MS Studying Life

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Printed: February 27, 2015

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CHAPTER 1 MS Studying Life

CHAPTER OUTLINE

Look at the plastic waste that has washed up on this beach. There's plastic everywhere in the ocean, and it's harmful to ocean life. It may take hundreds of years for plastic waste to break down in the environment. What if there was a quicker way to break down plastic? Bacteria decompose other kinds of waste, such as dead leaves. Can any bacteria decompose plastic? That's what two high school students, named Miranda Wang and Jeanny Yao, wondered. They decided to do a science project to find out.

1.1 Scientific Ways of Thinking

Lesson Objectives

- Define science.
- State what it means to think like a scientist.
- Distinguish between scientific laws and scientific theories.

Lesson Vocabulary

- science
- scientific law
- scientific theory

Introduction

Like Miranda Wang and Jeanny Yao, you've probably done science projects. But did you ever really think about what science is or what it means to be a scientist? In this lesson you'll consider these questions.

What Is Science?

Most people think of science as a collection of facts or a body of knowledge. For example, you may have memorized the processes of the water cycle. As shown in **Figure** 1.1, the processes include evaporation and precipitation.

Such knowledge of the natural world is only part of what science is. Science is as much about doing as knowing. **Science** is a way of learning about the natural world that depends on evidence, reasoning, and repeated testing. Scientists explain the world based on their observations. If they develop new ideas about the way the world works, they set up ways to test these new ideas. Scientific knowledge keeps changing because scientists are always "doing science."

Thinking Like a Scientist

When Miranda and Jeanny wondered whether bacteria might decompose plastic, they were thinking like a scientist. What does it mean to "think like a scientist?"

- A scientist is observant. Miranda and Jeanny observed all the plastic trash when they visited a landfill. They also saw a lot of plastic trash along a local river.

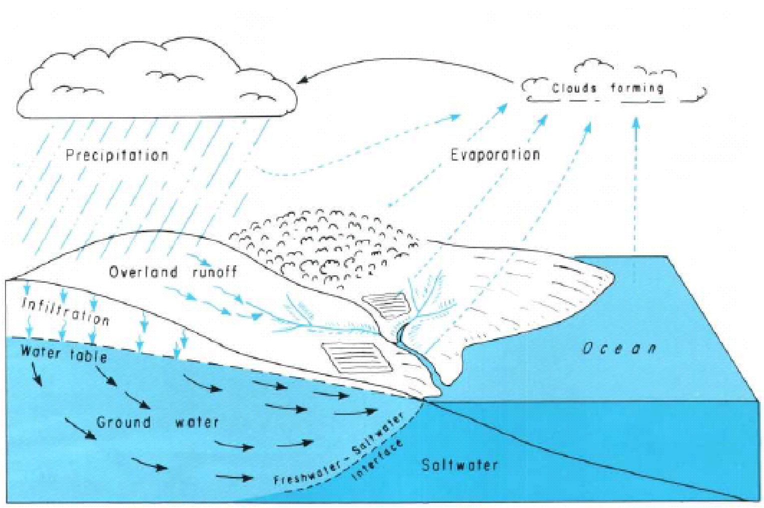

FIGURE 1.1
The water cycle

- A scientist wonders and asks questions. Miranda and Jeanny wondered if any bacteria could help break down plastic. They asked: "Can some bacteria consume chemicals in plastic for food?"
- A scientist tries to find answers using evidence and logic. Often, a scientist does experiments to gather more evidence and test ideas. Miranda and Jeanny did a lot of online research to find out what other scientists had already learned. Then they did their own experiments. They gathered and tested bacteria. For example, they grew bacteria on gel like the red gel in **Figure** 1.2. You can learn the details of their research and their amazing results by watching this video:

https://www.ted.com/talks/two_young_scientists_break_down_plastics_with_bacteria/transcript

- A scientist is skeptical. Claims must be backed by adequate evidence. Miranda and Jeanny repeated their experiments so they were confident in their results. Only then did they draw conclusions.
- A scientist has an open mind. Scientific knowledge is always evolving as new evidence comes in. Miranda and Jeanny made an important contribution with the evidence they gathered. They discovered two species of bacteria that could consume a harmful chemical in plastic.

Scientific Theories and Scientific Laws

Some knowledge in science gains the status of a theory. Scientists use the term "theory" differently than it is used in everyday language. You might say, "I think my dad is late because he got stuck in traffic, but it's just a theory." In other words, it's just one of many possible explanations for why he's late. In science, a theory is much more than that. A **scientific theory** is a broad explanation that is widely accepted because it is supported by a great deal of evidence. Scientific theories are tested and confirmed repeatedly. Because theories are broad explanations, they generally help explain many different observations. An example in life science is the theory of evolution by natural selection. It explains how living things change through time as they adapt to their environment. This theory is supported by a huge amount of evidence. The evidence ranges from DNA to fossils like the ones in **Figure** 1.3.

Another sort of scientific knowledge is called a law. A **scientific law** is a description of what always occurs under certain conditions in nature. In other words, it describes many observations but doesn't explain them. Examples of scientific laws in life science include Mendel's laws of inheritance. These laws describe how traits are passed from parents to their offspring.

FIGURE 1.2
Bacteria can be grown on different types of gel to see what they can consume.

FIGURE 1.3
This amazing fossil reptile is named Dimetrodon. It lived almost 300 million years ago. It was a dinosaur ancestor. What do you think scientists might be able to learn about it from its fossilized bones?

Lesson Summary

- Science is a way of learning about the natural world that depends on evidence, reasoning, and repeated testing.
- A scientist is observant and questioning. She tests ideas with evidence. A scientist is also skeptical and open minded.
- A scientific theory, such as the theory of evolution, is a broad explanation that is widely accepted because it is supported by a great deal of evidence. A scientific law, such as Mendel's laws of inheritance, is a description of what always occurs under certain conditions in nature.

Lesson Review Questions

Recall

1. Define science.
2. Identify traits of a good scientist.

Apply Concepts

3. Sometimes luck plays a role in science. What role did luck play in Miranda's and Jeanny's research?

Think Critically

4. Compare and contrast scientific theories and scientific laws. Give an example of each in life science.
5. Do you think that being a scientist requires creativity? Why or why not?

Points to Consider

Most scientists specialize in just one area of science. An example is life science.

1. What do you think life scientists study?
2. What do you think might be some specializations within life science?

1.2 What Is Life Science?

Lesson Objectives

- Describe the scope of life science.
- Identify the focus of specific fields within life science.
- Outline basic theories that underlie all the fields of life science.
- Distinguish between basic and applied life science.

Lesson Vocabulary

- applied science
- basic science
- life science
- organism

Introduction

Life science is the study of life and living things. Living things are also called **organisms**. Life science is often referred to as biology. Life scientists work in many different settings, from classrooms to labs to natural habitats. Dr. Katherine Smith, who is pictured in **Figure** 1.4 is a life scientist who works for NOAA (National Oceanic and Atmospheric Administration). She studies freshwater shrimp and fish in their natural habitats.

FIGURE 1.4
Dr. Katherine Smith (NOAA life scientist) and friend (freshwater shrimp)

Fields in Life Science

Life is complex, and there are millions of species alive today. Many millions more lived in the past and then went extinct. Organisms include microscopic, single-celled organisms. They also include complex, multicellular animals such as you. Clearly, life science is a huge science. That's why a life scientist usually specializes in just one field within life science. Dr. Smith, for example, specializes in ecology. You can see the focus of ecology and several other life science fields in **Table** 1.1. Click on the links provided if you want to learn about careers in these fields.

TABLE 1.1: Specific fields within life science

Field	Focus of Study	Learn about a Career in this Field
Ecology	interactions of organisms with each other and their environment	http://www.agriculture.purdue.edu/usda/careers/ecologist.html
Botany	plants	http://www.botany.org/bsa/careers/
Zoology	animals	http://www.bls.gov/ooh/life-physical-and-social-science/zoologists-and-wildlife-biologists.htm
Microbiology	microorganisms such as bacteria	http://www.asm.org/index.php/scientists-in-k-12-outreach/careers-in-microbiology
Entomology	insects	http://www.entsoc.org/resources/education
Cell biology	cells of living things	http://education-portal.com/articles/Careers_in_Cellular_Biology_Job_Options_and_Requirements.html
Physiology	tissues and organs and how they function	http://www.the-aps.org/mm/careers
Genetics	genes, traits, and inheritance	http://www.agriculture.purdue.edu/usda/careers/geneticist.html
Epidemiology	causes of diseases and how they spread	http://explorehealthcareers.org/en/Career/45/Epidemiology
Paleontology	fossils and evolution	http://www.priweb.org/ed/lol/careers.html

Life Science Theories

Each field of life science has its own specific body of knowledge and relevant theories. However, two theories are basic to all of the life sciences. They form the foundation of every life science field. They are the cell theory and the theory of evolution by natural selection. Both theories have been tested repeatedly. Both are supported by a great deal of evidence.

Cell Theory

According to the cell theory, all organisms are made up of one or more cells. Cells are the sites where all life processes take place. Cells come only from pre-existing cells. New cells forms when existing cells divide.

Most cells are too small to see without a microscope. If you were to look at a drop of your blood under a microscope, **Figure** 1.5 shows two types of cells you might see. You can learn more about cells and the cell theory in the chapter Cells and Their Structures.

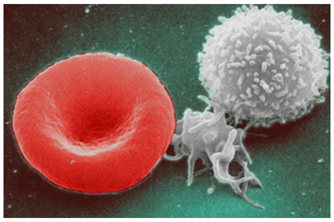

FIGURE 1.5
Human red and white blood cells

Theory of Evolution by Natural Selection

The theory of evolution by natural selection explains how populations of organisms can change over time. As environments change, so must the traits of organisms if they are to survive in the new conditions. Evolution by natural selection explains how this happens. It also explains why there are so many different species of organisms on Earth today. You can see examples of the incredible diversity of living animals in **Figure** 1.6. You can read more about the theory of evolution in the chapter Evolution.

FIGURE 1.6
Evolution explains how there came to be so many different species of organisms on Earth

Basic and Applied Life Science

Most scientific theories were developed by scientists doing basic scientific research. Like other sciences, life science may be either basic or applied science.

Basic Science

The aim of **basic science** is to discover new knowledge. It leads to a better understanding of the natural world. It doesn't necessarily have any practical use. An example of basic research in life science is studying how yeast cells grow and divide. Yeasts are single-celled organisms that are easy to study. By studying yeast cells, life scientists discovered the series of events called the cell cycle. The cell cycle works not only in yeasts but in all other organisms with similar cells. Therefore, this basic research made a major contribution to our understanding of living things. Watch the following animation to learn more about the basic yeast research and the cell cycle. You can also see yeast cells dividing.

http://www.dnalc.org/view/16784-Animation-38-Development-balances-cell-growth-and-death-.html

Applied Science

Knowledge gained by this basic research on yeast cells has been applied to practical problems. Scientists have developed drugs to treat cancer based on knowledge of the cell cycle. Cancer is a disease in which cells divide out of control. The new drugs interfere with the cell cycle of cancer cells, so the cells stop dividing. This is an example of applied science. The aim of **applied science** is to find solutions to practical problems. Applied science generally rests on knowledge gained by basic science.

Lesson Summary

- Life science is the study of life and living organisms. Life science is also called biology.
- Life is complex and living things are incredibly diverse. Therefore, life science is divided into many fields, such as ecology, botany, and zoology.
- Two theories underlie all of the fields of life science: the cell theory and the theory of evolution by natural selection.
- Life science may be basic or applied science. The aim of basic science is to gain new knowledge and a better understanding of the natural world. The aim of applied science is to find solutions to practical problems.

Lesson Review Questions

Recall

1. What is life science?
2. Define organism.
3. List three different fields in life science. What is the focus of study in each of these fields?

Apply Concepts

4. Many scientists may work together on the same research problem. Explain which fields of life science you think might be involved in studying the effects of an oil spill in the ocean.

Think Critically

5. Explain why the cell theory is basic to all of the fields of life science.
6. How does the theory of evolution by natural selection explain the tremendous diversity of living things on Earth?
7. Relate basic and applied scientific research.

Points to Consider

The cell theory and the theory of evolution by natural selection are basic to all of the fields of life science.

- Do you think that the same basic methods are used in all of the fields of life science?
- How do you think life scientists increase their knowledge of living things?

1.3 The Scientific Method

Lesson Objectives

- Outline the steps of the scientific method.
- State the meaning of scientific hypothesis.
- Define experiment.
- Identify independent and dependent variables and controls.

Lesson Vocabulary

- control
- dependent variable
- experiment
- hypothesis
- independent variable
- observation
- replication
- scientific method

Introduction

Look at the athletes in **Figure** 1.7. Some athletes, like the one on the left, seem destined to be weight lifters. They respond to exercise by building big muscles. Other athletes, like the one on the right, are better suited for long-distance running. They can develop awesome levels of endurance. What determines how the human body responds to training? Could it be "genetic?" Might our athletic potential be controlled by our genes? How would a life scientist try to answer this question?

FIGURE 1.7
Both of these athletes excel but in different athletic events

Steps in a Scientific Investigation

A life scientist would carry out a scientific investigation to try to answer this question. A scientific investigation follows a general plan called the scientific method. The **scientific method** is a series of logical steps for testing a possible answer to a question. The steps are shown in the flow chart in **Figure** 1.8.

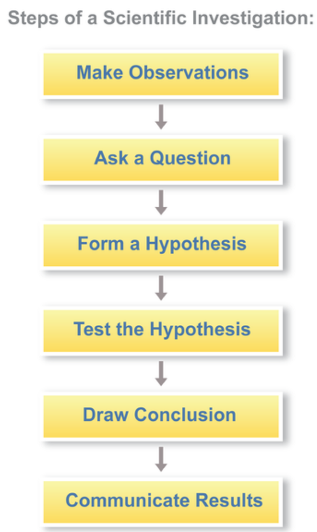

FIGURE 1.8
Scientific method flow chart

The Scientific Method: A Closer Look

The steps of the scientific method are described in greater detail below. Note that these steps are meant as a guide, not a rigid sequence. Steps may be followed in a somewhat different order, for example, or steps may be repeated or skipped.

1. Make observations. **Observations** refer to anything detected with one or more senses. The senses include sight, hearing, touch, smell, and taste.
2. Ask a question raised by the observations.
3. Form a hypothesis. A **hypothesis** is a potential, testable answer to a scientific question. Testable means that if the hypothesis is false, it's possible to find evidence showing that it's false. This step usually requires some research. You have to find out what other investigators have already learned about the observations. For example, has anyone already tried to answer the question? What other hypotheses have been proposed?
4. Test the hypothesis. Make predictions based on the hypothesis and then determine if they are correct. This may involve carrying out an experiment. An **experiment** is a controlled scientific test that often takes place in a lab. It investigates the effects of one factor, called the **independent variable**, on another factor, called the **dependent variable**. Experimental **controls** are other factors that might affect the dependent variable. Controls are kept constant so they will not affect the results of the experiment.
5. Analyze the results of the test and draw a conclusion. Do the results agree with the predictions? If so, they provide support for the hypothesis. If not, they disprove the hypothesis.
6. Communicate results. One way is by presenting a poster at a scientific conference, like the scientists in **Figure** 1.9. Other ways include reading papers at conferences or publishing them in scientific journals. When results

are communicated, scientists should describe their hypothesis and how it was tested in addition to the results of the test. This allows other scientists to repeat the investigation to see whether they get the same results. This is called **replication**. Replication is important because it adds weight to the findings. The results are more likely to be reliable if they can be repeated.

FIGURE 1.9

Posters are a quick, visual way for scientists to communicate the results of their research to other scientists. Professional science posters serve the same purpose as science fair posters.

Applying the Scientific Method

You can apply the scientific method to the question that was raised above about athletic ability. Assume you are a life scientist. You observe variation in athletic abilities. Some athletes tend to build more muscle mass. Others tend to develop greater endurance. You ask, “Is there a gene that might explain these differences?” You research the problem on the Internet. You learn about a gene named ACE that might affect how people respond to athletic training.

Based on all of your research, you develop a hypothesis. You hypothesize that people with different versions (D or I) of the ACE gene will respond differently to the same athletic training program. People with D genes will increase their muscle mass but not their endurance. People with I genes will increase their endurance but not their muscle mass.

How can you test your hypothesis? You can see how actual life science researchers did it by watching this video: http://www.youtube.com/watch?v=AsNytYms5OY .

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Lesson Summary

- Scientific investigations generally follow a process called the scientific method. Steps of the scientific method include making observations, asking a question, forming a hypothesis, testing the hypothesis, drawing a conclusion, and communicating the results.
- A hypothesis is a potential, testable answer to a scientific question. It must be possible to find evidence showing that the hypothesis is false if it really is false.
- An experiment is a controlled scientific test that often takes place in a lab. It investigates the effects of an independent variable on a dependent variable.
- Experimental controls are other factors that might affect the dependent variable. They are kept constant so they will not affect the results of the experiment.

Lesson Review Questions

Recall

1. Outline the steps of the scientific method.
2. Define scientific hypothesis.
3. What is a scientific experiment? Define independent and dependent variables and controls.

Apply Concepts

4. How did the ACE gene researchers in the video above test the hypothesis that people with D genes and people with I genes respond differently to the same athletic training program? Identify independent and dependent variables in their study. What factors were controlled?

Think Critically

5. Summarize the results of the ACE gene study. How would you communicate the results?
6. What is replication in science? Why is it important?

Points to Consider

Whether they do basic or applied research, many life scientists use microscopes as one of their most important tools.

1. What is a microscope?
2. Why do you think microscopes are so important in life science?

1.4 The Microscope

Lesson Objectives

- Define microscope.
- Explain why the microscope is so important in life science.
- Outline how the microscope was invented.
- Compare and contrast modern light microscopes and electron microscopes.

Lesson Vocabulary

- electron microscope
- light microscope
- microscope

Introduction

It's hard to overstate the importance of the microscope to life science. A **microscope** is an instrument that makes magnified images of very small objects so they are visible to the human eye.

Importance of the Microscope in Life Science

Many life science discoveries would not have been possible without the microscope. For example:

- Cells are the tiny building blocks of living things. They couldn't be discovered until the microscope was invented. The discovery of cells led to the cell theory. This is one of the most important theories in life science.
- Bacteria are among the most numerous living things on the planet. They also cause many diseases. However, no one knew bacteria even existed until they could be seen with a microscope.

The invention of the microscope allowed scientists to see cells, bacteria, and many other structures that are too small to be seen with the unaided eye. It gave them a direct view into the unseen world of the extremely tiny. You can get a glimpse of that world in **Figure** 1.10.

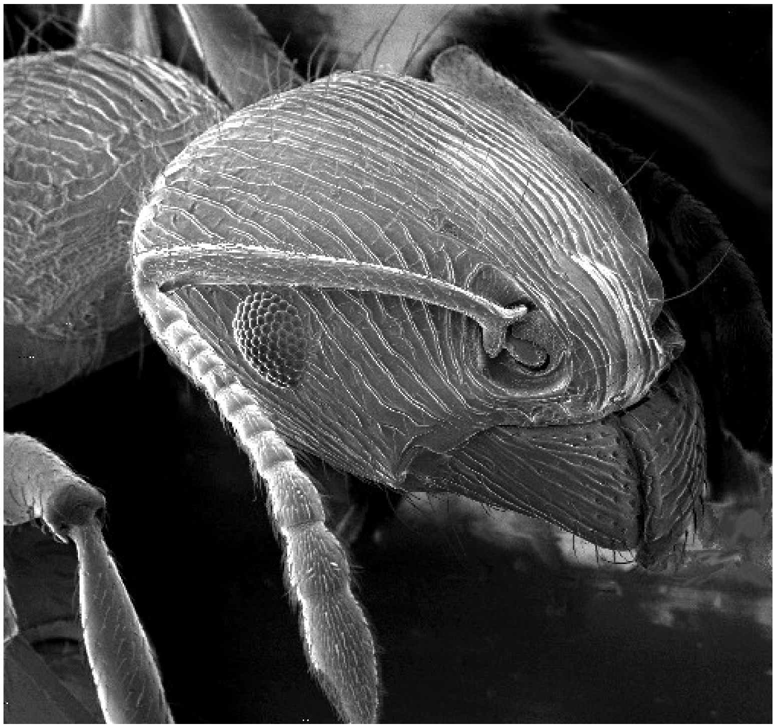

FIGURE 1.10
The head of ant as seen with an electron microscope

Invention of the Microscope

The microscope was invented more than four centuries ago. In the late 1500s, two Dutch eyeglass makers, Zacharias Jansen and his father Hans, built the first microscope. They put several magnifying lenses in a tube. They discovered that using more than one lens magnified objects more than a single lens. Their simple microscope could make small objects appear nine times bigger than they really were.

Hooke Discovers Cells

In the mid-1600s, the English scientist Robert Hooke was one of the first scientists to observe living things with a microscope. He published the first book of microscopic studies, called *Micrographia*. It includes wonderful drawings of microscopic organisms and other objects. One of Hooke's most important discoveries came when he viewed thin slices of cork under a microscope. Cork is made from the bark of a tree. When Hooke viewed it under a microscope, he saw many tiny compartments that he called cells. He made the drawing in **Figure** 1.11 to show what he observed. Hooke was the first person to observe the cells from a once-living organism.

Van Leeuwenhoek Sees Animalcules

In the late 1600s, Anton van Leeuwenhoek, a Dutch lens maker and scientist, started making much stronger microscopes. His microscopes could magnify objects as much as 270 times their actual size. Van Leeuwenhoek made many scientific discoveries using his microscopes. He was the first to see and describe bacteria. He observed them in a sample of plaque that he had scraped off his own teeth. He also saw yeast cells, human sperm cells, and the microscopic life teeming in a drop of pond water. He even saw blood cells circulating in tiny blood vessels called capillaries. The drawings in **Figure** 1.12 show some of tiny organisms and living cells that van Leeuwenhoek viewed with his microscopes. He called them "animalcules."

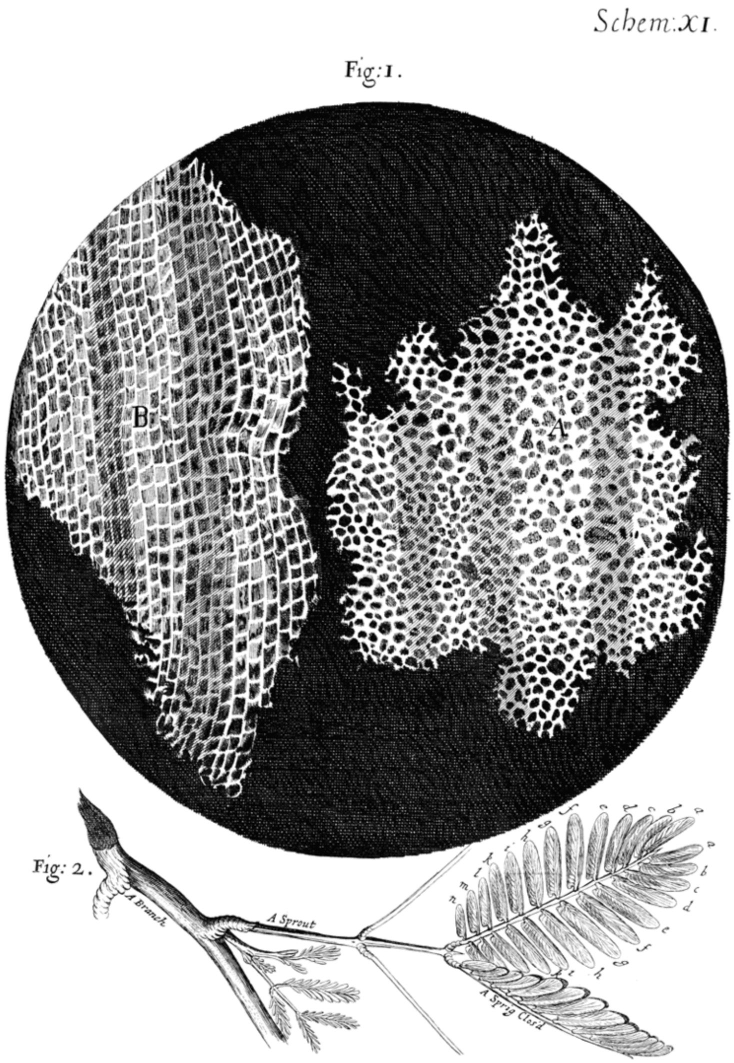

FIGURE 1.11
Cells in cork

Modern Microscopes

These early microscopes used lenses to refract light and create magnified images. This type of microscope is called a **light microscope**. Light microscopes continued to improve and are still used today. The microscope you might use in science class is a light microscope. The most powerful light microscopes now available can make objects look up to 2000 times their actual size. You can learn how to use a light microscope by watching this short video: http://www.youtube.com/watch?v=jP9HtcAvGDk .

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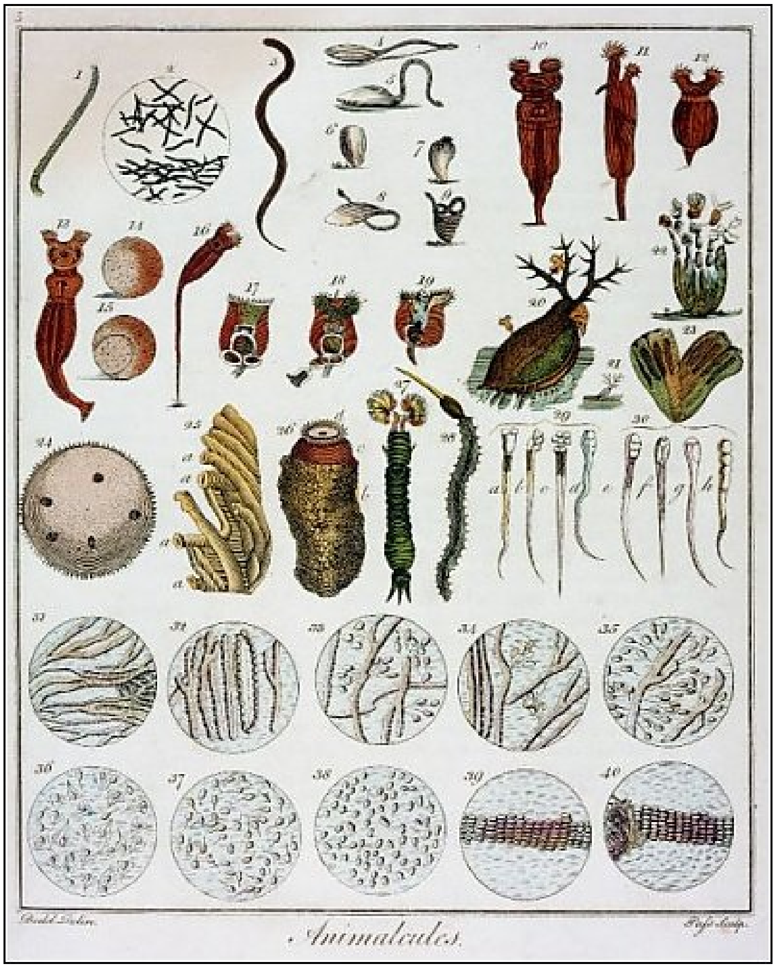

FIGURE 1.12
Van Leeuwenhoek's drawings of "animalcules" as they appeared under his microscope

To see what you might observe with a light microscope, watch the following video. It shows some amazing creatures in a drop of stagnant water from an old boat. What do you think the creatures might be? Do they look like any of van Leeuwenhoek's "animalcules" in **Figure** 1.12?

http://www.youtube.com/watch?v=7JIDkgE4HLk

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For an object to be visible with a light microscope, it can't be smaller than the wavelength of visible light (about 550 nanometers). To view smaller objects, a different type of microscope, such as an electron microscope, must be used. **Electron microscopes** pass beams of electrons through or across an object. They can make a very clear image that is up to 2 million times bigger than the actual object. An electron microscope was used to make the image of the ant head in **Figure** 1.10.

Lesson Summary

- A microscope is an instrument that makes magnified images of very small objects so they are visible to the human eye. Many important life science discoveries would not have been possible without the microscope.
- Hans and Zacharias Jansen made the first light microscope in the late 1500s. In the mid-1600s, Robert Hooke was the first scientist to study living things with a microscope. He was also the first to identify and describe cells. In the late 1600s, van Leeuwenhoek improved the microscope. He used it to observe many living cells and organisms. He was the first to observe bacteria.
- Light microscopes continued to improve and are still used today. However, to see extremely small objects, a different type of microscope, such as an electron microscope, must be used.

Lesson Review Questions

Recall

1. What is a microscope?
2. Outline the contributions of Hooke and van Leeuwenhoek to the microscope and to life science.

Apply Concepts

3. Assume you want to view a structure that is 400 nanometers wide. Explain which type of microscope you would use, a light microscope or an electron microscope.

Think Critically

4. Explain why the microscope is such an important tool in life science.

Points to Consider

Microscopes are usually used in a lab setting. Science labs can be dangerous places unless you follow safety rules.

1. Can you think of a danger you might be exposed to in a science lab?
2. What might be a common-sense lab safety rule?

1.5 Safety in Life Science Research

Lesson Objectives

- Identify common safety symbols and lab safety rules.
- Explain how to stay safe while doing field research.
- State what to do in case of an accident during scientific research.

Lesson Vocabulary

- fieldwork

Introduction

Some life scientists mainly do lab research. Other life scientists, like the botanist in **Figure** 1.13, work in natural settings. This is called **fieldwork**. Whether in the lab or the field, research in life science can be dangerous. It's important to be aware of the risks and how to stay safe.

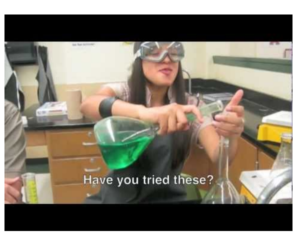
FIGURE 1.13
This field botanist is collecting water samples near the wild pitcher plants she is studying. These insect-eating plants are rare, and there are many unanswered questions about them. Why might her research be risky?

Safety in the Lab

A science lab has many potential dangers. That's why lab procedures and equipment are often labeled with safety symbols, like the ones in **Figure** 1.14. These symbols warn of specific hazards, such as flames or broken glass. Learn the symbols so you can recognize the dangers. Then learn how to avoid them.

FIGURE 1.14
Common safety symbols

The best way to avoid lab dangers is to follow the lab safety rules listed below. Following the rules can help prevent accidents. Watch this funny student video to see just how important some of these rules are: http://www.youtube.com/watch?v=NjJz85bQqdM .



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Lab Safety Rules

- Wear long sleeves and shoes that completely cover your feet.
- If your hair is long, tie it back or cover it with a hair net.
- Protect your eyes, skin, and clothing by wearing safety goggles, an apron, and gloves.
- Use hot mitts to handle hot objects.
- Never work alone in the lab.
- Never engage in horseplay in the lab.

- Never eat or drink in the lab.
- Never do experiments without your teacher's approval.
- Always add acid to water, never the other way around. Add the acid slowly to avoid splashing.
- Take care to avoid knocking over Bunsen burners. Keep them away from flammable materials such as paper.
- Use your hand to fan vapors toward your nose rather than smelling substances directly.
- Never point the open end of a test tube toward anyone—including you!
- Clean up any spills immediately.
- Dispose of lab wastes according to your teacher's instructions.
- Wash glassware and counters when you finish your work.
- Wash your hands with soap and water before leaving the lab.

Safety in the Field

Many of the lab safety rules are common-sense precautions. Common-sense should also prevail in the field. Be aware, however, that field research may have its own unique dangers. Therefore, other safety rules may apply when you work in the field. The rules will depend on the particular field setting and its specific risks.

Consider the field botanist in **Figure** 1.13. There may be microorganisms in the water that could make her sick. She might come into contact with plants that cause an allergic reaction. The water or shore might be strewn with dangerous objects such as broken glass that could cause serious injury. To stay safe in the field, she needs to be aware of these risks and take steps to avoid them. If you work in the field or take a science fieldtrip, you should do the same—and always follow your teacher's instructions.

In Case of Accident

Even when you follow the rules, accidents can happen. Immediately alert your teacher if an accident occurs. Report all accidents, whether or not you think they are serious.

Lesson Summary

- Lab safety symbols warn of specific hazards, such as flames or broken glass. Knowing the symbols allows you to recognize and avoid the dangers.
- Following basic safety rules, such as wearing safety gear, helps prevent accidents in the lab and in the field.
- All accidents should be reported immediately.

Lesson Review Questions

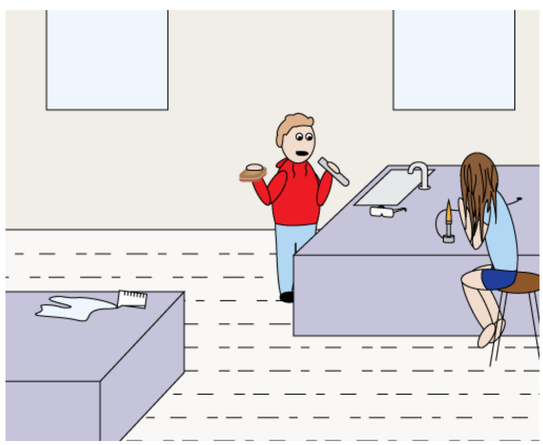
Recall

1. Look at the safety symbol in the picture below. What hazard does it represent?

2. Identify three safety rules that help prevent accidents in the lab.

Apply Concepts

3. Examine this sketch of students working in a lab. Identify at least three lab safety rules they are breaking.



Think Critically

4. Assume you are a field researcher studying ants. What risks might you face? How could you reduce or avoid these risks?

Points to Consider

In this chapter, you learned that life science is the study of life and living things.

1. What separates life from nonlife?
2. What characteristics define living organisms?

1.6 References

1. Heath, Ralph C.. The water cycle . Public Domain
2. USHHS. Bacteria on a gel . Public Domain
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