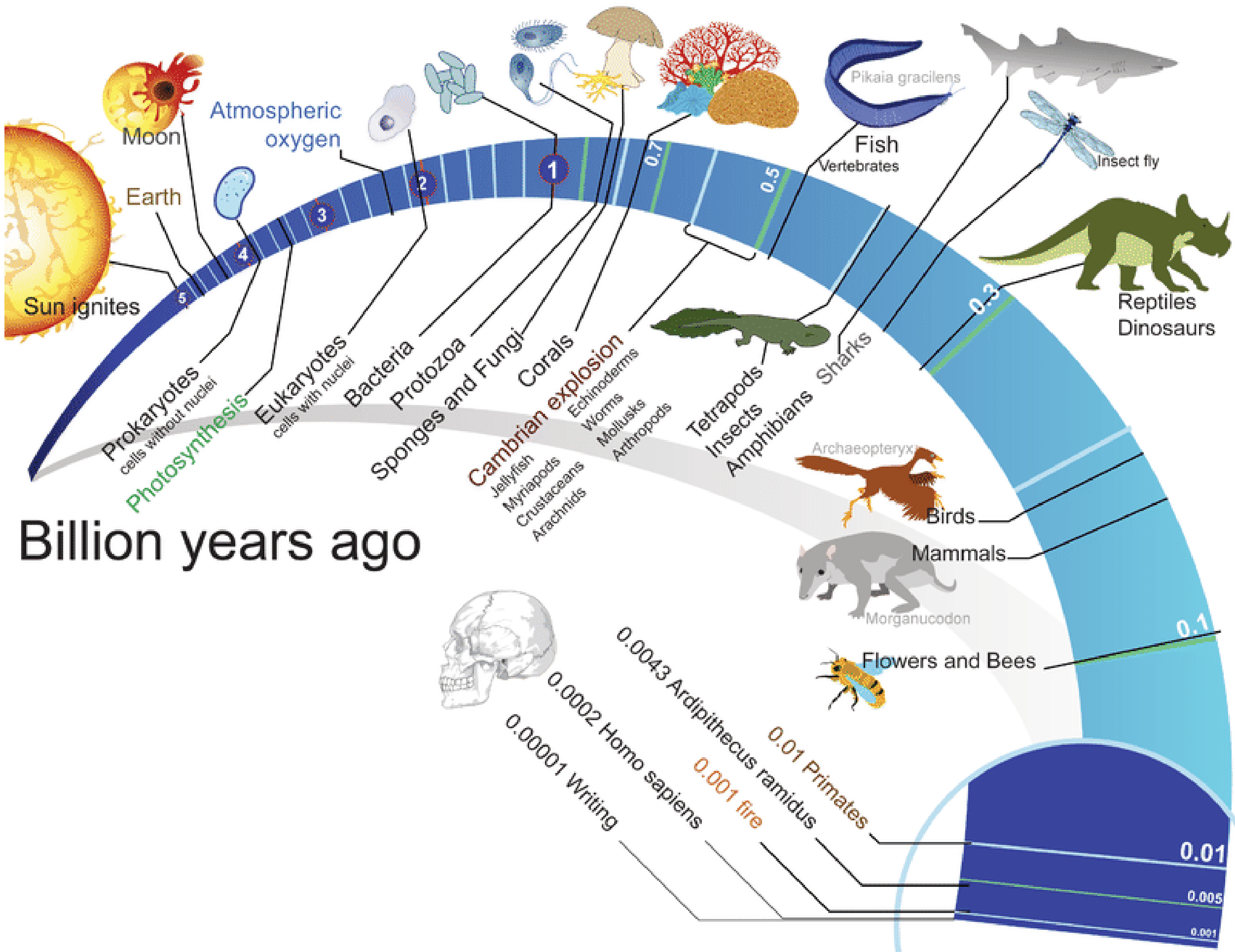

FIGURE 1.14
This timeline shows the history of life on Earth. In the entire span of the time, humans are a relatively new addition.

Darwin and the Theory of Evolution

The idea of evolution has been around for centuries. In fact, it goes all the way back to the ancient Greek philosopher Aristotle. However, evolution is most often associated with Charles Darwin. Darwin published a book on evolution in 1869 titled *On the Origin of Species*. In the book, Darwin stated the theory of evolution by natural selection. He also presented a great deal of evidence that evolution occurs.

Despite all the evidence Darwin presented, his theory was not well-received at first. Many people found it hard to accept the idea that humans had evolved from an ape-like ancestor, and they saw evolution as a challenge to their religious beliefs. Look at the cartoon in **Figure** 1.15. Drawn in 1871, it depicts Darwin himself as an ape. The cartoon reflects how many people felt about Darwin and his theory during his own time. Darwin had actually expected this type of reaction to his theory and had waited a long time before publishing his book for this reason. It was only when another scientist, named Alfred Wallace, developed essentially the same theory of evolution that Darwin put his book into print.

Although Darwin presented a great deal of evidence for evolution in his book, he was unable to explain how evolution

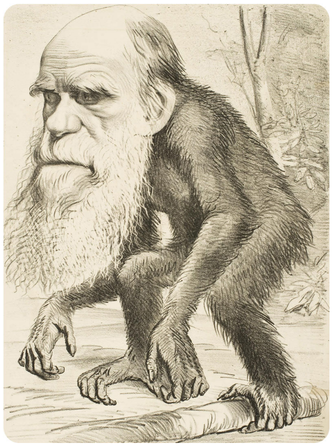

FIGURE 1.15
Charles Darwin's name is linked with the theory of evolution. This cartoon from the 1870s makes fun of both Darwin and his theory.

occurs. That's because he knew nothing about genes. As a result, he didn't know how characteristics are passed from parents to offspring, let alone how they could change over time.

Evolutionary Theory After Darwin

Since Darwin's time, scientists have gathered even more evidence to support the theory of evolution. Some of the evidence comes from fossils, and some comes from studies that show how similar living things are to one another. By the 1930s, scientists had also learned about genes. As a result, they could finally explain how characteristics of organisms could pass from one generation to the next and change over time.

Using modern technology, scientists can now directly compare the genes of living species. The more genes different species share in common, the more closely related the species are presumed to be. Consider humans and chimpanzees. They share about 98% of their genes. This means that they shared a common ancestor in the not-too-distant past. This is just one of many pieces of evidence that show we are part of the evolution of life on Earth.

Misconceptions About Evolution

Today, evolution is still questioned by some people. Often, people who disagree with the theory of evolution do not really understand it. For example, some people think that the theory of evolution explains how life on Earth first began. In fact, the theory explains only how life changed after it first appeared. Some people think the theory of evolution means that humans evolved from modern apes. In fact, humans and modern apes have a common ancestor that lived several million years ago. These and other misconceptions about evolution contribute to the controversy that still surrounds this fundamental principle of biology.

Lesson Summary

- Living things are distinguished from nonliving things on the basis of six characteristics: response to the environment, growth and development, reproduction, homeostasis, complex chemistry, and cells.
- Four underlying principles form the basis of biology. They are cell theory, gene theory, homeostasis, and evolution.
- Many living things interact with one another in some way. The interactions are often necessary for their survival.

- The great diversity of life on Earth today is the result of 4 billion years of evolution. During that time, living things evolved from simple, single-celled organisms to complex, multicellular life forms.

Lesson Review Questions

Recall

1. List the six characteristics of all living things.
2. Identify four unifying principles of modern biology.
3. Outline the levels of organization of a complex, multicellular organism such as a mouse, starting with the cell.
4. What is homeostasis? Give an example.

Apply Concepts

5. Describe examples of ways that you depend on other living things.
6. Assume that you found an object that looks like a dead twig. You wonder if it might be a stick insect. How could you determine if it is a living thing?

Think Critically

7. Compare and contrast symbiosis and competition.
8. Explain how a population differs from a community.
9. How is gene theory related to the theory of evolution?

Points to Consider

In this lesson, you learned that living things have complex chemistry.

- Do you know which chemicals make up living things?
- All living things need energy to carry out the processes of life. Where do you think this energy comes from? For example, where do you get the energy you need to get through your day?

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Concept 2 Science and the Natural World

Lesson 1.1: True or False

Name___________________ Class______________ Date________

Write true if the statement is true or false if the statement is false.

_____ 1. A hypothesis must be based on scientific knowledge.

_____ 2. A scientific theory is a guess about how or why something happens.

_____ 3. Scientists make predictions that tell what will happen under any and all conditions.

_____ 4. The scientific method includes the steps involved in a scientific investigation.

_____ 5. “Did life on Earth evolve over time?” This question can be answered scientifically.

_____ 6. Experiments are performed under controlled conditions.

_____ 7. Scientists can study all aspects of the natural world, including experimenting on an extinct animal.

_____ 8. The dependent variable is always the opposite of the independent variable.

_____ 9. Communicating your results allows others to test your hypothesis.

_____ 10. Experimental evidence that agrees with your prediction supports your hypothesis.

_____ 11. The first step in a scientific investigation is always to develop a hypothesis.

_____ 12. Scientists gradually build an increasingly accurate and detailed understanding of the natural world.

_____ 13. Newton discovered the law of gravity when an apple fell from a tree and hit him on the head.

_____ 14. Scientific evidence is any type of data that may either agree or disagree with a prediction.

_____ 15. Scientific theories are broad explanations that are widely accepted as true.

Lesson 1.1: Critical Reading

Name___________________ Class______________ Date________

Read these passages from the text and answer the questions that follow.

Nature Can Be Understood

Scientists think of nature as a single system controlled by natural laws. By discovering natural laws, scientists strive to increase their understanding of the natural world. Laws of nature are expressed as scientific laws. A scientific law is a statement that describes what always happens under certain conditions in nature.

An example of a scientific law is the law of gravity, which was discovered by Sir Isaac Newton. The law of gravity states that objects always fall towards Earth because of the pull of gravity. Based on this law, Newton could explain many natural events. He could explain not only why objects such as apples always fall to the ground, but he could also explain why the moon orbits Earth. Isaac Newton discovered laws of motion as well as the law of gravity. His laws of motion allowed him to explain why objects move as they do.

Science Cannot Answer All Questions

Science rests on evidence and logic, so it deals only with things that can be observed. An observation is anything that is detected either through human senses or with instruments and measuring devices that extend human senses. Things that cannot be observed or measured by current means — such as supernatural beings or events — are outside the bounds of science. Consider these two questions about life on Earth:

- Did life on Earth evolve over time?
- Was life on Earth created through another method?

The first question can be answered by science on the basis of scientific evidence and logic. The second question could be a matter of belief. Therefore, it is outside the realm of science.

Questions

1. What is an observation?

2. What is a scientific law?

3. What scientific law explains why the moon orbits the Earth? What does the law state? Who developed this law?

4. Complete this sentence: Natural laws allow scientists to ___________________.

5. Can science answer all questions? Justify your answer.

Lesson 1.1: Multiple Choice

Name____________________ Class_______________ Date_________

Circle the letter of the correct choice.

1. Assumptions scientists make include:
   a. Nature can be understood through systematic study.
   b. Scientific ideas never need to be revised.
   c. Science can provide answers to all questions.
   d. all of the above
2. A hypothesis
   a. is the first step in a scientific investigation.
   b. is based on what a scientist believes.
   c. is a possible question to a scientific answer.
   d. can be proved incorrect.
3. A scientific theory
   a. is based on lots of evidence.
   b. is a guess about how or why something happens.
   c. can never be altered or changed.
   d. none of the above
4. Which is the correct order in a scientific investigation?
   a. ask a question, test the hypothesis, communicate results, draw conclusions
   b. make observations, ask a question, form a hypothesis, test the hypothesis
   c. draw conclusions, ask a question, form a hypothesis, test the hypothesis
   d. ask a question, make observations, test the hypothesis, draw conclusions
5. To test a hypothesis,
   a. a scientist first collects evidence.
   b. a scientist first draws conclusions.
   c. a scientist first makes a prediction.
   d. a scientist first makes observations.
6. An experiment
   a. is performed under controlled conditions.
   b. generally tests how one variable is affected by another.
   c. contributes important evidence that helps scientists better understand the natural world.
   d. all of the above
7. Food chains are scientific models that
   a. represent simple systems in nature.
   b. make the scientific systems easier to understand.

c. are based on mathematical equations.
d. are based on a prediction.

8. *Science cannot answer all questions.*
   a. The above statement is true because science cannot answer matters of belief.
   b. The above statement is true because all science is based on logic.
   c. The above statement is false because science can prove that life evolves over time.
   d. The above statement is false because science is based on observations and evidence.

Lesson 1.1: Vocabulary I

Name___________________ Class______________ Date________

Match the vocabulary word with the proper definition.

Definitions

_____ 1. a statement that describes what always happens under certain conditions in nature

_____ 2. a possible answer to a scientific question

_____ 3. any type of data that may either agree or disagree with a prediction

_____ 4. a plan for asking questions and testing possible answers

_____ 5. a representation of part of the real world

_____ 6. a broad explanation for events that is widely accepted as true

_____ 7. detected either through human senses or with instruments and measuring devices that extend human senses

_____ 8. a special type of scientific investigation that is performed under controlled conditions

_____ 9. developed the laws of motion

_____ 10. a statement that tells what will happen under certain conditions

_____ 11. developed theory of relativity

_____ 12. a distinctive way of gaining knowledge about the natural world

Terms

a. Albert Einstein

b. evidence

c. experiment

d. hypothesis

e. Isaac Newton

f. model

g. observation

h. prediction

i. science

j. scientific investigation

k. scientific law

l. scientific theory

Lesson 1.1: Vocabulary II

Name___________________ Class______________ Date________

Fill in the blank with the appropriate term.

1. An ____________ is anything that is detected either through human senses or with instruments and measuring devices that extend human senses.

2. An ____________ is a special type of scientific investigation that is performed under controlled conditions.

3. A scientific ____________ is a statement that describes what always happens under certain conditions in nature.

4. A model is a representation of part of the real ____________.

5. ____________ is any type of data that may either agree or disagree with a prediction.

6. Scientific investigation is done by following the scientific ____________.

7. The goal of ____________ is to understand the natural world.

8. A hypothesis is a possible answer to a scientific ____________.

9. Matters of ____________ are outside the realm of science.

10. A scientific ____________ is a broad explanation for events that is widely accepted as true.

11. The last step in a scientific investigation is ____________ what you have learned with others.

12. ____________ is a distinctive way of gaining knowledge about the natural world that starts with a question and then tries to answer the question with evidence and logic.

Lesson 1.1: Critical Writing

Name___________________ Class______________ Date________

Thoroughly answer the question below. Use appropriate academic vocabulary and clear and complete sentences.

Discuss why science is not able to answer all questions. Incorporate the steps of the scientific method into your response.

CONCEPT 3 Biology: The Study of Life

Lesson 1.2: True or False

Name___________________ Class______________ Date________

Write true if the statement is true or false if the statement is false.

_____ 1. A cell is the basic unit of the structure and function of all living things

_____ 2. An adaptation is a characteristic that helps a living thing survive and reproduce.

_____ 3. Natural selection is a change in the characteristics of living things over time.

_____ 4. A population consists of many different species.

_____ 5. Charles Darwin developed the theory of evolution by natural selection.

_____ 6. All living things must maintain homeostasis.

_____ 7. The characteristics of all living things are controlled by genes.

_____ 8. The four unifying principles of biology are the cell theory, the gene theory, homeostasis, and gravity.

_____ 9. Deer sometimes eat the starlings (birds) that sit on them.

_____ 10. The cells of many different organisms are very similar.

_____ 11. Simple life forms, like bacteria, have simple chemistry.

_____ 12. Simple life forms, like bacteria, do not grow and develop.

_____ 13. Every living thing begins life as a single cell.

_____ 14. The mole's touch organ is an adaptation because it helps the mole survive in its dark.

_____ 15. There are at least 100 million different species live on Earth today.

Lesson 1.2: Critical Reading

Name___________________ Class______________ Date________

Read this passage from the text and answer the questions that follow.

Evolution of Life

The diversity of life on Earth today is the result of evolution. Life began on Earth at least 4 billion years ago, and it has been evolving ever since. At first, all living things on Earth were simple, single-celled organisms. Much later, the first multicellular organisms evolved, and after that, Earth's biodiversity greatly increased.

Today, scientists accept the evolution of life on Earth as a fact. There is too much evidence supporting evolution to doubt it. However, that wasn't always the case.

Darwin and the Theory of Evolution

The idea of evolution has been around for centuries. In fact, it goes all the way back to the ancient Greek philosopher Aristotle. However, evolution is most often associated with Charles Darwin. Darwin published a book on evolution in 1869 titled *On the Origin of Species*. In the book, Darwin stated the theory of evolution by natural selection. He also presented a great deal of evidence that evolution occurs.

Despite all the evidence Darwin presented, his theory was not well received at first. Many people found it hard to accept the idea that humans had evolved from an ape-like ancestor, and they saw evolution as a challenge to their religious beliefs. Darwin had actually expected this type of reaction to his theory and had waited a long time before publishing his book for this reason. It was only when another scientist, named Alfred Wallace, developed essentially the same theory of evolution that Darwin put his book into print.

Although Darwin presented a great deal of evidence for evolution in his book, he was unable to explain how evolution occurs. That's because he knew nothing about genes. As a result, he didn't know how characteristics are passed from parents to offspring, let alone how they could change over time.

Evolutionary Theory After Darwin

Since Darwin's time, scientists have gathered even more evidence to support the theory of evolution. Some of the evidence comes from fossils, and some comes from studies that show how similar living things are to one another. By the 1930s, scientists had also learned about genes. As a result, they could finally explain how characteristics of organisms could pass from one generation to the next and change over time.

Using modern technology, scientists can now directly compare the genes of living species. The more genes different species share in common, the more closely related the species are presumed to be. Consider humans and chimpanzees. They share about 98% of their genes. This means that they shared a common ancestor in the not-too-distant past. This is just one of many pieces of evidence that show we are part of the evolution of life on Earth.

Questions

1. What were the first living things on Earth?

2. Who is most often associated with developing the theory of evolution?

3. What is the name of the process by which evolution occurs?

4. What discovery allowed scientists to explain how characteristics are passed from parents to offspring?

5. Cite one piece of evidence that demonstrates we are evolutionarily closely related to chimpanzees.

Lesson 1.2: Multiple Choice

Name___________________ Class______________ Date________

Circle the letter of the correct choice.

1. The cell theory states that
   a. all living things are made up of cells.
   b. living cells may come from other living cells.
   c. all living things remain single-celled.
   d. all of the above
2. Levels of organization of an individual organism includes
   a. the tissue.
   b. the population.
   c. the community.
   d. all of the above

3. Which is the best definition of "biology"?
    a. The science of living organisms.
    b. The study of humans and animals.
    c. The study of plants, humans, and animals.
    d. The science of life.
4. Homeostasis is
    a. the ability to give rise to offspring.
    b. maintaining a stable internal environment.
    c. the ability to detect and respond to changes in their environment.
    d. the ability to grow and develop.
5. Evolution
    a. is a change in characteristics of living things over time.
    b. occurs by natural selection.
    c. explains how modern organisms have descended from ancient life forms.
    d. all of the above
6. An example of a symbiotic relationship in which one organism is harmed is
    a. the relationship between a flock of starlings and a red deer stag.
    b. the relationship between a lion and an antelope.
    c. the relationship between hummingbirds and flowers.
    d. the relationship between humans and their pet dogs.
7. Cells
    a. are all unique; no two cells are similar.
    b. come from other cells, except for the very first cell of a new organism.
    c. are the basic unit of structure and function of all living things.
    d. are all circular in shape.
8. To be classified as a living organism, an object must
    a. maintain homeostasis.
    b. have a complex chemistry.
    c. be made of at least one cell.
    d. all of the above

Lesson 1.2: Vocabulary I

Name___________________ **Class**______________ **Date**________

Match the vocabulary word with the proper definition.

Definitions

_____ 1. the basic unit of the structure and function of living things

_____ 2. the process by which evolution occurs

_____ 3. the same species that live in the same area

_____ 4. all of the populations that live in the same area

_____ 5. maintaining a stable internal environment

_____ 6. a change in the characteristics of living things over time

_____ 7. an individual living thing

_____ 8. the diversity of living things

_____ 9. all the living things in a given area, together with the nonliving environment

_____ 10. a characteristic that helps a living thing survive and reproduce

_____ 11. a group of similar ecosystems

_____ 12. the science of life

Terms

a. adaptation

b. biodiversity

c. biology

d. biome

e. cell

f. community

g. ecosystem

h. evolution

i. homeostasis

j. natural selection

k. organism

l. population

Lesson 1.2: Vocabulary II

Name___________________ **Class**______________ **Date**________

Fill in the blank with the appropriate term.

1. ____________ developed the theory of evolution by natural selection.

2. All living things grow and ____________.

3. A cell is the basic unit of the structure and ____________ of living things.

4. An adaptation is a characteristic that helps a living thing survive and ____________ in a given environment.

5. The process of maintaining a stable internal environment is ____________.

6. A ____________ is made of cells of the same kind.

7. An ____________ is an individual living thing.

8. __________ is a relationship between living things that depend on the same resources.

9. An ecosystem consists of all the living things in a given area, together with the nonliving ____________.

10. ____________ is a change in the characteristics of living things over time.

11. The ____________ is the part of Earth where all life exists.

12. ____________ is the process by which living things give rise to offspring.

Lesson 1.2: Critical Writing

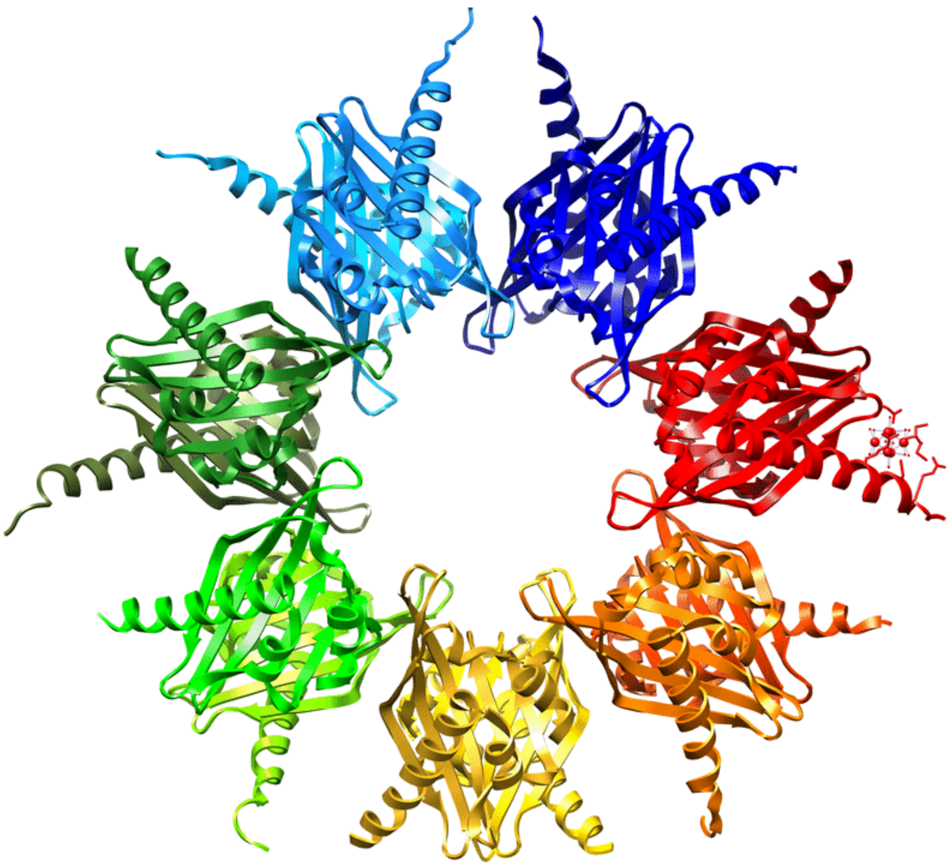
Name___________________ Class______________ Date________

Thoroughly answer the questions below. Use appropriate academic vocabulary and clear and complete sentences.

List and describe three characteristics necessary to define life.

CHAPTER 4 The Chemistry of Life

Chapter Outline



What do you see when you look at this picture? Is it just a mass of tangled ribbons? Look closely. It's actually a complex pattern of three-dimensional shapes. It represents the structure of a common chemical found inside living cells. The chemical is a protein called hemoglobin. It is the protein in red blood cells which transports oxygen around the body.

What are proteins? What other chemicals are found in living things? You will learn the answers to these questions as you read about the chemistry of life.

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4.1 Matter and Organic Compounds

Lesson Objectives

- Define elements and compounds.
- Explain why carbon is essential to life on Earth.
- Describe the structure and function of the four major types of organic compounds.

Vocabulary

- amino acid
- carbohydrate
- chemical bond
- chemical reaction
- complementary base pair
- compound
- DNA
- double helix
- element
- lipid
- matter
- monosaccharide
- nucleic acid
- nucleotide
- organic compound
- polynucleotide
- polypeptide
- polysaccharide
- protein
- RNA
- saturated fatty acid
- unsaturated fatty acid

Introduction

If you look at your hand, what do you see? Of course, you see skin, which consists of cells. But what are skin cells made of? Like all living cells, they are made of matter. In fact, all things are made of matter. **Matter** is anything that takes up space and has mass. Matter, in turn, is made up of chemical substances. In this lesson you will learn about the chemical substances that make up living things.

Chemical Substances

A chemical substance is matter that has a definite composition. It also has the same composition throughout. A chemical substance may be either an element or a compound.

Elements

An **element** is a pure substance. It cannot be broken down into other types of substances. Each element is made up of just one type of atom. An atom is the smallest particle of an element that still has the properties of that element.

There are almost 120 known elements. As you can see from **Figure** 4.1, the majority of elements are metals. Examples of metals are iron (Fe) and copper (Cu). Metals are shiny and good conductors of electricity and heat. Nonmetal elements are far fewer in number. They include hydrogen (H) and oxygen (O). They lack the properties of metals.

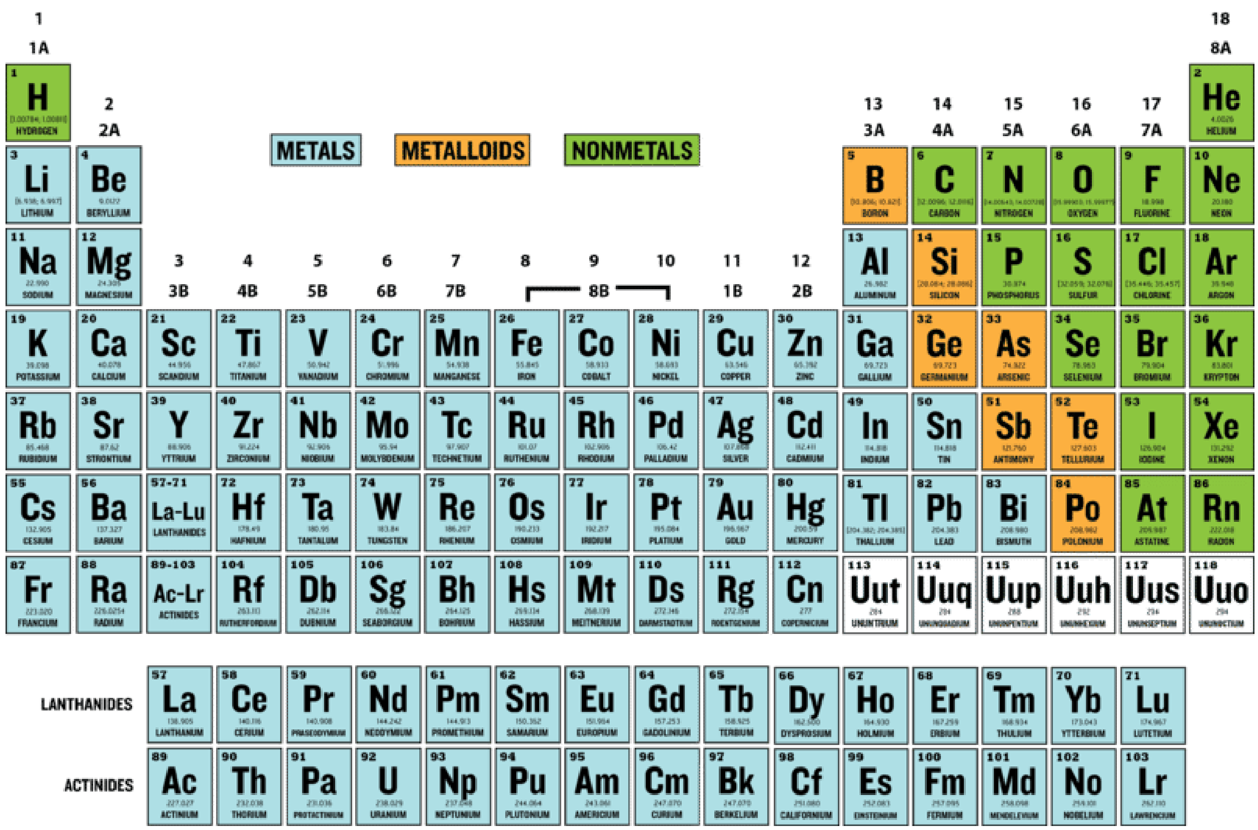


FIGURE 4.1

Periodic Table of the Elements. The periodic table of the elements arranges elements in groups based on their properties. The element most important to life is carbon (C). Find carbon in the table. What type of element is it, metal or nonmetal?

Compounds

A **compound** is a substance that consists of two or more elements. A compound has a unique composition that is always the same. The smallest particle of a compound is called a molecule.

Consider water as an example. A molecule of water always contains one atom of oxygen and two atoms of hydrogen. The composition of water is expressed by the chemical formula H_2O. A model of a water molecule is shown in **Figure** 4.2.

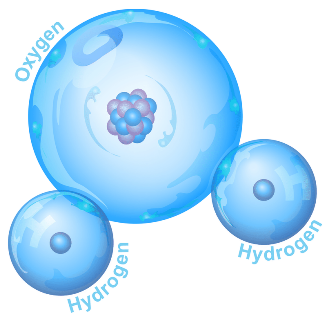


FIGURE 4.2
Water Molecule. A water molecule always has this composition, one atom of oxygen and two atoms of hydrogen.

What causes the atoms of a water molecule to "stick" together? The answer is chemical bonds. A **chemical bond** is a force that holds molecules together. Chemical bonds form when substances react with one another. A **chemical reaction** is a process that changes some chemical substances into others. A chemical reaction is needed to form a compound. Another chemical reaction is needed to separate the substances in a compound.

The Significance of Carbon

A compound found mainly in living things is known as an **organic compound**. Organic compounds make up the cells and other structures of organisms and carry out life processes. Carbon is the main element in organic compounds, so carbon is essential to life on Earth. Without carbon, life as we know it could not exist.

Why is carbon so basic to life? The reason is carbon's ability to form stable bonds with many elements, including itself. This property allows carbon to form a huge variety of very large and complex molecules. In fact, there are nearly 10 million carbon-based compounds in living things! However, the millions of organic compounds can be grouped into just four major types: carbohydrates, lipids, proteins, and nucleic acids. You can compare the four types in **Table** 5.1. Each type is also described below.

TABLE 4.1: Types of Organic Compounds

Type of Compound	Examples	Elements	Functions	Monomer
Carbohydrates	sugars, starches	carbon, hydrogen, oxygen	provides energy to cells, stores energy, forms body structures	monosaccharide
Lipids	fats, oils	carbon, hydrogen, oxygen	stores energy, forms cell membranes, carries messages	

TABLE 4.1: (continued)

Type of Compound	Examples	Elements	Functions	Monomer
Proteins	enzymes, antibodies	carbon, hydrogen, oxygen, nitrogen, sulfur	helps cells keep their shape, makes up muscles, speeds up chemical reactions, carries messages and materials	amino acid
Nucleic Acids	DNA, RNA	carbon, hydrogen, oxygen, nitrogen, phosphorus	contains instructions for proteins, passes instructions from parents to offspring, helps make proteins	nucleotide

Carbohydrates, proteins, and nucleic acids are large molecules (macromolecules) built from smaller molecules (monomers) through dehydration reactions. In a dehydration reaction, water is removed as two monomers are joined together.

KQED: Energy From Carbon?

It may look like waste, but to some people it's green power. Find out how California dairy farms and white tablecloth restaurants are taking their leftover waste and transforming it into clean energy. See *From Waste To Watts: Biofuel Bonanza* at http://www.kqed.org/quest/television/from-waste-to-watts-biofuel-bonanza for further information.

Carbohydrates are the most common type of organic compound. A **carbohydrate** is an organic compound such as sugar or starch, and is used to store energy. Like most organic compounds, carbohydrates are built of small, repeating units that form bonds with each other to make a larger molecule. In the case of carbohydrates, the small repeating units are called monosaccharides.

Monosaccharides

A **monosaccharide** is a simple sugar such as fructose or glucose. Fructose is found in fruits, whereas glucose generally results from the digestion of other carbohydrates. Glucose is used for energy by the cells of most organisms.

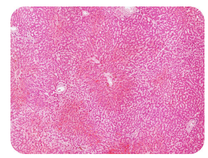
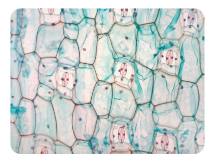
Polysaccharides

A **polysaccharide** is a complex carbohydrate that forms when simple sugars bind together in a chain. Polysaccharides may contain just a few simple sugars or thousands of them. Complex carbohydrates have two main functions: storing energy and forming structures of living things. Some examples of complex carbohydrates and their functions are shown in **Table** 4.2. Which type of complex carbohydrate does your own body use to store energy?

TABLE 4.2: Complex Carbohydrates

Name	Function	Example

TABLE 4.2: (continued)

Name	Function	Example
Starch	Used by plants to store energy.	A potato stores starch in underground tubers. 
Glycogen	Used by animals to store energy.	A human being stores glycogen in liver cells. 
Cellulose	Used by plants to form rigid walls around cells.	Plants use cellulose for their cell walls. 
Chitin	Used by some animals to form an external skeleton.	A housefly uses chitin for its exoskeleton. 

KQED: Biofuels: From Sugar to Energy

For years there's been buzz - both positive and negative - about generating ethanol fuel from corn. But thanks to recent developments, the Bay Area of California is rapidly becoming a world center for the next generation of green fuel alternatives. The Joint BioEnergy Institute is developing methods to isolate biofeuls from the sugars in cellulose.

MEDIA

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URL: http://www.ck12.org/flx/render/embeddedobject/466

Lipids

A **lipid** is an organic compound such as fat or oil. Organisms use lipids to store energy, but lipids have other important roles as well. Lipids consist of repeating units called fatty acids. There are two types of fatty acids: saturated fatty acids and unsaturated fatty acids.

Saturated Fatty Acids

In **saturated fatty acids**, carbon atoms are bonded to as many hydrogen atoms as possible. This causes the molecules to form straight chains, as shown in **Figure** 4.3. The straight chains can be packed together very tightly, allowing them to store energy in a compact form. This explains why saturated fatty acids are solids at room temperature. Animals use saturated fatty acids to store energy.

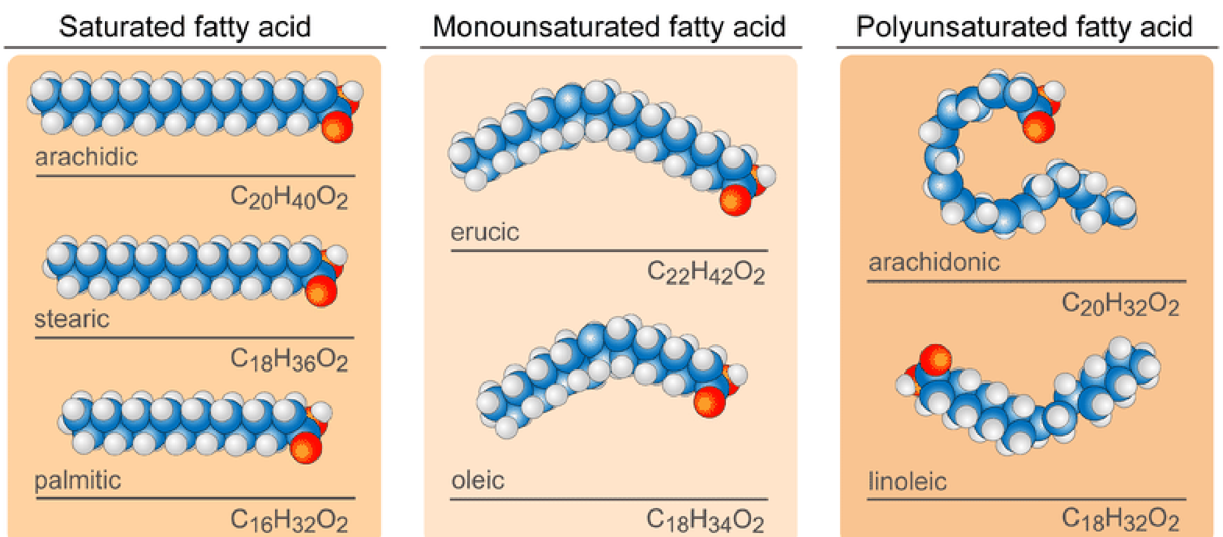


FIGURE 4.3
Fatty Acids. Saturated fatty acids have straight chains, like the three fatty acids shown on the left. Unsaturated fatty acids have bent chains, like all the other fatty acids in the figure.

Unsaturated Fatty Acids

In **unsaturated fatty acids**, there is a double bond between adjacent carbon atoms that results in a bend or kink in the molecule chain (see **Figure** 4.3). The bent chains cannot be packed together very tightly, so unsaturated fatty acids are liquids at room temperature. Plants use unsaturated fatty acids to store energy. Some examples are shown in **Figure** 4.4.

FIGURE 4.4
These plant products all contain unsaturated fatty acids.

Types of Lipids

Lipids may consist of fatty acids alone, or they may contain other molecules as well. For example, some lipids contain alcohol or phosphate groups. They include

1. triglycerides: the main form of stored energy in animals
2. phospholipids: the major components of cell membranes
3. steroids: serve as chemical messengers and have other roles

Proteins

A **protein** is an organic compound made up of small molecules called **amino acids**. There are 20 different amino acids commonly found in the proteins of living things. Small proteins may contain just a few hundred amino acids, whereas large proteins may contain thousands of amino acids.

Protein Structure

When amino acids bind together, they form a long chain called a **polypeptide**. A protein consists of one or more polypeptide chains. A protein may have up to four levels of structure. The lowest level, a protein's primary structure, is its sequence of amino acids. Higher levels of protein structure are described in **Figure** 4.5. The complex structures of different proteins give them unique properties, which they need to carry out their various jobs in living organisms. You can learn more about protein structure by watching the animation at the link below. http://www.stolaf.edu/people/giannini/flashanimat/proteins/protein%20structure.swf

Functions of Proteins

Proteins play many important roles in living things. Some proteins help cells keep their shape, and some make up muscle tissues. Many proteins speed up chemical reactions in cells. Other proteins are antibodies, which bind to

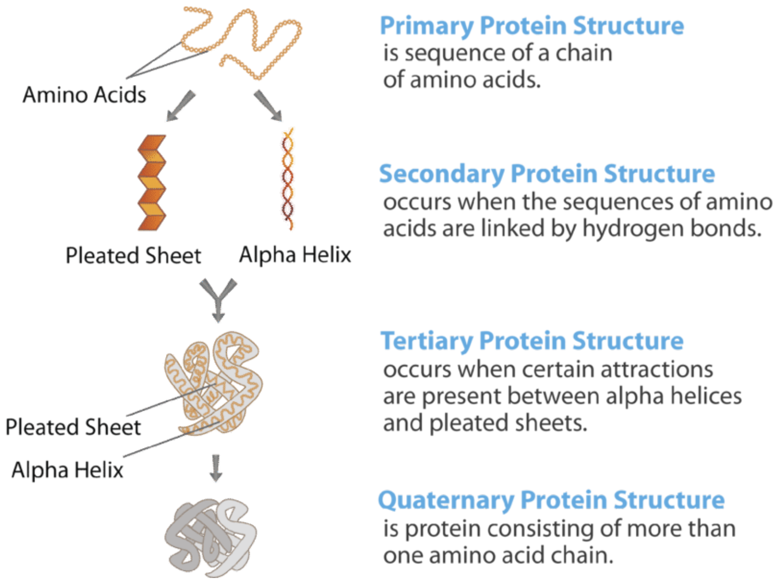


FIGURE 4.5
Protein Structure. The structure of a protein starts with its sequence of amino acids. What determines the secondary structure of a protein? What are two types of secondary protein structure?

foreign substances such as bacteria and target them for destruction. Still other proteins carry messages or materials. For example, human red blood cells contain a protein called hemoglobin, which binds with oxygen. Hemoglobin allows the blood to carry oxygen from the lungs to cells throughout the body. A model of the hemoglobin molecule is shown in **Figure** 4.6.

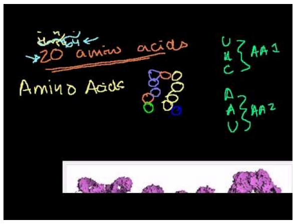
FIGURE 4.6
Hemoglobin Molecule. This model represents the protein hemoglobin. The purple part of the molecule contains iron. The iron binds with oxygen molecules.

A short video describing protein function can be viewed at http://www.youtube.com/watch?v=T500B5yTy58 (4:02).

Nucleic Acids

A **nucleic acid** is an organic compound, such as DNA or RNA, that is built of small units called **nucleotides**. Many nucleotides bind together to form a chain called a **polynucleotide**. The nucleic acid **DNA** (deoxyribonucleic acid) consists of two polynucleotide chains. The nucleic acid **RNA** (ribonucleic acid) consists of just one polynucleotide chain.

An overview of DNA can be seen at http://www.youtube.com/watch?v=_-vZ_g7K6P0 (28:05).



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Structure of Nucleic Acids

Each nucleotide consists of three smaller molecules:

1. sugar
2. phosphate group
3. nitrogen base

If you look at **Figure** 4.7, you will see that the sugar of one nucleotide binds to the phosphate group of the next nucleotide. These two molecules alternate to form the backbone of the nucleotide chain.

The nitrogen bases in a nucleic acid stick out from the backbone. There are four different types of bases: cytosine, adenine, guanine, and either thymine (in DNA) or uracil (in RNA). In DNA, bonds form between bases on the two nucleotide chains and hold the chains together. Each type of base binds with just one other type of base: cytosine always binds with guanine, and adenine always binds with thymine. These pairs of bases are called **complementary base pairs**.

The binding of complementary bases allows DNA molecules to take their well-known shape, called a **double helix**, which is shown in **Figure** 4.8. A double helix is like a spiral staircase. The double helix shape forms naturally and is very strong, making the two polynucleotide chains difficult to break apart. The structure of DNA will be further discussed in the chapter *Molecular Genetics: From DNA to Proteins*.

An animation of DNA structure can be viewed at http://www.youtube.com/watch?v=qy8dk5iS1f0 .

Roles of Nucleic Acids

DNA is found in genes, and its sequence of bases makes up a code. Between "starts" and "stops," the code carries instructions for the correct sequence of amino acids in a protein (see **Figure** 4.8). RNA uses the information in DNA to assemble the correct amino acids and help make the protein. The information in DNA is passed from parent cells to daughter cells whenever cells divide. The information in DNA is also passed from parents to offspring when organisms reproduce. This is how inherited characteristics are passed from one generation to the next.

Lesson Summary

- Living things consist of matter, which can be an element or a compound. A compound consists of two or more elements and forms as a result of a chemical reaction.
- Carbon's unique ability to form chemical bonds allows it to form millions of different large, organic compounds. These compounds make up living things and carry out life processes.

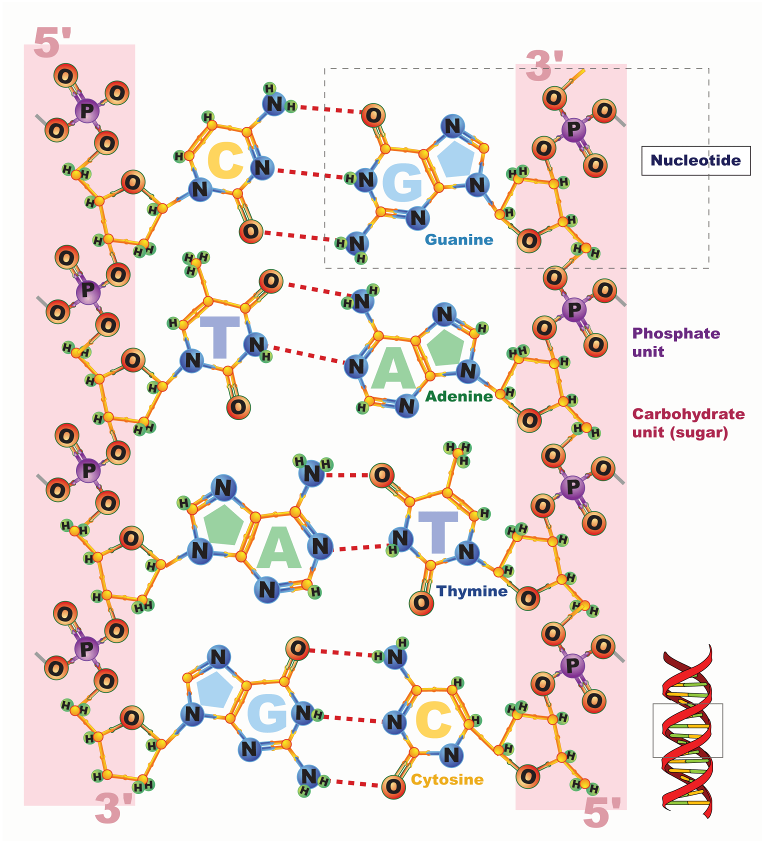

FIGURE 4.7

Nucleic Acid. Sugars and phosphate groups form the backbone of a polynucleotide chain. Hydrogen bonds between complementary bases hold two polynucleotide chains together.

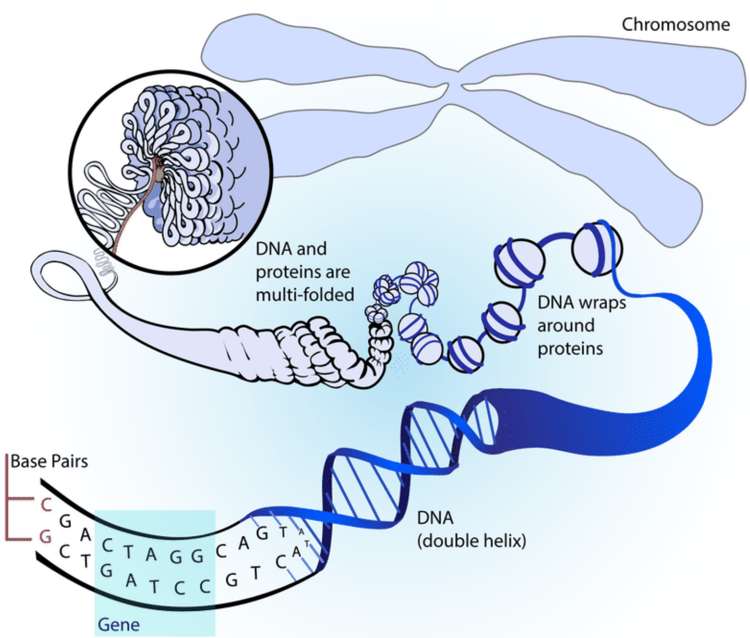

FIGURE 4.8

DNA Molecule. Hydrogen bonds between complementary bases help form the double helix of a DNA molecule. The letters A, T, G, and C stand for the bases adenine, thymine, guanine, and cytosine. The sequence of these four bases in DNA is a code that carries instructions for making proteins. Shown is a representation of how the double helix folds into a chromosome.

- Carbohydrates are organic compounds such as sugars and starches. They provide energy and form structures such as cell walls.
- Lipids are organic compounds such as fats and oils. They store energy and help form cell membranes in addition to having other functions in organisms.
- Proteins are organic compounds made up of amino acids. They form muscles, speed up chemical reactions, and perform many other cellular functions.
- Nucleic acids are organic compounds that include DNA and RNA. DNA contains genetic instructions for proteins, and RNA helps assemble the proteins.

Lesson Review Questions

Recall

1. What are elements and compounds? Give an example of each.

2. List the four major types of organic compounds.

3. What determines the primary structure of a protein?

4. State two functions of proteins.

5. Identify the three parts of a nucleotide.

Apply Concepts

6. Butter is a fat that is a solid at room temperature. What type of fatty acids does butter contain? How do you know?

7. Assume that you are trying to identify an unknown organic molecule. It contains only carbon, hydrogen, and oxygen and is found in the cell walls of a newly discovered plant species. What type of organic compound is it?

Think Critically

8. Explain why carbon is essential to all known life on Earth.

9. Compare and contrast the structures and functions of simple sugars and complex carbohydrates.

10. Explain why molecules of saturated and unsaturated fatty acids have different shapes.

Further Reading / Supplemental Links

- James D. Watson, *The Double Helix: A Personal Account of the Discovery of DNA*. Touchstone, 2001.
- The Chemistry of Biology: http://www.infoplease.com/cig/biology/organic-chemistry.html

Points to Consider

Large organic compounds consist of many smaller units that are linked together in chains.

- How can the smaller units become linked together? What process do you think is involved?
- What do you think holds the smaller units together in a chain?

4.2 Biochemical Reactions

Lesson Objectives

- Describe what happens in chemical reactions.
- State the role of energy in chemical reactions.
- Explain the importance of enzymes to living organisms.

Vocabulary

- activation energy
- anabolic reaction
- biochemical reaction
- catabolic reaction
- endothermic reaction
- enzyme
- exothermic reaction
- metabolism
- product
- reactant

Introduction

The element chlorine (Cl) is a greenish poison. Would you eat chlorine? Of course not, but you often eat a compound containing chlorine. In fact, you probably eat this chlorine compound just about every day. Do you know what it is? It's table salt. Table salt is sodium chloride (NaCl), which forms when chlorine and sodium (Na) combine in certain proportions. How does chlorine, a toxic green chemical, change into harmless white table salt? It happens in a chemical reaction.

What Are Chemical Reactions?

A chemical reaction is a process that changes some chemical substances into others. A substance that starts a chemical reaction is called a **reactant**, and a substance that forms as a result of a chemical reaction is called a **product**. During a chemical reaction, the reactants are used up to create the products.

An example of a chemical reaction is the burning of methane, which is shown in **Figure** 4.9. In this chemical reaction, the reactants are methane (CH_4) and oxygen (O_2), and the products are carbon dioxide (CO_2) and water (H_2O). A chemical reaction involves the breaking and forming of chemical bonds. When methane burns, bonds break in the methane and oxygen molecules, and new bonds form in the molecules of carbon dioxide and water.

FIGURE 4.9

Methane Burning. When methane burns, it combines with oxygen. What are the products of this chemical reaction?

Chemical Equations

A chemical reaction can be represented by a chemical equation. For example, the burning of methane can be represented by the chemical equation:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

The arrow in a chemical equation separates the reactants from the products and shows the direction in which the reaction proceeds. If the reaction could occur in the opposite direction as well, two arrows pointing in opposite directions would be used. The number 2 in front of O_2 and H_2O shows that two oxygen molecules and two water molecules are involved in the reaction. (With no number in front of a chemical symbol, just one molecule is involved.)

Conservation of Matter

In a chemical reaction, the quantity of each element does not change; there is the same amount of each element in the products as there was in the reactants. This is because matter is always conserved. The conservation of matter is reflected in a reaction's chemical equation. The same number of atoms of each element appears on each side of the arrow. For example, in the chemical equation above, there are four hydrogen atoms on each side of the arrow. Can you find all four of them on each side of this equation?

Chemical Reactions and Energy

Chemical reactions always involve energy. When methane burns, for example, it releases energy in the form of heat and light. Other chemical reactions absorb energy rather than release it.

Exothermic Reactions

A chemical reaction that releases energy (as heat) is called an **exothermic reaction**. This type of reaction can be represented by a general chemical equation:

Reactants $\rightarrow$ Products + Heat

In addition to methane burning, another example of an exothermic reaction is chlorine combining with sodium to form table salt. This reaction also releases energy.

Endothermic Reactions

A chemical reaction that absorbs energy is called an **endothermic reaction**. This type of reaction can also be represented by a general chemical equation:

Reactants + Heat $\rightarrow$ Products

Did you ever use a chemical cold pack like the one in **Figure** 4.10? The pack cools down because of an endothermic reaction. When a tube inside the pack is broken, it releases a chemical that reacts with water inside the pack. This reaction absorbs heat energy and quickly cools down the pack.

FIGURE 4.10
This pack gets cold due to an endothermic reaction.

Activation Energy

All chemical reactions need energy to get started. Even reactions that release energy need a boost of energy in order to begin. The energy needed to start a chemical reaction is called **activation energy**. Activation energy is like the push a child needs to start going down a playground slide. The push gives the child enough energy to start moving, but once she starts, she keeps moving without being pushed again. Activation energy is illustrated in **Figure** 4.11.

Why do all chemical reactions need energy to get started? In order for reactions to begin, reactant molecules must bump into each other, so they must be moving, and movement requires energy. When reactant molecules bump together, they may repel each other because of intermolecular forces pushing them apart. Overcoming these forces so the molecules can come together and react also takes energy.

An overview of activation energy can be viewed at http://www.youtube.com/watch?v=VbIaK6PLrRM (1:16).

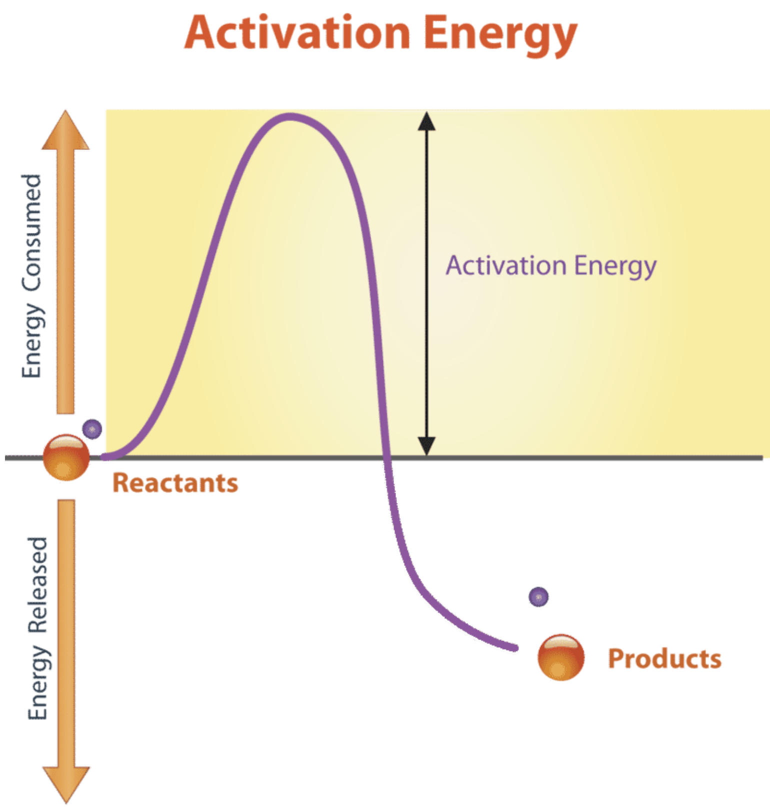

FIGURE 4.11
Activation Energy. Activation energy provides the "push" needed to start a chemical reaction. Is the chemical reaction in this figure an exothermic or endothermic reaction?

Biochemical Reactions and Enzymes

Biochemical reactions are chemical reactions that take place inside the cells of living things. The field of biochemistry demonstrates that knowledge of chemistry as well as biology is needed to understand fully the life processes of organisms at the level of the cell. The sum of all the biochemical reactions in an organism is called **metabolism**. It includes both exothermic and endothermic reactions.

Types of Biochemical Reactions

Exothermic reactions in organisms are called **catabolic reactions**. These reactions break down molecules into smaller units and release energy. An example of a catabolic reaction is the breakdown of glucose, which releases energy that cells need to carry out life processes. Endothermic reactions in organisms are called **anabolic reactions**. These reactions build up bigger molecules from smaller ones. An example of an anabolic reaction is the joining of amino acids to form a protein. Which type of reactions—catabolic or anabolic—do you think occur when your body digests food?

Enzymes

Most biochemical reactions in organisms need help in order to take place. Why is this the case? For one thing, temperatures are usually too low inside living things for biochemical reactions to occur quickly enough to maintain life. The concentrations of reactants may also be too low for them to come together and react. Where do the biochemical reactions get the help they need to proceed? The help comes from enzymes.

An **enzyme** is a protein that speeds up a biochemical reaction. An enzyme works by reducing the amount of activation energy needed to start the reaction. The graph in **Figure** 4.12 shows the activation energy needed for glucose to combine with oxygen. Less activation energy is needed when the correct enzyme is present than when it is not present. You can watch an animation of a biochemical reaction with and without an enzyme at the link below. This animation shows how the enzyme brings reactant molecules together so they can react: http://www.stolaf.edu/people/giannini/flashanimat/enzymes/prox-orien.swf .

An overview of enzymes can be viewed at http://www.youtube.com/watch?v=E90D4BmaVJM (9:43).

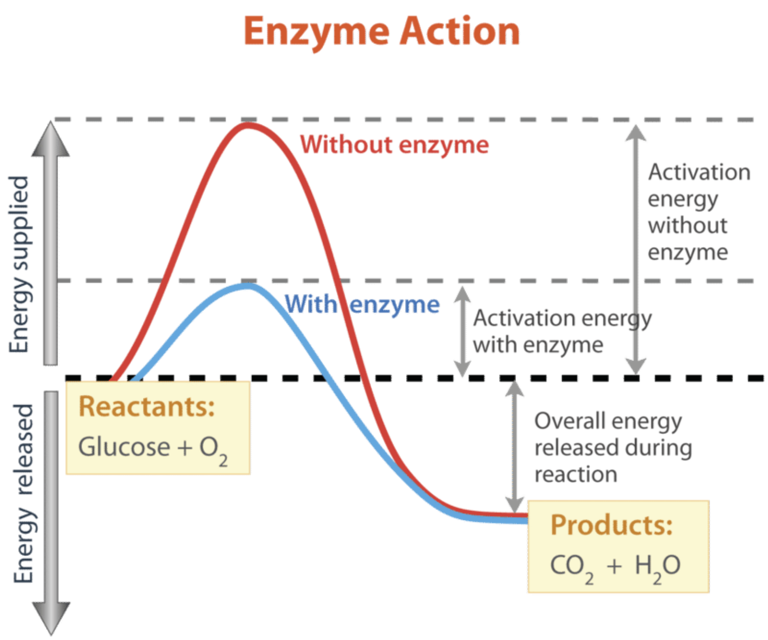

FIGURE 4.12
Enzyme Action. This graph shows what happens when glucose combines with oxygen. An enzyme speeds up the reaction by lowering the activation energy. Compare the activation energy needed with and without the enzyme.

Enzymes are involved in most biochemical reactions, and they do their job extremely well. A typical biochemical reaction could take several days to occur without an enzyme. With the proper enzyme, the same reaction can occur in just a split second! Without enzymes to speed up biochemical reactions, most organisms could not survive. The activities of enzymes depend on the temperature, ionic conditions, and the pH of the surroundings. Some enzymes work best at acidic pHs, while others work best in neutral environments.

An animation of how enzymes work can be seen at http://www.youtube.com/watch?v=CZD5xsOKres (2:02).

Lesson Summary

- A chemical reaction is a process that changes some chemical substances into others. It involves breaking and forming chemical bonds.
- Some chemical reactions release energy, whereas other chemical reactions absorb energy. All chemical reactions require activation energy to get started.
- Enzymes are needed to speed up biochemical reactions in organisms. They work by lowering activation energy.

Lesson Review Questions

Recall

1. Identify the roles of reactants and products in chemical reactions.
2. What is the general chemical equation for an endothermic reaction?
3. What are biochemical reactions? What is an example?
4. How do enzymes speed up biochemical reactions?

Apply Concepts

5. What is wrong with the chemical equation below? How could you fix it?

$CH_4 + O_2 \rightarrow CO_2 + 2H_2O$

6. What type of reaction is represented by the following chemical equation? Explain your answer.

$2Na + 2HCl \rightarrow 2NaCl + H_2 + \text{heat}$

Think Critically

7. How does a chemical equation show that matter is always conserved in a chemical reaction?
8. Why do all chemical reactions require activation energy?
9. Explain why organisms need enzymes to survive.

Points to Consider

Most chemical reactions in organisms take place in an environment that is mostly water.

- What do you know about water? How would you describe it?
- Water behaves differently than most other substances. Do you know why?

4.3 Water, Acids, and Bases

Lesson Objectives

- Describe the distribution of Earth's water.
- Identify water's structure and properties.
- Define acids, bases, and pH.
- Explain why water is essential for life.

Vocabulary

- acid
- base
- hydrogen bond
- pH
- polarity
- solution

Introduction

Water, like carbon, has a special role in living things. It is needed by all known forms of life. As you have seen, water is a simple molecule, containing just three atoms. Nonetheless, water's structure gives it unique properties that help explain why it is vital to all living organisms.

Water, Water Everywhere

Water is a common chemical substance on planet Earth. In fact, Earth is sometimes called the "water planet" because almost 75% of its surface is covered with water. If you look at **Figure** 4.13, you will see where Earth's water is found. The term *water* generally refers to its liquid state, and water is a liquid over a wide range of temperatures on Earth. However, water also occurs on Earth as a solid (ice) and as a gas (water vapor).

Structure and Properties of Water

No doubt, you are already aware of some of the properties of water. For example, you probably know that water is tasteless and odorless. You also probably know that water is transparent, which means that light can pass through it. This is important for organisms that live in the water, because some of them need sunlight to make food.

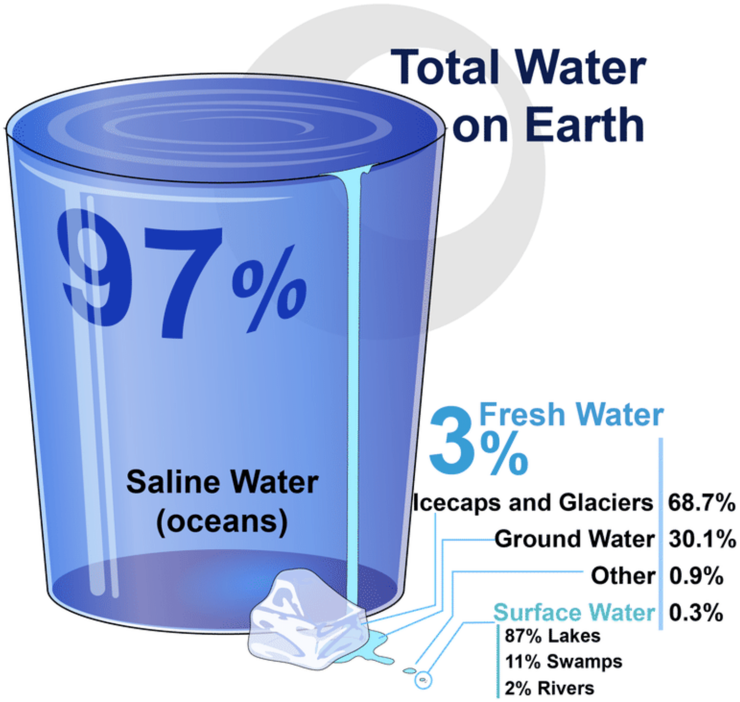

FIGURE 4.13
Most of the water on Earth consists of saltwater in the oceans. What percent of Earth's water is fresh water? Where is most of the fresh water found?

Chemical Structure of Water

To understand some of water's properties, you need to know more about its chemical structure. As you have seen, each molecule of water consists of one atom of oxygen and two atoms of hydrogen. The oxygen atom in a water molecule attracts electrons more strongly than the hydrogen atoms do. As a result, the oxygen atom has a slightly negative charge, and the hydrogen atoms have a slightly positive charge. A difference in electrical charge between different parts of the same molecule is called **polarity**. The diagram in **Figure** 4.14 shows water's polarity.

Opposites attract when it comes to charged molecules. In the case of water, the positive (hydrogen) end of one water molecule is attracted to the negative (oxygen) end of a nearby water molecule. Because of this attraction, weak bonds form between adjacent water molecules, as shown in **Figure** 4.15. The type of bond that forms between molecules is called a **hydrogen bond**. Bonds between molecules are not as strong as bonds within molecules, but in water they are strong enough to hold together nearby molecules.

Properties of Water

Hydrogen bonds between water molecules explain some of water's properties. For example, hydrogen bonds explain why water molecules tend to stick together. Did you ever watch water drip from a leaky faucet or from a melting icicle? If you did, then you know that water always falls in drops rather than as separate molecules. The dew drops in **Figure** 4.16 are another example of water molecules sticking together.

Hydrogen bonds cause water to have a relatively high boiling point of 100°C (212°F). Because of its high boiling point, most water on Earth is in a liquid state rather than in a gaseous state. Water in its liquid state is needed by all living things. Hydrogen bonds also cause water to expand when it freezes. This, in turn, causes ice to have a lower density (mass/volume) than liquid water. The lower density of ice means that it floats on water. For example, in cold climates, ice floats on top of the water in lakes. This allows lake animals such as fish to survive the winter by staying in the water under the ice.

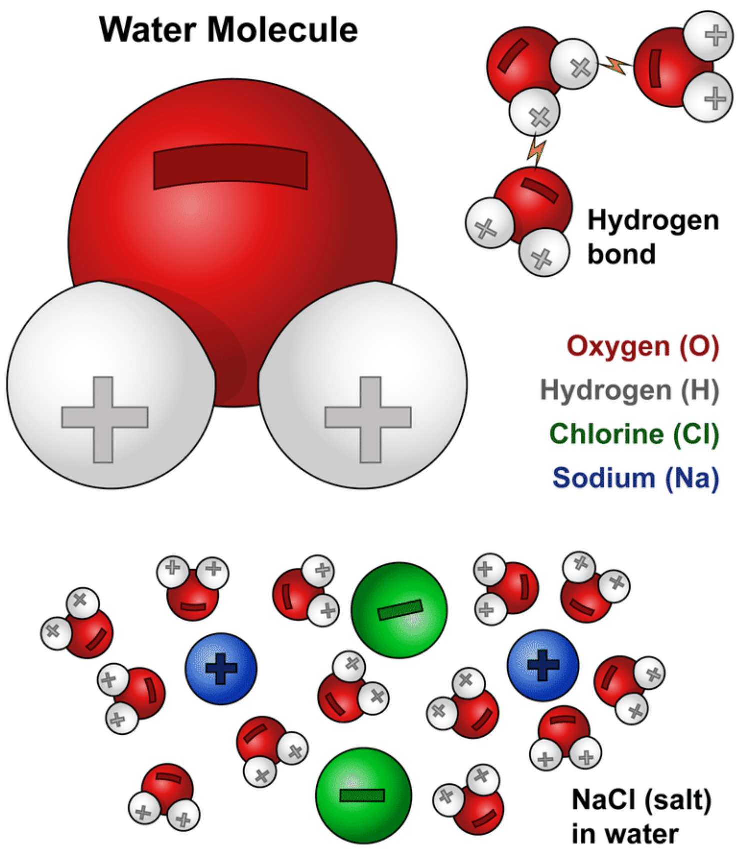

FIGURE 4.14
Water Molecule. This diagram shows the positive and negative parts of a water molecule. It also depicts how a charge, such as on an ion (Na or Cl, for example) can interact with a water molecule.

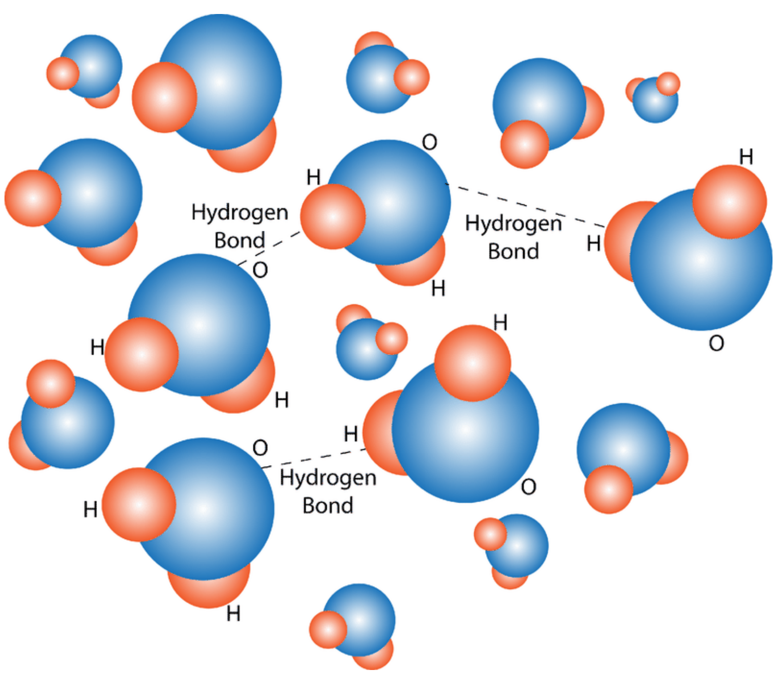

FIGURE 4.15
Hydrogen Bonding in Water Molecules. Hydrogen bonds form between nearby water molecules. How do you think this might affect water's properties?

FIGURE 4.16
Droplets of Dew. Drops of dew cling to a spider web in this picture. Can you think of other examples of water forming drops? (*Hint:* What happens when rain falls on a newly waxed car?)

Acids and Bases

Water is the main ingredient of many solutions. A **solution** is a mixture of two or more substances that has the same composition throughout. Some solutions are acids and some are bases. To understand acids and bases, you need to know more about pure water. In pure water (such as distilled water), a tiny fraction of water molecules naturally breaks down to form ions. An ion is an electrically charged atom or molecule. The breakdown of water is represented by the chemical equation

$2\ H_2O \rightarrow H_3O^+ + OH^-$

The products of this reaction are a hydronium ion (H_3O^+) and a hydroxide ion (OH^-). The hydroxide ion, which has a negative charge, forms when a water molecule gives up a positively charged hydrogen ion (H^+). The hydronium ion, which has positive charge, forms when another water molecule accepts the hydrogen ion.

Acidity and pH

The concentration of hydronium ions in a solution is known as acidity. In pure water, the concentration of hydronium ions is very low; only about 1 in 10 million water molecules naturally breaks down to form a hydronium ion. As a result, pure water is essentially neutral. Acidity is measured on a scale called **pH**, as shown in **Figure** 4.17. Pure water has a pH of 7, so the point of neutrality on the pH scale is 7.

Acids

If a solution has a higher concentration of hydronium ions than pure water, it has a pH lower than 7. A solution with a pH lower than 7 is called an **acid**. As the hydronium ion concentration increases, the pH value decreases. Therefore, the more acidic a solution is, the lower its pH value is. Did you ever taste vinegar? Like other acids, it tastes sour. Stronger acids can be harmful to organisms. For example, stomach acid would eat through the stomach if it were not lined with a layer of mucus. Strong acids can also damage materials, even hard materials such as glass.

Bases

If a solution has a lower concentration of hydronium ions than pure water, it has a pH higher than 7. A solution with a pH higher than 7 is called a **base**. Bases, such as baking soda, have a bitter taste. Like strong acids, strong bases can harm organisms and damage materials. For example, lye can burn the skin, and bleach can remove the color from clothing.

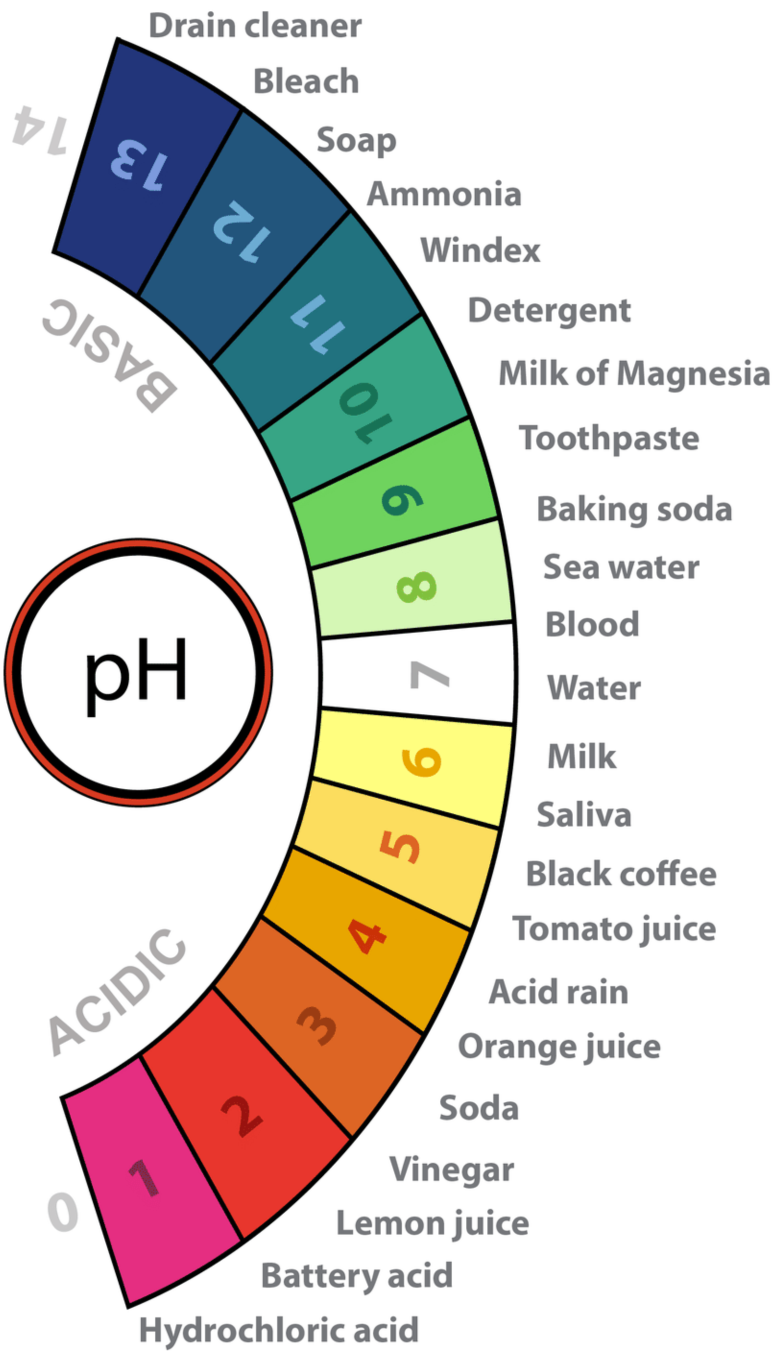

FIGURE 4.17

Acidity and the pH Scale. Water has a pH of 7, so this is the point of neutrality on the pH scale. Acids have a pH less than 7, and bases have a pH greater than 7. The approximate pHs of numerous substances is shown.

Acids and Bases in Organisms

Acids and bases are important in living things because most enzymes can do their job only at a certain level of acidity. Cells secrete acids and bases to maintain the proper pH for enzymes to work. For example, every time you digest food, acids and bases are at work in your digestive system. Consider the enzyme pepsin, which helps break down proteins in the stomach. Pepsin needs an acidic environment to do its job, and the stomach secretes a strong acid that allows pepsin to work. However, when stomach contents enter the small intestine, the acid must be neutralized. This is because enzymes in the small intestine need a basic environment in order to work. An organ called the pancreas secretes a strong base into the small intestine, and this base neutralizes the acid.

Water and Life

The human body is about 70% water (not counting the water in body fat, which varies from person to person). The body needs all this water to function normally. Just why is so much water required by human beings and other organisms? Water can dissolve many substances that organisms need, and it is necessary for many biochemical reactions. The examples below are among the most important biochemical processes that occur in living things, but they are just two of many ways that water is involved in biochemical reactions.

- Photosynthesis—In this process, cells use the energy in sunlight to change carbon dioxide and water to glucose and oxygen. The reactions of photosynthesis can be represented by the chemical equation:

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

- Cellular respiration—In this process, cells break down glucose in the presence of oxygen and release carbon dioxide, water, and energy. The reactions of cellular respiration can be represented by the chemical equation:

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

Water is involved in many other biochemical reactions. As a result, just about all life processes depend on water. Clearly, life as we know it could not exist without water.

Lesson Summary

- Most of Earth's water is salt water in the oceans. Less than 3% is freshwater.
- Water molecules are polar, so they form hydrogen bonds. This gives water unique properties, such as a relatively high boiling point.
- The extremely low hydronium ion concentration of pure water gives pure water a neutral pH of 7. Acids have a pH lower than 7, and bases have a pH higher than 7.
- Water is involved in most biochemical reactions. Therefore, water is essential to life.

Lesson Review Questions

Recall

1. Where is most of Earth's water found?

2. What is polarity? Describe the polarity of water.

3. What is the pH of a neutral solution?

4. Describe an example of an acid or a base that is involved in human digestion.

Apply Concepts

5. Assume that you test an unknown solution and find that it has a pH of 7.2. What type of solution is it? How do you know?

6. How could you demonstrate to a child that solid water is less dense than liquid water?

Think Critically

7. Explain how water's polarity is related to its boiling point.

8. Explain why metabolism in organisms depends on water.

Points to Consider

Most biochemical reactions take place within cells. Cells are the microscopic building blocks of organisms.

- What do you think you would see if you could look inside the cell of an organism? What structures do you think you might observe?
- What biochemical processes might be occurring?

For **Table** 4.2, from top to bottom:

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4.4 References

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CONCEPT 5 Matter and Organic Compounds

Lesson 2.1: True or False

Name___________________ Class______________ Date________

Write true if the statement is true or false if the statement is false.

_____ 1. An atom is smaller than an element.

_____ 2. Organic compounds are found in living organisms.

_____ 3. Proteins are made out of amino acids.

_____ 4. Proteins speed up chemical reactions.

_____ 5. The DNA code carries instructions for the correct sequence of nucleic acids in a protein

_____ 6. Sugars and phosphate groups form the middle of a nucleic acid chain.

_____ 7. DNA (and RNA) is made out of nucleotides.

_____ 8. A protein consists of one or more polypeptide chains.

_____ 9. Lipids include fats, oils, and sugars.

_____ 10. Carbohydrates are the most common type of organic compound.

_____ 11. Peanut oil is an unsaturated fatty acid.

_____ 12. Cytosine and adenine are complementary bases in DNA.

_____ 13. A double helix is like a spiral staircase.

_____ 14. Phospholipids form cell membranes.

_____ 15. Carbohydrates are made out of monosaccharides.

Lesson 2.1: Critical Reading

Name___________________ Class______________ Date________

Read these passages from the text and answer the questions that follow.

The Significance of Carbon

A compound found mainly in living things is known as an **organic compound**. Organic compounds make up the cells and other structures of organisms and carry out life processes. Carbon is the main element in organic compounds, so carbon is essential to life on Earth. Without carbon, life as we know it could not exist.

Why is carbon so basic to life? The reason is carbon's ability to form stable bonds with many elements, including itself. This property allows carbon to form a huge variety of very large and complex molecules. In fact, there are nearly 10 million carbon-based compounds in living things! However, the millions of organic compounds can be grouped into just four major types: carbohydrates, lipids, proteins, and nucleic acids. You can compare the four types in **Table** 5.1. Each type is also described below.

TABLE 5.1: Types of Organic Compounds

Type of Compound	Examples	Elements	Functions
Carbohydrates	sugars, starches	carbon, hydrogen, oxygen	provides energy to cells, stores energy, forms body structures
Lipids	fats, oils	carbon, hydrogen, oxygen	stores energy, forms cell membranes, carries messages
Proteins	enzymes, antibodies	carbon, hydrogen, oxygen, nitrogen, sulfur	helps cells keep their shape, makes up muscles, speeds up chemical reactions, carries messages and materials
Nucleic Acids	DNA, RNA	carbon, hydrogen, oxygen, nitrogen, phosphorus	contains instructions for proteins, passes instructions from parents to offspring, helps make proteins

Carbohydrates

Carbohydrates are the most common type of organic compound. A **carbohydrate** is an organic compound such as sugar or starch, and is used to store energy. Like most organic compounds, carbohydrates are built of small, repeating units that form bonds with each other to make a larger molecule. In the case of carbohydrates, the small, repeating units are called monosaccharides.

Lipids

A **lipid** is an organic compound such as fat or oil. Organisms use lipids to store energy, but lipids have other important roles as well. Lipids consist of repeating units called fatty acids. There are two types of fatty acids: saturated fatty acids and unsaturated fatty acids.

Proteins

A **protein** is an organic compound made up of small molecules called **amino acids**. There are 20 different amino acids commonly found in the proteins of living things. Small proteins may contain just a few hundred amino acids, whereas large proteins may contain thousands of amino acids.

Nucleic Acids

A **nucleic acid** is an organic compound, such as DNA or RNA, that is built of small units called nucleotides. Many nucleotides bind together to form a chain called a **polynucleotide**. The nucleic acid **DNA** (deoxyribonucleic acid) consists of two polynucleotide chains. The nucleic acid **RNA** (ribonucleic acid) consists of just one polynucleotide chain.

Questions

1. List two functions of organic compounds.

2. Which two categories of organic compounds store energy? Which of these organic compounds is more common?

3. What is a main difference between DNA and RNA?

4. Describe a difference between large and small proteins.

5. Why is carbon considered the essential element of life?

Lesson 2.1: Multiple Choice

Name___________________ **Class**______________ **Date**________

Circle the letter of the correct choice.

1. Water (H_2O) is a(n)
    a. element.
    b. atom.
    c. compound.
    d. carbohydrate.
2. A process that changes some chemical substances into others is a
    a. chemical bond.
    b. chemical reaction.
    c. chemical equation.
    d. chemical formula.
3. The main difference between saturated and unsaturated fatty acids is
    a. the amount of energy found in the fatty acid.
    b. saturated fatty acids are liquids.
    c. unsaturated fatty acids can be packed together very tightly.
    d. the number of hydrogen atoms bonded to the carbon atoms.
4. The function of proteins can include
    a. helping cells keep their shape.
    b. helping to destroy foreign substances.
    c. speeding up biochemical reactions.
    d. all of the above
5. The characteristics of DNA includes which of the following?
    a. DNA is made of nucleotides consisting of a sugar, a phosphate group, and a carbon base.
    b. DNA is made of a single polynucleotide chain, which winds into a double helix.
    c. DNA is how inherited characteristics are passed from one generation to the next.
    d. all of the above
6. Which category of organic compound is the major component of cell membranes?
    a. carbohydrate
    b. lipid
    c. protein
    d. nucleic acid
7. The cell wall of plants is made out of
    a. starch.
    b. glycogen.
    c. cellulose.
    d. chitin.
8. The main element of organic compounds is
    a. hydrogen.
    b. oxygen.
    c. nitrogen.
    d. carbon.

Lesson 2.1: Vocabulary I

Name___________________ **Class**______________ **Date**________

Match the vocabulary word with the proper definition.

Definitions

_____ 1. an organic compound that stores energy, forms cell membranes, carries messages

_____ 2. an organic compound that contains instructions for proteins

_____ 3. an organic compound that provides energy to cells, stores energy, forms body structures

_____ 4. an organic compound that helps cells keep their shape

_____ 5. a pure substance, like carbon

_____ 6. may contain just a few simple sugars or thousands

_____ 7. subunit that make up proteins

_____ 8. subunit used to make nucleic acids

_____ 9. lipid in which carbon atoms are bonded to as many hydrogen atoms as possible

_____ 10. lipid in which carbon atoms are bonded to groups of atoms other then hydrogen

_____ 11. the major component of cell membranes

_____ 12. anything that takes up space and has mass

Terms

a. amino acid

b. carbohydrate

c. DNA

d. element

e. lipid

f. matter

g. nucleotide

h. phospholipid

i. polysaccharide

j. protein

k. saturated fatty acid

l. unsaturated fatty acid

Lesson 2.1: Vocabulary II

Name___________________ **Class**______________ **Date**________

Fill in the blank with the appropriate term.

1. A substance that consists of two or more elements is a ____________.

2. The information in _____________ is passed from parents to offspring when organisms reproduce.
3. _____________ are proteins which bind to foreign substances such as bacteria and target them for destruction.
4. _____________ compounds make up the cells and other structures of organisms and carry out _____________-processes.
5. _____________ is the monosaccharide used for energy by the cells of most organisms.
6. _____________ are the most common type of organic compound.
7. ___________ is a protein that binds with oxygen molecules.
8. The shape of DNA is that of a _____________.
9. _____________ is used by plants to store energy.
10. _____________ is used by plants to form rigid walls around cells.
11. DNA contains _____________ instructions for proteins, and _____________ helps assemble the proteins.
12. Matter is anything that takes up space and has _____________.

Lesson 2.1: Critical Writing

Name____________________ Class_______________ Date_________

Thoroughly answer the question below. Use appropriate academic vocabulary and clear and complete sentences.

Describe the main functions of each of the four classes of organic compounds.

CONCEPT 6 Biochemical Reactions

Lesson 2.2: True or False

Name___________________ **Class**______________ **Date**________

Write true if the statement is true or false if the statement is false.

_____ 1. A substance that forms as a result of a chemical reaction is called a reactant.

_____ 2. Only some chemical reactions need energy to get started.

_____ 3. Biochemical reactions take place inside the cells.

_____ 4. A chemical reaction that releases heat is an exothermic reaction.

_____ 5. Most biochemical reactions need help to get started.

_____ 6. Anabolic reactions give off energy.

_____ 7. Metabolism is the sum of all the biochemical reactions in an organism.

_____ 8. In a chemical reaction, the quantity of an element may change.

_____ 9. During a chemical reaction, some bonds break and new bonds form.

_____ 10. Activation energy is the energy needed to start a chemical reaction.

_____ 11. An enzyme speeds up the reaction by lowering the activation energy.

_____ 12. In a chemical reaction, the number of atoms on one side of the arrow may differ from the number of atoms on the other side.

_____ 13. Matter is always conserved.

_____ 14. Understanding chemistry is needed to understand fully the processes within the cell.

_____ 15. In a chemical reaction, the quantity of each element does not change.

Lesson 2.2: Critical Reading

Name___________________ **Class**______________ **Date**________

Read these passages from the text and answer the questions that follow.

Biochemical Reactions and Enzymes

Biochemical reactions are chemical reactions that take place inside the cells of living things. Biochemistry is a relatively new field that emerged at the interface of biology and chemistry. Its emergence shows that knowledge of chemistry as well as biology is needed to understand fully the life processes of organisms at the level of the cell. The sum of all the biochemical reactions in an organism is called **metabolism**. It includes both exothermic and endothermic reactions.

Types of Biochemical Reactions

Exothermic reactions in organisms are called **catabolic reactions**. These reactions break down molecules into smaller units and release energy. An example of a catabolic reaction is the breakdown of glucose, which releases energy that cells need to carry out life processes. Endothermic reactions in organisms are called **anabolic reactions**. These reactions build up bigger molecules from smaller ones. An example of an anabolic reaction is the joining of amino acids to form a protein. Which type of reactions — catabolic or anabolic — do you think occur when your body digests food?

Enzymes

Most biochemical reactions in organisms need help in order to take place. Why is this the case? For one thing, temperatures are usually too low inside living things for biochemical reactions to occur quickly enough to maintain life. The concentrations of reactants may also be too low for them to come together and react. Where do the biochemical reactions get the help they need to proceed? The help comes from enzymes.

An **enzyme** is a protein that speeds up a biochemical reaction. An enzyme works by reducing the amount of activation energy needed to start the reaction. Less activation energy is needed when the correct enzyme is present than when it is not present.

Enzymes are involved in most biochemical reactions, and they do their job extremely well. A typical biochemical reaction could take several days to occur without an enzyme. With the proper enzyme, the same reaction can occur in just a split second! Without enzymes to speed up biochemical reactions, most organisms could not survive. The activities of enzymes depend on the temperature, ionic conditions, and the pH of the surroundings. Some enzymes work best at an acidic pH, while others work best in neutral environments.

Questions

1. What is an enzyme?

2. How are biochemistry and metabolism related?

3. Which type of reactions — catabolic or anabolic — do you think occur when your body digests food?

4. How do enzymes work?

5. What is activation energy?

Lesson 2.2: Multiple Choice

Name____________________ Class_______________ Date________

Circle the letter of the correct choice.

1. Reactants in the burning of methane include
   a. CH_4 and $2O_2$.
   b. CO_2 and $2H_2O$.
   c. CH_4 and CO_2.
   d. CO_2 and $2O_2$.
2. Activities of enzymes depend on
   a. pH.
   b. temperature.
   c. ionic conditions.
   d. all of the above

3. An enzyme is a ____________.
   a. carbohydrate
   b. lipid
   c. protein
   d. nucleic acid
4. Reactions that take place inside cells are
   a. cellular reactions.
   b. enzyme reactions.
   c. metabolic reactions.
   d. biochemical reactions.
5. What is the main difference between an endothermic reaction and an exothermic reaction?
   a. An endothermic reaction gives off energy and an exothermic reaction absorbs energy.
   b. An exothermic reaction gives off energy and an endothermic reaction absorbs energy.
   c. An endothermic reaction does not need activation energy.
   d. Only endothermic reactions involve enzymes.
6. Another name for a "biological catalyst" could be a(n)
   a. enzyme.
   b. reactant.
   c. activator.
   d. metabolism.
7. The joining of amino acids to form a protein is a(n)
   a. anabolic reaction.
   b. catabolic reaction.
   c. amino acid reaction.
   d. polypeptide reaction.
8. The "push" needed to start a chemical reaction is the
   a. enzymatic energy.
   b. endothermic energy.
   c. activation energy.
   d. reactant energy.

Lesson 2.2: Vocabulary I

Name___________________ **Class**______________ **Date**________

Match the vocabulary word with the proper definition.

Definitions

_____ 1. represents a chemical reaction

_____ 2. a protein that speeds up a biochemical reaction

_____ 3. a substance that forms as a result of a chemical reaction

_____ 4. a substance that starts a chemical reaction

_____ 5. sum of all the biochemical reactions in an organism

_____ 6. a process that changes some chemical substances into others

_____ 7. exothermic reactions in organisms

_____ 8. endothermic reactions in organisms

_____ 9. chemical reactions that take place inside the cells of living things

_____ 10. a chemical reaction that releases energy

_____ 11. a chemical reaction that absorbs energy

_____ 12. the energy needed to start a chemical reaction

Terms

a. activation energy

b. anabolic reaction

c. biochemical reaction

d. catabolic reaction

e. chemical equation

f. chemical reaction

g. enzyme

h. endothermic

i. exothermic

j. metabolism

k. product

l. reactant

Lesson 2.2: Vocabulary II

Name____________________ **Class**______________ **Date**________

Fill in the blank with the appropriate term.

1. Biochemical reactions are chemical reactions that take place inside the ____________ of living things.

2. During a chemical reaction, the ____________ are used up to create the products.

3. All chemical reactions need ____________ to get started.

4. ____________ reactions in organisms are called catabolic reactions.

5. ____________ energy provides the push needed to start a chemical reaction.

6. Your ____________ includes both exothermic and endothermic reactions.

7. A chemical reaction involves the breaking and forming of ___________.

8. In a chemical reaction, all matter is ____________.

9. Energy can be released during a chemical reaction in the form of ____________ and light.

10. In a chemical reaction, there is the same amount of each ____________ in the products as there was in the reactants.

11. An ____________ reaction builds up bigger molecules from smaller ones.

12. An ____________ works by reducing the amount of activation energy needed to start the reaction.

Lesson 2.2: Critical Writing

Name___________________ Class______________ Date________

Thoroughly answer the question below. Use appropriate academic vocabulary and clear and complete sentences.

Describe the roles of enzymes in biochemical reactions. Use specifics in discussing how enzymes work. Provide an example of a biochemical reaction involving an enzyme.

CONCEPT 7 Water, Acids, and Bases

Lesson 2.3: True or False

Name___________________ **Class**______________ **Date**________

Write true if the statement is true or false if the statement is false.

_____ 1. Water is a chemical.

_____ 2. The hydrogen atoms in a water molecule attract electrons more strongly than the oxygen atom does.

_____ 3. Hydrogen bonds are very strong bonds.

_____ 4. Water is a reactant in photosynthesis.

_____ 5. Enzymes in the small intestine need an acidic environment in order to work.

_____ 6. Pure water has a pH of 7.

_____ 7. Lemon juice is a stronger acid than orange juice.

_____ 8. An ion is an electrically charged atom or molecule.

_____ 9. The stomach is a very acidic environment.

_____ 10. Water is released during cellular respiration.

_____ 11. Soap is very acidic.

_____ 12. Hydrogen bonds cause water to have a relatively high boiling point of 100°F.

_____ 13. Acids have a pH lower than 7.

_____ 14. Bases have a pH lower than 7.

_____ 15. A water molecule has positive and negative parts to it.

Lesson 2.3: Critical Reading

Name___________________ **Class**______________ **Date**________

Read these passages from the text and answer the questions that follow.

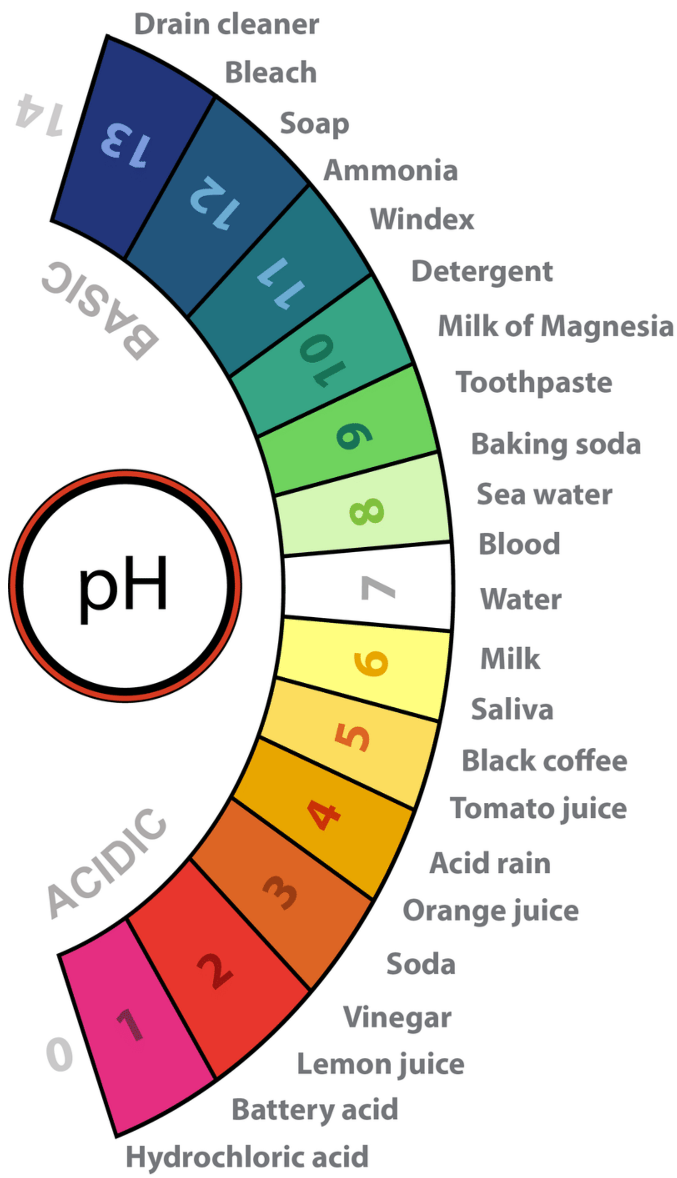
Acids and Bases

Water is the main ingredient of many solutions. A **solution** is a mixture of two or more substances that has the same composition throughout. Some solutions are acids and some are bases. To understand acids and bases, you need to know more about pure water. In pure water (such as distilled water), a tiny fraction of water molecules naturally break down to form ions. An ion is an electrically charged atom or molecule. The breakdown of water is represented by the chemical equation

$2H_2O \rightarrow H_3O^+ + OH^-$

The products of this reaction are a hydronium ion (H_3O^+) and a hydroxide ion (OH^-). The hydroxide ion, which has a negative charge, forms when a water molecule gives up a positively charged hydrogen ion (H^+). The hydronium ion, which has positive charge, forms when another water molecule accepts the hydrogen ion.

Acidity and pH The concentration of hydronium ions in a solution is known as acidity. In pure water, the concentration of hydronium ions is very low; only about 1 in 10 million water molecules naturally breaks down to form a hydronium ion. As a result, pure water is essentially neutral. Acidity is measured on a scale called **pH**, as shown in the figure below. Pure water has a pH of 7, so the point of neutrality on the pH scale is 7.



pH Scale. The pH scale ranges from 0 to 14, with 7 being the point of neutrality. What is the pH of lemon juice? Of milk?

Acids and Bases in Organisms

Acids and bases are important in living things because most enzymes can do their job only at a certain level of acidity. Cells secrete acids and bases to maintain the proper pH for enzymes to work. For example, every time you digest food, acids and bases are at work in your digestive system. Consider the enzyme pepsin, which helps break down proteins in the stomach. Pepsin needs an acidic environment to do its job, and the stomach secretes a strong acid that allows pepsin to work. However, when stomach contents enter the small intestine, the acid must be neutralized. This is because enzymes in the small intestine need a basic environment in order to work. An organ called the pancreas secretes a strong base into the small intestine, and this base neutralizes the acid.

Water and Life

The human body is about 70% water (not counting the water in body fat, which varies from person to person). The body needs all this water to function normally. Just why is so much water required by human beings and other organisms? Water can dissolve many substances that organisms need, and it is necessary for many biochemical reactions. The examples below are among the most important biochemical processes that occur in living things, but they are just two of many ways that water is involved in biochemical reactions.

- Photosynthesis — In this process, cells use the energy in sunlight to change carbon dioxide and water to glucose and oxygen. The reactions of photosynthesis can be represented by the chemical equation

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

- Cellular respiration — In this process, cells break down glucose in the presence of oxygen and release carbon dioxide, water, and energy. The reactions of cellular respiration can be represented by the chemical equation

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

Water is involved in many other biochemical reactions. As a result, just about all life processes depend on water. Clearly, life as we know it could not exist without water.

Questions

1. Describe the best environment for the enzyme pepsin.

2. Why is water so important for life?

3. Which is a stronger acid: lemon juice or soda pop? Why?

4. What is a hydronium ion? How does one form?

5. In terms of water, what is one main difference between photosynthesis and cellular respiration?

Lesson 2.3: Multiple Choice

Name___________________ Class______________ Date________

Circle the letter of the correct choice.

1. Earth is sometimes called the
   a. "water planet," because almost 75% of its surface is covered with water.
   b. "oxygen planet," because oxygen is necessary for life.
   c. "carbon planet," because carbon is the central element in organic compounds.
   d. all of the above.
2. The oxygen in a water molecule
   a. attracts electrons more strongly than the hydrogen atoms.
   b. has a slight negative charge.
   c. binds to a hydrogen of another water molecule through a hydrogen bond.

d. all of the above

3. Which of the following is an example of a solution?
    a. a pepperoni pizza
    b. a box of Lucky Charms cereal
    c. a glass of orange juice
    d. a hot fudge sundae
4. Which is the strongest acid?
    a. vinegar
    b. soda pop
    c. orange juice
    d. lemon juice
5. A solution with a lower concentration of hydronium ions than pure water
    a. can have a pH of 6.5.
    b. is a base.
    c. can taste sweet.
    d. all of the above
6. How do hydrogen bonds affect water's properties?
    a. Hydrogen bonds explain why water molecules stick together.
    b. Hydrogen bonds cause water to have a relatively high boiling point.
    c. Hydrogen bonds also cause water to expand when it freezes.
    d. all of the above
7. Where is most of the freshwater found?
    a. as ground water
    b. in icecaps, glaciers and inland seas
    c. in the oceans
    d. in other areas

Lesson 2.3: Vocabulary I

Name___________________ Class______________ Date________

Match the vocabulary word with the proper definition.

Definitions

_____ 1. for water, 212°F or 100°C

_____ 2. a range from 0 to 14

_____ 3. has a pH less than 7

_____ 4. has a pH more than 7

_____ 5. photosynthesis

_____ 6. OH^-

_____ 7. a measure of the acidity of a solution

_____ 8. has the same composition throughout

_____ 9. needs an acidic environment to work

_____ 10. an organ that secretes a strong base into the small intestine

_____ 11. a difference in electrical charge within the same molecule

_____ 12. holds water molecules together

Terms

a. acid

b. base

c. boiling point

d. hydrogen bond

e. hydroxide ion

f. pancreas

g. pepsin

h. pH

i. pH scale

j. polarity

k. solution

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

Lesson 2.3: Vocabulary II

Name___________________ **Class**______________ **Date**________

Fill in the blank with the appropriate term.

1. Water's ____________ gives it unique properties that help explain why it is vital to all living organisms.
2. In water, the ___________ atom attracts electrons more strongly than the ___________ atoms do.
3. Ice floats on water because ice has a ____________ density.
4. A mixture of two or more substances with the same composition throughout is a ___________.
5. pH is a measure of the ____________ of a solution.
6. A(n) ____________ has a pH lower than 7.
7. Water molecules are held together by ____________ bonds.
8. ____________ is a difference in electrical charge between different parts of the same molecule.
9. 100°C is water's ____________ point.
10. Water is essentially neutral, with a pH of ____________.
11. ____________ is slightly basic with a pH just above 7.
12. In a water molecule, the hydrogen atoms have a ____________ charge.

Lesson 2.3: Critical Writing

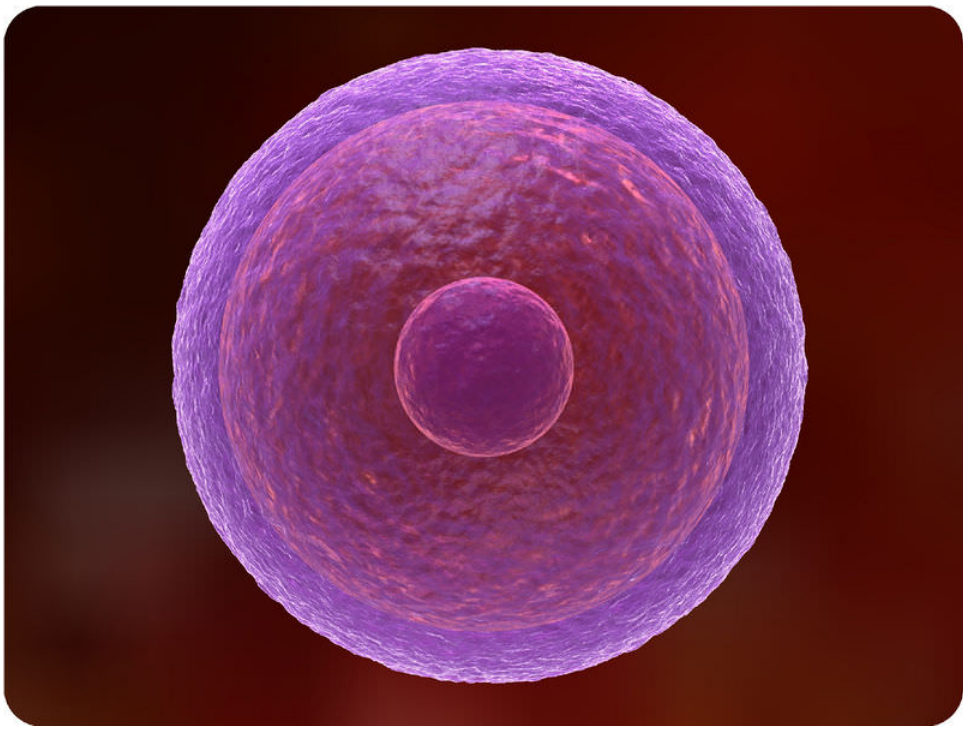
Name___________________ Class______________ Date________

Thoroughly answer the question below. Use appropriate academic vocabulary and clear and complete sentences.

Using specifics in describing the structure of the water molecule, and discuss why water is referred to as a "polar molecule."

CHAPTER 8 Cellular Structure and Function

Chapter Outline



What is this incredible object? Would it surprise you to learn that it represents a human cell? The image represents a cell, similar to one that may be produced by a type of modern microscope called an electron microscope. Without this technology, we wouldn't be able to see the structures inside cells.

Cells may be small in size, but they are extremely important to life. Like all other living things, you are made of cells. Cells are the basis of life, and without cells, life as we know it would not exist. You will learn more about these amazing building blocks of life when you read this chapter.

8.1 Introduction to Cells

Lesson Objectives

- State the cell theory, and list the discoveries that led to it.
- Describe the diversity of cell shapes, and explain why cells are so small.
- Identify the parts that all cells have in common.
- Contrast prokaryotic and eukaryotic cells.

Vocabulary

- cytoplasm
- eukaryote
- eukaryotic cell
- nucleus
- organelle
- plasma membrane
- prokaryote
- prokaryotic cell
- ribosome
- virus

Introduction

If you look at living matter with a microscope—even a simple light microscope—you will see that it consists of cells. Cells are the basic units of the structure and function of living things. They are the smallest units that can carry out the processes of life. All organisms are made up of one or more cells, and all cells have many of the same structures and carry out the same basic life processes. Knowing the structures of cells and the processes they carry out is necessary to understanding life itself.

Discovery of Cells

The first time the word *cell* was used to refer to these tiny units of life was in 1665 by a British scientist named Robert Hooke. Hooke was one of the earliest scientists to study living things under a microscope. The microscopes of his day were not very strong, but Hooke was still able to make an important discovery. When he looked at a thin slice of cork under his microscope, he was surprised to see what looked like a honeycomb. Hooke made the drawing in **Figure** 8.1 to show what he saw. As you can see, the cork was made up of many tiny units, which Hooke called cells.

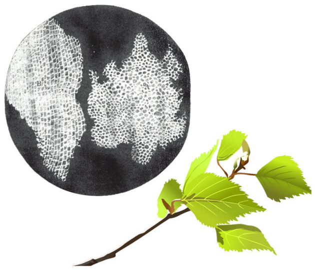


FIGURE 8.1
Cork Cells. This is what Robert Hooke saw when he looked at a thin slice of cork under his microscope. What type of material is cork? Do you know where cork comes from?

Leeuwenhoek's Discoveries

Soon after Robert Hooke discovered cells in cork, Anton van Leeuwenhoek in Holland made other important discoveries using a microscope. Leeuwenhoek made his own microscope lenses, and he was so good at it that his microscope was more powerful than other microscopes of his day. In fact, Leeuwenhoek's microscope was almost as strong as modern light microscopes.

Using his microscope, Leeuwenhoek discovered tiny animals such as rotifers. The magnified image of a rotifer in **Figure** 8.2 is similar to what Leeuwenhoek observed. Leeuwenhoek also discovered human blood cells. He even scraped plaque from his own teeth and observed it under the microscope. What do you think Leeuwenhoek saw in the plaque? He saw tiny living things with a single cell that he named *animalcules* ("tiny animals"). Today, we call Leeuwenhoek's animalcules bacteria.

FIGURE 8.2
Microscopic Rotifer. Rotifers like this one were first observed by Aton van Leeuwenhoek. This tiny animal is too small to be seen without a microscope.

The Cell Theory

By the early 1800s, scientists had observed the cells of many different organisms. These observations led two German scientists, named Theodor Schwann and Matthias Jakob Schleiden, to propose that cells are the basic building blocks of all living things. Around 1850, a German doctor named Rudolf Virchow was studying cells under a microscope when he happened to see them dividing and forming new cells. He realized that living cells produce new cells through division. Based on this realization, Virchow proposed that living cells arise only from other living cells.

The ideas of all three scientists—Schwann, Schleiden, and Virchow—led to the cell theory, which is one of the fundamental theories of biology. The cell theory states that:

- All organisms are made of one or more cells.
- All the life functions of organisms occur within cells.
- All cells come from already existing cells.

Microscopes

Starting with Robert Hooke in the 1600s, the microscope opened up an amazing new world—the world of life at the level of the cell. As microscopes continued to improve, more discoveries were made about the cells of living things. However, by the late 1800s, light microscopes had reached their limit. Objects much smaller than cells, including the structures inside cells, were too small to be seen with even the strongest light microscope.

Then, in the 1950s, a new type of microscope was invented. Called the electron microscope, it used a beam of electrons instead of light to observe extremely small objects. With an electron microscope, scientists could finally see the tiny structures inside cells. In fact, they could even see individual molecules and atoms. The electron microscope had a huge impact on biology. It allowed scientists to study organisms at the level of their molecules and led to the emergence of the field of molecular biology. With the electron microscope, many more cell discoveries were made. **Figure** 8.3 shows how the cell structures called organelles appear when scanned by an electron microscope.

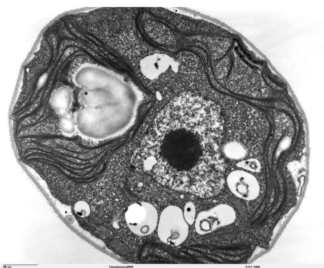


FIGURE 8.3

Electron Microscope Image of Organelles. An electron microscope produced this image of a cell.

KQED: The World's Most Powerful Microscope

Lawrence Berkeley National labs uses a $27 million electron microscope to make images to a resolution of half the width of a hydrogen atom. This makes it the world's most powerful microscope.

MEDIA

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KQED: Confocal Microscopy

Cutting-edge microscopes, called confocal microscopes, at the University of California, San Francisco are helping scientists create three-dimensional images of cells, and may help lead to new medical breakthroughs, including a treatment for Type 1 diabetes. See http://www.kqed.org/quest/television/super-microscope for a description of this work.

Diversity of Cells

Today, we know that all living cells have certain things in common. For example, all cells share functions such as obtaining and using energy, responding to the environment, and reproducing. We also know that different types of cells—even within the same organism—may have their own unique functions as well. Cells with different functions generally have different shapes that suit them for their particular job.

Cells vary in size as well as shape, but all cells are very small. In fact, most cells are much smaller than the period at the end of this sentence. If cells have such an important role in living organisms, why are they so small? Even the largest organisms have microscopic cells. What limits cell size?

Cell Size

The answer to these questions is clear once you know how a cell functions. To carry out life processes, a cell must be able to quickly pass substances into and out of the cell. For example, it must be able to pass nutrients and oxygen into the cell and waste products out of the cell. Anything that enters or leaves a cell must cross its outer surface. It is this need to pass substances across the surface that limits how large a cell can be.

Look at the two cubes in **Figure** 8.4. As this figure shows, a larger cube has less surface area relative to its volume than a smaller cube. This relationship also applies to cells; a larger cell has less surface area relative to its volume than a smaller cell. A cell with a larger volume also needs more nutrients and oxygen and produces more wastes. Because all of these substances must pass through the surface of the cell, a cell with a large volume will not have enough surface area to allow it to meet its needs. The larger the cell is, the smaller its ratio of surface area to volume, and the harder it will be for the cell to get rid of its wastes and take in necessary substances. This is what limits the size of the cell.

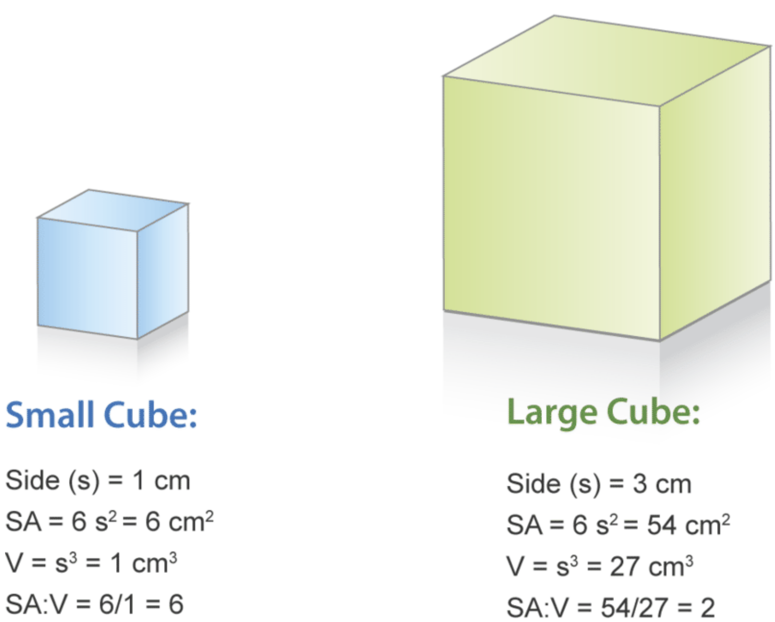


FIGURE 8.4
Surface Area to Volume Comparison. A larger cube has a smaller surface area (SA) to volume (V) ratio than a smaller cube. This also holds true for cells and limits how large they can be.

Cell Shape

Cells with different functions often have different shapes. The cells pictured in **Figure** 8.5 are just a few examples of the many different shapes that cells may have. Each type of cell in the figure has a shape that helps it do its job. For example, the job of the nerve cell is to carry messages to other cells. The nerve cell has many long extensions that reach out in all directions, allowing it to pass messages to many other cells at once. Do you see the tail-like projections on the algae cells? Algae live in water, and their tails help them swim. Pollen grains have spikes that help them stick to insects such as bees. How do you think the spikes help the pollen grains do their job? (*Hint:* Insects pollinate flowers.)

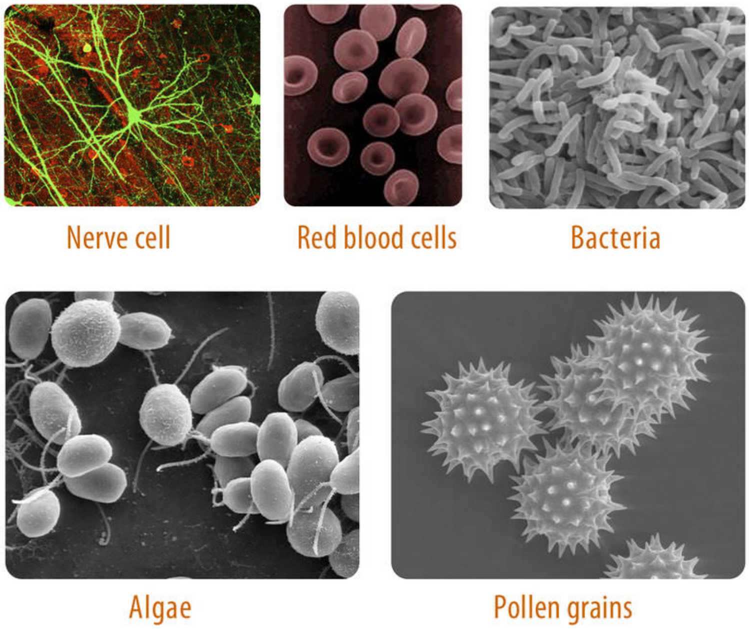


FIGURE 8.5

As these pictures show, cells come in many different shapes. Clockwise from the upper left photo are a nerve cell, red blood cells, bacteria, pollen grains, and algae. How are the shapes of these cells related to their functions?

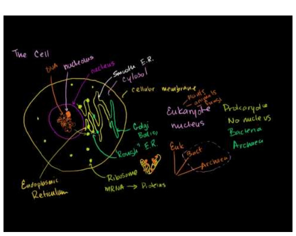
Parts of a Cell

Although cells are diverse, all cells have certain parts in common. The parts include a plasma membrane, cytoplasm, ribosomes, and DNA.

1. The **plasma membrane** (also called the cell membrane) is a thin coat of lipids that surrounds a cell. It forms the physical boundary between the cell and its environment, so you can think of it as the "skin" of the cell.
2. **Cytoplasm** refers to all of the cellular material inside the plasma membrane. Cytoplasm is made up of a watery substance called cytosol and contains other cell structures such as ribosomes.
3. **Ribosomes** are structures in the cytoplasm where proteins are made.
4. DNA is a nucleic acid found in cells. It contains the genetic instructions that cells need to make proteins.

These parts are common to all cells, from organisms as different as bacteria and human beings. How did all known organisms come to have such similar cells? The similarities show that all life on Earth has a common evolutionary history.

A nice introduction to the cell is available at http://www.youtube.com/watch?v=Hmwvj9X4GNY (21:03).



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Two Types of Cells

There is another basic cell structure that is present in many but not all living cells: the nucleus. The **nucleus** of a cell is a structure in the cytoplasm that is surrounded by a membrane (the nuclear membrane) and contains DNA. Based on whether they have a nucleus, there are two basic types of cells: prokaryotic cells and eukaryotic cells. You can watch animations of both types of cells at the link below. http://www.learnerstv.com/animation/animation.php?ani=162&cat=biology

Prokaryotic Cells

Prokaryotic cells are cells without a nucleus. The DNA in prokaryotic cells is in the cytoplasm rather than enclosed within a nuclear membrane. Prokaryotic cells are found in single-celled organisms, such as bacteria, like the one shown in **Figure** 8.6. Organisms with prokaryotic cells are called **prokaryotes**. They were the first type of organisms to evolve and are still the most common organisms today.

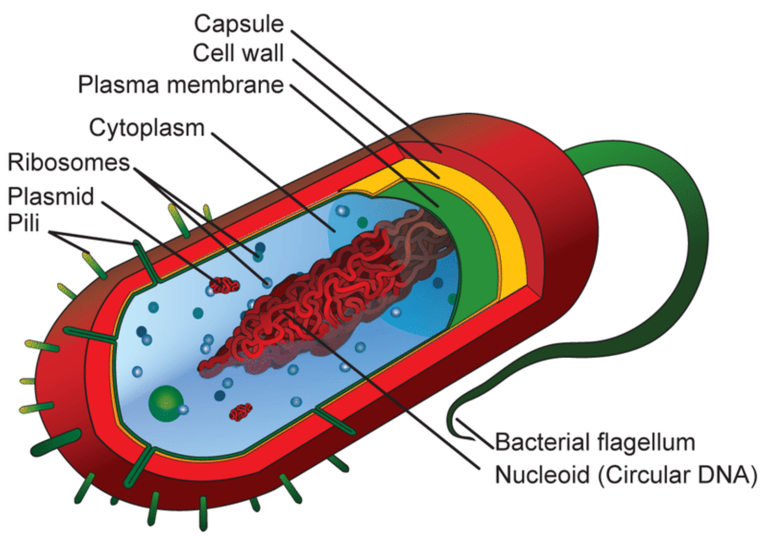

FIGURE 8.6
Model of a prokaryotic cell: bacterium

Eukaryotic Cells

Eukaryotic cells are cells that contain a nucleus. A typical eukaryotic cell is shown in **Figure** 8.7. Eukaryotic cells are usually larger than prokaryotic cells, and they are found mainly in multicellular organisms. Organisms with eukaryotic cells are called **eukaryotes**, and they range from fungi to people.

Eukaryotic cells also contain other organelles besides the nucleus. An **organelle** is a structure within the cytoplasm that performs a specific job in the cell. Organelles called mitochondria, for example, provide energy to the cell, and organelles called vacuoles store substances in the cell. Organelles allow eukaryotic cells to carry out more functions than prokaryotic cells can.

Viruses: Prokaryotes or Eukaryotes?

Viruses, like the one depicted in **Figure** 8.8, are tiny particles that may cause disease. Human diseases caused by viruses include the common cold and flu. Do you think viruses are prokaryotes or eukaryotes? The answer may

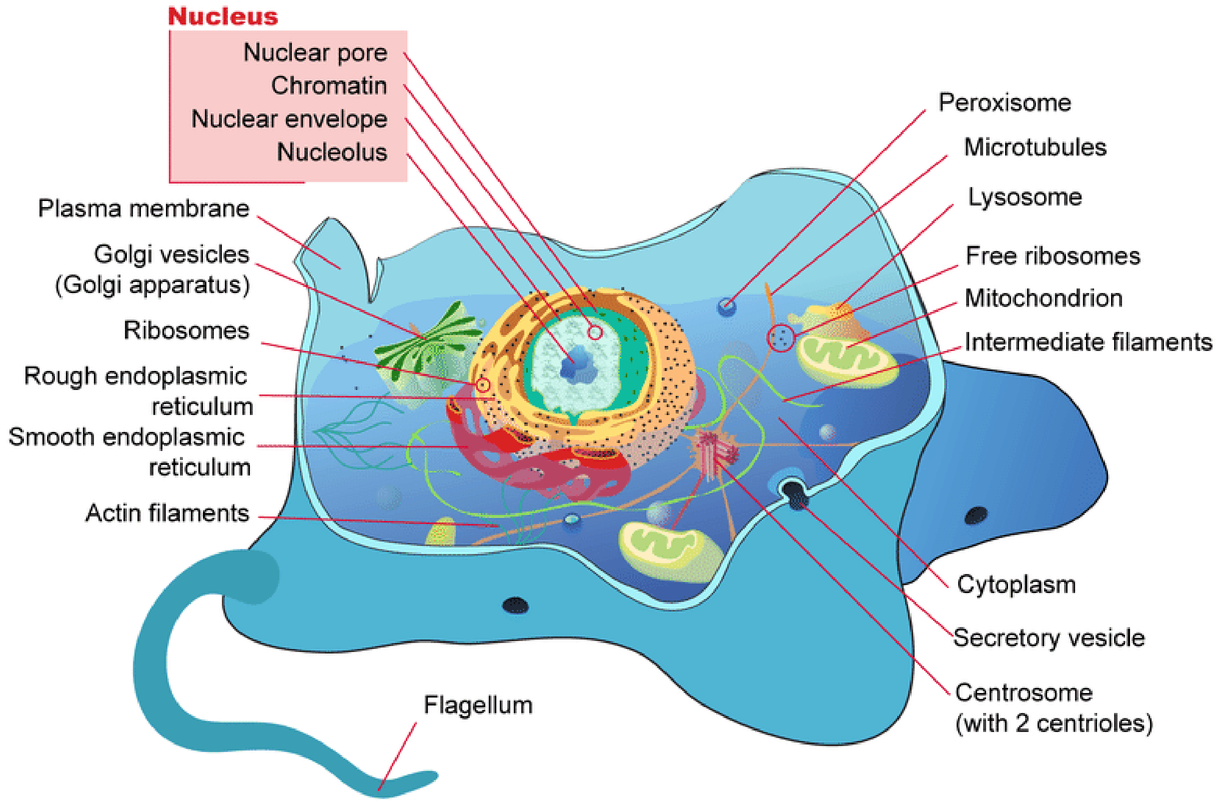

FIGURE 8.7
Eukaryotic Cell. Compare and contrast the eukaryotic cell shown here with the prokaryotic cell. What similarities and differences do you see?

surprise you. Viruses are not cells at all, so they are neither prokaryotes nor eukaryotes.

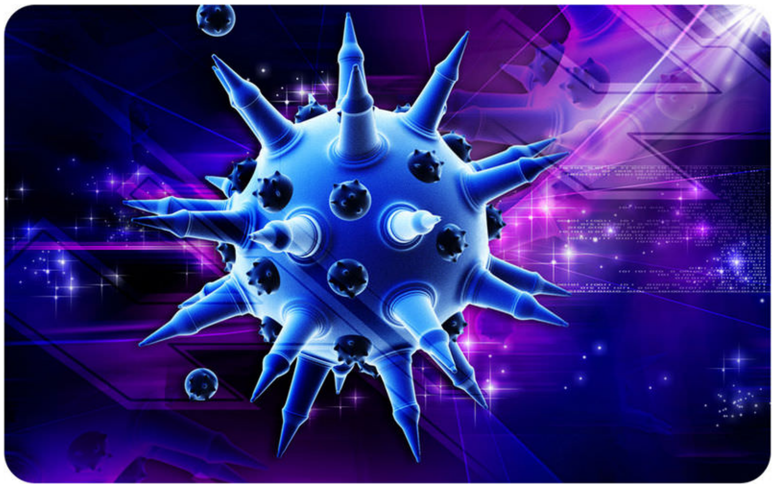

FIGURE 8.8
Cartoon of a flu virus. The flu virus is a tiny particle that may cause illness in humans. What is a virus? Is it a cell? Is it even alive?

Viruses contain DNA but not much else. They lack the other parts shared by all cells, including a plasma membrane, cytoplasm, and ribosomes. Therefore, viruses are not cells, but are they alive? All living things not only have cells; they are also capable of reproduction. Viruses cannot reproduce by themselves. Instead, they infect living hosts, and use the hosts' cells to make copies of their own DNA. For these reasons, most scientists do not consider viruses to be living things.

An overview of viruses can be seen at http://www.youtube.com/watch?v=0h5Jd7sgQWY (23:17).

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URL: http://www.ck12.org/flx/render/embeddedobject/248

Lesson Summary

- Discoveries about cells using the microscope led to the development of the cell theory. This theory states that all organisms are made of one or more cells, all the life functions of organisms occur within cells, and all cells come from already existing cells.
- All cells are very small because they need to pass substances across their surface. Their small size gives them a relatively large ratio of surface area to volume, facilitating the transfer of substances. The shapes of cells may vary, and a cell's shape generally suits its function.
- Cells are diverse, but all cells contain a plasma membrane, cytoplasm, ribosomes, and DNA.
- Prokaryotic cells are cells without a nucleus. They are found in single-celled organisms. Eukaryotic cells are cells with a nucleus and other organelles. They are found mainly in multicellular organisms.

Review Questions

Recall

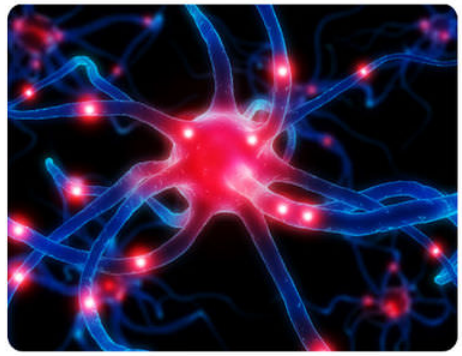
1. What did Hooke and Leeuwenhoek discover about cells by using a microscope?

2. What does the cell theory state? Name the three scientists mainly responsible for developing the cell theory.

3. List the four parts that are found in all living cells.

Apply Concepts

4. One of the cells pictured below is a human brain cell. The other cell is found in human blood. Which cell came from the brain? Explain your answer.



Think Critically

5. Why are all cells very small? Explain what limits the size of cells.
6. Compare and contrast prokaryotic cells and eukaryotic cells.
7. Explain why viruses are not considered to be living.

Points to Consider

Cells have many different structures that carry out the processes of life.

- Beside the cell parts described in this lesson, what other structures do you think cells might have? What life processes might these other structures carry out?
- Do you think plant and animal cells are just alike? Or do they differ in some way? How might they differ?

8.2 Cell Structures

Lesson Objectives

- Describe the structure and function of the plasma membrane.
- Identify the roles of the cytoplasm and cytoskeleton.
- Outline the form and function of the nucleus and other organelles.
- List special structures of plant cells, and state what they do.
- Explain how cells are organized in living things.

Vocabulary

- ATP
- cell wall
- central vacuole
- chloroplast
- cytoskeleton
- endoplasmic reticulum
- endosymbiotic theory
- Golgi apparatus
- mitochondria
- phospholipid bilayer
- vacuole
- vesicle

Introduction

Your body is made up of trillions of cells, but all of them perform the same basic life functions. They all obtain and use energy, respond to the environment, and reproduce. How do your cells carry out these basic functions and keep themselves—and you—alive? To answer these questions, you need to know more about the structures that make up cells.

Overview of Cell Structures

In some ways, a cell resembles a plastic bag full of Jell-O. Its basic structure is a plasma membrane filled with cytoplasm. Like Jell-O containing mixed fruit, the cytoplasm of the cell also contains various structures, such as a nucleus and other organelles. **Figure** 8.9 shows the structures inside a typical eukaryotic cell, in this case the cell of an animal. Refer to the figure as you read about the structures below. You can also explore the structures of an interactive animal cell at this link: http://www.cellsalive.com/cells/cell_model.htm .

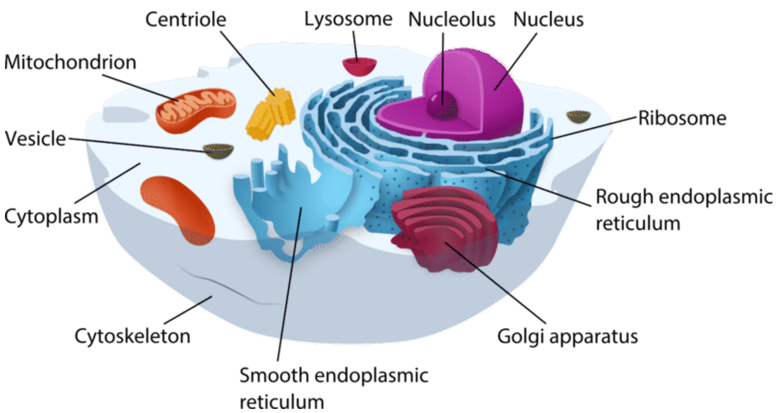


FIGURE 8.9

Animal Cell. This animal cell consists of cytoplasm enclosed within a plasma membrane. The cytoplasm contains many different organelles.

The Plasma Membrane

The plasma membrane forms a barrier between the cytoplasm inside the cell and the environment outside the cell. It protects and supports the cell and also controls everything that enters and leaves the cell. It allows only certain substances to pass through, while keeping others in or out. The ability to allow only certain molecules in or out of the cell is referred to as selective permeability or semipermeability. To understand how the plasma membrane controls what crosses into or out of the cell, you need to know its composition.

The plasma membrane is discussed at http://www.youtube.com/watch?v=-aSfoB8Cmic (6:16). The cell wall (see below) is also discussed in this video.

The Phospholipid Bilayer

The plasma membrane is composed mainly of phospholipids, which consist of fatty acids and alcohol. The phospholipids in the plasma membrane are arranged in two layers, called a **phospholipid bilayer**. As shown in **Figure** 8.10, each phospholipid molecule has a head and two tails. The head "loves" water (hydrophilic) and the tails "hate" water (hydrophobic). The water-hating tails are on the interior of the membrane, whereas the water-loving heads point outwards, toward either the cytoplasm or the fluid that surrounds the cell.

Molecules that are hydrophobic can easily pass through the plasma membrane, if they are small enough, because they are water-hating like the interior of the membrane. Molecules that are hydrophilic, on the other hand, cannot pass through the plasma membrane—at least not without help—because they are water-loving like the exterior of the membrane.

Other Molecules in the Plasma Membrane

The plasma membrane also contains other molecules, primarily other lipids and proteins. The green molecules in **Figure** 8.10, for example, are the lipid cholesterol. Molecules of cholesterol help the plasma membrane keep its shape. Many of the proteins in the plasma membrane assist other substances in crossing the membrane.

Extensions of the Plasma Membrane

The plasma membrane may have extensions, such as whip-like flagella or brush-like cilia. In single-celled organisms, like those shown in **Figure** 8.11, the membrane extensions may help the organisms move. In multicellular organisms,

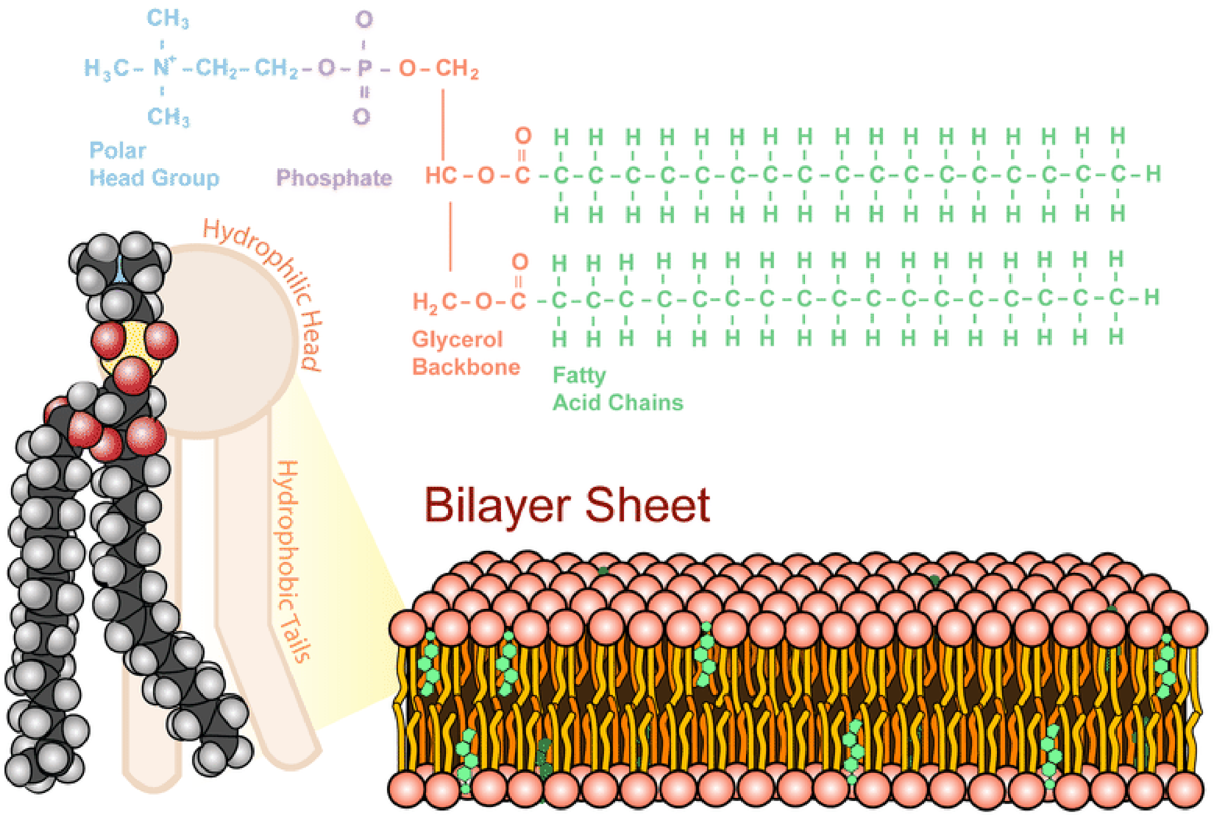


FIGURE 8.10

Phospholipid Bilayer. The phospholipid bilayer consists of two layers of phospholipids, with a hydrophobic, or water-hating, interior and a hydrophilic, or water-loving, exterior. The hydrophilic (polar) head group and hydrophobic tails (fatty acid chains) are depicted in the single phospholipid molecule. The polar head group and fatty acid chains are attached by a 3-carbon glycerol unit.

the extensions have other functions. For example, the cilia on human lung cells sweep foreign particles and mucus toward the mouth and nose.

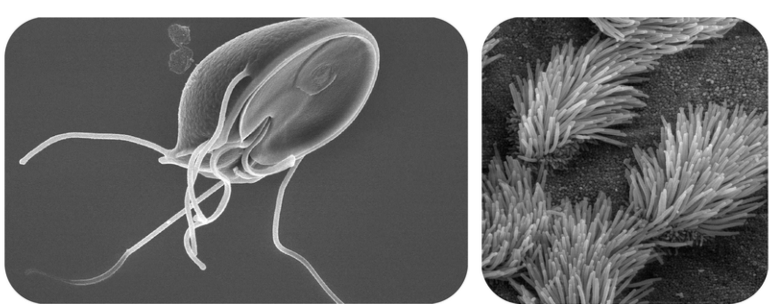


FIGURE 8.11

Flagella (left) and cilia (right). Flagella and cilia are extensions of the plasma membrane of many cells.

Cytoplasm and Cytoskeleton

The cytoplasm consists of everything inside the plasma membrane of the cell. It includes the watery, gel-like material called cytosol, as well as various structures. The water in the cytoplasm makes up about two thirds of the cell's weight and gives the cell many of its properties.

Functions of the Cytoplasm

The cytoplasm has several important functions, including

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

Cytoskeleton

Crisscrossing the cytoplasm is a structure called the **cytoskeleton**, which consists of thread-like filaments and tubules. You can see these filaments and tubules in the cells in **Figure** 8.12. As its name suggests, the cytoskeleton is like a cellular "skeleton." It helps the cell maintain its shape and also holds cell organelles in place within the cytoplasm.

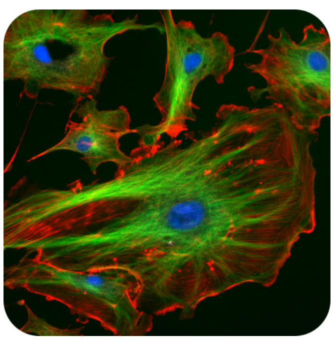


FIGURE 8.12
Cytoskeleton. The cytoskeleton gives the cell an internal structure, like the frame of a house. In this photograph, filaments and tubules of the cytoskeleton are green and red, respectively. The blue dots are cell nuclei.

The cytoskeleton is discussed in the following video http://www.youtube.com/watch?v=5rqbmLiSkpk (4:50).

The Nucleus and Other Organelles

Eukaryotic cells contain a nucleus and several other types of organelles. These structures are involved in many vital cell functions.

The Nucleus

The nucleus is the largest organelle in a eukaryotic cell and is often considered to be the cell's control center. This is because the nucleus controls which proteins the cell makes. The nucleus of a eukaryotic cell contains most of the cell's DNA, which makes up chromosomes and is encoded with genetic instructions for making proteins.

Mitochondria

The mitochondrion (plural, **mitochondria**) is an organelle that makes energy available to the cell. This is why mitochondria are sometimes referred to as the power plants of the cell. They use energy from organic compounds such as glucose to make molecules of **ATP** (adenosine triphosphate), an energy-carrying molecule that is used almost universally inside cells for energy.

Scientists think that mitochondria were once free-living organisms because they contain their own DNA. They theorize that ancient prokaryotes infected (or were engulfed by) larger prokaryotic cells, and the two organisms evolved a symbiotic relationship that benefited both of them. The larger cells provided the smaller prokaryotes with a place to live. In return, the larger cells got extra energy from the smaller prokaryotes. Eventually, the prokaryotes became permanent *guests* of the larger cells, as organelles inside them. This theory is called the **endosymbiotic theory,** and it is widely accepted by biologists today

Endoplasmic Reticulum

The **endoplasmic reticulum** (ER) is an organelle that helps make and transport proteins and lipids. There are two types of endoplasmic reticulum: rough endoplasmic reticulum (RER) and smooth endoplasmic reticulum (SER). Both types are shown in **Figure** 8.13.

- RER looks rough because it is studded with ribosomes. It provides a framework for the ribosomes, which make proteins. Bits of its membrane pinch off to form tiny sacs called vesicles, which carry proteins away from the ER.
- SER looks smooth because it does not have ribosomes. SER also makes lipids, stores substances, and plays other roles.

Ribosomes

Ribosomes are small organelles where proteins are made. They contain the nucleic acid RNA, which assembles and joins amino acids to make proteins. Ribosomes can be found alone or in groups within the cytoplasm as well as on the RER.

Golgi Apparatus

The **Golgi apparatus** is a large organelle that processes proteins and prepares them for use both inside and outside the cell. It is shown in **Figure** 8.13. The Golgi apparatus is somewhat like a post office. It receives items (proteins from the ER), packages and labels them, and then sends them on to their destinations (to different parts of the cell or to the cell membrane for transport out of the cell). The Golgi apparatus is also involved in the transport of lipids around the cell. At the link below, you can watch an animation showing how the Golgi apparatus does all these jobs. http://www.johnkyrk.com/golgiAlone.html

Vesicles and Vacuoles

Both **vesicles** and **vacuoles** are sac-like organelles that store and transport materials in the cell. Vesicles are much smaller than vacuoles and have a variety of functions. The vesicles that pinch off from the membranes of the ER and Golgi apparatus (see **Figure** 8.13) store and transport protein and lipid molecules. Some vesicles are used as chambers for biochemical reactions. Other vesicles include:

- Lysosomes, which use enzymes to break down foreign matter and dead cells.
- Peroxisomes, which use oxygen to break down poisons.

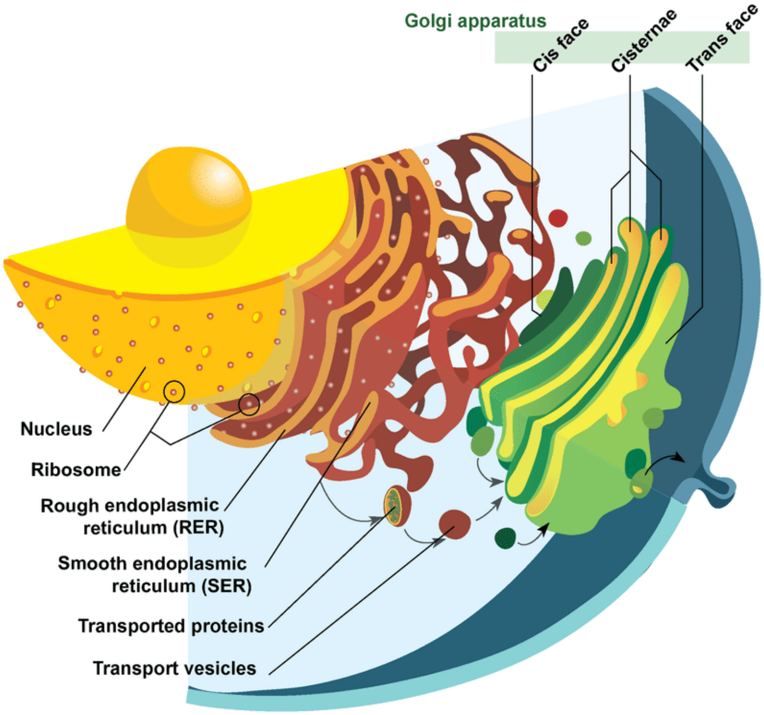


FIGURE 8.13
This drawing includes the nucleus, RER, SER, and Golgi apparatus. From the drawing, you can see how all these organelles work together to make and transport proteins.

Centrioles

Centrioles are organelles involved in cell division. They help organize the chromosomes before cell division so that each daughter cell has the correct number of chromosomes after the cell divides. Centrioles are found only in animal cells and are located near the nucleus (see **Figure** 8.9).

Special Structures in Plant Cells

Plant cells have several structures that are not found in animal cells, including a cell wall, a large central vacuole, and organelles called plastids. You can see each of these structures in **Figure** 8.14. You can also view them in an interactive plant cell at the link below. http://www.cellsalive.com/cells/cell_model.htm

Cell Wall

The **cell wall** is a rigid layer that surrounds the plasma membrane of a plant cell. It supports and protects the cell. Tiny holes, or pores, in the cell wall allow water, nutrients, and other substances to move into and out of the cell. The cell wall is made up mainly of complex carbohydrates, including cellulose.

Central Vacuole

Most mature plant cells have a large **central vacuole**. This vacuole can make up as much as 90% of the cell's volume. The central vacuole has a number of functions, including storing substances such as water, enzymes, and salts. It also helps plant tissues, such as stems and leaves, stay rigid and hold their shape. It even helps give flowers, like the ones in **Figure** 8.15, their beautiful colors.

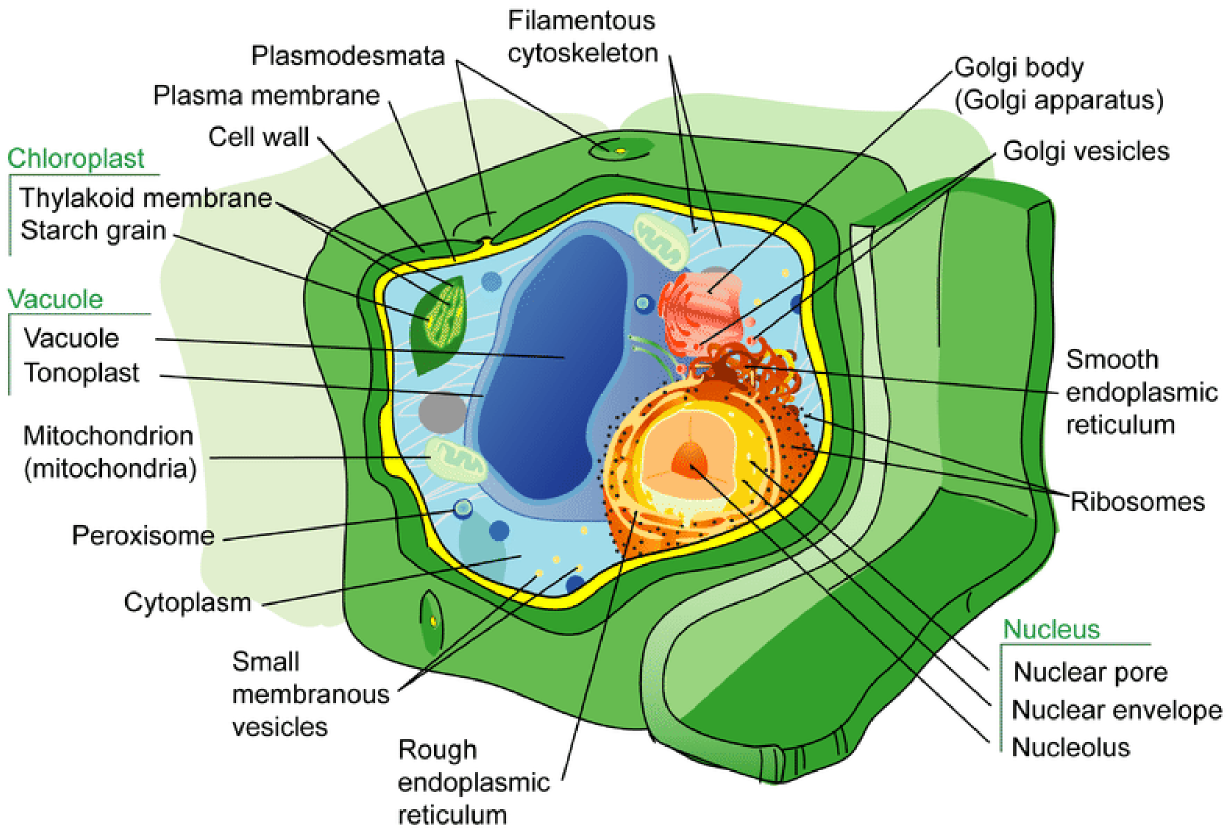


FIGURE 8.14

Plant Cell. In addition to the organelles and other structures found inside animal cells, plant cells also have a cell wall, a large central vacuole, and plastids such as chloroplasts. Can you find each of these structures in the figure?

Plastids

Plastids are organelles in plant cells that carry out a variety of different functions. The main types of plastids and their functions are described below.

- **Chloroplasts** are plastids that contain the green pigment chlorophyll. They capture light energy from the sun and use it to make food. A chloroplast is shown in **Figure** 8.14.
- Chromoplasts are plastids that make and store other pigments. The red pigment that colors the flower petals in **Figure** 8.15 was made by chromoplasts.
- Leucoplasts are plastids that store substances such as starch or make small molecules such as amino acids.

Like mitochondria, plastids contain their own DNA. Therefore, according to endosymbiotic theory, plastids may also have evolved from ancient, free-living prokaryotes that invaded larger prokaryotic cells. If so, they allowed early eukaryotes to make food and produce oxygen.

FIGURE 8.15
These flowers are red because of red pigment molecules in the central vacuoles of their cells. The bright colors are an important adaptation. They help the flowers attract pollinators such as hummingbirds so the plants can reproduce.

Organization of Cells

Cells can exist as individual cells or as groups of cells. Cells in groups can be organized at several levels.

From One Cell to Many

The simplest level of cell organization is a single-celled organism, and the most complex level is a multicellular organism. In between these two levels are biofilms and colonies.

- A single-celled organism floats freely and lives independently. Its single cell is able to carry out all the processes of life without any help from other cells.
- A biofilm is a thin layer of bacteria that sticks to a surface. Cells in a biofilm are all alike, but they may play different roles, such as taking in nutrients or making the "glue" that sticks the biofilm to the surface. The sticky plaque that forms on teeth is a biofilm of bacterial cells.
- Some single-celled organisms, such as algae, live in colonies. A colony is an organized structure composed of many cells, like the Volvox sphere in **Figure** 8.16. Volvox are algae that live in colonies of hundreds of cells. All of the cells in the colony live and work cooperatively. For example, they can coordinate the movement of their flagella, allowing them to swim together through the water as though they were part of a single organism.
- A multicellular organism consists of many cells and has different types of cells that are specialized for various functions. All the cells work together and depend on each other to carry out the life processes of the organism. Individual cells are unable to survive on their own.

Levels of Organization in Multicellular Organisms

Scientists think that multicellular organisms evolved when many single-celled organisms of the same species started to work together and benefited from the relationship. The oldest known multicellular organisms are algae that lived 1.2 billion years ago. As multicellular organisms continued to evolve, they developed increasingly complex levels of organization. Today there are multicellular organisms at all levels of organization, from the simplest, cell level of organization to the most complex, organ-system level of organization. Consider these examples:

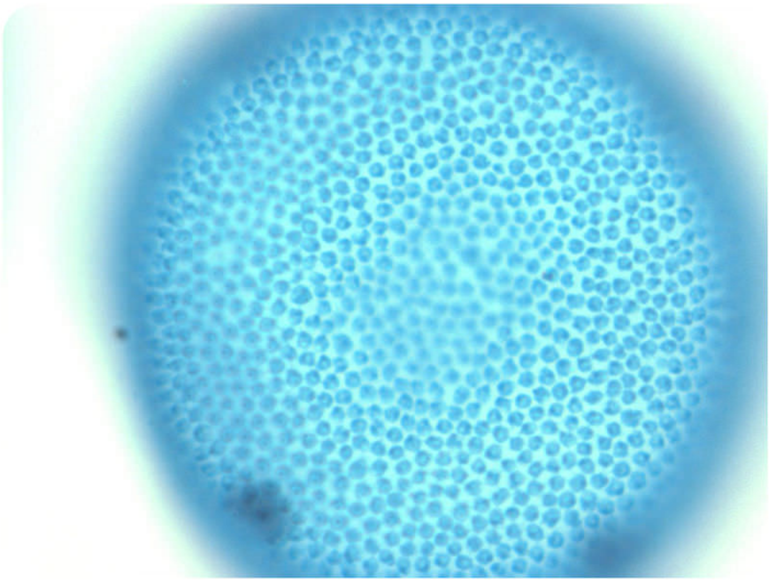


FIGURE 8.16
Volvox Colony. Volvox cells live in a colony shaped like a hollow ball. The cells of the colony may be connected by strands of cytoplasm and can function together. For example, the whole colony can swim from one place to another as one.

- Sponges have cell-level organization, in which different cells are specialized for different functions, but each cell works alone. For example, some cells digest food, while other cells let water pass through the sponge.
- Jellyfish have tissue-level organization, in which groups of cells of the same kind that do the same job form tissues. For example, jellyfish have some tissues that digest food and other tissues that sense the environment.
- Roundworms have organ-level organization, in which two or more types of tissues work together to perform a particular function as an organ. For example, a roundworm has a primitive brain that controls how the organism responds to the environment.
- Human beings have organ system-level organization, in which groups of organs work together to do a certain job, with each organ doing part of the overall task. An example is the human digestive system. Each digestive system organ—from the mouth to the small intestine—does part of the overall task of breaking down food and absorbing nutrients.

Lesson Summary

- The plasma membrane is a phospholipid bilayer that supports and protects a cell and controls what enters and leaves it.
- The cytoplasm consists of everything inside the plasma membrane, including watery cytosol and organelles. The cytoplasm suspends the organelles and does other jobs. The cytoskeleton crisscrosses the cytoplasm and gives the cell an internal framework.
- The nucleus is the largest organelle in a eukaryotic cell and contains most of the cell's DNA. Other organelles in eukaryotic cells include the mitochondria, endoplasmic reticulum, ribosomes, Golgi apparatus, vesicles, vacuoles, and centrioles (in animal cells only). Each type of organelle has important functions in the cell.
- Plant cells have special structures that are not found in animal cells, including a cell wall, a large central vacuole, and organelles called plastids.
- Cells can exist independently as single-celled organisms or with other cells as multicellular organisms. Cells of a multicellular organism can be organized at the level of cells, tissues, organs, and organ systems.

Lesson Review Questions

Recall

1. Describe the composition of the plasma membrane.

2. List functions of the cytoplasm and cytoskeleton.

3. What is the role of the nucleus of a eukaryotic cell?

4. List three structures that are found in plant cells but not in animal cells.

5. Outline the levels of organization of cells in living things, starting with the simplest level, that of single-celled organisms.

Apply Concepts

6. Create a diagram to show how the cells of multicellular organisms may be organized at different levels, from the level of the cell to the level of the organ system. Give an example of a multicellular organism at each level of organization.

Think Critically

7. Explain why hydrophobic ("water-hating") molecules can easily cross the plasma membrane, while hydrophilic ("water-loving") molecules cannot.

8. What is endosymbiotic theory? How does it explain the presence of certain organelles in eukaryotic cells?

9. Explain how the following organelles ensure that a cell has the proteins it needs: nucleus, rough and smooth ER, vesicles, and Golgi apparatus.

Points to Consider

Cells carry out all the functions of life, and they use nutrients and oxygen and produce wastes. These substances must cross the plasma membrane.

- How do you think substances cross the plasma membrane to enter or leave the cell? Does the membrane have tiny holes in it like a sieve?
- What if the substances are large? Protein molecules, for example, are very large. How do they enter or leave the cell?

8.3 Cell Transport and Homeostasis

Lesson Objectives

- Describe different types of passive transport.
- Explain how different types of active transport occur.
- Outline the role of cell transport in homeostasis.

Vocabulary

- active transport
- diffusion
- endocytosis
- exocytosis
- facilitated diffusion
- osmosis
- passive transport
- sodium-potassium pump
- transport protein
- vesicle transport

Introduction

Imagine living in a house that has walls without any windows or doors. Nothing could enter or leave the house. Now imagine living in a house with holes in the walls instead of windows and doors. Things could enter or leave the house, but you wouldn't be able to control what came in or went out. Only if a house has walls with windows and doors that can be opened or closed can you control what enters or leaves. For example, windows and doors allow you to let the dog in and keep the bugs out.

Transport Across Membranes

If a cell were a house, the plasma membrane would be walls with windows and doors. Moving things in and out of the cell is an important role of the plasma membrane. It controls everything that enters and leaves the cell. There are two basic ways that substances can cross the plasma membrane: passive transport and active transport.

Passive Transport

Passive transport occurs when substances cross the plasma membrane without any input of energy from the cell. No energy is needed because the substances are moving from an area where they have a higher concentration to an area where they have a lower concentration. Concentration refers to the number of particles of a substance per unit of volume. The more particles of a substance in a given volume, the higher the concentration. A substance always moves from an area where it is more concentrated to an area where it is less concentrated. It's a little like a ball rolling down a hill. It goes by itself without any input of extra energy.

There are several different types of passive transport, including simple diffusion, osmosis, and facilitated diffusion. Each type is described below.

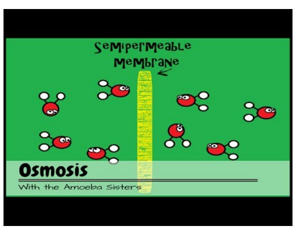
Simple Diffusion

Diffusion is the movement of a substance across a membrane, due to a difference in concentration, without any help from other molecules. The substance simply moves from the side of the membrane where it is more concentrated to the side where it is less concentrated. **Figure** 8.17 shows how diffusion works. Substances that can squeeze between the lipid molecules in the plasma membrane by simple diffusion are generally very small, hydrophobic molecules, such as molecules of oxygen and carbon dioxide.

Osmosis

Osmosis is a special type of diffusion — the diffusion of water molecules across a membrane. Like other molecules, water moves from an area of higher concentration to an area of lower concentration. Water moves in or out of a cell until its concentration is the same on both sides of the plasma membrane.

Osmosis is discussed at https://www.youtube.com/watch?v=IaZ8MtF3C6M



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Facilitated Diffusion

Water and many other substances cannot simply diffuse across a membrane. Hydrophilic molecules, charged ions, and relatively large molecules such as glucose all need help with diffusion. The help comes from special proteins in the membrane known as **transport proteins**. Diffusion with the help of transport proteins is called **facilitated diffusion**. There are several types of transport proteins, including channel proteins and carrier proteins. Both are shown in **Figure** 8.18.

- Channel proteins form pores, or tiny holes, in the membrane. This allows water molecules and small ions to pass through the membrane without coming into contact with the hydrophobic tails of the lipid molecules in the interior of the membrane.

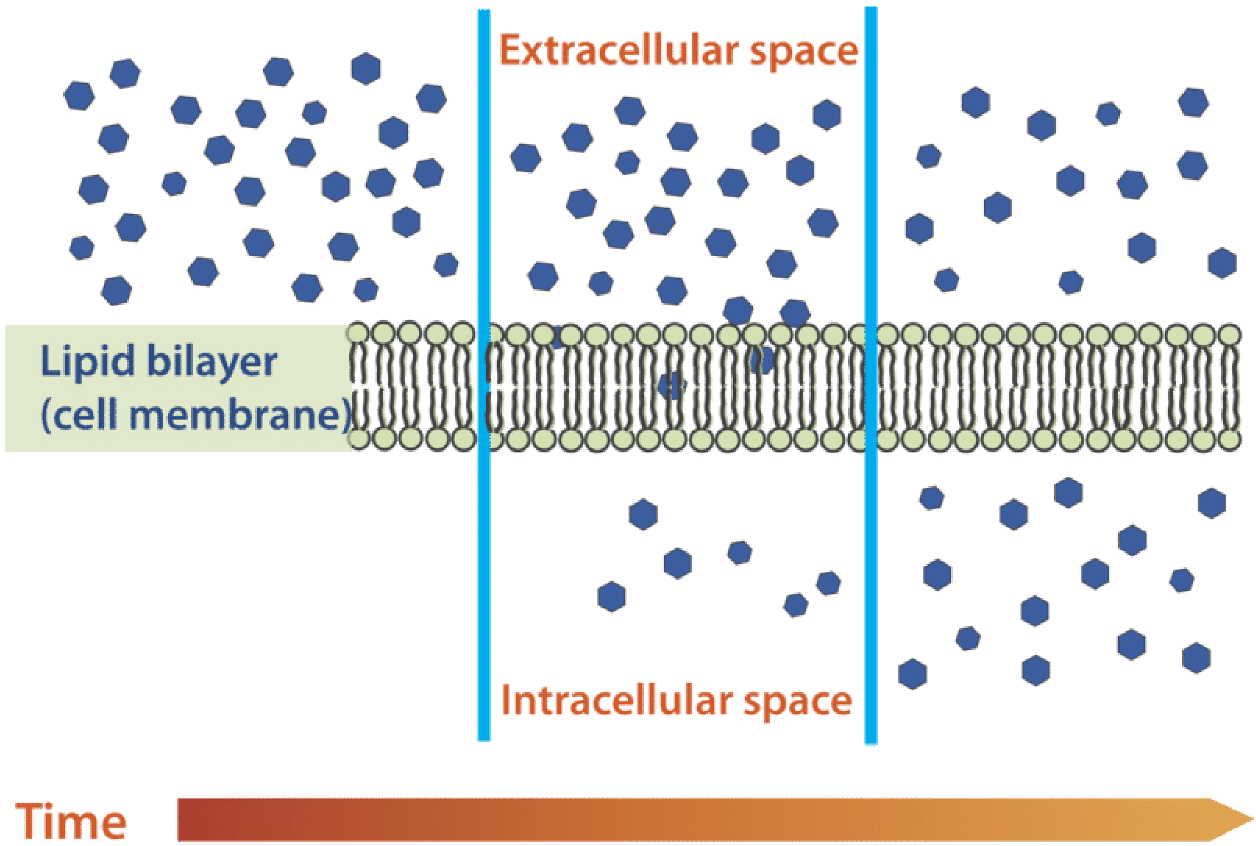

FIGURE 8.17
Diffusion Across a Cell Membrane. Molecules diffuse across a membrane from an area of higher concentration to an area of lower concentration until the concentration is the same on both sides of the membrane.

- Carrier proteins bind with specific ions or molecules, and in doing so, they change shape. As carrier proteins change shape, they carry the ions or molecules across the membrane.

Active Transport

Active transport occurs when energy is needed for a substance to move across a plasma membrane. Energy is needed because the substance is moving from an area of lower concentration to an area of higher concentration. This is a little like moving a ball uphill; it can't be done without adding energy. The energy for active transport comes from the energy-carrying molecule called ATP. Like passive transport, active transport may also involve transport proteins.

Sodium-Potassium Pump

An example of active transport is the **sodium-potassium pump**. When this pump is in operation, sodium ions are pumped out of the cell, and potassium ions are pumped into the cell. Both ions move from areas of lower to higher

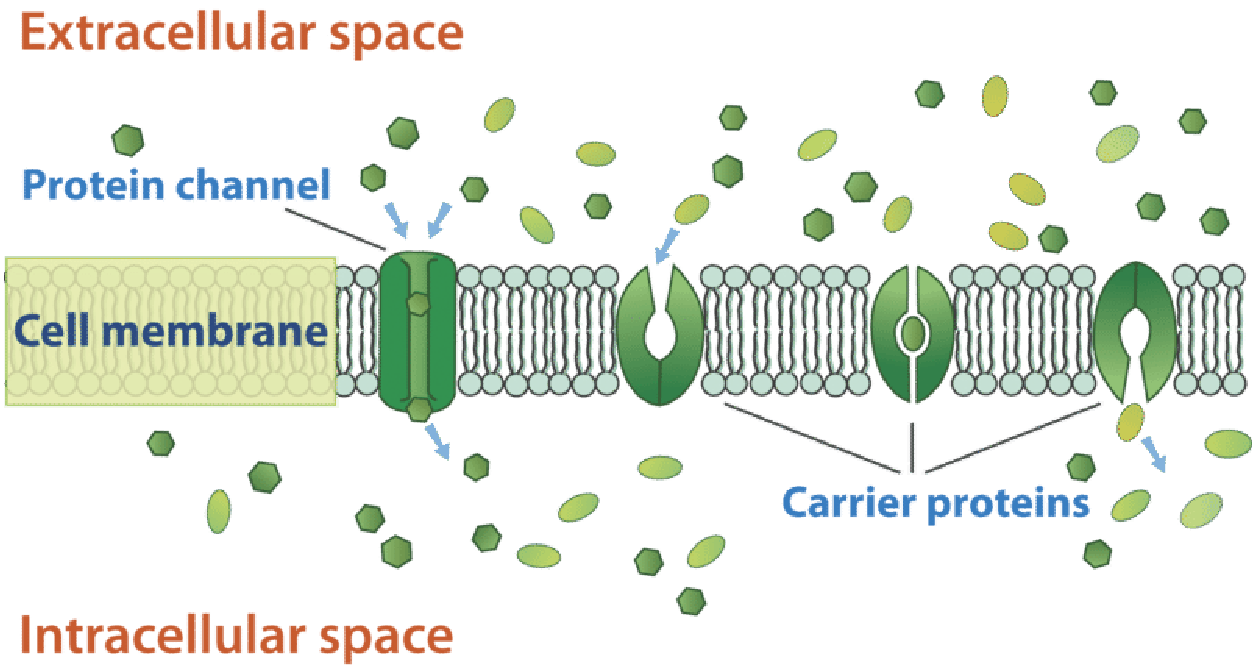

FIGURE 8.18
Facilitated Diffusion Across a Cell Membrane. Channel proteins and carrier proteins help substances diffuse across a cell membrane. In this diagram, the channel and carrier proteins are helping substances move into the cell (from the extracellular space to the intracellular space).

concentration, so ATP is needed to provide energy for this "uphill" process. **Figure** 8.19 explains in more detail how this type of active transport occurs.

A more detailed look at the sodium-potassium pump is available at http://www.youtube.com/watch?v=C_H-ONQFjpQ and http://www.youtube.com/watch?v=ye3rTjLCvAU .

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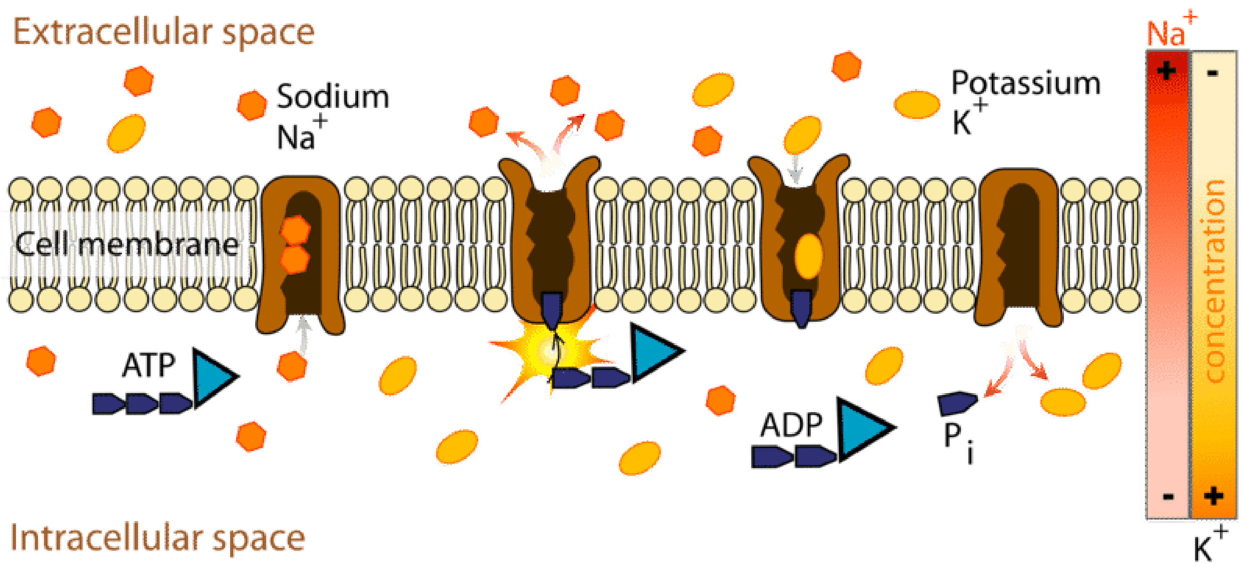

FIGURE 8.19

The sodium-potassium pump. The sodium-potassium pump moves sodium ions (Na^+) out of the cell and potassium ions (K^+) into the cell. First, three sodium ions bind with a carrier protein in the cell membrane. Then, the carrier protein receives a phosphate group from ATP. When ATP loses a phosphate group, energy is released. The carrier protein changes shape, and as it does, it pumps the three sodium ions out of the cell. At that point, two potassium ions bind to the carrier protein. The process is reversed, and the potassium ions are pumped into the cell.

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Vesicle Transport

Some molecules, such as proteins, are too large to pass through the plasma membrane, regardless of their concentration inside and outside the cell. Very large molecules cross the plasma membrane with a different sort of help, called **vesicle transport**. Vesicle transport requires energy, so it is also a form of active transport. There are two types of vesicle transport: endocytosis and exocytosis. Both types are shown in **Figure** 8.20 and described below.

- **Endocytosis** is the type of vesicle transport that moves a substance into the cell. The plasma membrane completely engulfs the substance, a vesicle pinches off from the membrane, and the vesicle carries the substance into the cell. When an entire cell is engulfed, the process is called phagocytosis. When fluid is engulfed, the process is called pinocytosis.

- **Exocytosis** is the type of vesicle transport that moves a substance out of the cell. A vesicle containing the substance moves through the cytoplasm to the cell membrane. Then, the vesicle membrane fuses with the cell membrane, and the substance is released outside the cell. You can watch an animation of exocytosis at the link below.

http://www.stanford.edu/group/Urchin/GIFS/exocyt.gif

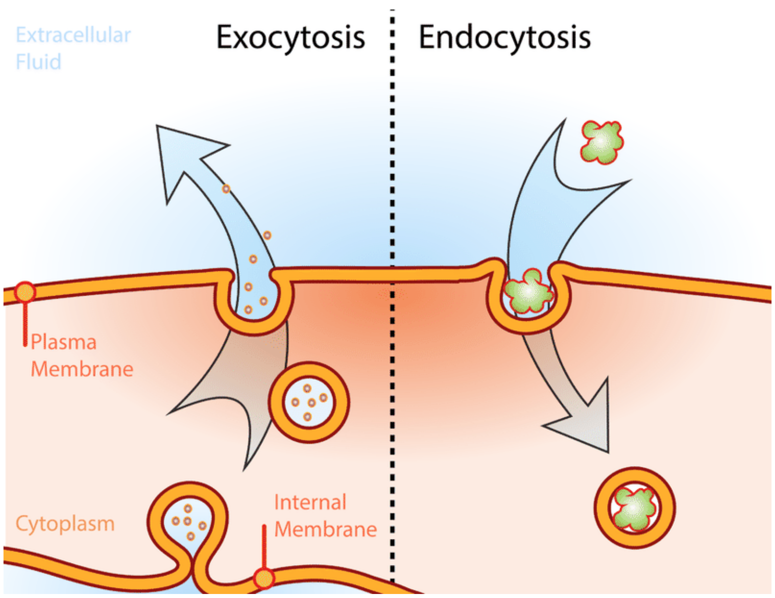


FIGURE 8.20
Illustration of the two types of vesicle transport, exocytosis and endocytosis.

Homeostasis and Cell Function

For a cell to function normally, a stable state must be maintained inside the cell. For example, the concentration of salts, nutrients, and other substances must be kept within a certain range. The process of maintaining stable conditions inside a cell (or an entire organism) is homeostasis. Homeostasis requires constant adjustments, because conditions are always changing both inside and outside the cell. The processes described in this lesson play important roles in homeostasis. By moving substances into and out of cells, they keep conditions within normal ranges inside the cells and the organism as a whole.

Lesson Summary

- A major role of the plasma membrane is transporting substances into and out of the cell. There are two major types of cell transport: passive transport and active transport.
- Passive transport requires no energy. It occurs when substances move from areas of higher to lower concentration. Types of passive transport include simple diffusion, osmosis, and facilitated diffusion.
- Active transport requires energy from the cell. It occurs when substances move from areas of lower to higher concentration or when very large molecules are transported. Types of active transport include ion pumps, such as the sodium-potassium pump, and vesicle transport, which includes endocytosis and exocytosis.
- Cell transport helps cells maintain homeostasis by keeping conditions within normal ranges inside all of an organism's cells.

Lesson Review Questions

Recall

1. What is osmosis? What type of transport is it?

2. Describe the roles of transport proteins in cell transport.

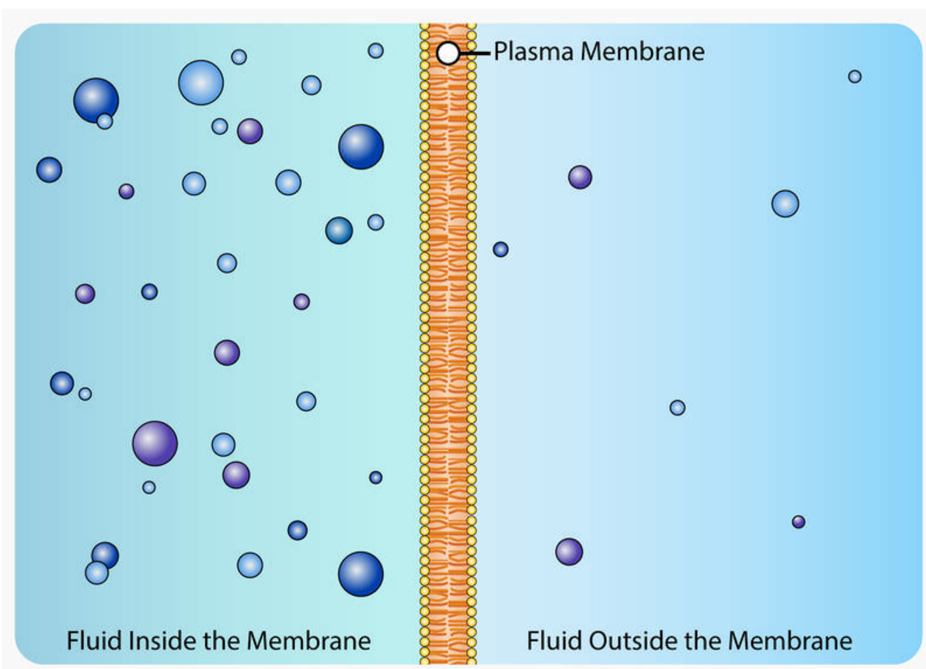
3. What is the sodium-potassium pump?

4. Name two types of vesicle transport. Which type moves substances out of the cell?

Apply Concepts

5. Assume a molecule must cross the plasma membrane into a cell. The molecule is a very large protein. How will it be transported into the cell? Explain your answer.

6. The drawing below shows the fluid inside and outside a cell. The dots represent molecules of a substance needed by the cell. The molecules are very small and hydrophobic. What type of transport will move the molecules into the cell?



Think Critically

7. Compare and contrast simple diffusion and facilitated diffusion. For each type of diffusion, give an example of a molecule that is transported that way.

8. Explain how cell transport helps an organism maintain homeostasis.

Points to Consider

All cells share some of the same structures and basic functions, but cells also vary.

- Plant cells have structures that animal cells lack. What important process takes place in plant cells but not in animal cells that might explain their differences?
- All cells, including both plant and animal cells, need energy for processes such as active transport. How do cells obtain the energy they need?

8.4 References

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Concept 9 Introduction to Cells

Lesson 3.1: True or False

Name____________________ Class_______________ Date_________

Write true if the statement is true or false if the statement is false.

_____ 1. All organisms are made of more than one cell.

_____ 2. Early microscopes created by Leeuwenhoek were almost as strong as modern light microscopes.

_____ 3. Proteins are made on ribosomes.

_____ 4. Prokaryotic cells have a nucleus.

_____ 5. The plasma membrane forms the physical boundary between the cell and its environment.

_____ 6. For cells, a smaller size is more efficient.

_____ 7. Compared to eukaryotic cells, prokaryotic cells are very complex.

_____ 8. Organelles are located within the cytoplasm.

_____ 9. Viruses are similar to prokaryotic cells.

_____ 10. All cells have a plasma membrane, cytoplasm, and ribosomes.

_____ 11. DNA is located in the nucleus of prokaryotic cells.

_____ 12. Organelles allow eukaryotic cells to carry out more functions than prokaryotic cells.

_____ 13. Viruses are considered living organisms.

_____ 14. Most cells are about the size of the period at the end of this sentence.

_____ 15. Observation of cork helped in the discovery of cells.

Lesson 3.1: Critical Reading

Name____________________ Class_______________ Date_________

Read these passages from the text and answer the questions that follow.

Two Types of Cells

There is another basic cell structure that is present in many but not all living cells: the nucleus. The **nucleus** of a cell is a structure in the cytoplasm that is surrounded by a membrane (the nuclear membrane) and contains DNA. Based on whether they have a nucleus, there are two basic types of cells: prokaryotic cells and eukaryotic cells.

Prokaryotic Cells

Prokaryotic cells are cells without a nucleus. The DNA in prokaryotic cells is in the cytoplasm rather than enclosed within a nuclear membrane. Prokaryotic cells are found in single-celled organisms, such as bacteria. Organisms with prokaryotic cells are called **prokaryotes**. They were the first type of organisms to evolve and are still the most common organisms today.

Eukaryotic Cells

Eukaryotic cells are cells that contain a nucleus. Eukaryotic cells are usually larger than prokaryotic cells, and they are found mainly in multicellular organisms. Organisms with eukaryotic cells are called eukaryotes, and they range from fungi to people.

Eukaryotic cells also contain other organelles besides the nucleus. An **organelle** is a structure within the cytoplasm that performs a specific job in the cell. Organelles called mitochondria, for example, provide energy to the cell, and organelles called vacuoles store substances in the cell. Organelles allow eukaryotic cells to carry out more functions than prokaryotic cells can.

Viruses: Prokaryotes or Eukaryotes?

Viruses are tiny particles that may cause disease. Human diseases caused by viruses include the common cold and flu. Do you think viruses are prokaryotes or eukaryotes? The answer may surprise you. Viruses are not cells at all, so they are neither prokaryotes nor eukaryotes.

Viruses contain DNA but not much else. They lack the other parts shared by all cells, including a plasma membrane, cytoplasm, and ribosomes. Therefore, viruses are not cells, but are they alive? All living things not only have cells; they are also capable of reproduction. Viruses cannot reproduce by themselves. Instead, they infect living hosts, and use the hosts' cells to make copies of their own DNA. For these reasons, most scientists do not consider viruses to be living things.

Questions

1. What is one main difference between prokaryotic and eukaryotic cells?

2. Give an example of a prokaryotic organism.

3. What is an organelle? Give three examples. (*Hint: See the Eukaryotic Cell figure in the FlexBook® textbook.*)

4. Describe the nucleus. What can be found inside the nucleus?

5. Are viruses alive? Discuss why or why not.

Lesson 3.1: Multiple Choice

Name___________________ **Class**______________ **Date**________

Circle the letter of the correct choice.

1. Organelles in prokaryotic cells include the
   a. mitochondria.
   b. cytoskeleton.
   c. Golgi complex.
   d. none of the above
2. A major difference between prokaryotic and eukaryotic cells is that

a. prokaryotic cells have a flagellum.
b. eukaryotic cells have a nucleus.
c. prokaryotic cells have cytoplasm.
d. eukaryotic cells have ribosomes.

3. Robert Hooke was the first person to observe cells. He observed these cells in

a. a piece of cork.
b. a slice of honeycomb.
c. human blood.
d. plaque from his own teeth.

4. Cell size is limited by the

a. amount of cytoplasm.
b. cell's ability to get rid of wastes.
c. the size of the nucleus.
d. the size of the plasma membrane.

5. The spikes on pollen grains probably

a. allow the pollen grain to stick to insects.
b. allow the pollen grain to fly through the air.
c. protect the pollen grain from being eaten.
d. allow insects to stick to the pollen grain.

6. All cells have the following:

a. plasma membrane, cytoplasm, and ribosomes.
b. plasma membrane, nucleus, and DNA.
c. DNA, ribosomes, and cell wall.
d. plasma membrane, cytoplasm, and nucleus.

7. The first microscopes were made around

a. 1965.
b. 1665.
c. 1950.
d. 1776.

8. The cell theory states that

a. all organisms are made of one or more cells.
b. all cells come from already existing cells.
c. all the life functions of organisms occur within cells.
d. all of the above

Lesson 3.1: Vocabulary I

Name___________________ Class______________ Date________

Match the vocabulary word with the proper definition.

Definitions

_____ 1. organism that has cells containing a nucleus and other organelles

_____ 2. an organelle inside eukaryotic cells where the DNA is located

_____ 3. cell without a nucleus

_____ 4. a structure within the cytoplasm of a cell that is enclosed within a membrane and performs a specific job

_____ 5. phospholipid bilayer that surrounds and encloses a cell

_____ 6. first person to use the word “cell”

_____ 7. tiny, non-living particles that may cause disease

_____ 8. the material inside the plasma membrane of a cell

_____ 9. cell that contains a nucleus and other organelles

_____ 10. organelle where proteins are made

_____ 11. discovered human blood cells

_____ 12. a single-celled organism that lacks a nucleus

Terms

a. Anton van Leeuwenhoek

b. cytoplasm

c. eukaryote

d. eukaryotic cell

e. nucleus

f. organelle

g. plasma membrane

h. prokaryote

i. prokaryotic cell

j. ribosome

k. Robert Hooke

l. virus

Lesson 3.1: Vocabulary II

Name____________________ **Class**_______________ **Date**________

Fill in the blanks with the appropriate term.

1. All organisms are made up of one or more _____________.

2. All cells have certain parts in common, including a plasma membrane, _____________, _____________, and DNA.

3. Proteins are made on the _____________.

4. A _____________ is a typical prokaryotic cell.

5. _____________ cells are usually larger than _____________ cells.

6. Leeuwenhoek discovered _____________ by looking at the plaque from his own teeth.

7. _____________ contain DNA, but do not contain cytoplasm or ribosomes.

8. In an eukaryotic cell, DNA is found in the _____________.

9. _____________ is the genetic instructions that cells need to make proteins.

10. The plasma membrane is a bilayer of ____________ that surrounds a cell.
11. A cell's shape is generally related to the cell's ____________.
12. ____________ are cells without a nucleus.

Lesson 3.1: Critical Writing

Name___________________ Class______________ Date________

Thoroughly answer the question below. Use appropriate academic vocabulary and clear and complete sentences.

Compare and contrast eukaryotic cells with prokaryotic cells. Include at least 5 specific similarities and/or differences.

Concept 10 Cell Structures

Lesson 3.2: True or False

Name___________________ **Class**______________ **Date**________

Write true if the statement is true or false if the statement is false.

_____ 1. The water-hating hydrophobic tails of the phospholipid bilayer face the outside of the cell membrane.

_____ 2. The cytoplasm essentially acts as a "skeleton" inside the cell.

_____ 3. Roundworms have organ system-level organization, in which groups of organs work together to do a specific job.

_____ 4. Plant cells have special structures that are not found in animal cells, including a cell membrane, a large central vacuole, and plastids.

_____ 5. Centrioles help organize chromosomes before cell division.

_____ 6. Ribosomes can be found attached to the endoplasmic reticulum.

_____ 7. ATP is made in the mitochondria.

_____ 8. Many of the biochemical reactions of the cell occur in the cytoplasm.

_____ 9. Animal cells have chloroplasts, organelles that capture light energy from the sun and use it to make food.

_____ 10. Small hydrophobic molecules can easily pass through the plasma membrane.

_____ 11. In cell-level organization, different cells are specialized for different functions.

_____ 12. The flagella on your lung cells sweep foreign particles and mucus toward the mouth and nose.

_____ 13. Mitochondria contains its own DNA.

_____ 14. The plasma membrane is a single phospholipid layer that supports and protects a cell and controls what enters and leaves it.

_____ 15. The cytoskeleton is made from thread-like filaments and tubules.

Lesson 3.2: Critical Reading

Name___________________ **Class**______________ **Date**________

Read these passages from the text and answer the questions that follow.

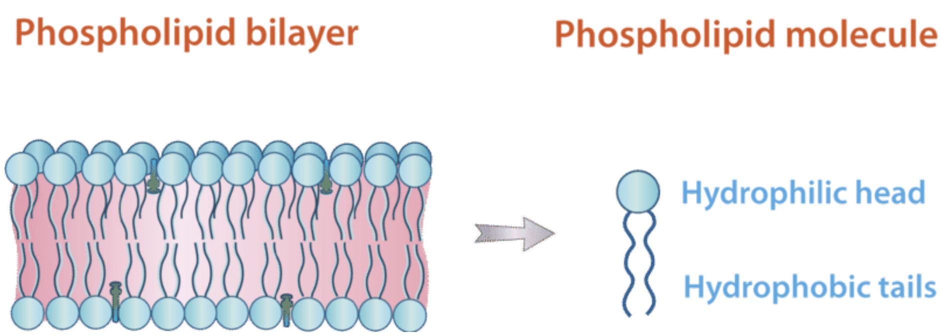
Plasma Membrane

The plasma membrane forms a barrier between the cytoplasm inside the cell and the environment outside the cell. It protects and supports the cell and also controls everything that enters and leaves the cell. It allows only certain substances to pass through, while keeping others in or out. The ability to allow only certain molecules in or out of the cell is referred to as selective permeability or semipermeability. To understand how the plasma membrane controls what crosses into or out of the cell, you need to know its composition.

Phospholipid Bilayer

The plasma membrane is composed mainly of phospholipids, which consist of fatty acids and alcohol. The phospholipids in the plasma membrane are arranged in two layers, called a phospholipid bilayer. As shown in the figure below, each phospholipid molecule has a head and two tails. The head "loves" water (hydrophilic) and the tails "hate" water (hydrophobic). The water-hating tails are on the interior of the membrane, whereas the water-loving heads point outwards, toward either the cytoplasm or the fluid that surrounds the cell.

Molecules that are hydrophobic can easily pass through the plasma membrane, if they are small enough, because they are water-hating like the interior of the membrane. Molecules that are hydrophilic, on the other hand, cannot pass through the plasma membrane — at least not without help — because they are water-loving like the exterior of the membrane.



The phospholipid bilayer consists of two layers of phospholipids (left), with a hydrophobic, or water-hating, interior and a hydrophilic, or water-loving, exterior. A single phospholipid molecule is depicted on the right.

Other Molecules in the Plasma Membrane

The plasma membrane also contains other molecules, primarily other lipids and proteins. The green molecules in the figure above, for example, are the lipid cholesterol. Molecules of cholesterol help the plasma membrane keep its shape. Many of the proteins in the plasma membrane assist other substances in crossing the membrane.

Extensions of the Plasma Membrane

The plasma membrane may have extensions, such as whip-like flagella or brush-like cilia. In single-celled organisms, the membrane extensions may help the organisms move. In multicellular organisms, the extensions have other functions. For example, the cilia on human lung cells sweep foreign particles and mucus toward the mouth and nose.

Questions

1. What is the plasma membrane?

2. What is the meaning of *semipermeability*?

3. Discuss why the plasma membrane must be a bilayer.

4. What are some of the “other” molecules in the plasma membrane? Describe their function.

5. What are cilia and flagella?

Lesson 3.2: Multiple Choice

Name___________________ Class______________ Date________

Circle the letter of the correct choice.

1. The "power plant" of the cell is the
   a. nucleus.
   b. ribosome.
   c. chloroplast.
   d. mitochondria.
2. Which organelle ensures that after cell division each daughter cell has the correct number of chromosomes?
   a. the nucleus
   b. the endoplasmic reticulum
   c. the centriole
   d. the cytoskeleton
3. Structures specific in plant cells but not in animal cells include
   a. a large central vacuole.
   b. the mitochondria.
   c. the cell membrane.
   d. the cytoplasts.
4. Having tissues that digest food, such as in the jellyfish, is an example of
   a. cell-level organization.
   b. tissue-level organization.
   c. organ-level organization.
   d. organ system-level organization.
5. The plasma membrane contains which of the following?
   a. phospholipids
   b. cholesterol molecules
   c. many proteins
   d. all of the above
6. Which of the following is true of the nucleus?
   a. The nucleus is considered the control center of the cell.
   b. The nucleus contains all the cell's DNA.
   c. All cells have a nucleus.
   d. all of the above
7. Which structure determines what molecules can enter and leave the cell?
   a. the plasma membrane
   b. the cell wall
   c. the nucleus
   d. all of the above
8. Which organelle may have allowed early eukaryotes to make food and produce oxygen?
   a. the Golgi apparatus
   b. the central vacuole
   c. the plastids
   d. the cell wall

Lesson 3.2: Vocabulary I

Name___________________ **Class**______________ **Date**________

Match the vocabulary word with the proper definition.

Definitions

_____ 1. the arrangement of phospholipids in the plasma membrane

_____ 2. helps make and transport proteins and lipids

_____ 3. stores and transports protein and lipid molecules

_____ 4. helps the cell maintain its shape and holds cell organelles in place within the cytoplasm

_____ 5. layer that surrounds the plasma membrane of a plant cell

_____ 6. help organize the chromosomes before cell division

_____ 7. organelle that processes proteins and prepares them for use both inside and outside the cell

_____ 8. larger of the sac-like organelles that store and transport materials in the cell

_____ 9. describes the formation of eukaryotic cells

_____ 10. energy-carrying molecule

_____ 11. stores substances such as water, enzymes, and salts in plant cells

_____ 12. "power plant" of the cell

Terms

a. ATP

b. cell wall

c. central vacuole

d. centriole

e. cytoskeleton

f. endoplasmic reticulum

g. endosymbiotic theory

h. Golgi apparatus

i. mitochondria

j. phospholipid bilayer

k. vacuole

l. vesicle

Lesson 3.2: Vocabulary II

Name____________________ Class_______________ Date________

Fill in the blank with the appropriate term.

1. The _____________ is often considered to be the cell's control center.

2. The _____________ consists of everything inside the plasma membrane of the cell.

3. The plasma membrane forms a _____________ between the inside and outside of the cell.

4. The _____________ is essentially a "skeleton" inside the cell.

5. The rough endoplasmic reticulum is covered with ____________.

6. Lysosomes use ____________ to break down foreign matter and dead cells.

7. ____________ cells specifically have a cell wall, a large central vacuole, and chloroplasts.

8. The endoplasmic reticulum is an organelle that helps make and transport ____________ and lipids.

9. Mitochondria are sometimes referred to as the ____________ of the cell

10. Human beings have ____________-level organization, in which groups of organs work together to do a certain job.

11. Centrioles help make sure each daughter cell has the correct number of ____________ after the cell divides.

12. Cilia and ____________ are extensions of the plasma membrane of many cells.

Lesson 3.2: Critical Writing

Name___________________ **Class**______________ **Date**________

Thoroughly answer the question below. Use appropriate academic vocabulary and clear and complete sentences.

Discuss the properties of the plasma membrane that allow it to act as a barrier around the cell. Include the specifics of the phospholipid bilayer.

CONCEPT 11 Cell Transport and Homeostasis

Lesson 3.3: True or False

Name___________________ Class______________ Date________

Write true if the statement is true or false if the statement is false.

_____ 1. Passive transport needs energy.

_____ 2. Active transport needs energy.

_____ 3. Carrier proteins change shape when they transport substances.

_____ 4. Diffusion does not require any help from other molecules.

_____ 5. Facilitated diffusion does not require any help from other molecules.

_____ 6. Endocytosis removes large molecules from the cell.

_____ 7. In diffusion, substances move from an area of lower concentration to an area of higher concentration.

_____ 8. The sodium-potassium pump is a type of channel protein.

_____ 9. Ions can easily flow through a carrier protein.

_____ 10. Diffusion is the osmosis of water.

_____ 11. Endocytosis and exocytosis are types of vesicle transport.

_____ 12. Channel proteins form small "holes" in the plasma membrane.

_____ 13. Transport of substances across the cell membrane helps maintain homeostasis by keeping the cell's conditions within normal ranges.

_____ 14. Channel proteins and carrier proteins are both transport proteins.

_____ 15. The plasma membrane controls what enters and leaves the cell.

Lesson 3.3: Critical Reading

Name___________________ Class______________ Date________

Read these passages from the text and answer the questions that follow.

Passive Transport

Passive transport occurs when substances cross the plasma membrane without any input of energy from the cell. No energy is needed because the substances are moving from an area where they have a higher concentration to an area where they have a lower concentration. Concentration refers to the number of particles of a substance per unit of volume. The more particles of a substance in a given volume, the higher the concentration. A substance always moves from an area where it is more concentrated to an area where it is less concentrated. It's a little like a ball rolling down a hill. It goes by itself without any input of extra energy.

Simple Diffusion

Diffusion is the movement of a substance across a membrane, due to a difference in concentration, without any help from other molecules. The substance simply moves from the side of the membrane where it is more concentrated to the side where it is less concentrated. Substances that can squeeze between the lipid molecules in the plasma membrane by simple diffusion are generally very small, hydrophobic molecules, such as molecules of oxygen and carbon dioxide.

Osmosis

Osmosis is a special type of diffusion — the diffusion of water molecules across a membrane. Like other molecules, water moves from an area of higher concentration to an area of lower concentration. Water moves in or out of a cell until its concentration is the same on both sides of the plasma membrane.

Facilitated Diffusion

Water and many other substances cannot simply diffuse across a membrane. Hydrophilic molecules, charged ions, and relatively large molecules, such as glucose, all need help with diffusion. The help comes from special proteins in the membrane known as **transport proteins**. Diffusion with the help of transport proteins is called **facilitated diffusion**. There are several types of transport proteins, including channel proteins and carrier proteins.

- Channel proteins form pores, or tiny holes, in the membrane. This allows water molecules and small ions to pass through the membrane without coming into contact with the hydrophobic tails of the lipid molecules in the interior of the membrane.
- Carrier proteins bind with specific ions or molecules, and in doing so, they change shape. As carrier proteins change shape, they carry the ions or molecules across the membrane.

Questions

1. Explain why passive transport does not require energy.

2. What is a main difference between diffusion and facilitated diffusion?

3. Describe how simple diffusion proceeds. What kind of molecules can move across the membrane by simple diffusion?

4. How is water transported across the membrane?

5. What are the two types of transport proteins? Describe how they function.

Lesson 3.3: Multiple Choice

Name___________________ Class______________ Date________

Circle the letter of the correct choice.

1. Controlling what enters and leaves the cell in an important function of the
   a. nucleus.
   b. vesicle.
   c. plasma membrane.
   d. Golgi apparatus.
2. During diffusion, substances move from an area of ____________ concentration to an area of ___________-_ concentration.
   a. higher, lower
   b. lower, higher
   c. higher, equal

   d. lower, equal

3. A channel protein does which of the following?
   a. Carries ions or molecules across the membrane.
   b. Forms tiny holes in the membrane.
   c. Changes shape as it transports molecules.
   d. all of the above
4. The sodium-potassium pump
   a. uses energy to move sodium ions out of the cell and potassium ions into the cell.
   b. uses energy to move potassium ions out of the cell and sodium ions into the cell.
   c. moves sodium ions out of the cell and potassium ions into the cell without using energy.
   d. moves potassium ions out of the cell and sodium ions into the cell without using energy.
5. Osmosis
   a. is the diffusion of water.
   b. is the diffusion of water and other small molecules.
   c. is the diffusion of water and small ions.
   d. is the diffusion of small molecules and ions.
6. Types of passive transport include which of the following? (1) simple diffusion, (2) osmosis, (3) facilitated diffusion, (4) active transport, and (5) vesicle transport.
   a. 1 and 2
   b. 1, 2, and 3
   c. 4 and 5
   d. 1, 2, 3, 4, and 5
7. Endocytosis and exocytosis
   a. are both a type of vesicle transport.
   b. move very large molecules either in or out of the cell.
   c. are both a form of active transport.
   d. all of the above
8. Which of the following needs energy? (1) passive transport, (2) active transport, (3) exocytosis, and (4) osmosis.
   a. 1 only
   b. 2 only
   c. 2 and 3
   d. 2, 3, and 4

Lesson 3.3: Vocabulary I

Name___________________ **Class**______________ **Date**________

Match the vocabulary word with the proper definition.

Definitions

_____ 1. transport across a membrane without any additional energy requirement

_____ 2. the diffusion of water

_____ 3. type of vesicle transport that moves a substance into the cell

_____ 4. type of vesicle transport that moves a substance out of the cell

_____ 5. special proteins in the membrane that aid diffusion

_____ 6. membrane protein that forms a small hole that allows ions to pass through

_____ 7. an active transport protein

_____ 8. diffusion with the help of transport proteins

_____ 9. the movement of a substance across a membrane without any help from other molecules

_____ 10. the transport of very large molecules, such as proteins

_____ 11. transport across a membrane in which energy is required

Terms

a. active transport

b. channel protein

c. diffusion

d. endocytosis

e. exocytosis

f. facilitated diffusion

g. osmosis

h. passive transport

i. sodium-potassium pump

j. transport protein

k. vesicle transport

Lesson 3.3: Vocabulary II

Name___________________ **Class**______________ **Date**________

Fill in the blank with the appropriate term.

1. By moving substances into and out of cells, ____________ , the process of keeping stable conditions inside a cell, is maintained.

2. A ____________ protein changes shape as it carries ions or molecules across the membrane.

3. Exocytosis is the type of ____________ transport that moves a substance out of the cell.

4. ____________ transport is movement across the plasma membrane that does not require an input of energy.

5. The sodium-potassium ____________ is involved in the active-transport of ions.

6. Facilitated diffusion needs the help of ____________ proteins

7. ____________ refers to the number of particles of a substance per unit of volume.

8. ____________ is the type of vesicle transport that moves a substance into the cell.

9. Energy for active transport is supplied by molecules of ____________.

10. ____________ is the diffusion of water.

11. During active transport, a substance is moving from an area of ____________ concentration to an area of ____________ concentration.

12. Moving molecules in and out of the cell is an important role of the ____________.

Lesson 3.3: Critical Writing

Name___________________ Class______________ Date________

Thoroughly answer the question below. Use appropriate academic vocabulary and clear and complete sentences.

Discuss passive and active transport. Describe the main differences between these two types of transport, and provide examples of each type.

CHAPTER 12 Biology Glossary

Chapter Outline

12.1 A

abiotic factor
nonliving aspect of the environment such as sunlight and soil

absolute dating
carbon-14 or other method of dating fossils that gives an approximate age in years

absorption
process in which substances such as nutrients pass into the blood stream

acid
solution with a pH lower than 7

acid rain
low-pH precipitation that forms with air pollution combines with water

acquired immunodeficiency syndrome (AIDS)
disorder characterized by frequent opportunistic infections that eventually develops in people who are infected with human immunodeficiency virus (HIV)

action potential
reversal of electrical charge across the membrane of a resting neuron that travels down the axon of the neuron as a nerve impulse

activation energy
energy needed to start a chemical reaction

active immunity
ability to resist a pathogen that results when an immune response to the pathogen produces memory cells

active transport
movement of substances across a plasma membrane that requires energy

adaptation
characteristic that helps living things survive and reproduce in a given environment

adaptive radiation
process by which a single species evolves into many new species to fill available niches

adolescence
period of transition between the beginning of puberty and adulthood during which significant physical, mental, emotional, and social changes occur

adolescent growth spurt
period of rapid growth that occurs during puberty

adrenal glands
pair of endocrine glands located above the kidneys that secrete hormones such as cortisol and adrenaline

aerobic respiration
type of cellular respiration that requires oxygen

age-sex structure
number of individuals of each sex and age in a population

aggression
behavior that is intended to cause harm or pain

air pollution
chemical substances and particles released into the air mainly by human actions such as burning fossil fuels

Air Quality Index (AQI)
assessment of the levels of pollutants in the outdoor air that is based on their human health effects

alcoholic fermentation
type of anaerobic respiration that includes glycolysis followed by the conversion of pyruvic acid to ethanol and carbon dioxide and the formation of NAD^+

algae (singular, alga)
plant-like protists such as diatoms and seaweeds

algal bloom
excessive growth of algae in bodies of water because of high levels of nutrients, usually from fertilizer in runoff

allele
one of two or more different versions of the same gene

allele frequency
how often an allele occurs in a gene pool relative to the other alleles for that gene

allergen
any antigen that causes an allergy

allergy
disease in which the immune system makes an inflammatory response to a harmless antigen

allopatric speciation
evolution of a new species that occurs when some members of an original species become geographically separated from the rest of the species

alternation of generations
change back and forth from one generation to the next between haploid gametophyte and diploid sporophyte stages in the life cycle of plants

alveoli (singular, alveolus)
tiny sacs at the ends of bronchioles in the lungs where pulmonary gas exchange takes place

amoeboid
type of protozoa, such as *Amoeba,* that moves with pseudopods

amino acid
small molecule that is a building block of proteins

amniote
animal that produces eggs with internal membranes that allow gases but not water to pass through so the embryo can breathe without drying out (reptile, bird, or mammal)

amniotic sac
enclosed membrane containing fluid that surrounds and protects a fetus

amphibian
ectothermic, tetrapod vertebrate that may live on land but must return to water in order to reproduce

anabolic reaction
endothermic reaction in organisms

anaerobic respiration
type of cellular respiration that does not require oxygen

analogous structure
structure that is similar in unrelated organisms because it evolved to do the same job, not because it was inherited from a common ancestor

anaphase
third phase of mitosis during which sister chromatids separate and move to opposite poles of the cell

angiosperm
type of seed plant that produces seeds in the ovary of a flower

animal
heterotrophic, multicellular eukaryote with cells that lack cell walls; member of the animal kingdom

animal behavior
any way that animals interact with each other or the environment

Annelida
invertebrate phylum of segmented worms such as earthworms

antheridia (singular, antheridium)
male reproductive organs of the gametophyte generation of plants that produce motile sperm

antibiotic drug
drug that kills bacteria and cures bacterial infections and diseases

antibiotic resistance
ability to withstand antibiotic drugs that has evolved in some bacteria

antibody
large, Y-shaped proteins produced by B cells that recognize and bind to antigens in a humoral immune response

antigen
molecule that the immune system identifies as foreign and responds to by forming antibodies

aphotic zone
area in aquatic biomes deeper than 200 meters

aquatic biome
water-based biomes, defined by the availability of sunlight and the concentration of dissolved oxygen and nutrients in the water

aquifer
underground layer of rock that stores water

arboreal
of or pertaining to trees, as in arboreal, or tree-living, mammal

Archaea
one of two prokaryote domains that includes organisms that live in extreme environments

archegonia (singular, archegonium)
female reproductive organs of the gametophyte generation of plants that produce eggs

artery
type of blood vessel that carries blood away from the heart toward the lungs or body

arthropod
invertebrate in the phylum Arthropoda, characterized by a segmented body, hard exoskeleton, and jointed appendages

artificial selection
process in which organisms evolve traits useful to humans because people select which individuals are allowed to reproduce and pass on their genes to successive generations

asexual reproduction
reproduction that involves a single parent and results in offspring that are all genetically identical to the parent

asthma
respiratory system disease in which air passages of the lungs periodically become too narrow, making breathing difficult

atherosclerosis
condition in which plaque builds up inside arteries

athlete's foot
infection of the skin between the toes by the fungus *Trichophyton*

ATP (adenosine triphosphate)
energy-carrying molecule that cells use to power their metabolic processes

autoimmune disease
type of disease, such as type 1 diabetes, in which the immune system attacks the body's cells as though they were pathogens

autonomic nervous system (ANS)
division of the peripheral nervous system that controls involuntary activities not under conscious control such as heart rate and digestion

autosome
chromosomes 1–22 in humans that contain genes for characteristics unrelated to sex

autotroph
organism that makes its own food

axon
long extension of the cell body of a neuron that transmits nerve impulses to other cells

12.2 B

Bacteria
: domain of prokaryotes, some of which cause human diseases

bark
: tissue that provides a rough, woody external covering on the stems of trees

base
: solution with a pH higher than 7

B cell
: type of lymphocyte that fights infections by forming antibodies

bilateral symmetry
: symmetry of a body plan in which there are distinct head and tail ends, so the body can be divided into two identical right and left halves

bile
: fluid produced by the liver and stored in the gall bladder that is secreted into the small intestine to help digest lipids and neutralize acid from the stomach

binary fission
: type of cell division that occurs in prokaryotic cells in which a parent cells divides into two identical daughter cells

binomial nomenclature
: method of naming species with two names, consisting of the genus name and species name

biochemical reaction
: chemical reaction that occurs inside the cells of living things

biodiversity
: the variety of life and its processes; including the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur

biofilm
: colony of prokaryotes that is stuck to a surface such as a rock or a host's tissue

biogeochemical cycle
: interconnected pathways through which water or a chemical element such as carbon is continuously recycled through the biotic and abiotic components of the biosphere

biogeography
: study of how and why plants and animals live where they do

biology
science of life, study of life

biomass
total mass of organisms at a trophic level

biome
group of similar ecosystems with the same general type of physical environment

biosphere
part of Earth where all life exists, including land, water, and air

biotechnology
use of technology to change the genetic makeup of living things in order to produce useful products

bioterrorism
intentional release or spread of agents of disease

biotic factor
living aspects of the environment, including organisms of the same and different species

bird
bipedal, endothermic, tetrapod vertebrate that lays amniotic eggs and has wings and feathers

bladder
hollow, sac-like organ that stores urine until it is excreted from the body

blastocyst
fluid-filled ball of cells that develops a few days after fertilization in humans

blood
fluid connective tissue that circulates throughout the body through blood vessels

blood pressure
force exerted by circulating blood on the walls of blood vessels

blood type
genetic characteristic associated with the presence or absence of antigens on the surface of red blood cells

body mass index (BMI)
estimate of the fat content of the body calculated by dividing a person’s weight (in kilograms) by the square of the person’s height (in meters)

bone
hard tissue in most vertebrates that consists of a collagen matrix, or framework, filled in with minerals such a calcium

bone marrow
soft connective tissue in spongy bone that produces blood cells

bone matrix
rigid framework of bone that consists of tough protein fibers and mineral crystals

brain
central nervous system organ inside the skull that is the control center of the nervous system

brain stem
lowest part of the brain that connects the brain with the spinal cord and controls unconscious functions such as heart rate and breathing

bryophyte
type of plant that lacks vascular tissues, such as a liverwort, hornwort, or moss

budding
type of asexual reproduction in yeasts in which an offspring cell pinches off from the parent cell

12.3 C

Calvin cycle
: second stage of photosynthesis in which carbon atoms from carbon dioxide are combined, using the energy in ATP and NADPH, to make glucose

Cambrian explosion
: spectacular burst of new life that occurred at the start of the Paleozoic Era

cancer
: disease that occurs when the cell cycle is no longer regulated and cells divide out of control

candidiasis
: infection of the mouth or of the vagina in females that is caused by the yeast *Candida*

capillary
: smallest type of blood vessel that connects very small arteries and veins

capsid
: protein coat that surrounds the DNA or RNA of a virus particle

carbohydrate
: organic compound such as sugar or starch

carbon cycle
: interconnected pathways through which carbon is recycled through the biotic and abiotic components of the biosphere

carcinogen
: anything that can cause cancer

cardiac muscle
: involuntary, striated muscle found only in the walls of the heart

cardiovascular disease (CVD)
: any disease that affects the heart or blood vessels

carnivore
: consumer that eats animals

carrying capacity (K)
: largest population size that can be supported in an area without harming the environment

cartilage
: dense connective tissue that provides a smooth surface for the movement of bones at joints

catabolic reaction
exothermic reaction in organisms

cell
basic unit of structure and function of living things

cell body
central part of a neuron that contains the nucleus and other cell organelles

cell cycle
repeating series of events that a cell goes through during its life, including growth, DNA, synthesis, and cell division

cell division
process in which a parent cell divides to form two daughter cells

cell-mediated immune response
type of immune response in which T cells destroy cells that are infected with viruses

cell theory
theory that all living things are made up of cells, all life functions occur within cells, and all cells come from already existing cells

cellular respiration
process in which cells break down glucose and make ATP for energy

cell wall
rigid layer that surrounds the plasma membrane of a plant cell and helps support and protect the cell

Cenozoic Era
age of mammals that lasted from 65 million years ago to the present

central dogma of molecule biology
doctrine that genetic instructions in DNA are copied by RNA, which carries them to a ribosome where they are used to synthesize a protein (DNA $\rightarrow$ RNA $\rightarrow$ protein)

central nervous system (CNS)
one of two main divisions of the nervous system that includes the brain and spinal cord

central vacuole
large saclike organelle in plant cells that stores substances such as water and helps keep plant tissues rigid

centromere
region of sister chromatids where they are joined together

cephalization
concentration of nerve tissue in one end of an animal, forming a head region

cerebellum
part of the brain below the cerebrum that coordinates body movements

cerebrum
largest part of the brain that controls conscious functions such as reasoning and sight

Chargaff's rules
observations by Erwin Chargaff that concentrations of the four nucleotide bases differ among species; and that, within a species, the concentrations of adenine and thymine are always about the same and the concentrations of cytosine and guanine are always about the same

chemical bond
force that holds molecules together

chemical digestion
chemical breakdown of large, complex food molecules into smaller, simpler nutrient molecules that can be absorbed by the blood

chemical reaction
process that changes some chemical substances into others

chemoautotroph
producer that uses energy from chemical compounds to make food by chemosynthesis

chemosynthesis
process of using the energy in chemical compounds to make food

chitin
tough carbohydrate that makes up the cell walls of fungi and the exoskeletons of insects and other arthropods

chlamydia
sexually transmitted bacterial infection that is the most common STI in the United States

chlorophyll
green pigment in a chloroplast that absorbs sunlight in the light reactions of photosynthesis

chloroplast
organelle in the cells of plants and algae where photosynthesis takes place

chordates
consists of all animals with a notochord, dorsal hollow nerve cord, post-anal tail, and pharyngeal slits during at least some stage of their life

chromatid
one of two identical copies of a chromosome that are joined together at a centromere before a cell divides

chromatin
grainy material that DNA forms when it is not coiled into chromosomes

chromosomal alteration
mutation that changes chromosome structure

chromosome
coiled structure made of DNA and proteins containing sister chromatids that is the form in which the genetic material of a cell goes through cell division

cilia (singular, cilium)
short, hairlike projections, similar to flagella, that allow some cells to move

ciliate
type of protozoa, such as *Paramecium,* that moves with cilia

circadian rhythm
regular change in biology or behavior that occurs in a 24-hour cycle

circulatory system
organ system consisting of the heart, blood vessels, and blood that transports materials around the body

clade
group of related organisms that includes an ancestor and all of its descendants

climate
average weather in an area over a long period of time

climax community
final stable stage of ecological succession that may be reached in an undisturbed community

cloaca
body cavity with a single opening in amphibians, reptiles, and monotreme mammals that collects and excretes wastes from the digestive and excretory systems and gametes from the reproductive system

Cnidaria
invertebrate phylum that includes animals such as jellyfish and corals that are characterized by radial symmetry, tissues, and a stinger called a nematocyst

codominance
relationship between two alleles for the same gene in which both alleles are expressed equally in the phenotype of the heterozygote

codon
group of three nitrogen bases in nucleic acids that makes up a code "word" of the genetic code and stands for an amino acid, start, or stop

coelom
fluid-filled body cavity

coevolution
process in which two interacting species evolve together, with each species influencing the other's evolution

commensalism
symbiotic relationship in which one species benefits while the other species is not affected

community
all of the populations of different species that live in the same area

compact bone
dense outer layer of bone that is very hard and strong

comparative anatomy
study of the similarities and differences in the structures of different species

comparative embryology
study of the similarities and differences in the embryos of different species

competition
relationship between living things that depend on the same resources in the same place and at the same time

competitive exclusion principle
principle of ecology stating that two different species cannot occupy the same niche in the same place for very long

complementary base pair
pair of nucleotide bases that bond together—either adenine and thymine (or uracil) or cytosine and guanine

complete digestive system
digestive system consisting of a digestive tract and two body openings (mouth and anus)

compound
substance with a unique, fixed composition that consists of two or more elements

condensation
process in which water vapor changes to tiny droplets of liquid water

cone
structure consisting of scales that bear naked seeds in the type of seed plants called gymnosperms

connective tissue
tissue made up of cells that form the body's structure, such as bone and cartilage

consumer
organism that consumes other organisms for food

cooperation
type of animal behavior in which social animals live and work together for the good of the group

courtship
animal behavior that is intended to attract a mate

cranium
part of a vertebrate endoskeleton that encloses and protects the brain; also called the skull

crop
sac-like structure in the digestive system of birds that stores and moistens food before it is digested

crossing-over
exchange of genetic material between homologous chromosomes when they are closely paired during meiosis I

cuticle
waxy, waterproof substance produced by epidermal cells of leaves, shoots, and other above-ground parts of plants to prevent damage and loss of water by evaporation

cyanobacteria
Gram-positive blue-green photosynthetic bacteria of the type that added oxygen to Earth's early atmosphere and evolved into chloroplasts of eukaryotic cells

cytokinesis
splitting of the cytoplasm to form daughter cells when a cell divides

cytoplasm
all of the material inside the plasma membrane of a cell (excluding organelles)

cytoskeleton
structure of filaments and tubules in the cytoplasm that provides a cell with an internal framework

12.4 D

dead zone
: area in the ocean or other body of water where low oxygen levels from excessive growth of algae have killed all aquatic organisms

deciduous plant
: type of plant that seasonally loses its leaves to reduce water loss during the cold or dry season each year and grows new leaves later in the year

decomposer
: organism that breaks down the remains of dead organisms and other organic wastes

demographic transition
: changes in population that occurred in Europe and North America beginning in the 18^{th} century, in which death rates fell and population growth rates increased, followed by birth rates falling and population growth rates decreasing

dendrite
: extension of the cell body of a neuron that receives nerve impulses from other neurons

dependent variable
: variable in a scientific experiment that is affected by another variable, called the independent variable

deposit feeder
: animal that obtains organic matter for nutrition by eating soil or the sediments at the bottom of a body of water

dermal tissue
: type of plant tissue that covers the outside of a plant in a single layer of cells called the epidermis

dermis
: lower layer of the skin that is made of tough connective tissue and contains blood vessels, nerve endings, hair follicles, and glands

detritivore
: decomposer that consumes detritus

detritus
: substance composed of dead leaves, other plant remains, and animal feces that collects on the soil or at the bottom of a body of water

dialysis
: medical procedure in which blood is filtered through a machine in patients with kidney failure

diaphragm
large, sheet-like muscle below the lungs that allows breathing to occur when it contracts and relaxes

differentiation
process by which unspecialized cells become specialized into one of many different types of cells, such as neurons or epithelial cells

diffusion
type of passive transport that does not require the help of transport proteins

digestion
process of breaking down food into nutrients that can be absorbed by the blood

digestive system
organ system that breaks down food, absorbs nutrients, and eliminates any remaining waste

diploid
having two of each type of chromosome

directional selection
type of natural selection for a polygenic trait in which one of two extreme phenotypes is selected for, resulting in a shift of the phenotypic distribution toward that extreme

dispersal
movement of offspring away from their parents

disruptive selection
type of natural selection for a polygenic trait in which phenotypes in the middle of the phenotypic distribution are selected against, resulting in two overlapping phenotypes, one at each end of the distribution

DNA (deoxyribonucleic acid)
double-stranded nucleic acid that makes up genes and chromosomes

DNA replication
process of copying of DNA prior to cell division

domain
taxon in the revised Linnaean system that is larger and more inclusive than the kingdom

dominant allele
allele that masks the presence of another allele for the same gene when they occur together in a heterozygote

dormancy
state in which a plant slows down cellular activity and may shed its leaves

double helix
double spiral shape of the DNA molecule

drug abuse
use of a drug without the advice of a medical professional and for reasons not originally intended

drug addiction
situation in which a drug user is unable to stop using a drug

12.5 E

eating disorder
mental illness in which people feel compelled to eat in a way that causes physical, mental, and emotional health problems

echinoderms
invertebrates such as sea stars and sand dollars that are characterized by a spiny endoskeleton, radial symmetry as adults, and a water vascular system

ecological succession
changes through time in the numbers and types of species that make up the community of an ecosystem

ecology
branch of biology that is the study of how living things interact with each other and with their environment

ecosystem
all the living things in a given area together with the physical factors of the nonliving environment

ectoderm
outer embryonic cell layer in animals

ectothermy
regulation of body temperature from the outside through behavioral changes such as basking in the sun

egg
female gamete

ejaculation
muscle contractions that propel sperm from the epididymes and out through the urethra in males

electron transport chain
series of electron-transport molecules that pass high-energy electrons from molecule to molecule and capture their energy

element
pure substance that cannot be broken down into other types of substances

elimination
process in which waste passes out of the body

embryo
stage of growth and development that occurs from implantation through the eighth week after fertilization in humans

emigration
movement of individuals out of a population

emphysema
lung disease, usually caused by smoking, in which walls of alveoli break down, so less gas can be exchanged in the lungs

endocrine system
human body system of glands that release hormones into the blood

endocytosis
type of vesicle transport that moves substances into a cell

endoderm
inner embryonic cell layer in animals

endoplasmic reticulum (ER)
organelle in eukaryotic cells that helps make and transport proteins

endoskeleton
internal skeleton that provides support and protection

endosperm
stored food inside a plant seed

endospore
spores that form inside prokaryotic cells when they are under stress, enclosing the DNA and helping it survive conditions that may kill the cell

endosymbiotic theory
theory that eukaryotic organelles such as mitochondria evolved from ancient, free-living prokaryotes that invaded primitive eukaryotic cells

endothermic reaction
chemical reaction that absorbs energy

endothermy
regulation of body temperature from the inside through metabolic or other physical changes

energy
ability to do work

enzyme
protein that speeds up biochemical reactions

epidermis
outer layer of skin that consists mainly of epithelial cells and lacks nerve endings and blood vessels

epididymis (plural, epididymes)
one of two male reproductive organs where sperm mature and are stored until they leave the body

epiphyte
plant that is adapted to grow on other plants and obtain moisture from the air

epistasis
situation in which one gene affects the expression of another gene

epithelial tissue
tissue made up of cells that line inner and outer body surfaces, such as skin

esophagus
long, narrow digestive organ that passes food from the pharynx to the stomach

estrogen
female sex hormone secreted by the ovaries

estuary
a partly enclosed coastal body of water with one or more rivers or streams flowing into it, and with a free connection to the ocean

ethology
branch of biology that studies animal behavior

eukaryote
organism that has cells containing a nucleus and other organelles

eukaryotic cell
cell that contains a nucleus and other organelles

evaporation
process in which liquid water changes to water vapor

evergreen plant
type of plant that keeps its leaves and stays green year-round

evidence
any type of data that may be used to test a hypothesis

evolution
change in the characteristics of living things over time; the change in species over time

exchange pool
part of a biogeochemical cycle that holds an element or water for a short period of time

excretion
process of removing wastes and excess water from the body

excretory system
organ system that removes wastes and excess water from the body and includes the kidneys, large intestine, liver, skin, and lungs

exocytosis
type of vesicle transport that moves substances out of a cell

exoskeleton
non-bony skeleton that forms on the outside of the body of some invertebrates and provides protection and support

exothermic reaction
chemical reaction that releases energy

exotic species
species that is introduced (usually by human actions) into a new habitat where it may lack local predators and out-compete native species

experiment
special type of scientific investigation that is performed under controlled conditions

exponential growth
pattern of population growth in which a population starts out growing slowly but grows faster and faster as population size increases

extinction
situation in which a species completely dies out and no members of the species remain

extremophile
any type of Archaea that lives in an extreme environment, such as a very salty, hot, or acidic environment

12.6 F

facilitated diffusion
diffusion with the help of transport proteins

Fallopian tube
one of two female reproductive organs that carry eggs from the ovary to the uterus and provide the site where fertilization usually takes place

feces
solid waste that remains after food is digested and is eliminated from the body through the anus

fermentation
type of anaerobic respiration that includes glycolysis followed by the conversion of pyruvic acid to one or more other compounds and the formation of NAD^+

fertilization
union of two gametes that produces a diploid zygote

fetus
developing human organism between weeks 8 and 38 after fertilization

fibrous root
threadlike root that makes up part of the fibrous root system of some plants

filter feeder
animal that obtains organic matter for nutrition by filtering particles out of water

fish
ectothermic, aquatic vertebrate with a streamlined body and gills for absorbing oxygen from water

fitness
relative ability of an organism to survive and produce fertile offspring

flagella (singular, flagellum)
long, thin protein extensions of the plasma membrane in most prokaryotic cells that help the cells move

flagellate
type of protozoa, such as *Giardia,* that moves with flagella

flower
structure in angiosperms consisting of male and female reproductive structures that attracts animal pollinators

follicle-stimulating hormone (FSH)
pituitary gland hormone that stimulates the ovaries to secrete estrogen and follicles in the ovaries to mature

food
: organic molecules such as glucose that organisms use for chemical energy

food chain
: diagram that represents a single pathway through which energy and matter flow through an ecosystem

food web
: diagram that represents multiple intersecting pathways through which energy and matter flow through an ecosystem

fossil
: preserved remains or traces of organisms that lived in the past

fossil record
: the record of life as told by the study and analysis of fossils

frameshift mutation
: deletion or insertion of one or more nucleotides that changes the reading frame of the genetic material

freshwater biome
: aquatic biome such as a pond, lake, stream, or river in which the water contains little or no salt

fruit
: structure in many flowering plants that develops from the ovary and contains seeds

fungi (singular, fungus)
: kingdom in the domain Eukarya that includes molds, mushrooms, and yeasts

12.7 G

Galápagos Islands
group of 16 small volcanic islands in the Pacific Ocean 966 kilometers (600 miles) off the west coast of South America, where Darwin made some of his most important observations during his voyage on the *HMS Beagle*

gall bladder
sac-like organ that stores bile from the liver and secretes it into the duodenum of the small intestine

gamete
reproductive cell produced during meiosis that has the haploid number of chromosomes

gametogenesis
development of haploid cells into gametes such as sperm and egg

gametophyte
haploid generation in the life cycle of a plant that results from asexual reproduction with spores and that produces gametes for sexual reproduction

gastrointestinal (GI) tract
organs of the digestive system through which food passes during digestion, including the mouth, esophagus, stomach, and small and large intestines

gene
unit of DNA on a chromosome that is encoded with the instructions for a single protein

gene cloning
process of isolating and making copies of a gene

gene expression
use of a gene to make a protein

gene flow
change in allele frequencies that occurs when individuals move into or out of a population

gene pool
all the genes of all the members of a population

generalist
organism that can consume many different types of food

gene theory
theory that the characteristics of living things are controlled by genes that are passed from parents to offspring

gene therapy
way to cure genetic disorders by inserting normal genes into cells with mutant genes

genetic code
universal code of three-base codons that encodes the genetic instructions for the amino acid sequence of proteins

genetic disorder
disease caused by a mutation in one or a few genes

genetic drift
a random change in allele frequencies that occurs in a small population

genetic engineering
using biotechnology to change the genetic makeup of an organism

genetics
the science of heredity

genetic trait
characteristic that is encoded in DNA

genetic transfer
method of increasing genetic variation in prokaryotes that involves cells “grabbing” stray pieces of DNA from their environment or exchanging DNA directly with other cells

genital herpes
sexually transmitted infection caused by a herpes virus that is characterized by periodic outbreaks of blisters on the genitals

genital warts
small, rough growths on the genitals caused by a sexually transmitted infection with human papillomavirus (HPV)

genotype
alleles an individual inherits at a particular genetic locus

genus
taxon above the species in the Linnaean classification system; group of closely related species

geologic time scale
time line of Earth based on major events in geology, climate, and the evolution of life

germination
early growth and development of a plant embryo in a seed

germline mutation
mutation that occur in gametes

giardiasis
disease caused by *Giardia* protozoa that spreads through contaminated food or water

gills
organs in aquatic organisms composed of thin filaments that absorb oxygen from water

gizzard
food-grinding organ in the digestive system of birds and some other animals that may contain swallowed stones

global warming
recent rise in Earth's average surface temperature generally attributed to an increased greenhouse effect

glucose
simple carbohydrate with the chemical formula $C_6H_{12}O_6$ that is the nearly universal food for life

glycolysis
first stage of cellular respiration in which glucose is split, in the absence of oxygen, to form two molecules of pyruvate (pyruvic acid) and two (net) molecules of ATP

Golgi apparatus
organelle in eukaryotic cells that processes proteins and prepares them for use both inside and outside the cell

gonads
glands that secrete sex hormones and produce gametes; testes in males and ovaries in females

gonorrhea
common sexually transmitted infection that is caused by bacteria

gradualism
model of the timing of evolution in which evolutionary change occurs at a slow and steady pace

Gram-negative bacteria
type of bacteria that stain red with Gram stain and have a thin cell wall with an outer membrane

Gram-positive bacteria
type of bacteria that stain purple with Gram stain and have a thick cell wall without an outer membrane

grana
within the chloroplast, consists of sac-like membranes, known as thylakoid membranes

greenhouse effect
natural feature of Earth's atmosphere that occurs when gases in the atmosphere radiate the sun's heat back down to Earth's surface, making Earth's temperature far warmer than it otherwise would be

ground tissue
type of plant tissue making up most of the interior of the roots and stems of plants that carries out basic metabolic functions and provides support and storage

groundwater
: water that exists in the ground either in the soil or in rock layers below the surface

growing season
: period of time each year when it is warm enough and wet enough for plants to grow

gymnosperm
: type of seed plant that produces bare seeds in cones

12.8 H

habitat
physical environment in which a species lives and to which it has become adapted

habitat loss
destruction or disruption of Earth's natural habitats, most often due to human actions such as agriculture, forestry, mining, and urbanization

hair follicle
structure in the dermis of skin where a hair originates

haploid
having only one chromosome of each type

Hardy-Weinberg theorem
founding principle of population genetics that proves allele and genotype frequencies do not change in a population that meets the conditions of no mutation, no migration, large population size, random mating, and no natural selection

heart
muscular organ in the chest that that pumps blood through blood vessels when it contracts

heart attack
blockage of blood flow to heart muscle tissues that may result in the death of cardiac muscle fibers

hepatitis B
inflammation of the liver caused by infection with hepatitis B virus, which is often transmitted through sexual contact

herbivore
consumer that eats producers such as plants or algae

heterotroph
organism that gets food by consuming other organisms

heterozygote
organism that inherits two different alleles for a given gene

homeobox gene
gene that codes of regulatory proteins that control gene expression during development

homeostasis
process of maintaining a stable environment inside a cell or an entire organism

homologous chromosomes
pair of chromosomes that have the same size and shape and contain the same genes

homologous structure
structure that is similar in related organisms because it was inherited from a common ancestor

homozygote
organism that inherits two alleles of the same type for a given gene

host
species that is harmed in a parasitic relationship

human genome
all of the DNA of the human species

Human Genome Project
international science project that sequenced all 3 billion base pairs of the human genome

human immunodeficiency virus (HIV)
virus transmitted through body fluids that infects and destroys helper T cells and eventually causes acquired immunodeficiency syndrome (AIDS)

human papilloma virus (HPV)
sexually transmitted virus that causes genital warts and cervical cancer

humoral immune response
type of immune response in which B cells produce antibodies against antigens in blood and lymph

hybrid
offspring that results from a cross between two different types of parents

hydrogen bond
type of chemical bond that forms between molecules: found between water molecules

hydrostatic skeleton
type of internal support in an animal body that results from the pressure of fluid within the body cavity known as the coelom

hypertension
high blood pressure

hyphae (singular, hypha)
thread-like filaments that make up the body of a fungus and consist of one or more cells surrounded by a tubular cell wall

hypothalamus
part of the brain that secretes hormones

hypothesis
possible answer to a scientific question; must be falsifiable

12.9 I

immigration
movement of individuals into a population

immune response
specific defense against a particular pathogen

immune system
body system that consists of skin, mucous, membranes, and other tissues and organs that defends the body from pathogens and cancer

immunity
ability to resist a pathogen due to memory lymphocytes or antibodies to the antigens the pathogen carries

immunization
deliberate exposure of a person to a pathogen in order to provoke an immune response and the formation of memory cells specific to that pathogen

immunodeficiency
inability of the immune system to fight off pathogens that a normal immune system would be able to resist

implantation
process in which a blastocyst embeds in the endometrium lining the uterus

incomplete digestive system
digestive system that consists of a digestive cavity and a single opening that serves as both mouth and anus

incomplete dominance
relationship between the alleles for a gene in which one allele is only partly dominant to the other allele so an intermediate phenotype results

incubation
period of bird reproduction when one or both parents sit on, or brood, the eggs in order to keep them warm until they hatch

independent assortment
independent segregation of chromosomes to gametes during meiosis

independent variable
variable in a scientific experiment that is manipulated by the researcher to investigate its effect on another variable called the dependent variable

infancy
first year of life after birth in humans

inflammatory response
: nonspecific response the body first makes to tissue damage or infection

inheritance of acquired characteristics
: mistaken idea of Jean Baptiste Lamarck that evolution occurs through the inheritance of traits that an organism develops in its own life time

innate behavior
: behavior closely controlled by genes that occurs naturally, without learning or practice, in all members of a species whenever they are exposed to a certain stimulus; also called instinctive behavior

instinct
: ability of an animal to perform a behavior the first time it is exposed to the proper stimulus

integumentary system
: human body system that includes the skin, nails, and hair

interneuron
: type of neuron that carries nerve impulses back and forth between sensory and motor neurons

interphase
: stage of the eukaryotic cell cycle when the cell grows, synthesizes DNA, and prepares to divide

interspecific competition
: relationship between organisms of different species that strive for the same resources in the same place

intertidal zone
: in marine biomes, the narrow strip along the coastline that is covered by water at high tide and exposed to air at low tide

intraspecific competition
: relationship between organisms of the same species that strive for the same resources in the same place

invertebrate
: animal that lacks a vertebral column, or backbone

12.10 J

joint

place where two or more bones of the skeleton meet

12.11 K

kelp
multicellular seaweed that may grow as large as a tree and occurs in forests found throughout the ocean in temperate and arctic climates

keratin
tough, fibrous protein in skin, nails, and hair

keystone species
species that plays an especially important role in its community so that major changes in its numbers affect the populations of many other species in the community

kidney
main organ of the excretory system that filters blood and forms urine

kidney failure
loss of the ability of nephrons of the kidney to function fully

kingdom
largest and most inclusive taxon in the original Linnaean classification system

Krebs cycle
second stage of aerobic respiration in which two pyruvate (pyruvic acid) molecules from the first stage react to form ATP, NADH, and $FADH_2$

***K*-selected**
species in which population growth is controlled by density-dependent factors and population size is generally at or near carrying capacity

12.12 L

lactation
production of milk for an offspring by mammary glands, which occurs in all female mammals after giving birth or laying eggs

lactic acid fermentation
type of anaerobic respiration that includes glycolysis followed by the conversion of pyruvic acid to lactic acid and the formation of NAD^+

lancelets
members of the subphylum Cephalochordata

large intestine
organ of the digestive system that removes water from food waste and forms feces

larva (plural, larvae)
juvenile stage that occurs in the life cycle of many invertebrates, fish, and amphibians and that differs in form and function from the adult stage

larynx
organ of the respiratory system between the pharynx and trachea that is also called the voice box because it allows the production of vocal sounds

last universal common ancestor (LUCA)
hypothetical early cell (or group of cells) that gave rise to all subsequent life on Earth

latency
period of dormancy of a virus inside a living body that may last for many years

law of independent assortment
Mendel's second law stating that factors controlling different characteristics are inherited independently of each other

law of segregation
Mendel's first law stating that the two factors controlling a characteristics separate and go to different gametes

learning
change in behavior that occurs as a result of experience

leukocyte
white blood cell produced by bone marrow to fight infections

lichen
an organism that results from a mutualistic relationship between a fungus and a cyanobacterium or green alga

life cycle
series of stages a sexually reproducing organism goes through from one generation to the next

ligament
band of fibrous connective tissue that holds bones together

light reactions
first stage of photosynthesis in which light energy from the sun is captured and changed into chemical energy that is stored in ATP and NADPH

lignin
tough, hydrophobic carbohydrate molecule that stiffens and waterproofs vascular tissues of plants

linkage map
map that shows the positions of genes on a chromosome based on the frequency of crossing-over between the genes

linked genes
genes that are located on the same chromosome

Linnaean classification system
system of classifying organisms based on observable physical traits; consists of a hierarchy of taxa, fro the kingdom to the species

lipid
organic compound such as fat or oil

liver
organ of digestion and excretion that secretes bile for lipid digestion and breaks down excess amino acids and toxins in the blood

locus
position of a gene on a chromosome

logistic growth
pattern of population growth in which growth slows and population size levels off as the population approaches the carrying capacity

lung
organ of the respiratory system in which gas exchange takes place between the blood and the atmosphere

luteinizing hormone (LH)
pituitary gland hormone that stimulates the testes to secrete testosterone and the ovaries to secrete estrogen

lymph
fluid that leaks out of capillaries into spaces between cells and circulates in the vessels of the lymphatic system

lymphatic system
system of the body consisting of organs, vessels, nodes, and lymph that produces lymphocytes and filters pathogens from body fluids

lymph node
small structures located on lymphatic vessels where pathogens are filtered from lymph and destroyed by lymphocytes

lymphocyte
type of leukocyte that is a key cell in the immune response to a specific pathogen

12.13 M

macroevolution
evolutionary change that occurs over geologic time above the level of the species

macronutrient
nutrient such as carbohydrates, proteins, lipids, or water that is needed by the body in relatively large amounts

malaria
disease caused by *Plasmodium* protozoa and transmitted by mosquitoes in tropical and subtropical regions of the world

mammal
endothermic, tetrapod vertebrate that lays amniotic eggs and has mammary glands (in females) and hair or fur

mammary gland
gland in female mammals that produces milk for offspring

mantle
layer of tissue that lies between the shell and body of a mollusk and forms a cavity, called the mantle cavity, that pumps water for filter feeding

marine biome
aquatic biome in the salt water of the ocean

marsupial
therian mammal in which the embryo is born at an early, immature stage and completes its development outside the mother's body in a pouch on her belly

mass extinction
extinction event in which many if not most species abruptly disappear from Earth

matter
anything that takes up space and has mass

mechanical digestion
physical breakdown of chunks of food into smaller pieces by organs of the digestive system

medusa (plural, medusae)
basic body plan in cnidarians such as jellyfish that is bell-shaped and typically motile

meiosis
type of cell division in which the number of chromosomes is reduced by half and four haploid cells result

melanin
brown pigment produced by melanocytes in the skin that gives skin most of its color and prevents UV light from penetrating the skin

memory cell
lymphocyte (B or T cell) that retains a "memory" of a specific pathogen after an infection is over and thus provides immunity to the pathogen

menarche
beginning of menstruation; first monthly period in females

menopause
period during which menstrual cycles slow down and eventually stop in middle adulthood

menstrual cycle
monthly cycle of processes and events in the ovaries and uterus of a sexually mature human female

menstruation
process in which the endometrium of the uterus is shed from the body during the first several days of the menstrual cycle; also called monthly period

meristem
type of plant tissue consisting of undifferentiated cells that can continue to divide and differentiate and from which plants grow in length or width

mesoderm
embryonic cell layer in many animals that is located between the endoderm (inner cell layer) and ectoderm (outer cell layer)

mesophyll
specialized tissue inside plant leaves where photosynthesis takes place

Mesozoic Era
age of dinosaurs that lasted from 245–65 million years ago

messenger RNA (mRNA)
type of RNA that copies genetic instructions from DNA in the nucleus and carries them to the cytoplasm

metabolism
sum of all the biochemical reactions in an organism

metamorphosis
process in which a larva undergoes a major transformation to change into the adult form, which occurs in amphibians, arthropods, and other invertebrates

metaphase
second phase of mitosis during which chromosomes line up at the equator of the cell

microevolution
evolutionary change that occurs over a relatively short period of time within a population or species

micronutrient
nutrient such as a vitamin or mineral that is needed by the body in relatively small amounts

migration
regular movement of individuals or populations each year during certain seasons, usually to find food, mates, or other resources

mineral
chemical element such as calcium or potassium that is needed in relatively small amounts for proper body functioning

mitochondria (singular, mitochondrion)
organelle in eukaryotic cells that makes energy available to the cell in the form of ATP molecules

mitosis
process in which the nucleus of a eukaryotic cell divides

model
representation of part of the real world

molecular clock
using DNA (or proteins) to measure how long it has been since related species diverged from a common ancestor

Mollusca
phylum of invertebrates that are generally characterized by a hard outer shell, a mantle, and a feeding organ called a radula

molting
process in which an animal sheds and replaces the outer covering of the body, such as the exoskeleton in arthropods

monosaccharide
simple sugar such as glucose that is a building block of carbohydrates

monotreme
type of mammal that reproduces by laying eggs

motility
the ability to move

motor neuron
type of neuron that carries nerve impulses from the central nervous system to muscles and glands

mucous membrane
epithelial tissue that lines inner body surfaces and body openings and produces mucus

mucus
slimy substance produced by mucous membranes that traps pathogens, particles, and debris

multiple allele trait
trait controlled by one gene with more than two alleles

muscle fiber
long, thin muscle cell that has the ability to contract, or shorten

muscle tissue
tissue made up of cells that can contract; includes smooth, skeletal, and cardiac muscle tissue

muscular system
human body system that includes all the muscles of the body

mutagen
environmental factors that causes mutations

mutation
change in the sequence of bases in DNA or RNA

mutualism
type of symbiotic relationship in which both species benefit

mycelium
body of a fungus that consists of a mass of threadlike filaments called hyphae

mycorrhiza
mutualistic relationship between a plant and a fungus that grows in or on its roots

myelin sheath
lipid layer around the axon of a neuron that allows nerve impulses to travel more rapidly down the axon

MyPlate
visual guideline for balanced eating, replacing MyPyramid in 2011

MyPyramid
visual dietary guideline that shows the relative amounts of foods in different food groups that should be eaten each day

12.14 N

natural resource
something supplied by nature that helps support life

natural selection
evolutionary process in which some living things produce more offspring than others so the characteristics of organisms change over time

nature-nurture debate
debate over the extent to which genes (nature) or experiences in a given environment (nurture) control traits such as animal behaviors

nectar
sweet, sugary liquid produced by the flowers of many angiosperms to attract animal pollinators

Nematoda
phylum of invertebrates called roundworms, which have a pseudocoelom and complete digestive system

neocortex
layer of nerve cells covering the cerebrum of the mammalian brain that plays an important role in many complex brain functions

nephron
structural and functional unit of the kidney that filters blood and forms urine

nerve
one of many cable-like bundles of axons that make up the peripheral nervous system

nerve impulse
electrical signal transmitted by the nervous system

nervous system
human body system that carries electrical messages throughout the body

nervous tissue
tissue made up of neurons, or nerve cells, that carry electrical messages

neuron
nerve cell; structural and functional unit of the nervous system

neurotransmitter
chemical that carries a nerve impulse from one nerve to another at a synapse

niche
: role of a species in its ecosystem that includes all the ways the species interacts with the biotic and abiotic factors of the ecosystem

nitrogen cycle
: interconnected pathways through which nitrogen is recycled through the biotic and abiotic components of the biosphere

nitrogen fixation
: process of changing nitrogen gas to nitrates that is carried out by nitrogen-fixing bacteria in the soil or in the roots of legumes

nondisjunction
: failure of replicated chromosomes to separate during meiosis II, resulting in some gametes with a missing chromosome and some with an extra chromosome

nonrenewable resource
: natural resource that exists in a fixed amount and can be used up

notochord
: stiff support rod that runs from one end of the body to the other in animals called chordates

nucleic acid
: organic compound such as DNA or RNA

nucleotide
: small molecule containing a sugar, phosphate group, and base that is a building block of nucleic acids

nucleus (plural, nuclei)
: organelle inside eukaryotic cells that contains most of the cell's DNA and acts as the control center of the cell

nutrient
: substance the body needs for energy, building materials, or control of body processes

12.15 O

obesity
condition in which the body mass index is 30.0 kg/m^2 or greater

observation
anything that is detected with the senses

omnivore
consumer that eats both plants and animals

oogenesis
process of producing eggs in the ovary

open circulatory system
type of circulatory system in which blood flows not only through blood vessels but also through a body cavity

operator
a region of an operon where regulatory proteins bind

operon
region of prokaryotic DNA that consists of a promoter, an operator, and one or more genes that encode proteins needed for a specific function

organ
structure composed of more than one type of tissue that performs a particular function

organelle
structure within the cytoplasm of a cell that is enclosed within a membrane and performs a specific job

organic compound
compound found in living things that contains mainly carbon

organism
an individual living thing

organ system
group of organs that work together to do a certain job

osmosis
diffusion of water molecules across a membrane

ossification
process in which mineral deposits replace cartilage and change it into bone

osteoblast
type of bone cell that makes new bone cells and secretes collagen

osteoclast
type of bone cell that dissolves minerals in bone and releases them back into the blood

osteocyte
type of bone cell that regulates mineral homeostasis by directing the uptake of minerals from the blood and the release of minerals back into the blood as needed

ovary
one of two female reproductive organs that produces eggs and secretes estrogen

ovipary
type of reproduction in which an embryo develops within an egg outside the mother's body

ovovivipary
type of reproduction in which an embryo develops inside an egg within the mother's body but in which the mother provides no nourishment to the developing embryo in the egg

ovulation
release of a secondary oocyte from the uterus about half way through the menstrual cycle

ozone hole
hole in the ozone layer high in the atmosphere over Antarctica caused by air pollution destroying ozone

12.16 P

paleontologist
scientist who finds and studies fossils to learn about evolution and understand the past

Paleozoic Era
age of "old life" from 544–245 million years ago that began with the Cambrian explosion and ended with the Permian extinction

pancreas
gland near the stomach that secretes insulin and glucagon to regulate blood glucose and enzymes to help digest food

parasite
species that benefits in a parasitic relationship

parasitism
symbiotic relationship in which one species benefits while the other species is harmed

parathyroid glands
a pair of small glands in the neck that secretes hormones that regulate blood calcium

passive immunity
type of immunity to a particular pathogen that results when antibodies are transferred to a person who has never been exposed to the pathogen

passive transport
movement of substances across a plasma membrane that does not require energy

pathogen
disease-causing agent such as a bacterium, virus, fungus, or protozoan

pedigree
chart showing how a trait is passed from generation to generation within a family

penis
male reproductive organ containing the urethra, through which sperm and urine pass out of the body

periosteum
tough, fibrous membrane that covers the outer surface of bone

peripheral nervous system (PNS)
one of two major divisions of the nervous system that consists of all the nervous tissue that lies outside the central nervous system

peristalsis
: rapid, involuntary, wave-like contraction of muscles that pushes food through the GI tract and urine through the ureters

Permian extinction
: extinction at the end of the Paleozoic Period that was the biggest mass extinction the world had ever seen until then

petal
: outer parts of flowers that are usually brightly colored to attract animal pollinators

pH
: scale that is used to measure acidity

phagocytosis
: process in which leukocytes engulf and break down pathogens and debris

pharmacogenomics
: field that is tailoring medical treatments to fit our genetic profiles

pharynx
: long, tubular organ that connects the mouth and nasal cavity with the larynx through which air and food pass

phenotype
: characteristics of an organism that depend on how the organism's genotype is expressed

phloem
: type of vascular tissue in a plant that transports food from photosynthetic cells to other parts of the plant

phospholipid bilayer
: double layer of phospholipid molecules that makes up a plasma membrane

photic zone
: area in an aquatic biome that extends to a maximum depth of 200 meters

photoautotroph
: producer that uses energy from sunlight to make food by photosynthesis

photosynthesis
: process of using the energy in sunlight to make food (glucose)

photosystem
: group of molecules, including chlorophyll, in the thylakoid membrane of a chloroplast that captures light energy

phylogenetic tree
: diagram that shows how species are related to each other through common ancestors

phylogeny
evolutionary history of a group of related organisms

phytoplankton
bacteria and algae that use sunlight to make food

pineal gland
gland of the endocrine system that secretes the hormone melatonin that regulates sleep-wake cycles

pioneer species
type of species that first colonizes a disturbed area

pistil
female reproductive structure of a flower that consists of a stigma, style, and ovary

pituitary gland
master gland of the endocrine system that secretes many hormones, the majority of which regulate other endocrine glands

placenta
temporary organ that consists of a large mass of maternal and fetal blood vessels through the mother's and fetus's blood exchange substances

placental mammal
therian mammal in which a placenta develops during pregnancy to sustain the fetus while it develops inside the mother's uterus

plant
multicellular eukaryote with chloroplasts, cell walls made of cellulose, and specialized reproductive organs

plasma
golden-yellow fluid part of blood that contains many dissolved substances and blood cells

plasma membrane
thin coat of lipids (phospholipids) that surrounds and encloses a cell

plasmid
small, circular piece of DNA in a prokaryotic cell

platelet
cell fragment in blood that helps blood clot

Platyhelminthes
invertebrate phylum of flatworms that are characterized by a flat body because they lack a coelom or pseudo-coelom

pleiotropy
situation in which a single gene affects more than one trait

pneumonia
disease in which the alveoli of the lungs become inflamed and filled with fluid as a result of infection or injury

point mutation
change in a single nucleotide base in the genetic material

polarity
difference in electrical charge between different parts of the same molecule

pollen
tiny grains that bear the male gametes of seed plants and transfer sperm to female reproductive structures

pollination
fertilization in plants in which pollen is transferred to female gametes in an ovary

polygenic characteristic
characteristic, or trait, controlled by more than one gene, each of which may have two or more alleles

polymerase chain reaction (PCR)
biotechnology process that makes many copies of a gene or other DNA segment

polynucleotide
chain of nucleotides that alone or with another such chain makes up a nucleic acid

polyp
basic body plan in cnidarians such as jellyfish that is tubular in shape and typically sessile

polypeptide
chain of amino acids that alone or with other such chains makes up a protein

polysaccharide
chain of monosaccharides that makes up a complex carbohydrate such as starch

population
all the organisms of the same species that live in the same area

population density
average number of individuals in a population per unit of area or volume

population distribution
describes how the individuals are distributed, or spread throughout their habitat

population genetics
science focusing on evolution within populations that is the area of overlap between evolutionary theory and Mendelian genetics

population growth rate (r)
how fast a population changes in size over time

population pyramid
bar graph that represents the age-structure of a population

Porifera
invertebrate phylum of sponges, which have a non-bony endoskeleton and are sessile as adults

precipitation
water that falls from clouds in the atmosphere to Earth's in the form of rain, snow, sleet, hail, or freezing rain

predation
relationship in which members of one species consume members of another species

predator
species that consumes another in a predator-prey relationship

prediction
statement that tells what will happen under certain conditions

pregnancy
carrying of one or more offspring from fertilization until birth

prey
species that is consumed by another in a predator-prey relationship

primary succession
change in the numbers and types of species that live in a community that occurs in an area that has never before been colonized

probability
the likelihood, or chance, than a certain event will occur

producer
organism that produces food for itself and other organisms

product
substance that forms as the result of a chemical reaction

prokaryote
single-celled organism that lacks a nucleus

prokaryotic cell
cell without a nucleus that is found in single-celled organisms

promoter
region of a gene where a RNA polymerase binds to initiate transcription of the gene

prophase
first phase of mitosis during which chromatin condense into chromosomes, the nuclear envelope breaks down, centrioles separate, and a spindle begins to form

protein
organic compound made up of amino acids

protein synthesis
process in which cells make proteins that includes transcription of DNA and translation of mRNA

protist
kingdom in the domain Eukarya that includes all eukaryotes except plants, animals, and fungi

protozoa (singular, protozoan)
animal-like protists such as *Amoeba* and *Paramecium*

pseudocoelom
partial, fluid-filled cavity inside the body of some invertebrates

pseudopod
temporary, foot-like extension of the cytoplasm that some cells use for movement or feeding

psychoactive drug
drug that affects the central nervous system, generally by influencing the transmission of never impulses in the brain

puberty
period during which humans become sexually mature

pulmonary circulation
part of the circulatory system that carries blood between the heart and lungs

punctuated equilibrium
model of the timing of evolution in which long periods of little evolutionary change are interrupted by bursts of rapid evolutionary change

Punnett square
chart for determining the expected percentages of different genotypes in the offspring of two parents

pupa
life cycle stage of many insects that occurs between the larval and adult stages and during which the insect is immobile, may be encased within a cocoon, and changes into the adult form

12.17 R

radial symmetry
: symmetry of a body plan in which there is a distinct top and bottom but not distinct head and tail ends, so the body can be divided into two halves like a pie

reactant
: starting material in a chemical reaction

recessive allele
: allele that is masked by the presence of another allele for the same gene when they occur together in a heterozygote

recombinant DNA
: DNA that results when DNA from two organisms is combined

red blood cell
: type of cell in blood that contains hemoglobin and carries oxygen

reflex
: rapid motor response to a sensory stimulus in which nerve impulses travel in an arc that includes the spinal cord but not the brain

regeneration
: regrowing of tissues, organs, or limbs that have been lost or damaged

regulatory element
: region of DNA where a regulatory protein binds

regulatory protein
: protein that regulates gene expression

relative dating
: method of dating fossils by their location in rock layers; determines which fossils are older or younger but not their age in years

renewable resource
: natural resource that can be replenished by natural processes as quickly as humans use it

reproduction
: process by which living things give rise to offspring

reproductive system
: system of organs that produces gametes and secretes sex hormones

reptile
ectothermic, tetrapod vertebrate that lays amniotic eggs; includes crocodiles, lizards, snakes, and turtles

reservoir
part of a biogeochemical cycle that holds an element or water for a long period of time

respiration
exchange of gases between the body and the outside air

respiratory system
organ system that brings oxygen into the body and releases carbon dioxide into the atmosphere

resting potential
difference in electrical charge across the plasma membrane of a neuron that is not actively transmitting a nerve impulse

rhizoid
hair-like structure in a nonvascular plant that absorbs water and minerals and anchors the plant to a surface

ribosomal RNA
type of RNA that helps form ribosomes and assemble proteins

ribosome
organelle inside all cells where proteins are made

ringworm
skin infection caused by the fungus *Trichophyton* that causes a characteristic ring-shaped rash

RNA (ribonucleic acid)
single-stranded nucleic acid that helps make proteins

RNA world hypothesis
hypothesis that RNA was the first organic molecule to evolve and that early life was based on RNA, rather than DNA or protein

root hair
tiny hairlike structure that extends from an epidermal cell of a plant root and increases the surface area for absorption

root system
all the roots of a plant, including primary roots and secondary roots

***r*-selected**
species in which population growth is rapid but death rates are high so population size is generally below the carrying capacity

runoff
precipitation that falls on land and flows over the surface of the ground

12.18 S

saprotroph
decomposer such as a fungus or protozoan that feeds on any remaining organic matter that is left after other decomposers do their work

saturated fatty acid
molecule in lipids in which carbon atoms are bonded to as many hydrogen atoms as possible

sauropsid
type of early amniote that evolved during the Carboniferous Period and eventually gave rise to dinosaurs, reptiles, and birds

scavenger
decomposer that consumers the soft tissues of dead animals

science
distinctive way of gaining knowledge about the natural world that tries to answer questions with evidence and logic

scientific investigation
plan for asking questions and testing possible answers

scientific law
statement describing what always happens under certain conditions in nature

scientific method
the process of a scientific investigation

scientific theory
broad explanation that is widely accepted as true because it is supported by a great deal of evidence

sebaceous gland
gland in the dermis of skin that produces sebum, an oily substance that waterproofs the skin and hair

secondary succession
change in the numbers and types of species that live in a community that occurs in an area that was previously colonized but has been disturbed

seed
structure produced by a seed plant that contains an embryo and food supply enclosed within a tough coat

seed coat
tough covering of a seed that protects the embryo and keeps it from drying out until conditions are favorable for germination

segmentation
division of an animal body into multiple segments

semen
fluid containing sperm and gland secretions that nourish sperm and carry them through the urethra and out of the body

sensory neuron
type of neuron that carries nerve impulses from tissue and organs to the spinal cord and brain

sensory receptor
specialized nerve cell that responds to a particular type of stimulus such as light or chemicals

sepal
part of a flower that helps protect it while it is still in bud

sessile
of or relating to an animal that is unable to move from place to place

sex chromosome
X or Y chromosome (in humans)

sex hormone
chemical messenger that controls sexual development and reproduction

sex-linked gene
gene located on a sex chromosome

sex-linked trait
traits controlled by a gene located on a sex chromosome

sexual dimorphism
differences between the phenotypes of males and females of the same species

sexually transmitted infection (STI)
infection caused by a pathogen that spreads mainly through sexual contact; also known as sexually transmitted disease (STD)

sexual reproduction
type of reproduction that involves the fertilization of gametes produced by two parents and produces genetically variable offspring

sixth mass extinction
current mass extinction caused primarily by habitat loss due to human actions

skeletal muscle
voluntary, striated muscle that is attached to bones of the skeleton and helps the body move

skeletal system
human body system that consists of all the bones of the body as well as cartilage and ligaments

sliding filament theory
theory that explains muscle contraction by the sliding of myosin filaments over actin filaments within muscle fibers

slime mold
fungus-like protist commonly found on rotting logs and other decaying organic matter

small intestine
long, narrow, tube-like organ of the digestive system where most chemical digestion of food and virtually all absorption of nutrients take place

smooth muscle
involuntary, nonstriated muscle that is found in the walls of internal organs such as the stomach

social animal
animal that lives in a society

society
close-knit group of animals of the same species that live and work together

sodium-potassium pump
type of active transport in which sodium ions are pumped out of the cell and potassium ions are pumped into the cell with the help of a carrier protein and energy from ATP

soil
mixture of eroded rock, minerals, organic matter, and other materials that is essential for plant growth and forms the foundation of terrestrial ecosystems

solution
mixture that has the same composition throughout

somatic mutation
mutation that occurs in cells of the body other than gametes

somatic nervous system (SNS)
division of the peripheral nervous system that controls voluntary, conscious activities and reflexes

spawning
depositing large numbers of gametes in the same place and at the same time by fish or amphibians

specialization
evolution of different adaptations in competing species, which allows them to live in the same area without competing

speciation
process by which a new species evolves

species
group of organisms that are similar enough to mate together and produce fertile offspring

sperm
male gamete

spermatogenesis
process of producing sperm in the testes

spermatophyte
type of plant that reproduces by producing seeds

spinal cord
thin, tubular bundle of nervous tissue that extends from the brainstem down the back to the pelvis and connects the brain with the peripheral nervous system

spongy bone
light, porous inner layer of bone that contains bone marrow

sporangium (plural, sporangia)
structure on a plant of the sporophyte generation that produces spores for asexual reproduction

sporophyte
diploid generation in the life cycle of a plant that results from sexual reproduction with gametes and that produces spores for asexual reproduction

sporozoa (singular, sporozoan)
type of protozoa that cannot move as adults

stabilizing selection
type of natural selection for a polygenic trait in which phenotypes at both extremes of the phenotypic distribution are selected against, resulting in a narrowing of the range of phenotypic variation

stamen
male reproductive structure of a flower that consists of a stalk-like filament and a pollen-producing anther

stimulus
something that triggers a behavior

stomach
sac-like organ of the digestive system between the esophagus and small intestine in which both mechanical and chemical digestion take place

stomata (singular, stoma)
tiny pore in the epidermis of a plant leaf that controls transpiration and gas exchange with the air

stroma
space outside the thylakoid membranes of a chloroplast where the Calvin cycle of photosynthesis takes place

sublimation
: process in which ice and snow change directly to water vapor

survivorship curve
: graph that represents the individuals still alive at each age in a population

sustainable use
: use of resources in a way that meets the needs of the present and also preserves the resources for the use of future generations

sweat gland
: gland in the dermis of skin that produces the salty fluid called sweat, which excretes wastes and helps cool the body

swim bladder
: balloon-like internal organ in most fish that can be used to move up or down through the water column by changing the amount of gas it contains

symbiosis
: close relationship between organisms of different species in which at least one of the organisms benefits from the relationship

sympatric speciation
: evolution of a new species that occurs when without geographic separation first occurring between members of an original species

synapse
: place where an axon terminal meets another cell

synapsid
: type of early amniote that evolved during the Carboniferous Period and eventually gave rise to mammals

synthetic biology
: field of biology involved in engineering new functions from living systems

syphilis
: sexually transmitted infection caused by bacteria that may eventually be fatal if untreated

systemic circulation
: part of the circulatory system that carries blood between the heart and body

12.19 T

taproot
: single, thick primary root that characterizes the root system of some plants

target cell
: type of cell on which a particular hormone has an effect because it has receptor molecules for the hormone

TATA box
: regulatory element that is part of the promoter of most eukaryotic genes

taxa
: a grouping of organisms in a classification system such as the Linnaean system; for example, species or genus

taxonomy
: science of classifying organisms

T cell
: type of lymphocyte involved in cell-mediated immunity in which cells infected with viruses are destroyed

telophase
: last stage of mitosis during which chromosomes uncoil to form chromatin, the spindle breaks down, and new nuclear membranes form

tendon
: tough connective tissue that attaches skeletal muscle to bones of the skeleton

terrestrial biome
: a biome of or pertaining to land, as in terrestrial ecosystem

testis (plural, testes)
: one of two male reproductive organs that produces sperm and secretes testosterone

testosterone
: male sex hormone secreted by the testes

tetrapod
: vertebrate with four legs (amphibian, reptile, bird, or mammal)

therapsid
: type of extinct organism that lived during the Permian Period and gave rise to mammals

therian mammal
: viviparous mammal that may be either a marsupial or placental mammal

thylakoid membrane
: membrane in a chloroplast where the light reactions of photosynthesis occur

thyroid gland
: large endocrine gland in the neck that secretes hormones that control the rate of cellular metabolism throughout the body

tissue
: group of cells of the same kind that perform a particular function in an organism

trachea
: long, tubular organ of the respiratory system, also called the wind pipe, that carries air between the larynx and lungs

tracheophyte
: type of plant that has vascular tissues, such as a seed plant or flowering plant

transcription
: process in which genetic instructions in DNA are copied to form a complementary strand of mRNA

transfer RNA (tRNA)
: type of RNA that brings amino acids to ribosomes where they are joined together to form proteins

transgenic crop
: crop that has been genetically modified with new genes that code for traits useful to humans

translation
: process in which genetic instructions in mRNA are "read" to synthesize a protein

transpiration
: process in which plants give off water vapor from photosynthesis through tiny pores, called stomata, in their leaves

transport protein
: protein in a plasma membrane that helps other substances cross the membrane

trichomoniasis
: common sexually transmitted infection that is caused by protozoa

trilobite
: oldest known arthropod, which is now extinct and known only from numerous fossils

trophic level
: feeding position in a food chain or food web, such as producer, primary consumer, or secondary consumer

tropism
: turning by an organism or part of an organism toward or away from an environmental stimulus

tumor
: abnormal mass of cells that may be cancerous

tunicates
: members of the subphylum Urochordata are tunicates (also called sea squirts)

12.20 U

unsaturated fatty acid
molecule in lipids in which some carbon atoms are bonded to other groups of atoms rather than to hydrogen atoms

ureter
muscular, tube-like organ of the urinary system that moves urine by peristalsis from a kidney to the bladder

urethra
muscular, tube-like organ of the urinary system that carries urine out of the body from the bladder; in males, it also carries sperm out of the body

urinary system
organ system that includes the kidneys and is responsible for filtering waste products and excess water from the blood and excreting them from the body

urination
process in which urine leaves the body through a sphincter at the end of the urethra

urine
liquid waste product of the body that is formed by the kidneys and excreted by the other organs of the urinary system

uterus (plural, uteri)
female reproductive organ in therian mammals where an embryo or fetus grows and develops until birth

12.21 V

vaccine
: substance containing modified pathogens that does not cause disease but provokes an immune response and results in immunity to the pathogen

vacuole
: large saclike organelle that stores and transports materials inside a cell

vagina
: female reproductive organ that receives sperm during sexual intercourse and provides a passageway for a baby to leave the mother's body during birth

vascular tissue
: type of tissue in plants that transports fluids through the plant; includes xylem and phloem

vector
: organism such as an insect that spreads pathogens from host to host

vegetative reproduction
: asexual reproduction in plants using nonreproductive tissues such as leaves, stems, or roots

vein
: type of blood vessel that carries blood toward the heart from the lungs or body

ventilation
: process of carrying air from the atmosphere into the lungs

vertebrae (singular, vertebra)
: repeating bony units that make up the vertebral column of vertebrates

vertebral column
: bony support structure that runs down the back of a vertebrate animal; also called a backbone

vertebrate
: animal with a vertebral column, or backbone

vesicle
: small saclike organelle that stores and transports materials inside a cell

vesicle transport
: type of active transport in which substances are carried across the cell membrane by vesicles

vestigial structure
: structure such as the human tailbone or appendix that evolution has reduced in size because it is no longer used

villi (singular, villus)
: microscopic, finger-like projections in the mucous membrane lining the small intestine that form a large surface area for the absorption of nutrients

virion
: individual virus particle that consists of nucleic acid within a protein capsid

virus
: tiny, nonliving particle that contains DNA but lacks other characteristics of living cells

vitamin
: organic compound needed in small amounts for proper body functioning

vivipary
: type of reproduction in which an embryo develops within, and is nourished by, the mother's body

vulva
: external female reproductive structures, including the labia and vaginal opening

12.22 W

water cycle
interconnected pathways through which water is recycled through the biotic and abiotic components of the biosphere

water mold
fungus-like protist commonly found in moist soil and surface water

weed
plant that is growing where people do not want it

wetland
area that is saturated with water or covered by water for at least one season of the year

white blood cell
type of cell in blood that defends the body against invading microorganisms or other threats in blood or extracellular fluid

12.23 X

xerophyte
plant that is adapted to a very dry environment

X-linked gene
gene located on the X chromosome

X-linked trait
trait controlled by a gene located on the X chromosome

xylem
type of vascular tissue in a plant that transports water and dissolved nutrients from roots to stems and leaves

12.24 Z

zooplankton
tiny animals that feed on phytoplankton

zygospore
diploid spore in fungi that is produced by the fusion of two haploid parent cells

zygote
diploid cell that forms when two haploid gametes unite during fertilization