Introduction to Life Science

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CHAPTER 1 Introduction to Life Science

CHAPTER OUTLINE

Introduction

What does it mean to be alive?

Scientifically, there is an actual definition of living. Living organisms must have certain characteristics. If they do not have these characteristics, are they living? This butterfly, like all other insects, animals, plants, and every other living organism, shares common characteristics with all life. What exactly does it mean to be alive? This chapter will answer this question. These concepts will serve as an introduction to life science, discussing the basics of studying the life sciences and addressing the question, "What is a living organism?"

1.1 Scientific Ways of Thinking

- Describe the role of a scientist.
- Describe what is meant by "thinking like a scientist."

What was that noise?

If you let your emotions rule your thinking, you might think a thumping noise was a ghost. If you think like a scientist, however, you ask questions and make observations. You'd observe the shutters are loose and blowing in the wind.

Scientific Ways of Thinking

Modern science is a way of understanding the physical world, based on observable evidence, reasoning, and repeated testing. That means scientists explain the world based on their own observations. If they develop new ideas about the way the world works, they set up a way to test these new ideas.

Thinking Like a Scientist

How can you think like a scientist? Thinking like a scientist is based on asking and answering questions. Though you may not know it, you do this all day long. Scientists ask questions, and then make detailed observations to try to ask more specific questions and develop a **hypothesis**. They may design and perform an **experiment** to try to answer their question. From the results of their experiment, scientists draw **conclusions**.

- **Scientists ask questions**: The key to being a great scientist is to ask questions. Imagine you are a scientist in the African Congo. While in the field, you observe one group of healthy chimpanzees on the north side of the jungle. On the other side of the jungle, you find a group of chimpanzees that are mysteriously dying. What questions might you ask? A good scientist might ask the following two questions:

- 1. "What differs between the two environments where the chimpanzees live?"
  2. "Are there differences in behavior between the two groups of chimpanzees?"

- **Scientists make detailed observations**: To **observe** means to watch and study attentively. A person untrained in the sciences may only observe, "The chimps on one side of the jungle are dying, while chimps on the other side of the jungle are healthy." A scientist, however, will make more detailed observations. Can you think of ways to make this observation more detailed? What about the number of chimps? Are they male or female? Young or old? What do they eat? A good scientist may observe, "While all seven adult females and three adult males on the north side of the jungle are healthy and show normal behavior, four female and five male chimps under the age of five on the south side have died." Detailed observations can ultimately help scientists design their experiments and answer their questions. From these observations, a scientist will develop a hypothesis to explain the observations. A hypothesis is the scientist's proposed explanation for his observations. The scientist's hypothesis may be that "Young chimps on the south side die due to a lack of nutrients in their diet."

FIGURE 1.1
An adult and infant chimpanzee (*Pan troglodytes*).

- **Scientists find answers using tests**: When scientists want to answer a question, they search for evidence using experiments. An experiment is a test to see if their explanation is right or wrong. **Evidence** is made up of the observations a scientist makes during an experiment. To study the cause of death in the chimpanzees, scientists may give the chimps nutrients in the form of nuts, berries, and vitamins to see if they are dying from a lack of food. This test is the experiment. If fewer chimps die, then the experiment shows that the chimps may have died from not having enough food. This is the evidence.

- **Scientists question the answers**: Good scientists are skeptical. Scientists never use only one piece of evidence to form a conclusion. For example, the chimpanzees in the experiment may have died from a lack of food, but can you think of another explanation for their death? They may have died from a virus, or from another less obvious cause. More experiments need to be completed before scientists can be sure. Good scientists constantly question their own conclusions. They also find other scientists to confirm or disagree with their evidence.

Vocabulary

- **conclusion**: The answer to the proposed question; the meaning of the result or outcome of the experiment based on the evidence.
- **evidence**: Any type of data that may be used to test a hypothesis.
- **experiment**: A test to see if a hypothesis is right or wrong; a test to obtain new data.
- **hypothesis**: A proposed explanation for something that is testable; a proposed explanation that tries to explain an observation.
- **observe**: To watch and study attentively.

Summary

- Modern science is a way of understanding the physical world, based on observable evidence, reasoning, and repeated testing.
- To think like a scientist, you must ask questions, make detailed observations, develop a hypothesis, find answers using tests, and question your answers.

Explore More

Use the resource below to answer the questions that follow.

- **Understanding Science** at http://undsci.berkeley.edu/article/scienceflowchart

1. Once an experiment has been conducted and the results analyzed, what 4 possible responses are there when interpreting the data?
2. How does "peer review" fit into the scientific process? Why is it so important?
3. In the flowchart, what 5 processes are involved in "Exploration and Discovery"? Do you think any one of these processes is more important than the others? Explain your reasoning.

Explore More Answers

1. After interpretation of the data, the data may support a hypothesis, oppose a hypothesis, inspire a revised/new hypothesis, or inspire revised assumptions.
2. Peer review allows the scientific community to evaluate the data and results. This allows for new questions and ideas, and theories, to be developed.
3. The 5 processes are involved in "Exploration and Discovery" include making observations, asking questions, finding inspiration, exploring the literature, and sharing data and ideas. (The remainder of the answer will vary.)

Review

1. What is modern science?
2. How do you think scientifically?
3. What does it mean "to observe"?
4. What is a hypothesis?

Review Answers

1. Modern science is a way of understanding the physical world, based on observable evidence, reasoning, and repeated testing.
2. Thinking like a scientist is based on asking and answering questions.
3. To observe means to watch and study attentively.
4. A hypothesis is a proposed explanation for something that is testable, or a proposed explanation that tries to explain an observation.

1.2 Fields in the Life Sciences

- Define life science.
- Describe the major fields within the life sciences.
- Explain what is studied in cell biology, genetics, and evolution.

What kind of scientist studies dolphins?

Dolphins are living organisms, so studying them is part of the life sciences. The life sciences, however, are broken down into many fields. Scientists that study dolphins and other life in the ocean are called marine biologists.

Fields in the Life Sciences

The **life sciences** are the study of living organisms. They deal with every aspect of living organisms, from the biology of **cells**, to the biology of individual organisms, to how these organisms interact with other organisms and their environment.

The life sciences are so complex that most scientists focus on just one or two subspecialties. If you want to study insects, what would you be called? An entomologist. If you want to study the tiny things that give us the flu, then you need to enter the field of **virology**, the study of viruses. If you want to study the nervous system, which life science field is right for you (**Table** 1.1, **Table** 1.2, and **Table** 1.3)?

TABLE 1.1: **Subspecialties That Focus on One Type of Organism**

Field	Focus
Botany	Plants
Zoology	Animals

TABLE 1.1: (continued)

Field	Focus
Marine biology	Organisms living in oceans
Freshwater biology	Organisms living in and around freshwater lakes, streams, rivers, ponds, etc.
Microbiology	Microorganisms
Bacteriology	Bacteria
Virology	Viruses
Entomology	Insects
Taxonomy	The classification of organisms

TABLE 1.2: Subspecialties That Examine the Structure, Function, Growth, Development, and/or Evolution of Living Organisms

Field	Focus
Cell biology	Cells and their structures/functions
Anatomy	Structures of animals
Morphology	Form and structure of living organisms
Physiology	Physical and chemical functions of tissues and organs
Immunology	Mechanisms inside organisms that protect them from disease and infection
Neuroscience	The nervous system
Developmental biology and embryology	Growth and development of plants and animals
Genetics	Genetic makeup of living organisms and heredity
Biochemistry	Chemistry of living organisms
Molecular biology	Nucleic acids and proteins
Epidemiology	How diseases arise and spread
Evolution	The changing of species over time

TABLE 1.3: Fields of Biology That Examine the Distribution and Environments of Organisms

Field	Focus
Ecology	How various organisms interact with their environments
Biogeography	Distribution of living organisms
Population biology	The biodiversity, evolution, and environmental biology of populations of organisms

During the study of the life sciences, you will study **cell biology**, **genetics**, **molecular biology**, **botany**, **microbiology**, **zoology**, **evolution**, **ecology**, and **physiology**. Cell biology is the study of cellular structure and function (**Figure** 1.2). Genetics is the study of **heredity**, which is the passing of traits from one generation to the next. Molecular biology is the study of molecules, such as DNA and proteins. What will you study with the other subspecialties?

Vocabulary

- **botany**: The study of plants.

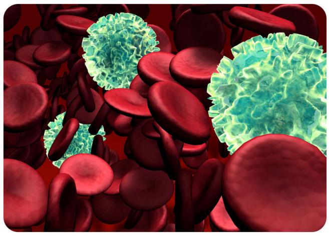


FIGURE 1.2
This illustration shows a virus among red blood cells. Which fields study red blood cells and viruses? (Keep in mind that viruses are actually much smaller than cells.)

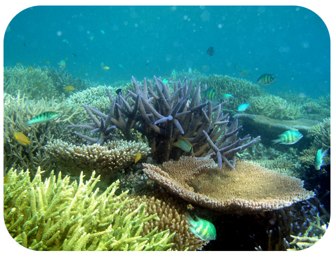


FIGURE 1.3
Other life science subspecialties include biogeography, which is the study of where organisms live and at what abundance.

- **cell**: The basic unit of structure and function of a living organism; the basic unit of life.
- **cell biology**: The study of cells, and their structures and functions.
- **ecology**: The study of how various organisms interact with each other and with their environments.
- **evolution**: The change in species over time.
- **genetics**: The study of heredity.
- **heredity**: The passing of traits from one generation to the next.
- **life sciences**: The study of living organisms.
- **microbiology**: The study of microorganisms.
- **molecular biology**: The study of molecules, such as DNA and proteins.
- **physiology**: The study of the physical and chemical functions of tissues and organs.
- **virology**: The study of viruses.
- **zoology**: The study of animals.

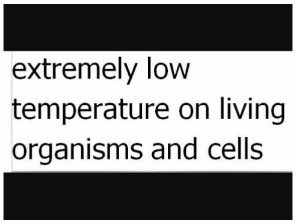
Summary

- There are several subspecialties within the life sciences that focus on one type of organism, such as virology and bacteriology.
- There are several fields of the life sciences that examine interactions between organisms and their environments, such as ecology.

Explore More

Use the resource below to answer the questions that follow.

- **Branches of Biology** at http://www.youtube.com/watch?v=OrlOOJ0Tm_E (3:28)



MEDIA
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URL: http://gamma.ck12.org/flx/render/embeddedobject/57470

1. What is the study of reptiles and amphibians?
2. What is the study of prehistoric life by means of fossils?
3. What is the study of mollusks?
4. What is the study of cells?
5. What is the study of fungi?
6. What is ecology?

Explore More Answers

1. Herpetology is the study of reptiles and amphibians.
2. Paleontology is the study of prehistoric life by means of fossils.
3. Malacology is the study of mollusks.
4. Cytology is the study of cells.
5. Mycology is the study of fungi.
6. Ecology is the study of the interrelationship of organisms and their environments.

Review

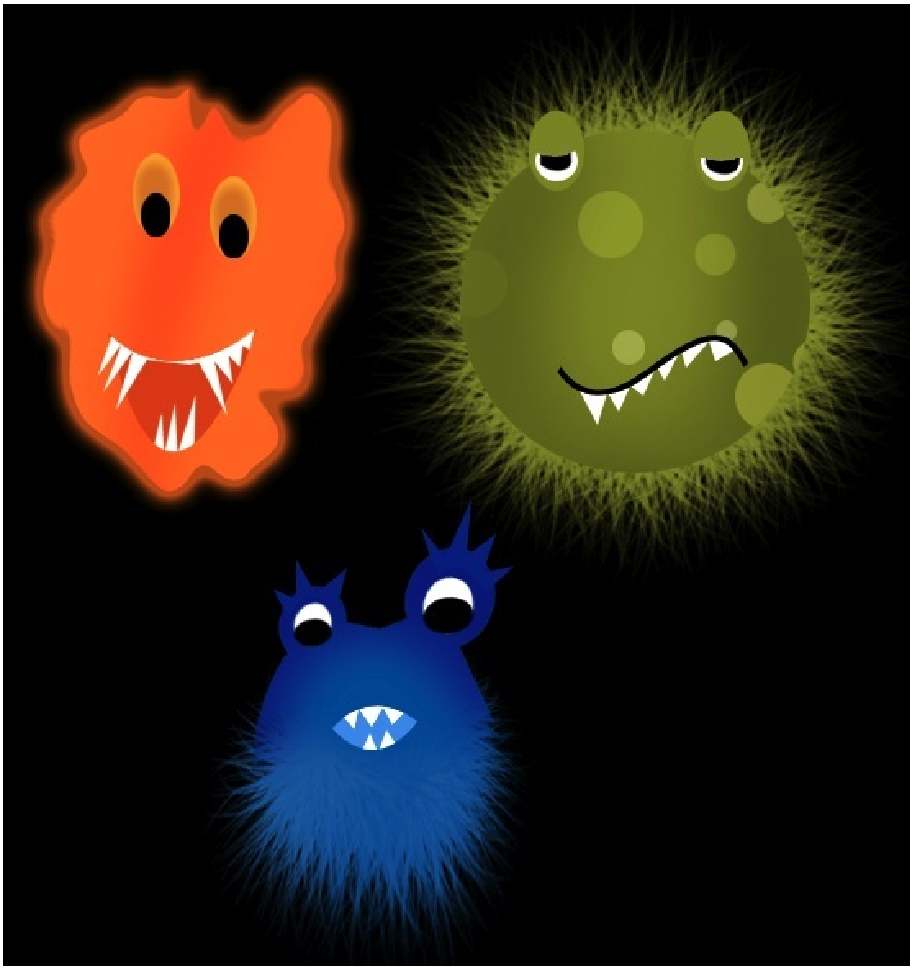
1. What is name of the field of the life sciences that studies insects?
2. What is name of the field of the life sciences that studies the nervous system?
3. What are cell biology, genetics, and molecular biology?

Review Answers

1. The name of the field of the life sciences that studies insects is entomology.
2. The name of the field of the life sciences that studies the nervous system is neuroscience.
3. Cell biology is the study of cellular structure and function. Genetics is the study of heredity, which is the passing of traits from one generation to the next. Molecular biology is the study of molecules, such as DNA and proteins.

1.3 Scientific Theories

- Explain the concepts of a hypothesis and scientific evidence.
- Distinguish between a scientific theory and a scientific law.



What causes disease?

Today most people realize that microorganisms, such as bacteria or viruses, are the cause of disease. This concept is known as the germ theory of disease, one of the few scientific theories in the field of the life sciences. Although it seems obvious now, people did not always understand the cause of disease. How does a theory such as this become established?

Scientific Evidence and Theories

One goal of a scientist is to find answers to scientific questions. To do this, scientists first develop a **hypothesis**, which is a proposed explanation that tries to explain an observation. To collect **evidence** to support (or disprove) their hypothesis, scientists must do **experiments.** Evidence is:

1. A direct, physical observation of something or a process over time.

2. Usually something measurable or "quantifiable."
3. The data resulting from an experiment.

For example, an apple falling to the ground is evidence in support of the law of gravity. A bear skeleton in the woods would be evidence of the presence of bears.

Looking at the image below might be confusing at first because this evidence seems to defy the law of gravity (**Figure** 1.4). Of course water cannot be poured out of bottle and flow upward. The law of gravity is a **scientific law**, which is a statement describing what always happens under certain conditions in nature. Scientific laws are developed from lots of collected information.

FIGURE 1.4
Water going upward against gravity.

If many experiments are performed, and lots of evidence is collected in support of a general hypothesis, a scientific theory can be developed. **Scientific theories** are well established explanations of evidence. Theories are usually tested and confirmed by many different people. Scientific theories usually have a lot of evidence in support of the theory, and no evidence disproving the theory. Scientific theories produce information that helps us understand our world. For example, the idea that matter is made up of atoms is a scientific theory. Scientists accept this theory as a fundamental principle of basic science. However, when scientists find new evidence, they can change their theories. In addition to the germ theory of disease, other scientific theories are the cell theory and the theory of evolution.

Vocabulary

- **evidence**: A direct, physical observation of something or a process.
- **experiment**: A test to see if a hypothesis is right or wrong; a test to obtain new data.
- **hypothesis**: A proposed explanation for something that is testable; a proposed explanation that tries to explain an observation.
- **scientific law**: A statement describing what always happens under certain conditions in nature.
- **scientific theory**: Explanation of an aspect of the natural world based on repeated observations.

Summary

- Evidence is a direct, physical observation of something or a process.
- Scientific theories are explanations of some aspect of the natural world based on repeated observations.

Explore More

Use the resource below to answer the questions that follow.

- **Scientific Theories** at http://www.youtube.com/watch?v=-M1hxGj5bMg (4:43)

MEDIA

Click image to the left for use the URL below.

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1. What happens to scientific ideas that do not match the natural world?
2. In science, what is meant by a fact, a hypothesis, a theory, and a law?
3. How do scientists' views of theories differ from the everyday use of these words?

Explore More Answers

1. Scientific ideas that do not match the natural world can be altered and revised or discarded.
2. A fact is a conformed observation. A hypothesis is a testable statement. A theory is an explanation of observed phenomena. A law is a descriptive generalization.
3. A scientific theory is based on repeated testing and observations. In everyday use, a theory can be associated with a guess. These have very different meanings in terms of how they are used.

Review

1. What is evidence?
2. What is a scientific theory?
3. What is a scientific law?

Review Answers

1. Evidence comes from a direct, physical observation of something or a process.
2. Scientific theories are well established explanations of evidence, or explanation of an aspect of the natural world based on repeated observations.
3. A scientific law is a statement describing what always happens under certain conditions in nature.

1.4 Scientific Investigation

- Define and describe the scientific method.
- Summarize the characteristics of a scientific hypothesis.
- Develop a scientific hypothesis.
- Explain the importance of communicating results.

How do scientists obtain new knowledge?

All the information in textbooks had to come from somewhere. In the sciences, new information about the natural world is a result of scientific investigations. These investigations are shaped by the scientific method.

Scientific Method

The **scientific method** is a process used to investigate the unknown (**Figure** 1.5). It is the general process of a **scientific investigation**. This process uses evidence and testing. Scientists use the scientific method so they can find information. A common method allows all scientists to answer questions in a similar way. Scientists who use this method can reproduce another scientist's experiments.

Almost all versions of the scientific method include the following steps, although some scientists do use slight variations.

1. Make observations.
2. Identify a question you would like to answer based on the observation.
3. Find out what is already known about your observation (research).
4. Form a hypothesis.
5. Test the hypothesis.
6. Analyze your results and draw conclusions.
7. Communicate your results.

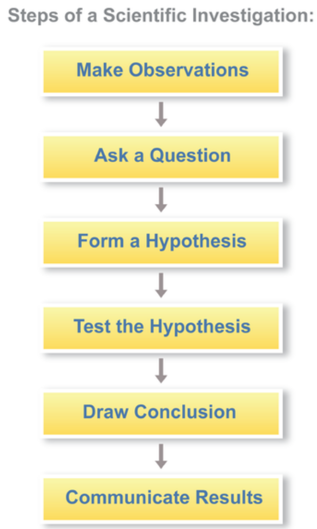


FIGURE 1.5
Steps of a Scientific Investigation. A scientific investigation typically has these steps.

Making Observations

Imagine that you are a scientist. While collecting water samples at a local pond, you notice a frog with five legs instead of four (**Figure** 1.6). As you start to look around, you discover that many of the frogs have extra limbs, extra eyes, or no eyes. One frog even has limbs coming out of its mouth. These are your **observations**, or things you notice about an environment using your five senses.

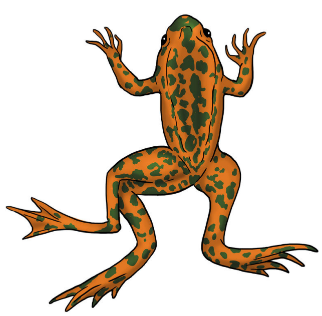


FIGURE 1.6
A frog with an extra leg.

Identify a Question Based on Your Observations

The next step is to ask a question about the frogs. You may ask, "Why are so many frogs deformed?" Or, "Is there something in their environment causing these defects, like water pollution?" Yet, you do not know if this large number of deformities is "normal" for frogs. What if many of the frogs found in ponds and lakes all over the world have similar deformities? Before you look for causes, you need to find out if the number and kind of deformities is unusual. So besides finding out *why* the frogs are deformed, you should also ask: "Is the percentage of deformed frogs in this pond greater than the percentage of deformed frogs in other places?"

FIGURE 1.7
A pond with frogs.

Research Existing Knowledge About the Topic

No matter what you observe, you need to find out what is already known about your questions. For example, is anyone else doing research on deformed frogs? If yes, what did they find out? Do you think that you should repeat their research to see if it can be duplicated? During your research, you might learn something that convinces you to change or refine your question. From this, you will construct your hypothesis.

Construct a Hypothesis

A **hypothesis** is a proposed explanation that tries to explain an observation. A good hypothesis allows you to make more predictions. For example, you might hypothesize that a pesticide from a nearby farm is running into the pond and causing frogs to have extra legs. If that's true, then you can predict that the water in a pond of non-deformed frogs will have lower levels of that pesticide. That's a prediction you can test by measuring pesticide levels in two sets of ponds, those with deformed frogs and those with nothing but healthy frogs. Every hypothesis needs to be written in a way that it can:

1. Be tested using evidence.
2. Be proven wrong.
3. Provide measurable results.
4. Provide yes or no answers.

For example, do you think the following hypothesis meets the four criteria above? Let's see. Hypothesis: "The number of deformed frogs in five ponds that are polluted with chemical X is higher than the number of deformed frogs in five ponds without chemical X." Of course, next you will have to test your hypothesis.

Test Your Hypothesis

To test the hypothesis, an **experiment** will be done. You would count the healthy and deformed frogs and measure the amount of chemical X in all of the ponds. The hypothesis will be either true or false. Doing an experiment will test most hypotheses. The experiment may generate evidence in support of the hypothesis. The experiment may also generate evidence proving the hypothesis false. Once you collect your data, it will need to be analyzed.

Analyze Data and Draw a Conclusion

If a hypothesis and experiment are well designed, the experiment will produce results that you can measure, collect, and analyze. The analysis should tell you if the hypothesis is true or false. Refer to the table for the experimental results (**Table** 1.4).

TABLE 1.4: Deformed Frog Data

Polluted Pond	Number of Deformed Frogs	Non-Polluted Pond	Number of Deformed Frogs
1	20	1	23
2	23	2	25
3	25	3	30
4	26	4	16
5	21	5	20
Average:	23	Average:	22.8

Your results show that pesticide levels in the two sets of ponds are different, but the average number of deformed frogs is almost the same. Your results demonstrate that your hypothesis is false. The situation may be more complicated than you thought. This gives you new information that will help you decide what to do next. Even if the results supported your hypothesis, you would probably ask a new question to try to better understand what is happening to the frogs and why.

Drawing Conclusions and Communicating Results

If a hypothesis and experiment are well designed, the results will indicate whether your hypothesis is true or false. If a hypothesis is true, scientists will often continue testing the hypothesis in new ways to learn more. If a hypothesis is false, the results may be used to come up with and test a new hypothesis. A scientist will then communicate the results to the scientific community. This will allow others to review the information and extend the studies. The scientific community can also use the information for related studies. Scientists communicate their results in a number of ways. For example, they may talk to small groups of scientists and give talks at large scientific meetings. They will also write articles for scientific journals. Their findings may also be communicated to journalists.

If you conclude that frogs are deformed due to a pesticide not previously measured, you would publish an article and give talks about your research. Your conclusion could eventually help find solutions to this problem.

Vocabulary

- **experiment**: A test to see if a hypothesis is right or wrong; a test to obtain new data.
- **hypothesis**: A proposed explanation for something that is testable; a proposed explanation that tries to explain an observation.
- **observations**: Significant details you notice using your five senses.
- **scientific investigation**: Plan for asking questions and testing possible answers.
- **scientific method**: A process used to investigate natural phenomena; includes making observations, formulating a hypothesis, designing experiments, and drawing conclusions.

Summary

- To study new problems, scientists use the scientific method; this includes making observations, forming a hypothesis, designing an experiment, and drawing conclusions.

Explore More

Use the resource below to answer the questions that follow.

- **Control Variables** at http://www.youtube.com/watch?v=hjCvIbYoi-w (7:05)

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/57464

1. What is the difference between a dependent and an independent variable?
2. How many dependent variables do you want in an experiment?
3. What are control variables?
4. Why are control variables important?

Explore More Answers

1. The independent variable (cause) is changed in an experiment, whereas the dependent variable is what is measured (the effect of the independent variable).
2. In an experiment, there can be only one dependent variable.
3. Control variables are variables that are kept the same (or constant) in an experiment.
4. Control variables are important because they allow you to define/determine a cause and effect relationship between the dependent and an independent variable?

Review

1. What steps are usually included in the scientific method?
2. What are the features of a good hypothesis?
3. Why is it important for a scientist to communicate the results and conclusions of a study?

Review Answers

1. The steps of the scientific method usually include making observations, formulating a hypothesis, designing and performing experiments, and drawing conclusions, and communicating your results.
2. A good hypothesis allows you to make more predictions. It must be (1) testable, (2) able to be proven wrong, (3) able to provide measurable results, and (4) able to provide yes or no answers.
3. It is important for scientists to communicate their results for a number of reasons. Communication allows others to review the information and extend the studies. The scientific community can also use the information for related studies.

1.5 Basic and Applied Science

- Define basic science and applied science.
- Distinguish between basic science and applied science.

Why should we study the rainforest?

Some scientists study problems that seem to have very little impact on our lives. For example, scientists are working to describe every type of plant and animal in the rainforest. What is the purpose? Many of our medicines come from plants and animals of the rainforest. So what medicines have not yet been discovered? There might be new cures to diseases yet to be identified. This is an example of how science can be applied to our lives.

Basic and Applied Science

Science can be "basic" or "applied." The goal of **basic science** is to understand how things work—whether it is a single **cell**, an organism made of trillions of cells, or a whole **ecosystem**. Scientists working on basic science questions are simply looking to increase human knowledge of nature and the world around us. The knowledge obtained through the study of the subspecialties of the life sciences is mostly basic science. Basic science is the source of most **scientific theories**. For example, a scientist that tries to figure out how the body makes cholesterol is performing basic science. This is also known as basic research.

The study of the cell (cell biology), the study of inheritance (genetics), the study of molecules (molecular biology), the study of microorganisms and viruses (microbiology and virology), the study of tissues and organs (physiology) have all generated lots of information that is applied to humans and human health. **Applied science** is using scientific discoveries to solve practical problems. For example, medicine, and all that is known about how to treat patients, is applied science based on basic research (**Figure** 1.8). A doctor administering a drug to lower a person's cholesterol is an example of applied science. Applied science also creates new technologies based on basic science. For example, designing windmills to capture wind energy is applied science (**Figure** 1.9). This technology relies, however, on basic science. Studies of wind patterns and bird migration routes help determine the best placement for the windmills.

FIGURE 1.8
Surgeons operating on a person, an example of applied science.

FIGURE 1.9
Windmills capturing energy, an example of applied science.

Vocabulary

- **applied science**: The application of basic scientific knowledge to solve practical problems.
- **basic science**: Research aimed at understanding fundamental problems and how things work.
- **cell**: The basic unit of structure and function of a living organism; the basic unit of life.
- **ecosystem**: All the living things in an area interacting with all of the non-living parts of the environment.
- **scientific theory**: Explanation of an aspect of the natural world based on repeated observations.

Summary

- Basic science, such as understanding how cells work, is research aimed at understanding fundamental problems.
- Applied science, such as the medical field, is the application of basic scientific knowledge to solve practical problems.

- Applied science uses and applies information obtained through basic science.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Basic vs. Applied Research** at http://www.sjsu.edu/people/fred.prochaska/courses/ScWk170/s0/Basic%20vs.%20Applied%20Research.pdf

1. What is basic research? Give two examples of basic research.
2. What is applied research? Give two examples of applied research.
3. What is the relationship between basic research and applied science?
4. Why do some scientists believe more emphasis needs to be placed on applied science?

Explore More II

- **Reinvesting in Basic Research** at http://www.youtube.com/watch?v=NHjrMtECVo0 (3:58)

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/57477

1. How could basic biomedical research lead to better physicians?
2. What is BMPER? Did its discovery come from basic or applied research? Explain your resoning fully.

Explore More Answers

Explore More I

1. Basic research is done to expand knowledge. Examples of basic research include understanding how certain organisms reproduce, or understanding the genetics of an organism (answers will vary).
2. Applied research is done to solve practical problems. Examples include finding improvements in agriculture and medicine (answers will vary).
3. Basic research lays down the foundation for the applied science that follows.
4. Some scientists believe more emphasis needs to be placed into the applied sciences due to the problems resulting from global overpopulation, pollution, and the overuse of the earth's natural resources.

Explore More II

1. Basic biomedical research leads to better physicians as it teaches them how to find answers, and learning how to understand the connection between biomedical research and medicine (answers will vary).
2. BMPER is a protein thought to have certain protective measures against heart disease. It was identified through basic research.

Review

1. What is the difference between basic and applied science?
2. What is an example of applied science?

Review Answers

1. Basic science is aimed at understanding fundamental problems and how things work, whereas applied science is the application of basic scientific knowledge to solve practical problems. In other words, applied science uses the results of basic science.
2. Examples of applied science: medicine, and all that is known about how to treat patients, is applied science based on basic research; a doctor administering a drug to lower a person's cholesterol is an example of applied science; designing windmills to capture wind energy is applied science.

1.6 Microscopes

- Describe how microscopes are used in the life sciences.
- Identify how cells were first identified.

How can we see the details of bacteria?

With the naked eye, bacteria just look like a slimy smear on a petri dish. How can we study them in more detail? The invention of the microscope has allowed us to see bacteria, cells, and other things too small to be seen with the naked eye.

The Microscope

Microscopes, tools that you may get to use in your class, are some of the most important tools in biology (**Figure** 1.10). A **microscope** is a tool used to make things that are too small to be seen by the human eye look bigger. **Microscopy** is the study of small objects using microscopes. Look at your fingertips. Before microscopes were invented in 1595, the smallest things you could see on yourself were the tiny lines in your skin. But what else is hidden in your skin?

Invention of the Microscope

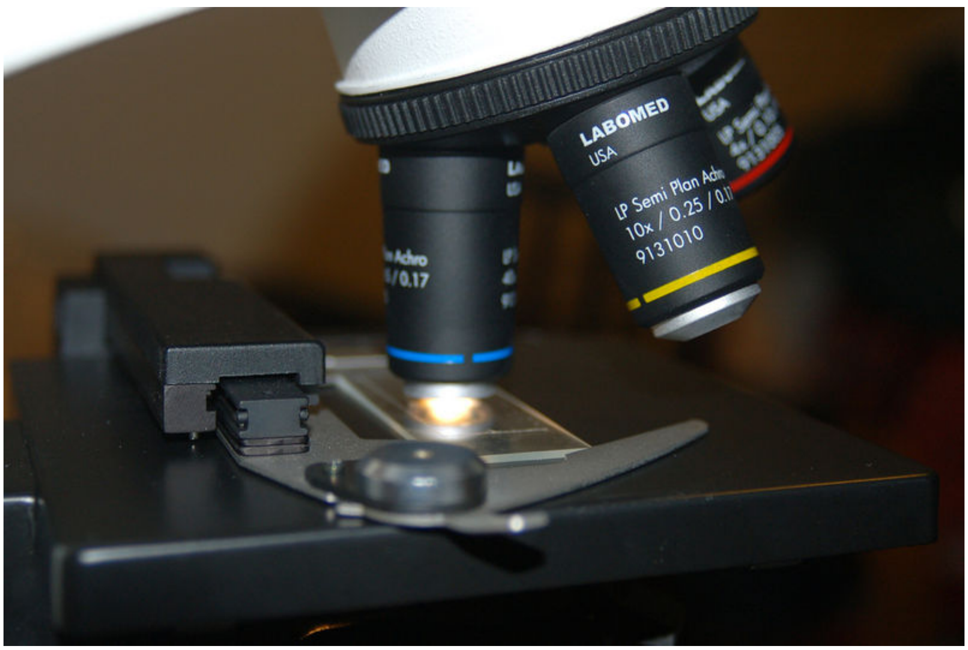
Over four hundred years ago, two Dutch spectacle makers, Zaccharias Janssen and his son Hans, were experimenting with several lenses in a tube. They discovered that nearby objects appeared greatly enlarged, or **magnified**. This was the forerunner of the compound microscope and of the telescope. Later, the father of microscopy, Dutch scientist Antoine van Leeuwenhoek (**Figure** 1.11) taught himself to make one of the first microscopes. In one of his early experiments, van Leeuwenhoek took a sample of scum from his own teeth and used his microscope to discover **bacteria**, the smallest living organism on the planet. Using microscopes, van Leeuwenhoek also discovered one-celled **protists** and sperm cells.

FIGURE 1.10
Basic light microscopes opened up a new world to curious people.

In 1665, Robert Hooke, an English natural scientist, used a microscope to zoom in on a piece of cork—the stuff that makes up the stoppers in wine bottles, which is made from tree bark. Inside of cork, he discovered tiny structures, which he called **cells**. It turns out that cells are the smallest structural unit of living organisms. This finding eventually led to the development of the theory that *all living things are made up of cells.* Without microscopes, this theory would not have been developed.

FIGURE 1.11
Antoine van Leeuwenhoek, a Dutch cloth merchant with a passion for microscopy.

Types of Microscopes



Some modern microscopes use light, as Hooke's and van Leeuwenhoek's did. Others may use electron beams or sound waves. Researchers now use these four types of microscopes:

1. **Light microscopes** allow biologists to see small details of a specimen. Most of the microscopes used in schools and laboratories are light microscopes. Light microscopes use lenses, typically made of glass or plastic, to focus light either into the eye, a camera, or some other light detector. The most powerful light microscopes can make images up to 2,000 times larger.
2. **Transmission electron microscopes (TEM)** focus a beam of electrons through an object and can make an image up to two million times bigger, with a very clear image.
3. **Scanning electron microscopes (SEM)** allow scientists to find the shape and surface texture of extremely small objects, including a paperclip, a bedbug, or even an atom. These microscopes slide a beam of electrons across the surface of a specimen, producing detailed maps of the surface of objects. Magnification in a SEM can be controlled over a range from about 10 to 500,000 times.
4. **Scanning acoustic microscopes** use sound waves to scan a specimen. These microscopes are useful in biology and medical research.

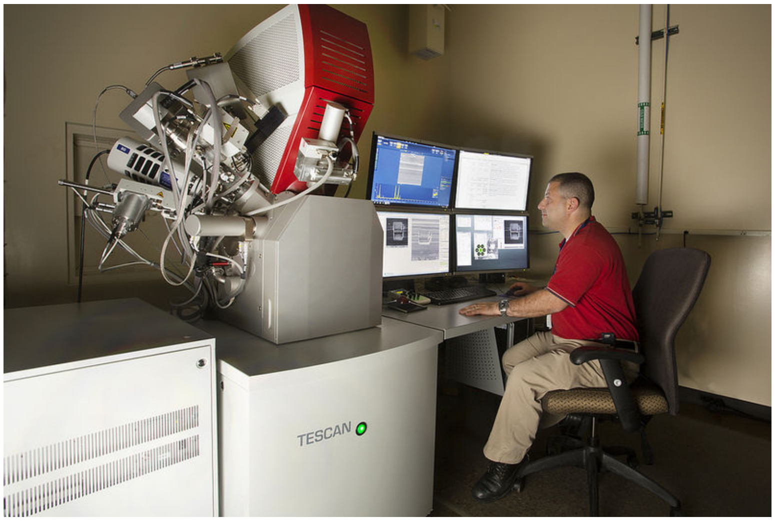


FIGURE 1.12
A scanning electron microscope.

Vocabulary

- **bacteria**: Microscopic one-celled prokaryotic organisms (without a nucleus).
- **cell**: Basic unit of structure and function of a living organism; the basic unit of life.
- **light microscope**: Tool that uses lenses to focus light in order to make things appear larger.
- **magnify**: Making objects appear larger than they are.
- **microscope**: Tool used to make things that are too small to be seen by the human eye look bigger.
- **microscopy**: The technology for studying small objects using microscopes.
- **protist**: Eukaryotic organism that belongs to the kingdom Protista; not a plant, animal, or fungi.
- **scanning acoustic microscope**: Tool that uses sound waves to study a specimen too small to be seen with the naked eye.
- **scanning electron microscope (SEM)**: Tool that sends a beam of electrons across the surface of a specimen, producing detailed maps of the shapes of objects.
- **transmission electron microscope (TEM)**: Tool that focuses a beam of electrons through an object, magnifying it.

Summary

- A microscope is a tool used to make things that are too small to be seen by the naked eye look bigger.
- Types of microscopes include light microscopes, transmission electron microscopes (TEM), scanning electron microscopes (SEM), and scanning acoustic microscopes.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Using a microscope** at http://www.youtube.com/watch?v=bGBgABLEV4g (4:01)

MEDIA
Click image to the left for use the URL below.
URL: http://gamma.ck12.org/flx/render/embeddedobject/57471

1. How should you carry a compound optical microscope?
2. What procedure should you use when seeking to use the most powerful optical lenses?

Explore More II

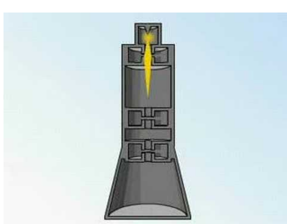
- **Dissecting Microscope** at http://www.youtube.com/watch?v=JoqOwzLyMIA (5:05)

MEDIA
Click image to the left for use the URL below.
URL: http://gamma.ck12.org/flx/render/embeddedobject/57472

1. What light sources can you use with a dissecting microscope?
2. Why is it important to have a fixed ocular lens and an adjustable ocular lens?
3. What happens to your field of view as you increase magnification? Can you explain why this happens?

Explore More III

- **Structure and Function of the Electron Microscope** at http://www.youtube.com/watch?v=fToTFjwUc5M (1:49)

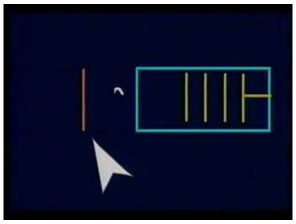


MEDIA
Click image to the left for use the URL below.
URL: http://gamma.ck12.org/flx/render/embeddedobject/57473

1. How does an electron microscope differ from a light microscope? List all the differences you can think of.
2. How should you carry an electron microscope?

Practice IV

- **Scanning Electron Microscope** at http://www.youtube.com/watch?v=lrXMIghANbg (5:04)



MEDIA
Click image to the left for use the URL below.
URL: http://gamma.ck12.org/flx/render/embeddedobject/57474

1. How is the electron beam focused?
2. What part of a specimen does a scanning electron microscope look at?
3. Why is it important that a specimen for an electron microscope be placed in a vacuum? Why is this step unnecessary for a light microscope?

Explore More Answers

Explore More I

1. A compound optical microscope should be carried with two hands, one hand on the arm and the other supporting the base.
2. When using the most powerful optical lenses, stat with the lowest magnification and focus the slide, move to the next magnification and refocus (usually with the fine focus knob), and then move to the most powerful magnification and refocus with the fine focus knob.

Explore More II

1. With a dissecting microscope, use an external source, such as a desk lamp, as a light source.
2. A fixed ocular lens and an adjustable ocular lens allows for the difference in focus of the two eyes.
3. As you increase magnification, the field of view gets smaller, as the microscope "zooms" in on the specimen.

Explore More III

1. An electron microscope is much bigger. It uses a thin beam of rapidly moving electrons flowing through a vacuum chamber.
2. You shouldn't carry an electron microscope.

Practice IV

1. The electron beam is focused using focusing magnets (lenses).
2. The scanning electron microscope looks at the surface of things.
3. It is important that a specimen for an electron microscope be placed in a vacuum as particles (air molecules) in a non-vacuum space will interfere with the flow of electrons.

Review

1. What is the purpose of a microscope?
2. What were the findings of Hooke and van Leeuwenhoek?
3. What are the differences between a light microscope and a scanning electron microscope?

Review Answers

1. A microscope allows things that are too small to be seen by the human eye look bigger.

2. Hooke discovered cells and van Leeuwenhoek discovered bacteria, protists and sperm cells.
3. A light microscope allows one to see small details of a specimen, and a scanning electron microscope allows scientists to find the shape and surface texture of extremely small objects. The most powerful light microscopes can make images up to 2,000 times larger. A scanning electron microscope can magnify up to 500,000 times.

1.7 Safety in the Life Sciences

- Recognize the types of hazards that a scientist faces.
- Describe laboratory safety guidelines that minimize potential risks.

What does this sign mean?

If a substance is corrosive, it can eat through objects. Many scientists have to work with chemicals that are corrosive or otherwise dangerous. That's one reason that following safety precautions in the laboratory or field is very important.

Safety in the Life Sciences

There can be some very serious safety risks in scientific research. If researchers are not careful, they could poison themselves or contract a deadly illness. The kinds of risks that scientists face depend on the kind of research they perform. For example, a scientist working with bacteria in a laboratory faces different risks than a scientist studying the behavior of lions in Africa, but both scientists must still follow safety guidelines. Safety practices must be followed when working with the hazardous things such as parasites, radiation and radioactive materials, toxins, and wild animals. Also, **carcinogens**, which are chemical that cause cancer, **pathogens**, which are disease-causing virus, bacteria or fungi, and **teratogens**, which are chemical that cause deformities in developing embryos, are extremely hazardous, and extreme care must be used when working with these items as well. For example, scientists studying dangerous organisms such as *Yersinia pestis*, the cause of bubonic plague, use special equipment that helps keep the organism from escaping the lab.

A **biohazard** is any biological material that could make someone sick, including disease-causing organisms. Therefore, a used needle is a biohazard because it could harbor blood contaminated with a disease-causing organism. Bacteria grown in a laboratory are also biohazards if they could potentially cause disease.

FIGURE 1.13

Science laboratory safety and chemical hazard signs.

Laboratory Safety

If you perform an experiment in your classroom, your teacher will explain how to be safe. Professional scientists follow safety rules as well, especially for the study of dangerous organisms like the bacteria that cause bubonic plague (**Figure** 1.14).

Sharp objects, chemicals, heat, and electricity are all used at times in laboratories. Below is a list of safety guidelines that you should follow when in the laboratory:

- Be sure to obey all safety guidelines given in lab instructions and by your teacher.
- Follow directions carefully.
- Tie back long hair.
- Wear closed toe shoes with flat heels and shirts with no hanging sleeves, hoods, or drawstrings.
- Use gloves, goggles, or safety aprons when instructed to do so.
- Broken glass should only be cleaned up with a dust pan and broom. Never touch broken glass with your bare hands.
- Never eat or drink anything in the science lab. Table tops and counters could have dangerous substances on them.

- Be sure to completely clean materials like test tubes and beakers. Leftover substances could interact with other substances in future experiments.
- If you are using flames or heat plates, be careful when you reach. Be sure your arms and hair are kept far away from heat.
- Alert your teacher immediately if anything out of the ordinary occurs. An accident report may be required if someone is hurt. Also, the teacher must know if any materials are damaged or discarded.

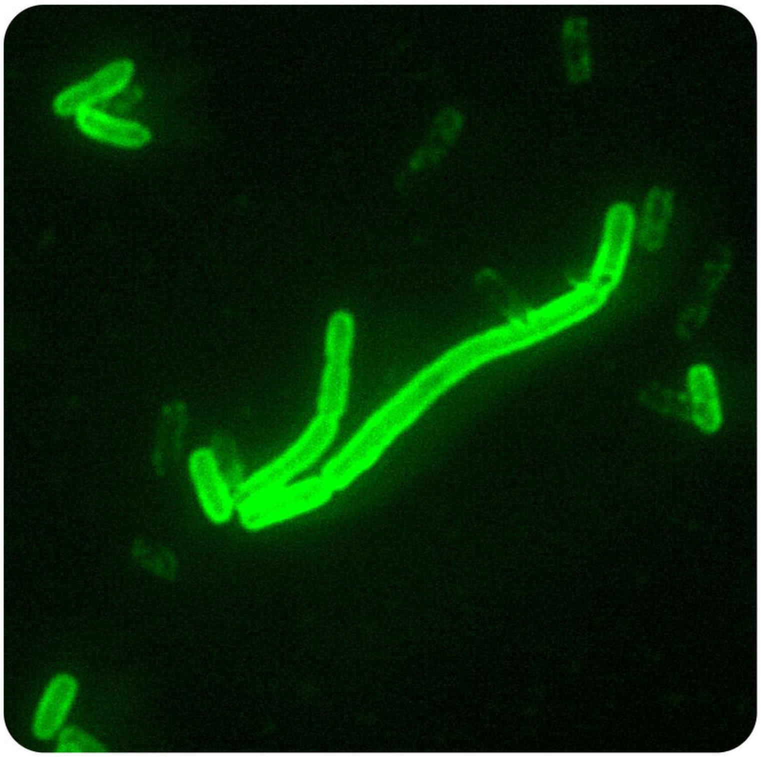


FIGURE 1.14
Scientists studying dangerous organisms such as *Yersinia pestis*, the cause of bubonic plague, use special equipment that helps keep the organism from escaping the lab.

Field Research Safety

Scientists who work outdoors, called **field scientists**, are also required to follow safety regulations. These safety regulations are designed to prevent harm to themselves, other humans, animals, and the environment. If scientists work outside the country, they are required to learn about and follow the laws and restrictions of the country in which they are doing research. For example, entomologists following monarch butterfly (**Figure** 1.15) migrations between the United States and Mexico must follow regulations in both countries. Before biologists can study protected wildlife or plant species, they must apply for permission to do so. This is important to protect these fragile species. For example, if scientists collect rare butterflies, they must first get a permit. They must also be careful to not disturb the habitat.

Vocabulary

- **biohazard**: Any material that could carry disease.
- **carcinogen**: Chemical that can cause cancer.
- **field scientist**: Scientist that works outdoors.
- **pathogen**: Disease causing agent, such as a bacterium, virus, fungus, or protozoan.
- **teratogen**: Chemical causing deformities in a developing embryo.

FIGURE 1.15
A monarch butterfly.

Summary

- There are serious risks in scientific research, including carcinogens, biohazards, and toxins.
- You need to carefully follow all safety rules while working in the laboratory.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **FSU Chemistry Lab Safety** at http://www.youtube.com/watch?v=hv9imJzZWrY (6:51)

MEDIA
Click image to the left for use the URL below.
URL: http://gamma.ck12.org/flx/render/embeddedobject/57465

1. Is applying cosmetics in a lab allowed?
2. What should you do if there is an accident?
3. How should you dispose of waste?

Explore More II

- **Science Lab Safety Rules** at http://www.youtube.com/watch?v=yclOrqEv7kw (2:24)

MEDIA
Click image to the left for use the URL below.
URL: http://gamma.ck12.org/flx/render/embeddedobject/57466

1. List five lab safety rules covered in the video.
2. What kind of clothing should you wear in a science lab?
3. What should you wear in a science lab that you would not wear usually outside a science lab?

Explore More Answers

Explore More I

1. Cosmetics should not be applied in the lab.
2. If there is an accident, you should immediately report it to the instructor.
3. Waste should be disposed in the appropriate containers.

Explore More II

1. Lab rules (answers may vary):
   a. Observe good housekeeping practices.
   b. Follow all written and verbal instructions carefully.
   c. Never work alone in the lab.
   d. Conduct yourself in a responsible manner at all times in the laboratory.
   e. Perform only those experiments authorized by your teacher.
2. No open toed shoes, a lab coat, goggles, gloves
3. see #2

Review

1. What is a biohazard?
2. List three hazards found in scientific research.
3. List three safety guidelines that you should follow in the laboratory.

Review Answers

1. A biohazard is any material that could carry disease.
2. Hazards found in scientific research include working with parasites, radiation and radioactive materials, toxins, and wild animals.
3. Safety guidelines to be followed in the laboratory include:
   a. Be sure to obey all safety guidelines given in lab instructions and by your teacher.
   b. Follow directions carefully.
   c. Tie back long hair.
   d. Wear closed toe shoes with flat heels and shirts with no hanging sleeves, hoods, or drawstrings.
   e. Use gloves, goggles, or safety aprons when instructed to do so.
   f. Broken glass should only be cleaned up with a dust pan and broom. Never touch broken glass with your bare hands.

g. Never eat or drink anything in the science lab. Table tops and counters could have dangerous substances on them.
h. Be sure to completely clean materials like test tubes and beakers. Leftover substances could interact with other substances in future experiments.
i. If you are using flames or heat plates, be careful when you reach. Be sure your arms and hair are kept far away from heat.
j. Alert your teacher immediately if anything out of the ordinary occurs.

1.8 Characteristics of Life

- Define what it means to be living.
- Know the five characteristics of living organisms.
- Describe the five characteristics shared by all living organisms.
- Identify the role of the five characteristics shared by all living organisms.
- Summarize in detail the role of each characteristic in life.

Is fire alive?

Fire can grow. Fire needs fuel and oxygen. But fire is not a form of life, although it shares a few traits with some living things. How can you distinguish between non-living and living things?

The Characteristics of Life

How do you define a living thing? What do mushrooms, daisies, cats, and bacteria have in common? All of these are living things, or **organisms**. It might seem hard to think of similarities among such different organisms, but they actually have many properties in common. Living organisms are similar to each other because all organisms evolved from the same common ancestor that lived billions of years ago.

All living organisms:

1. Need energy to carry out life processes.
2. Are composed of one or more cells.
3. Respond to their environment.
4. Grow and reproduce.
5. Maintain a stable internal environment.

Living Things Need Resources and Energy

Why do you eat everyday? To get energy. **Energy** is the ability to do work. Without energy, you could not do any "work." Though not doing any "work" may sound nice, the "work" fueled by energy includes everyday activities, such as walking, writing, and thinking. But you are not the only one who needs energy. In order to grow and reproduce and carry out the other process of life, all living organisms need energy. But where does this energy come from?

The source of energy differs for each type of living thing. In your body, the source of energy is the food you eat. Here is how animals, plants, and fungi obtain their energy:

- All animals must eat in order to obtain energy. Animals also eat to obtain building materials.
- Plants don't eat. Instead, they use energy from the sun to make their "food" through the process of **photosynthesis**.
- Mushrooms and other fungi obtain energy from other organisms. That's why you often see fungi growing on a fallen tree; the rotting tree is their source of energy (**Figure** 1.16).

Since plants harvest energy from the sun and other organisms get their energy from plants, nearly all the energy of living things initially comes from the sun.

FIGURE 1.16

Orange bracket fungi on a rotting log in the Oak Openings Preserve in Ohio. Fungi obtain energy from breaking down dead organisms, such as this rotting log.

Living Things Are Made of Cells

If you zoom in very close on a leaf of a plant, or on the skin on your hand, or a drop of blood, you will find cells, you will find cells (**Figure** 1.17). **Cells** are the smallest structural and functional unit of living organisms. Most cells are so small that they are usually visible only through a microscope. Some organisms, like bacteria, plankton that live in the ocean, or the *Paramecium* shown in **Figure** 1.18 are made of just one cell. Other organisms have millions, billions, or trillions of cells.

All cells share at least some structures. The **nucleus** is clearly visible in the blood cells (**Figure** 1.17). The nucleus can be described as the "information center," containing the instructions (**DNA**) for making all the **proteins** in a cell, as well as how much of each protein to make. The nucleus is also the main distinguishing feature between the two general categories of cell. Although the cells of different organisms are built differently, they all have certain general functions. Every cell must get energy from food, be able to grow and divide, and respond to its environment. More about cell structure and function will be discussed in additional concepts.

Living Organisms Respond to their Environment

All living organisms are able to react to something important or interesting in their external environment. For example, living organisms constantly respond to their environment. They respond to changes in light, heat, sound, and chemical and mechanical contact. Organisms have means for receiving information, such as eyes, ears, taste buds, or other structures.

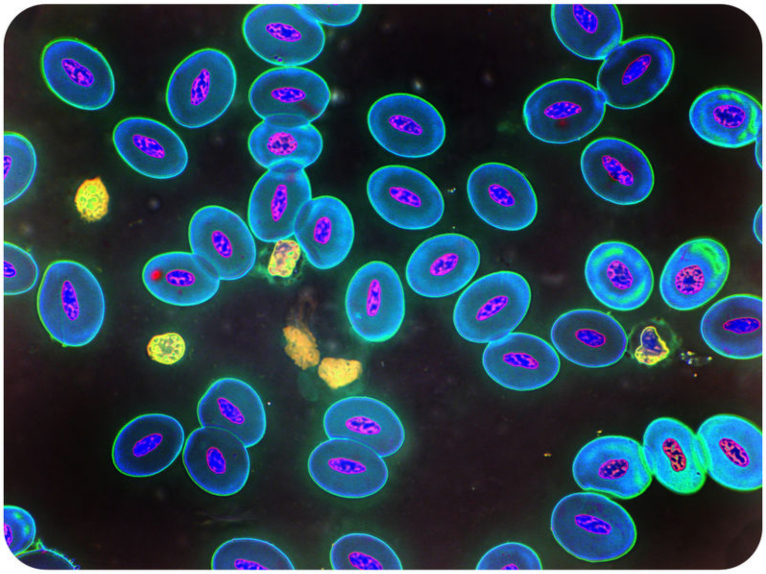


FIGURE 1.17
These cells show the characteristic nucleus. A few smaller cells are also visible. This image has been magnified 1000 times its real size.

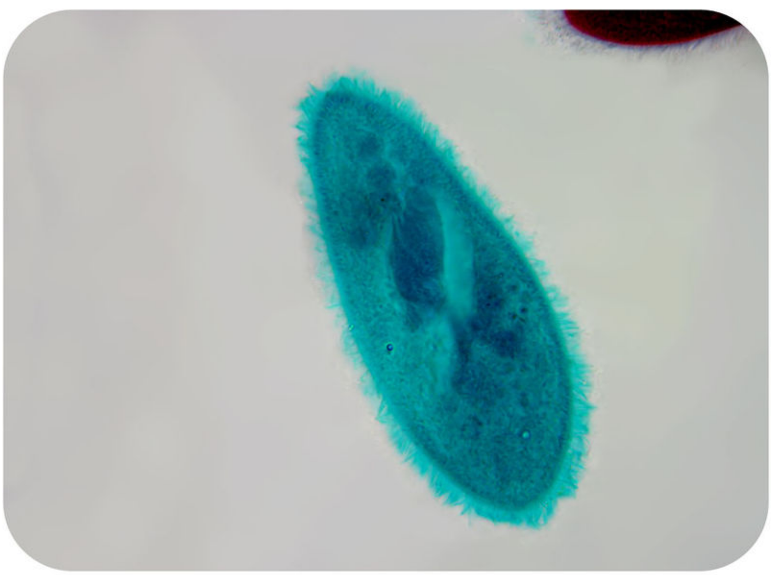


FIGURE 1.18
This *Paramecium* is a single-celled organism.

Living Things Grow and Reproduce

All living things **reproduce** to make the next generation. Organisms that do not reproduce will go extinct. As a result, there are no species that do not reproduce (**Figure** 1.19). Some organisms reproduce asexually (**asexual reproduction**), especially single-celled organisms, and make identical copies of themselves. Other organisms reproduce sexually (**sexual reproduction**), combining genetic information from two parents to make genetically unique offspring.

FIGURE 1.19
Like all living things, cats reproduce to make a new generation of cats.

Living Things Maintain Stable Internal Conditions

When you are cold, what does your body do to keep warm? You shiver to warm up your body. When you are too warm, you sweat to release heat. When any living organism gets thrown off balance, its body or cells help it return to normal. In other words, living organisms have the ability to keep a stable internal environment. Maintaining a balance inside the body or cells of organisms is known as **homeostasis**. Like us, many animals have evolved behaviors that control their internal temperature. A lizard may stretch out on a sunny rock to increase its internal temperature, and a bird may fluff its feathers to stay warm (**Figure** 1.20).

FIGURE 1.20
A bird fluffs its feathers to stay warm and to maintain homeostasis.

Vocabulary

- **asexual reproduction**: Process of forming a new individual from a single cell or individual.
- **cell**: Basic unit of structure and function of a living organism; the basic unit of life.

- **deoxyribonucleic acid (DNA)**: Nucleic acid that is the genetic material of all organisms.
- **energy**: Ability to do work.
- **homeostasis**: Ability to keep a stable internal environment; ability of the body to maintain a stable internal environment despite a changing environment.
- **nucleus**: Membrane enclosed organelle in eukaryotic cells that contains the DNA; primary distinguishing feature between a eukaryotic and prokaryotic cell; the information center, containing instructions for making all the proteins in a cell, as well as how much of each one to make.
- **organism**: Living thing.
- **photosynthesis**: Process by which specific organisms (including all plants) use the sun's energy to make their own food from carbon dioxide and water; process that converts the energy of the sun, or solar energy, into carbohydrates, a type of chemical energy.
- **protein**: Organic compound composed of amino acids and includes enzymes, antibodies, and muscle fibers.
- **reproduce**: Reproduction; process of forming a new individual.
- **sexual reproduction**: Process of forming a new individual from two parents.

Summary

- Living things are called organisms.
- All living organisms need energy to carry out life processes, are composed of one or more cells, respond to their environment, grow, reproduce, and maintain a stable internal environment.

Explore More

Use the resource below to answer the questions that follow.

- **Characteristics of Life** at http://www.youtube.com/watch?v=gJd65_Xrxs4 (3:15)

1. What are cell products? Do you think they should be included in characteristics of life? Why or why not?
2. Are all responses to the environment immediately obvious? Be specific and explain your reasoning.
3. Explain the concept of homeostasis. Give an example.
4. At what level does life evolve?

Explore More Answers

1. Cell products are made by cells, such as fingernails or hair (fur, feathers). The remainder of the answer will vary.
2. Not all responses to the environment are immediately obvious. In animals, a reaction to a stimulus may be immediately obvious, but reactions in plants, such as trees, may take much longer to observe. An animals reacting to pain is immediately obvious, but a tree reacting to a disturbance may take much longer to observe.
3. Homeostasis is the ability to maintain a stable internal environment. Sweating when your body gets too hot is part of homeostasis.
4. Life evolves at the species level.

Review

1. Is a crystal alive? Why or why not?
2. What is a cell?
3. What is homeostasis?
4. What are the two forms of reproduction? Describe the examples in your response.

Review Answers

1. A crystal is not alive. There are many reasons: to os not made of a cell or cells, does not maintain a stable internal environment, does not carry out life processes.
2. A cell is the basic unit of structure and function of a living organism.
3. Homeostasis is the ability to keep a stable internal environment.
4. Two forms of reproduction are sexual and asexual. Asexual reproduction is the process of forming a new individual from a single or individual. Sexual reproduction is the process of forming a new individual from two parents.

1.9 Chemistry of Life

- Define matter, element, atom, molecule, and compound.
- Explain the relationship between an element, an atom, a molecule and a compound.
- Understand the basic structure of the Periodic Table.
- Diagram a chemical reaction and examine the relationship between chemical reactions and atoms, molecules and compounds.
- Explain the role of chemistry and chemicals of life in the life sciences.

What's happening in this beaker?

The bubbles indicate that vapor is being formed, which lets you know that a chemical reaction is taking place. Many chemical reactions are going on constantly inside your body. In fact, there are probably thousands of chemical reactions occurring every second in every one of your cells. And as all living things are comprised of chemicals, understanding how chemicals work is essential to understanding how living things work.

Chemicals of Life

The Elements

If you pull a flower petal from a plant and break it in half, and then take that piece and break it in half again, and take the next piece and break it half, and so on, and so on, until you cannot even see the flower anymore, what do you think you will find? We know that the flower petal is made of **cells**, but what are cells made of? Scientists have broken down **matter**, or anything that takes up space and has mass—like a cell—into the smallest pieces that cannot be broken down anymore. Rocks, animals, flowers, and your body are all made up of matter.

Matter is made up of a mixture of things called elements. **Elements** are substances that cannot be broken down into simpler substances. There are more than 100 known elements, and 92 occur naturally around us. The others have been made only in the laboratory.

Inside of elements, you will find identical atoms. An **atom** is the simplest and smallest particle of matter that still has chemical properties of the element. Atoms are the building block of all of the elements that make up the matter in your body or any other living or non-living thing. Atoms are so small that only the most powerful microscopes can see them.

Atoms themselves are composed of even smaller particles, including positively charged **protons**, uncharged **neutrons**, and negatively charged **electrons**. Protons and neutrons are located in the center of the atom, or the nucleus, and the electrons move around the nucleus. How many protons an atom has determines what element it is. For example, helium (He) always has two protons (**Figure** 1.21), while sodium (Na) always has 11. All the atoms of a particular element have the exact same number of protons, and the number of protons is that element's **atomic number**. An atom usually has the same number of protons and electrons, but sometimes an atom may gain or lose an electron, giving the atom a positive or negative charge. These atoms are known as **ions** and are depicted with a "+" or "-" sign. Ions, such as H^+, Na^+, K^+, or Cl^- have significant biological roles.

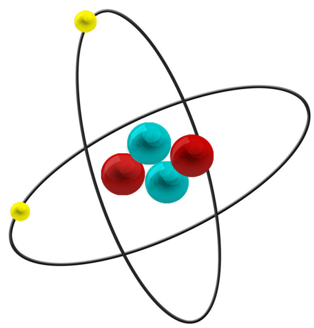


FIGURE 1.21
An atom of Helium (He) contains two positively charged protons (red), two uncharged neutrons (blue), and two negatively charged electrons (yellow).

The Periodic Table

In 1869, a Russian scientist named Dmitri Mendeleev created the **periodic table**, which is a way of organizing elements according to their unique characteristics, like atomic number, density, boiling point, and other values (**Figure** 1.22). Each element is represented by a one or two letter symbol. For example, H stands for hydrogen, and Au stands for gold. The vertical columns in the periodic table are known as groups, and elements in groups tend to have very similar properties. The table is also divided into rows, known as periods.

Chemical Reactions

A **molecule** is any combination of two or more atoms. The oxygen in the air we breathe is two oxygen atoms connected by a chemical bond to form O_2, or molecular oxygen. A carbon dioxide molecule is a combination of one carbon atom and two oxygen atoms, CO_2. Because carbon dioxide includes two different elements, it is a compound as well as a molecule.

A **compound** is any combination of two or more elements. A compound has different properties from the elements that it contains. Elements and combinations of elements (compounds) make up all the many types of matter in the Universe. A **chemical reaction** is a process that breaks or forms the bonds between atoms of molecules and compounds. For example, two hydrogens and one oxygen bind together to form water, H_2O. The molecules that come together to start a chemical reaction are the **reactants**. So hydrogen and oxygen are the reactants. The **product** is the end result of a reaction. In this example, water is the product.

Atoms also come together to form compounds much larger than water. It is some of these large compounds that come together to form the basis of the cell. So essentially, your cells are made out of compounds, which are made

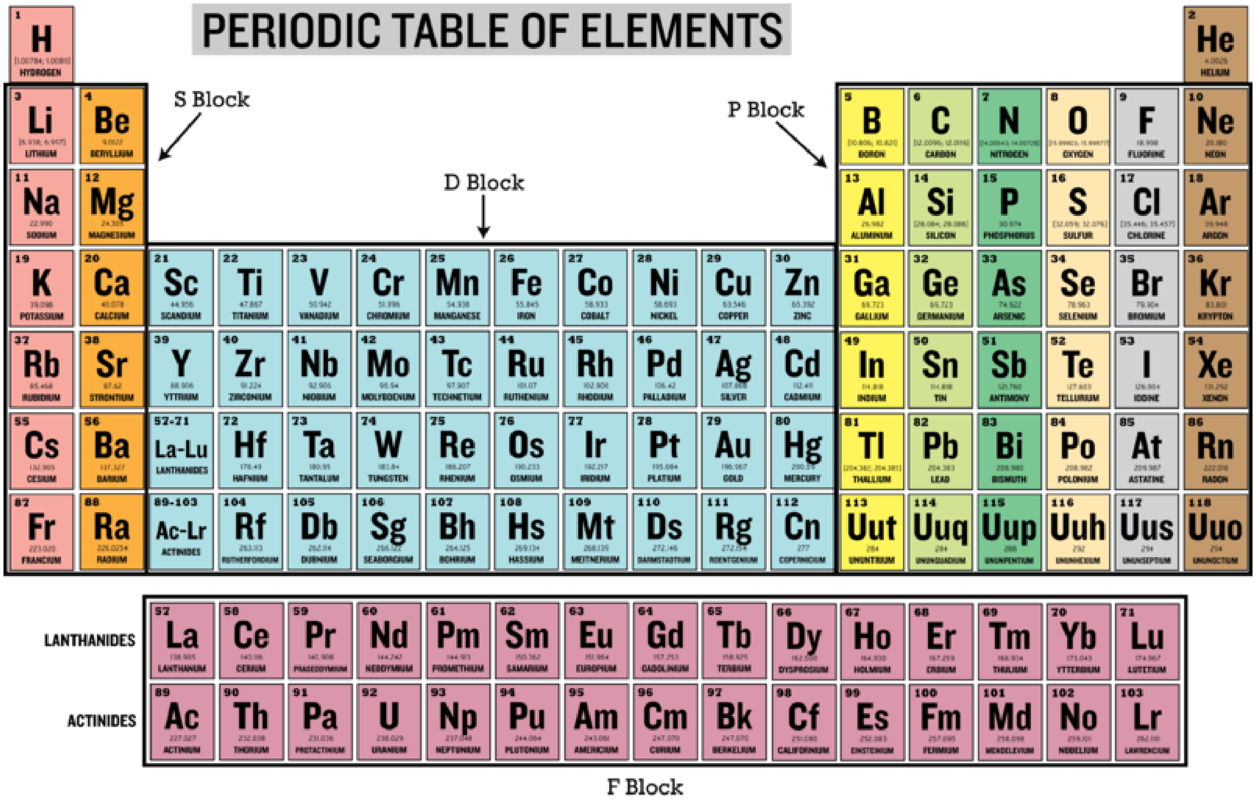


FIGURE 1.22
The periodic table groups the elements based on their properties.

out of atoms.

Vocabulary

- **atom**: Simplest and smallest particle of matter that still has chemical properties of the element.
- **atomic number**: Number of protons in an atom.
- **cell**: Basic unit of structure and function of a living organism; the basic unit of life.
- **chemical reaction**: Process that breaks or forms the bonds between atoms of molecules and compounds.
- **compound**: Combination of two or more elements.
- **electron**: Negatively charged particle that helps make up an atom.
- **element**: Substance that cannot be broken down into simpler substances.
- **ion**: Charged atom; an atom that has gained or lost one or more electrons.
- **matter**: Anything that has mass and takes up space.
- **molecule**: Combination of two or more atoms.
- **neutron**: Uncharged particle that helps make up an atom.
- **periodic table**: Chart that organizes elements according to their unique characteristics.
- **products**: End results of a chemical reaction.
- **proton**: Positively charged particle that helps make up an atom.
- **reactants**: Molecules that come together to start a chemical reaction.

Summary

- Elements are substances that cannot be broken down into simpler substances with different properties.
- Elements have been organized by their properties to form the periodic table.
- Two or more atoms can combine to form a molecule.
- Molecules consisting of more than one element are called compounds.
- Reactants can combine through chemical reactions to form products.

Explore More

Use the resource below to answer the following questions.

- **Periodic table** at http://www.webelements.com/

1. What is the atomic number of nitrogen? When and where was it identified? In what state of matter does nitrogen exist at room temperature?
2. What is the atomic number of oxygen? When and where was it identified? In what state of matter does oxygen exist at room temperature?
3. What is the atomic number of carbon? When and where was it identified? In what state of matter does it exist at room temperature?
4. What is the atomic number of phosphorus? From what was phosphorus originally isolated? In what state of matter does it exist at room temperature?

Explore More Answers

1. Nitrogen = 7. Nitrogen was discovered by Daniel Rutherford at 1772 in Scotland. Nitrogen is a gas at room temperature.
2. Oxygen = 8. Oxygen was discovered by Joseph Priestley, Carl Scheele at 1774 in England, Sweden. Oxygen is a gas at room temperature.
3. Carbon = 6. Carbon has been known since ancient times. Carbon is a solid at room temperature.
4. Phosphorus = 15. Phosphorus was discovered by Hennig Brand at 1669 in Germany. Phosphorus is a solid at room temperature.

Review

1. What is an element?
2. What is the difference between the terms molecule and compound?
3. Describe the composition of an atom.
4. Who is credited with developing the periodic table?

Review Answers

1. An element is a substance that cannot be broken down into simpler substances.
2. A molecule is any combination of two or more atoms. A compound is a combination of two or more elements. A molecule can be a combination of the same element, whereas a compound must be different elements.
3. Atoms are composed of smaller particles, including positively charged protons, uncharged neutrons, and negatively charged electrons. Protons and neutrons are located in the center of the atom, or the nucleus, and the electrons move around the nucleus.
4. Dmitri Mendeleev is credited with developing the first periodic table.

1.10 Organic Compounds

- Define proteins, carbohydrates, lipids, nucleic acids.
- Recognize the basic structure of organic compounds and explain their basic functions.
- Distinguish the categories of organic compounds, compare and contrast their roles, and analyze the components of each category.
- Summarize in detail the structure and function of the organic compounds, emphasizing the relationship between structure and function.

What makes up a healthy diet?

A healthy diet includes protein, fats, and carbohydrates. Why? Because these compounds are three of the main building blocks that make up your body. You obtain these building blocks from the food that you eat, and you use these building blocks to make the organic compounds necessary for life.

Organic Compounds

The main chemical components of living organisms are known as **organic compounds**. Organic compounds are molecules built around the element carbon (C). Living things are made up of very large molecules. These large molecules are called **macromolecules** because “macro” means large; they are made by smaller molecules bonding together. Our body gets these smaller molecules, the "building blocks" or **monomers**, of organic molecules from the food we eat. Which organic molecules do you recognize from the list below?

The four main types of macromolecules found in living organisms, shown in **Table** 1.5, are:

1. Proteins.
2. Carbohydrates.
3. Lipids.
4. Nucleic Acids.

TABLE 1.5: The Four Main Classes of Organic Molecules

	Proteins	Carbohydrates	Lipids	Nucleic Acids
Elements	C, H, O, N, S	C, H, O	C, H, O, P	C, H, O, P, N
Examples	Enzymes, muscle fibers, antibodies	Sugar, glucose, starch, glycogen, cellulose	Fats, oils, waxes, steroids, phospholipids in membranes	DNA, RNA, ATP
Monomer (small building block molecule)	Amino acids	Monosaccharides (simple sugars)	Often include fatty acids	Nucleotides

Carbohydrates

Carbohydrates are sugars, or long chains of sugars. An important role of carbohydrates is to store energy. **Glucose** (**Figure** 1.23) is an important simple sugar molecule with the chemical formula $C_6H_{12}O_6$. Simple sugars are known as **monosaccharides**. Carbohydrates also include long chains of connected sugar molecules. These long chains often consist of hundreds or thousands of monosaccharides bonded together to form **polysaccharides**. Plants store sugar in polysaccharides called **starch**. Animals store sugar in polysaccharides called **glycogen**. You get the carbohydrates you need for energy from eating carbohydrate-rich foods, including fruits and vegetables, as well as grains, such as bread, rice, or corn.

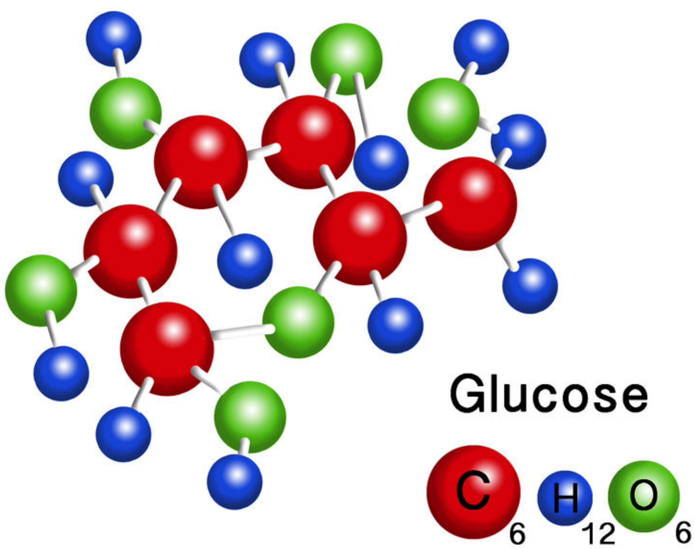


FIGURE 1.23
A molecule of glucose, a type of carbohydrate.

Proteins

Proteins are molecules that have many different functions in living things. All proteins are made of monomers called **amino acids** (**Figure** 1.24) that connect together like beads on a necklace (**Figure** 1.25). There are only 20 common amino acids needed to build proteins. These amino acids form in thousands of different combinations, making about 100,000 or more unique proteins in humans. Proteins can differ in both the number and order of amino acids. It is the number and order of amino acids that determines the shape of the protein, and it is the shape (structure) of the protein that determines the unique function of the protein. Small proteins have just a few hundred amino acids. The largest proteins have more than 25,000 amino acids.

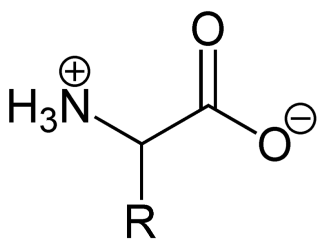


FIGURE 1.24
This model shows the general structure of all amino acids. Only the side chain, R, varies from one amino acid to another. KEY: H = hydrogen, N = nitrogen, C = carbon, O = oxygen, R = variable side chain.

FIGURE 1.25
Amino acids connect together like beads on a necklace. MET, ASN, TRP, and GLN refer to four different amino acids.

Many important molecules in your body are proteins. Examples include enzymes, antibodies, and muscle fiber. **Enzymes** are a type of protein that speed up chemical reactions. They are known as "biological catalysts." For example, your stomach would not be able to break down food if it did not have special enzymes to speed up the rate of digestion. **Antibodies** that protect you against disease are proteins. Muscle fiber is mostly protein (**Figure** 1.26).

FIGURE 1.26
Muscle fibers are made mostly of protein.

It's important for you and other animals to eat food with protein, because we cannot make certain amino acids on our own. You can get proteins from plant sources, such as beans, and from animal sources, like milk or meat. When you eat food with protein, your body breaks the proteins down into individual amino acids and uses them to build new proteins. You really are what you eat!

Lipids

Have you ever tried to put oil in water? They don't mix. Oil is a type of lipid. **Lipids** are molecules such as fats, oils, and waxes. The most common lipids in your diet are probably fats and oils. Fats are solid at room temperature, whereas oils are fluid. Animals use fats for long-term energy storage and to keep warm. Plants use oils for long-term energy storage. When preparing food, we often use animal fats, such as butter, or plant oils, such as olive oil or canola oil. There are many more type of lipids that are important to life. One of the most important are the **phospholipids** that make up the protective outer membrane of all cells (**Figure** 1.27).

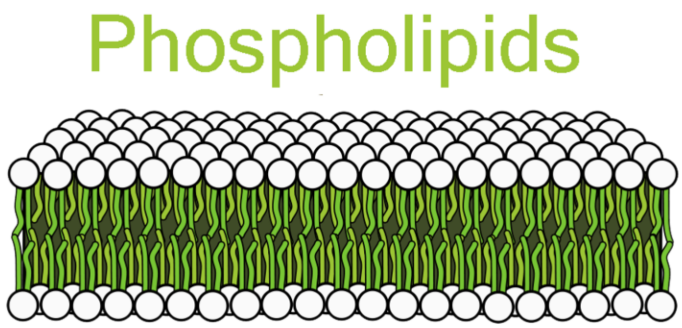


FIGURE 1.27
Phospholipids in a membrane, shown as two layers (a bilayer) of phospholipids facing each other.

Nucleic acids

Nucleic acids are long chains of nucleotides. Nucleotides are made of a sugar, a nitrogen-containing base, and a phosphate group. **Deoxyribonucleic acid (DNA)** and **ribonucleic acid (RNA)** are the two main nucleic acids. DNA is a double-stranded nucleic acid. DNA is the molecule that stores our genetic information (**Figure** 1.28). The single-stranded RNA is involved in making proteins. **ATP (adenosine triphosphate)**, known as the "energy currency" of the cell, is also a nucleic acid.

FIGURE 1.28
A model representing DNA, a nucleic acid.

Vocabulary

- **amino acid**: Small molecule used to build proteins.
- **antibody**: Protein that identifies pathogens or other substances as being harmful; can destroy pathogens by attaching to the cell membrane of the pathogen.
- **ATP (adenosine triphosphate)**: Usable form of energy inside the cell.
- **carbohydrate**: Organic compound such as sugar and starch that provides an energy source for animals.
- **deoxyribonucleic acid (DNA)**: Nucleic acid that is the genetic material of all organisms.
- **enzyme**: Protein that speeds up chemical reactions.
- **glucose**: Simple sugar molecule with the chemical formula $C_6H_{12}O_6$.
- **glycogen**: Storage carbohydrate in animals.
- **lipid**: Organic compound that is insoluble in water and includes fats, oils, and waxes.
- **macromolecule**: Molecule containing a large number of atoms.
- **monomer**: Small building block molecule.
- **monosaccharide**: Simple sugar, such as glucose, that is a building block of carbohydrates.
- **nucleic acid**: Organic compound that can carry genetic information.
- **organic compound**: Compound built around the element carbon.
- **phospholipid**: Lipid molecule with a hydrophilic ("water-loving") head and two hydrophobic ("water-hating") tails; makes up the cell membrane.
- **polysaccharide**: Large carbohydrate usually containing hundreds or thousands of monosaccharides.
- **protein**: Organic compound composed of amino acids and includes enzymes, antibodies, and muscle fibers.
- **ribonucleic acid (RNA)**: Single-stranded nucleic acid involved in protein synthesis.
- **starch**: Storage carbohydrate in plants.

Summary

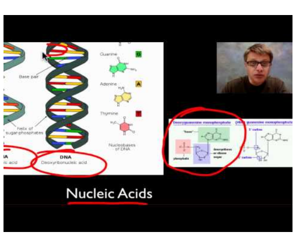
- Living organisms are comprised of organic compounds, molecules built around the element carbon.
- Living things are made of just four classes of organic compounds: proteins, carbohydrates, lipids, and nucleic acids.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Molecules of Life** at http://www.youtube.com/watch?v=QWf2jcznLsY (10:47)



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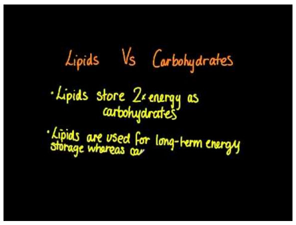
1. What four categories of macromolecules make up cells?
2. What about carbon makes it valuable to organisms?
3. What do functional groups do? How are they important to organisms?

4. What smaller units can proteins be broken down into?
5. What two nucleic acids are used by organisms?
6. What are three different types of carbohydrates?

Explore More II

- **Lipids vs. Carbohydrates** at http://www.youtube.com/watch?v=zTUCEY6CpVI (0:43)



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1. What function do both lipids and carbohydrates share? How do they differ in this regard?
2. How is the solubility of lipids different than the solubility of carbohydrates?

Explore More Answers

Explore More I

1. The four categories of macromolecules that make up cells are carbohydrates, lipids, proteins, and nucleic acids.
2. Carbon has four valence electrons, allowing it to make large stable carbon-based molecules.
3. Functional groups give behavior to the chemicals (functionality, properties), allowing carbon compounds to participate in many chemical reactions.
4. Proteins are broken down into amino acids.
5. Two nucleic acids used by organisms are DNA and RNA.
6. Three types of carbohydrates are monosaccharides, disaccharides, and polysaccharides.

Explore More II

1. Lipids and carbohydrates both store energy, though lipids store about twice the amount of energy as carbohydrates. Lipids are used for long-term energy storage.
2. Lipids are not soluble in water. Carbohydrates are soluble.

Review

1. What are the four main types of organic compounds that make up living things?
2. What are the monomers used to make carbohydrates, proteins, and nucleic acids?
3. What are examples of lipids?
4. What are examples of proteins?

Review Answers

1. Carbohydrates, lipids, proteins, and nucleic acids are the four main types of organic compounds that make up living things.

2. The monomers used to make carbohydrates are monosaccharides. The monomers used to make proteins are amino acids. The monomers used to make nucleic acids are nucleotides.
3. Examples of lipids include fats, oils, phospholipids, and waxes.
4. Examples of proteins include enzymes, antibodies, and muscle fiber.

1.11 Organization of Living Things

- Explain the main contribution of Carolus (Carl) Linnaeus.
- Define binomial nomenclature.
- Summarize modern classification of living organisms.
- Define a species.

How would you classify a horse?

It's easy enough to classify the horse in the animal kingdom. That's one level of classification. But what other groups does the horse belong to? Horses also belong to a class—the mammals. These animals all have fur and nurse their young.

Classification of Life

When you see an organism that you have never seen before, you probably put it into a group without even thinking. If it is green and leafy, you probably call it a plant. If it is long and slithers, you probably call it as a snake. How do you make these decisions? You look at the physical features of the organism and think about what it has in common with other organisms.

Scientists do the same thing when they **classify**, or put into categories, living things. Scientists classify organisms not only by their physical features, but also by how closely related they are. Lions and tigers look like each other more than they look like bears, but are lions and tigers related? Evolutionarily speaking, yes. **Evolution** is the change in a species over time. Lions and tigers both evolved from a common ancestor. So it turns out that the two cats are actually more closely related to each other than to bears. How an organism looks and how it is related to other organisms determines how it is classified.

Linnaean System of Classification

People have been concerned with classifying organisms for thousands of years. Over 2,000 years ago, the Greek philosopher Aristotle developed a classification system that divided living things into several groups that we still use today, including mammals, insects, and reptiles.

Carolus (Carl) Linnaeus (1707-1778) (**Figure** 1.29) built on Aristotle's work to create his own classification system. He invented the way we name organisms today, with each organism having a two word name. Linnaeus is considered the inventor of modern **taxonomy**, the science of naming and grouping organisms.

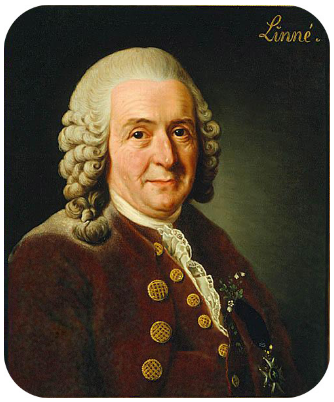

FIGURE 1.29
In the 18th century, Carl Linnaeus invented the two-name system of naming organisms (genus and species) and introduced the most complete classification system then known.

Linnaeus developed **binomial nomenclature**, a way to give a scientific name to every organism. In this system, each organism receives a two-part name in which the first word is the **genus** (a group of species), and the second word refers to one species in that genus. For example, a coyote's species name is *Canis latrans*. *Latrans* is the species and *Canis* is the genus, a larger group that includes dogs, wolves, and other dog-like animals. Here is another example: the red maple, *Acer rubra*, and the sugar maple, *Acer saccharum*, are both in the same genus and they look similar (**Figure** 1.30). Notice that the genus is capitalized and the species is not, and that the whole scientific name is in italics. The names may seem strange, but the names are written in a language called Latin.

FIGURE 1.30
These leaves are from two different species of trees in the *Acer*, or maple, genus. The green leaf (*far left*) is from the sugar maple, and the red leaf (*center*) are from the red maple. One of the characteristics of the maple genus is winged seeds (*far right*).

Modern Classification

Modern taxonomists have reordered many groups of organisms since Linnaeus. The main categories that biologists use are listed here from the most specific to the least specific category (**Figure** 1.31). All organisms can be classified into one of three **domains**, the least specific grouping. The three domains are Bacteria, Archaea, and Eukarya.

The Kingdom is the next category after the Domain. All life is divided among six kingdoms: Kingdom Bacteria, Kingdom Archaea, Kingdom Protista, Kingdom Plantae, Kingdom Fungi, and Kingdom Animalia.

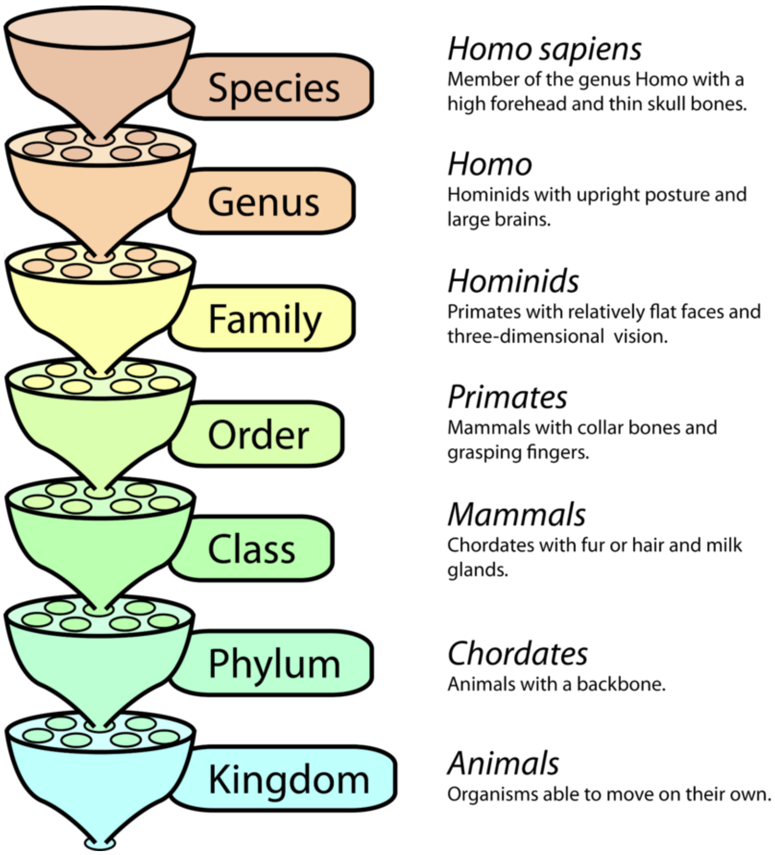

FIGURE 1.31
This diagram illustrates the classification categories for organisms, with the broadest category (kingdom) at the bottom, and the most specific category (species) at the top. We are *Homo sapiens. Homo* is the genus of great apes that includes modern humans and closely related species, and *sapiens* is the only living species of the genus.

Defining a Species

Even though naming species is straightforward, deciding if two organisms are the same species can sometimes be difficult. Linnaeus defined each species by the distinctive physical characteristics shared by these organisms. But two members of the same species may look quite different. For example, people from different parts of the world sometimes look very different, but we are all the same species (**Figure** 1.32).

So how is a species defined? A **species** is defined as a group of similar individuals that can interbreed with one another and produce fertile offspring. A species does not produce fertile offspring with other species.

Vocabulary

- **binomial nomenclature**: System of naming organisms using two terms, the first one indicating the genus and the second the species.
- **classify**: To place things into groups based on shared qualities.
- **domain**: Least specific category of classification.
- **evolution**: Process in which something passes to a different stage, such as a living organism turning into a more advanced or mature organism; the change of the inherited traits of a group of organisms over many generations.
- **genus**: Group of related species.

FIGURE 1.32

These children are all members of the same species, *Homo sapiens*.

- **species**: Group of similar individuals that can interbreed with one another and produce fertile offspring.
- **taxonomy**: Science of naming and grouping organisms.

Summary

- Scientists have defined several major categories for classifying organisms: domain, kingdom, phylum, class, order, family, genus, and species.
- The scientific name of an organism consists of its genus and species.

Explore More

Use the resources below to answer the following questions.

Explore More I

- **Taxonomy - Shape of Life** at http://shapeoflife.org/video/other-topics/taxonomy (2:52)

MEDIA

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1. What do taxonomists study? How does their work help other scientists?
2. Who was the first person we know of who developed a system to categorize things? How was this done? Is his system still used today?
3. What contribution to taxonomy did Carolus Linnaeus make?

Explore More II

Use the below activity to see specific examples of how organisms are categorized. Make sure you go through all three types of organisms so you can gain a good understanding of the level at which different types of organisms separate from each other.

- **Nova: Classifying Life** at http://www.pbs.org/wgbh/nova/nature/classifying-life.html

Explore More Answers

1. Taxonomists attempt to organize the diversity of life. Organizing life helps scientists make sense of life.
2. Aristotle was the first to attempt to classify organisms. He classified organisms based on internal and external similarities. His system is not used today.
3. Linnaeus introduced the genus and species naming system.

Review

1. Who is the inventor of the modern classification system?
2. List the classification categories for organisms from the broadest category to the most specific.
3. What is meant by binomial nomenclature?
4. Define a species.

Review Answers

1. Carl Linnaeus is considered the inventor of modern classification system (taxonomy).
2. Kingdon, Phylum, Class, Order, Family, Genus, Species
3. Binomial nomenclature is a way to give a two-part scientific name to every organism, in which the first word is the genus (a group of species), and the second word refers to one species in that genus.
4. A species is defined as a group of similar individuals that can interbreed with one another and produce fertile offspring.

1.12 Domains of Life

- Distinguish between the three domains of life.
- List the four Eukarya kingdoms.

What do you have in common with pond scum?

Humans are in the same domain as trees and algae, which makes up the "pond scum" you see here. What could they possibly have in common? It is the location of their DNA inside their cells. Their cells all have a nucleus that is home to their genetic material.

The Domains of Life

Let's explore the **domain**, the least specific category of classification.

All of life can be divided into three domains, based on the type of cell of the organism:

1. **Bacteria**: cells do not contain a nucleus.
2. **Archaea**: cells do not contain a nucleus; they have a different cell wall from bacteria.
3. **Eukarya**: cells do contain a nucleus.

Archaea and Bacteria

The Archaea and Bacteria domains (**Figure** 1.33) are both entirely composed of small, single-celled organisms and seem very similar, but they also have significant differences. Both are composed of **prokaryotic cells**, which are cells without a nucleus. In addition, both domains are composed of species that reproduce asexually (**asexual reproduction**) by dividing in two. Both domains also have species with cells surrounded by a **cell wall**, however, the cell walls are made of different materials. Bacterial cell walls contain the polysaccharide **peptidoglycan**. Lastly, Archaea often live in extreme environments including hot springs, geysers, and salt flats. Bacteria do not live in these environments.

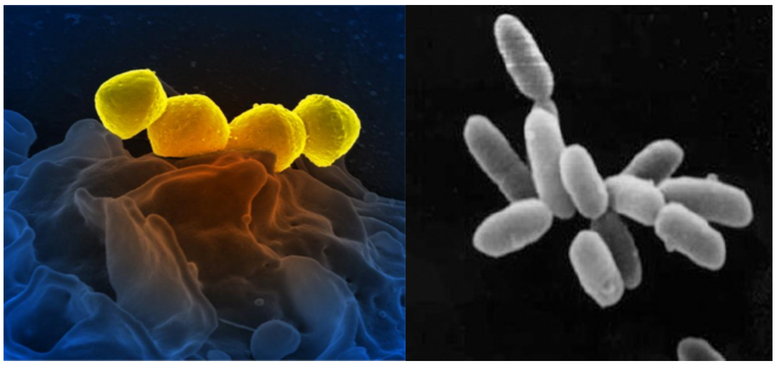


FIGURE 1.33
The Group A *Streptococcus* organism (*left*) is in the domain Bacteria, one of the three domains of life. The *Halobacterium* (*right*) is in the domain Archaea, another one of the three domains.

Eukarya

All of the cells in the domain Eukarya keep their genetic material, or **DNA**, inside the **nucleus**. The domain Eukarya is made up of four kingdoms:

1. Plantae: Plants, such as trees and grasses, survive by capturing energy from the sun, a process called **photosynthesis**.
2. Fungi: Fungi, such as mushrooms and molds, survive by "eating" other organisms or the remains of other organisms. These organisms absorb their nutrients from other organisms.
3. Animalia: Animals also survive by eating other organisms or the remains of other organisms. Animals range from tiny ants to the largest whales, and include arthropods, fish, amphibians, reptiles, and mammals (**Figure** 1.34).
4. Protista: Protists are not all descended from a single common ancestor in the way that plants, animals, and fungi are. Protists are all the eukaryotic organisms that do not fit into one of the other three kingdoms. They include many kinds of microscopic one-celled organisms, such as algae and plankton, but also giant seaweeds that can grow to be 200 feet long.

Plants, animals, fungi, and protists might seem very different, but remember that if you look through a microscope, you will find similar cells with a membrane-bound nucleus in all of them. These are **eukaryotic cells**. These cells also have membrane-bound **organelles**, which prokaryotic cells lack. The main characteristics of the three domains of life are summarized in **Table** 1.6.

TABLE 1.6: Characteristics of the Three Domains of Life

	Archaea	Bacteria	Eukarya
Multicelluar	No	No	Yes

TABLE 1.6: (continued)

	Archaea	**Bacteria**	**Eukarya**
Cell wall	Yes, without peptidoglycan	Yes, with peptidoglycan	Varies. Plants and fungi have a cell wall; animals do not.
Nucleus (Membrane-Enclosed DNA)	No	No	Yes
Membrane-Bound Organelles	No	No	Yes

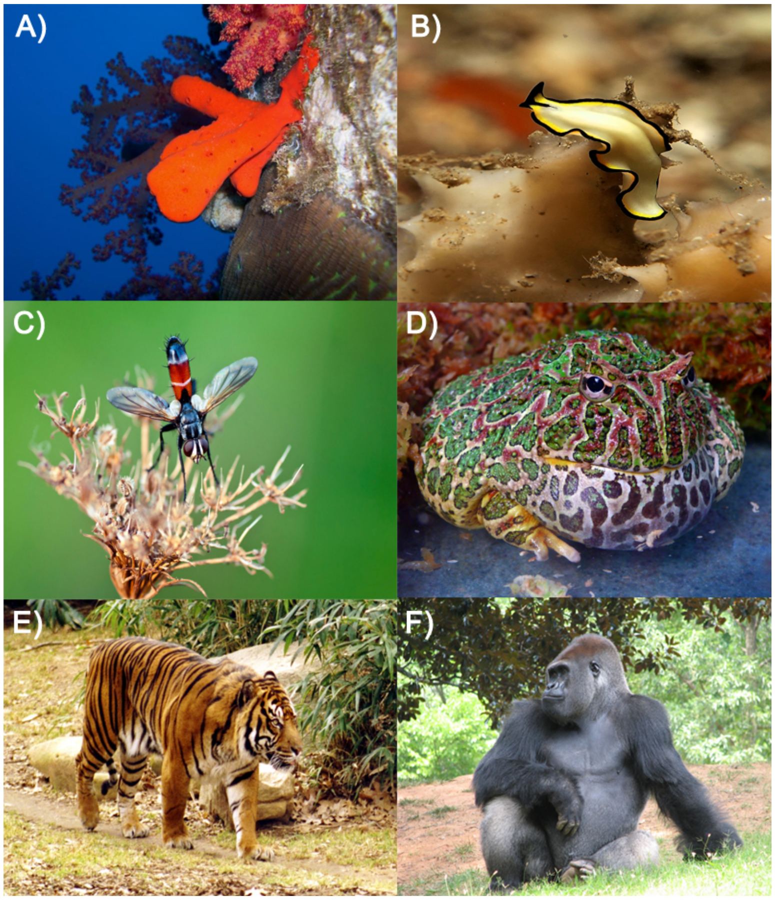


FIGURE 1.34

Diversity of Animals. These photos give just an inkling of the diversity of organisms that belong to the animal kingdom. (A) Sponge, (B) Flatworm, (C) Flying Insect, (D) Frog, (E) Tiger, (F) Gorilla.

Vocabulary

- **Archaea**: Single-celled organism with no nucleus and a different cell wall than bacteria, often thriving in extreme environments.
- **asexual reproduction**: Process of forming a new individual from a single.
- **Bacteria**: Single-celled organisms that do not contain a nucleus.
- **cell wall**: Tough outer layer of prokaryotic cells and plant cells; helps support and protect the cell.
- **DNA**: Deoxyribonucleic acid; a nucleic acid that is the genetic material of all organisms.
- **domain**: Three primary, broadest categories of living things.
- **Eukarya**: Organisms that keep their genetic material, or DNA, inside the nucleus.
- **eukaryotic cell**: Cell that contains a nucleus and membrane-bound organelles.
- **nucleus**: Membrane enclosed organelle in eukaryotic cells that contains the DNA; primary distinguishing feature between a eukaryotic and prokaryotic cell; the information center, containing instructions for making all the proteins in a cell, as well as how much of each one.
- **organelle**: Structure within the cell that has a specific role.
- **peptidoglycan**: Complex molecule consisting of sugars and amino acids that makes up the bacterial cell wall.
- **photosynthesis**: The process by which specific organisms (including all plants) use the sun's energy to make their own food from carbon dioxide and water; process that converts the energy of the sun, or solar energy, into carbohydrates, a type of chemical energy.
- **prokaryotic cell**: Cell without a nucleus or membrane-bound organelles.

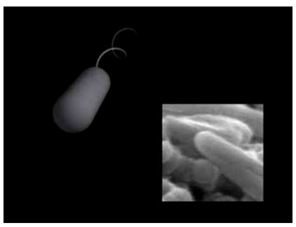
Summary

- All life can be classified into three domains: Bacteria, Archaea, and Eukarya.
- Organisms in the domain Eukarya keep their genetic material in a nucleus and include the plants, animals, fungi, and protists.

Explore More

Use the resource below to answer the questions that follow.

- **Exploring Deep-Subsurface: Life Domains** at http://www.youtube.com/watch?v=UI7Yvu4McDU (8:02)



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1. What are the three domains of life?
2. What category do the individual organisms that we can see with our naked eye fall into?
3. What is an extremophile? What domain is known for these organisms? (Note: recent work has shown that extremophiles are not the only members of this domain.)
4. How do Archaea and Bacteria differ? How are they the same?
5. Which domain of life seems to be absent for deep-subsurface communities?

Explore More Answers

1. The three domains of life are Eukarya, Bacteria, and Archaea.
2. Eukarya contain the individual organisms large enough to see without scientific assistance.
3. An extremophile lives in a condition dangerous to humans. They are members of the domain Archaea.
4. Archaea and Bacteria differ in the makeup of their cell walls (or outer cell membrane). They are both prokaryotic domains, with cells without a nucleus or membrane-bound organelles.
5. Domain Eukarya seems to be absent from deep-surface communities.

Review

1. Compare and contrast the domains Archaea and Bacteria.
2. What are the four kingdoms that make up the domain Eukarya?
3. Name three different examples of organisms in the domain Eukarya.

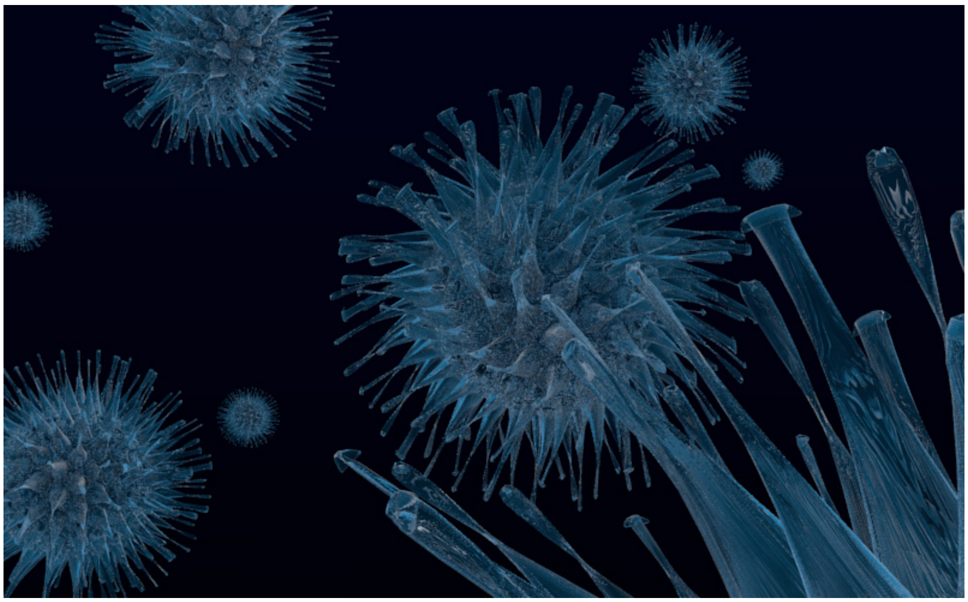
Review Answers

1. The Archaea and Bacteria domains are both entirely composed of small, single-celled prokaryotic organisms. Neither have cells with a nucleus. Their cells do differ in the composition of the cell wall. Archaea also often live in extreme environments including hot springs, geysers, and salt flats.
2. The domain Eukarya is composed of protists (Protista), plants (Plantae), fungi (Fungi), and animal (Animalia) kingdoms.

3. Examples will vary but may include sponge, flatworm, flying insect, frog, tiger, or gorilla.

1.13 Viruses

- Explain why viruses are not considered living.
- Describe the features and list examples of viruses.



What causes the common cold?

That miserable cough and runny nose is caused by one villain: a virus. Viruses come in many different shapes, including the prickly balls you see here. They are so tiny that they can only be seen with a very powerful microscope.

What is a Virus?

We have all heard of viruses. The flu, the common cold, and many other diseases are caused by viruses. But what is a virus? Do you think viruses are living? Which domain do they belong to? Bacteria? Archaea? Eukarya?

Are Viruses Alive?

The answer is actually "no." A **virus** is essentially DNA or RNA surrounded by a coat of protein (**Figure** 1.35). It is not made of a **cell**, and cannot maintain a stable internal environment (**homeostasis**). Recall that a cell is the basic unit of living organisms. So if a virus is not made of at least one cell, can it be living? Viruses also cannot reproduce on their own—they need to infect a **host cell** to reproduce. So a virus is very different from any of the organisms that fall into the three domains of life.

Though viruses are not considered living, they share two important traits with living organisms. They have **genetic material** like all cells do, and they can evolve. As the process of **evolution** has resulted in all life on the planet today, the classification of viruses has been controversial. It calls into question the very definition of life.

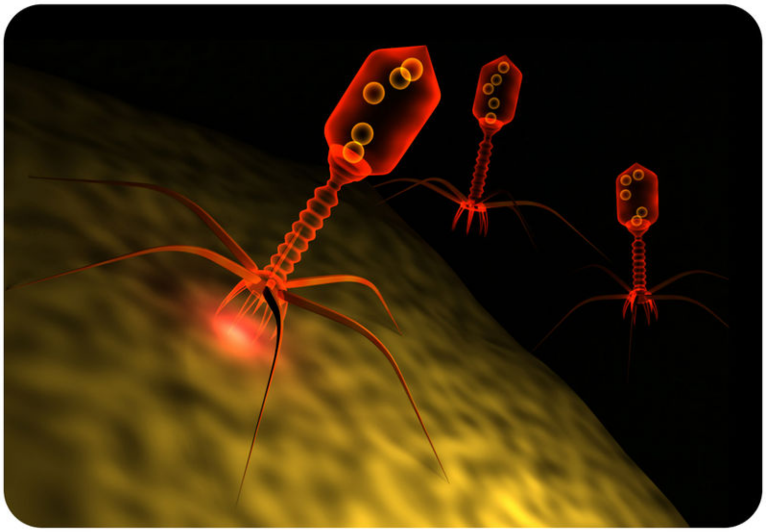


FIGURE 1.35
These little "alien" looking creatures are viruses, and these specific viruses infect *Escherichia coli* bacteria. Shown is a representation of viruses infecting a cell. The virus lands on the outside of the cell and injects its genetic material into the cell.

Replication

Viruses infect a variety of organisms, including plants, animals, and bacteria. Once inside the host cell, they use the cell's own **ATP** (energy), **ribosomes**, **enzymes**, and other cellular parts to make copies of themselves. The host cell makes a copy of the viral DNA and produces viral proteins. These are then packaged into new viruses. So viruses cannot **replicate** or reproduce on their own; they rely on a host cell to make additional viruses.

Viruses and Human Disease

Viruses cause many human diseases. In addition to the flu and the common cold, viruses cause rabies, diarrheal diseases, **AIDS**, cold sores, and many other diseases (**Figure** 1.36). Viral diseases range from mild to fatal.

FIGURE 1.36
Cold sores are caused by a herpes virus.

Vocabulary

- **AIDS**: Acquired immune deficiency syndrome, which is a fatal condition, unless treated with proper medications, caused by the human immunodeficiency virus (HIV).
- **ATP**: Adenosine triphosphate; a usable form of energy inside the cell.
- **cell**: Basic unit of structure and function of a living organism; the basic unit of life.
- **enzyme**: Protein that speeds up chemical reactions.
- **evolution**: Process in which something passes to a different stage, such as a living organism turning into a more advanced or mature organism; the change of the inherited traits of a group of organisms over many generations.
- **genetic material**: DNA and RNA
- **homeostasis**: Maintaining a stable internal environment.
- **host cell**: Cell infected by a virus.
- **replicate**: To make a copy of, as in viral replication or DNA replication.
- **ribosome**: Cell structure on which proteins are made; not surrounded by a membrane; found in both prokaryotic and eukaryotic cells.
- **virus**: Non-living particle consisting of RNA or DNA surrounded by a protein coat.

Summary

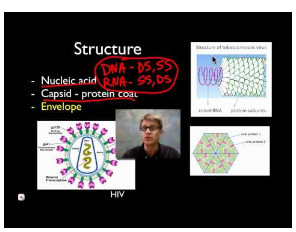
- A virus is composed of DNA or RNA surrounded by a coat of protein.
- Viruses are not considered living things because they cannot reproduce on their own, and they are not comprised of cells.

Explore More

Use the resources below to answer the questions that follow.

Explore More I

- **Viruses** at http://www.youtube.com/watch?v=L8oHs7G_syI (8:06)



MEDIA

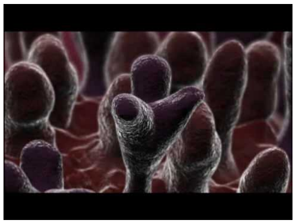
Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/57468

1. How do viruses reproduce? How does this differ from other organisms?
2. What kinds of nucleic acids can viruses have?
3. Explain one of the theories as to how viruses came to be.
4. What is the importance of the "envelope" to a virus? What is the envelope made of?
5. What is a difference between the lytic cycle of a virus and the lysogenic cycle?

Explore More II

- **How Flu Viruses Attack** at http://www.youtube.com/watch?v=TVLo2CtB3GA (3:48)



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URL: http://gamma.ck12.org/flx/render/embeddedobject/57469

1. What is one way a flu virus can kill a human?
2. Do mutations make viruses more deadly? Why or why not?

Explore More Answers

Explore More I

1. Viruses reproduce my injecting their nucleic acid (DNA) into a host cell, and then use the machinery of the host cell to make more viruses. Viruses need another type of organism (host cell) to reproduce, whereas other organisms do not.
2. Viruses can have DNA or RNA as its nucleic acid. Either may be double stranded or single stranded.
3. Answers may vary. The three theories are the cellular theory, regressive theory, and the coevolution theory.
4. The viral envelope surrounds the capsid or protein coat. The envelope, which is made of lipids, allows the virus to fuse with a cell membrane, making infection easier.
5. During the lysogenic cycle, viral DNA fuses into the host cell's chromosomes (genetic material). This does not happen in the lytic cycle. The lytic cycle makes new viruses, whereas the lysogenic cycle incorporates the viral DNA into the host cell's genome, where it can stay for many years.

Explore More II

1. A flu virus can hurt or kill a human by causing fluid to build up in the lungs. The person actually drowns.
2. Mutations do make viruses more deadly, as new strains of the virus emerge.

Review

1. Is a virus a living thing? Why or why not?
2. Name four examples of human diseases caused by a virus.

Review Answers

1. No, a virus is not living. A virus is essentially DNA or RNA surrounded by a coat of protein. It is not made of a cell, and cannot maintain a stable internal environment (homeostasis). Viruses also cannot reproduce on their own—they need to infect a host cell to reproduce. So a virus is very different from any of the organisms that fall into the three domains of life.
2. Answers may vary. Examples of human diseases caused by viruses include flu and the common cold, rabies, diarrheal diseases, AIDS, or cold sores.

Summary

Biology is the study of life, so the Life Sciences are essentially, the study of biology. The scientific method is the process by which biological information, like that of all other sciences, has been identified. This has resulted in a number of important biological scientific theories, including the cell theory and the theory of evolution. All life is built around the element carbon, and four categories of organic compounds: carbohydrates, lipids, proteins, and nucleic acids. One particular type of protein, enzymes, are biological catalysts, allowing biochemical reactions to proceed at the rate necessary to maintain life. All life can be classified into three domains. All members of these domains share characteristics in common. Viruses do not share all of the characteristics of life, and so many scientists do not consider viruses to be living.

1.14 References

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