CK-12 Life Science For Middle School

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CHAPTER 1

Studying the Life Sciences

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Printed: April 30, 2014

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CHAPTER 1

Studying the Life Sciences

1.1 Scientific Ways of Thinking

Lesson Objectives

- Describe the role of a scientist.
- Understand that science is a system based on evidence, testing, and reasoning.

Vocabulary

- evidence
- experiment

Modern Science

Modern science is:

- A way of understanding the physical world, based on observable evidence, reasoning, and repeated testing.
- A body of knowledge that is based on observable evidence, experimentation, reasoning, and repeated testing.

Thinking Like a Scientist

How can you think like a scientist?

- **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 will ask, "What differs between the two environments where the chimpanzees live?" and "Are there differences in behavior between the two chimps that allow one group to survive over another?"

- **Scientists make detailed observations:** A person untrained in the sciences may observe, "The chimps on one side of the jungle are dying, while chimps on the other side of the jungle are healthy." Can you think of ways to make this observation more detailed? What about the number of chimps? Are they male of female? Young or old? A good scientist may observe, "While all seven females and three 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 have died." Detailed observations can ultimately help scientists to design their experiments and answer their questions.

- **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 a hypothesis 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.

1.2 What Are the Life Sciences?

Lesson Objectives

- Define Life Science.
- Describe how evidence is used to create and support scientific theories.

Vocabulary

- cell theory
- life science
- scientific theory
- theory of evolution

Fields in the Life Sciences

The life sciences are the study of living organisms, and how they interact with each other and their environment.

Life sciences deal with every aspect of living organisms.

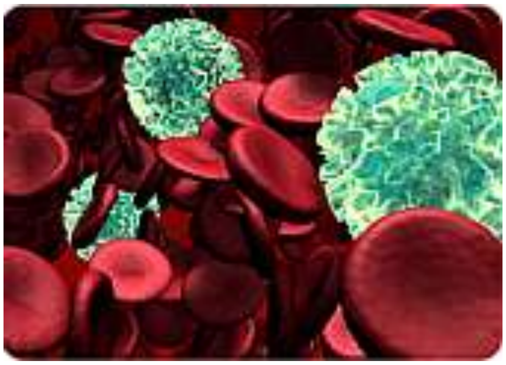
The life sciences are so complex that most scientists focus on just one or two subspecialties. If you want to study insects, what would you be called? An entomologist. If you want to study the tiny things that give us the flu, then you need to enter the field of virology. Look at Table 1.1, Table 1.2,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

TABLE 1.1: Subspecialties that focus on one type of organism

Subspecialty	Studies
Botany	plants
Zoology	animals
Marine biology	organisms living in and around oceans, and seas
Fresh water 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: Fields of life sciences that examine the structure, function, growth, development and/or evolution of living things	
Life Science	**What it Examines**
Cell biology	cells and their structures
Anatomy	the structures of animals
Physiology	the physical and chemical functions of tissues and organs
Morphology	the form and structure of living organisms
Immunology	the mechanisms inside organisms that protect them from disease and infection
Neuroscience	the nervous system
Developmental biology and embryology	the growth and development of plants and animals
Genetics	the genetic make up of all living organisms (heredity)
Biochemistry	the chemistry of living organisms
Molecular biology	biology at the molecular level
Epidemiology	how diseases arise and spread

TABLE 1.3: Fields of biology that examine the distribution and interactions between organisms and their environments	
Life Science	**What it Examines**
Ecology	how various organisms interact with their environments
Biogeography	the distribution of living organisms
Population biology	the biodiversity, evolution, and environmental biology of populations of organisms

	
This illustration shows red blood cells and a virus. - **Virology** is the study of viruses. - **Cell biology** is the study of cells. Though virology can be considered a life science, are viruses in fact living?	**Biogeography** looks at the variation of life forms within a given ecosystem, biome, or for the entire Earth. In other words, it tries to explain where organisms live and at what abundance.

Scientific Evidence and Theories in the Life Sciences

Scientists perform experiments and collect evidence. Evidence is:

1. A direct, physical observation of a thing, a group of things, 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 theory of gravity. A bear skeleton in the woods would be evidence of the presence of bears.

Scientific theories are well established and tested explanations of observations or evidence. Scientific theories are produced through repeated experiments. Theories are usually tested and confirmed by many different people.

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.

Two Important Life Science Theories

In the many life sciences, there are possibly hundreds or thousands of theories. The field of modern biology, however, really depends on two especially significant theories. They are:

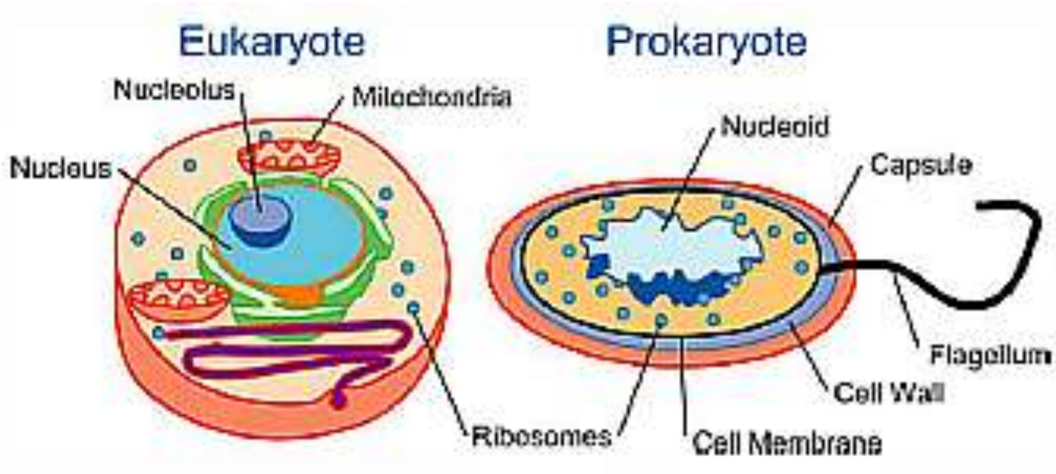
1. The Cell Theory
2. The Theory of Evolution.

The Cell Theory

The Cell Theory states that:

1. All organisms are composed of cells.
2. Cells are the basic units of structure and function in an organism.
3. Cells only come from preexisting cells; life comes from life.

The development of the microscope in the mid 1600s made it possible for scientists to develop this theory.



*The two types of cells, **eukaryotic** (left) and **prokaryotic** (right).*

The Theory of Evolution

The Theory of Evolution explains how populations of organisms can change over time. It also explains why there are many different types of organisms on Earth. This theory is often called the "great unifier" of biology, because it applies to every field of biology. It also explains how all living organisms on Earth come from common ancestors. You will learn more about the details of the theory of evolution in later chapters.

Lesson Summary

- Science is a way of understanding about the physical world.
- Science is based on evidence, reasoning, and testing predictions.
- Information that has been thoroughly tested can still undergo further testing and revisions, as new evidence and questioning are raised.

- Science differs from other ways of knowing because it is entirely based on observable evidence.
- Scientific explanations are constantly questioned and tested.
- Science produces theories and general knowledge.
- Science allows us to better understand the world.
- Science allows us to apply this knowledge to solve problems.

Review Questions

Recall

1. What do all fields of life science have in common?
2. What are the three characteristics of evidence?
3. What is the goal of science?

Apply Concepts

4. What would you study if you were a biogeographer?
5. Why do you think the development of microscopes led to the development of the Cell Theory?

Think Critically

6. What do you think the difference is between a theory and a set of observations?
7. If all cells come from pre-existing cells, where do you think the first cells came from?

1.3 The Scientific Method

Points to Consider

Next we discuss the scientific method.

- How does thinking like a scientist allow us to answer questions about life?
- What is the difference between science completed in a laboratory and science completed outside?

Lesson Objectives

- Describe the scientific method as a process.
- Explain why the scientific method allows scientists and others to examine the physical world more objectively than other ways of knowing.
- Describe the steps involved in the scientific method.

Vocabulary

- applied science
- basic science
- hypothesis
- scientific method

The Scientific Method

The scientific method is a process used to investigate the unknown. 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. Why do you think it is important that scientists reproduce each other's experiments? Almost all versions of the scientific method include the following steps, though not always in the same order:

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
7. Communicate your results

Making Observations

Imagine that you are scientist. While collecting water samples at a local pond, you notice a frog with five legs instead of four (Figure 1.8).

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.

A frog with an extra leg.

The next step is to ask a question about the frogs. You may ask, "Why are so many frogs are 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?"

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.

Construct a Hypothesis

A hypothesis is an educated guess 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."

Test Your Hypothesis

To test the hypothesis, 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. Here is an example of a hypothesis that is not testable: "The frogs are deformed because someone cast a magic spell on them." You cannot test a magic hypothesis or measure any results of magic. 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.

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. See Table 1.4 for the experimental results.

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 tell whether your hypothesis is true or false. If a hypothesis is true, scientists will often continuing 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.

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 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.

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 cell or a whole ecosystem. Basic science is the source of most scientific theories and new knowledge. For example, a scientist that tries to find the right drug to treat brain injuries is performing basic science. Applied science is using scientific discoveries to solve practical problems. Applied science also creates new technologies. For example, medicine and all that is known about how to treat patients is applied science based on basic research. A doctor administering a drug or performing surgery on a patient is an example of applied science.

Lesson Summary

- The scientific method is a process used to investigate questions.
- The scientific method uses observable evidence and testing.
- A hypothesis is a proposed explanation of an observation; it is used to test an idea.
- A hypothesis must be written in a way that can be tested, can be proved false, can be measured, and will help answer the original question.
- Basic research produces knowledge and theories.
- Applied research uses knowledge and theories from basic research to develop solutions to practical problems.

Review Questions

Recall

1. What does a hypothesis need to include?
2. What does "falsifiable" mean?
3. List the steps of the Scientific Method.

Apply Concepts

4. How is a hypothesis different from a theory?
5. A doctor treats a patient with HIV with a new anti-viral drug. Is this an example of basic or applied science?

Think Critically

6. What does a scientist do if their research contradicts previous theories or popular knowledge?
7. A field scientist studies mice and observes that mice in the desert have fewer offspring (children) than mice in the forest. She hypothesizes that mice in the desert have access to less water and therefore have fewer offspring to conserve the much-needed resource. Is this a testable hypothesis? Why or why not?

1.4 Tools of Science

Points to Consider

- How do you think scientific “tools” can help scientists?
- What do you think is one of the more common tools of the life scientist?

Lesson Objectives

- Describe the growing number of tools available to investigate different features of the physical world.
- Describe how microscopes have allowed humans to view increasingly small tissues and organisms that were never visible before.

Vocabulary

- electron microscope
- microscope
- microscopy
- optical (light) microscope
- scanning acoustic microscope
- scanning electron microscope (SEM)
- transmission electron microscope (TEM)

Using Microscopes

Microscopes, tools that you may get to use in your class, are some of the most important tools in biology (Figure 1.11). 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?

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. That was the forerunner of the compound microscope and of the telescope. Later, the father of microscopy, Dutch scientist Antoine van Leeuwenhoek taught himself to make one of the first microscopes.

FIGURE 1.11

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

See if you can identify the following parts of the microscope:

1, ocular lens or eyepiece;
2, objective turret;
3, objective lenses;
4, coarse adjustment knob;
5, fine adjustment knob;
6, object holder or stage;
7, mirror or light (illuminator);
8, diaphragm and condenser.

A microscope is a tool used to make things that are too small to be seen by the human eye look bigger. Microscopy is a technology for studying small objects using microscopes.

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. Inside of cork, he discovered the smallest building blocks of life, or cells (Figure 1.13 and Figure 1.14). 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. In one of his early experiments, van Leeuwenhoek took a sample of scum from his own teeth and used his microscope to discover bacteria, one of the tiniest living organisms on the planet. Using microscopes, van Leeuwenhoek also discovered one-celled organisms (protists) and sperm.

Some modern microscopes use light, as Hooke’s and van Leeuwenhoek’s did, but others may use electron beams or sound waves.

Researchers now use these 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 refractive 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 ("high resolution").

3. **Scanning electron microscopes** (SEM) (Figure 1.15 and Figure 1.16) 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 shapes of objects.

4. **Scanning acoustic microscopes** use sound waves to scan a specimen. These microscopes are useful in biology and medical research.

FIGURE 1.15
A scanning electron microscope.

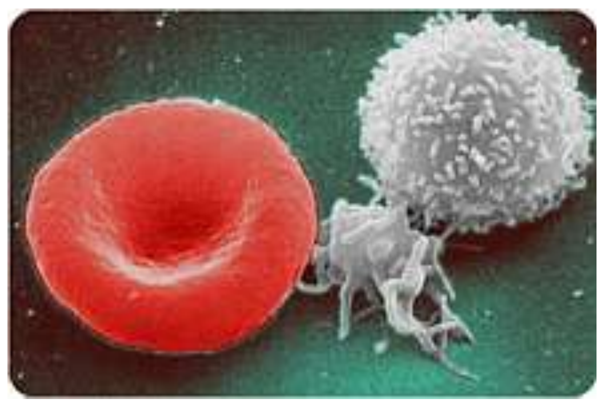


FIGURE 1.16
A scanning electron microscope image of blood cells.

Other Life Science Tools

What other kinds of tools and instruments would you expect to find in a biologist's laboratory or field station? Other than computers and lab notebooks, biologists use very different instruments and tools for the wide range of life science specialties. For example, a medical research laboratory and a marine biology field station might not use any of the same tools.

		
A radio telemetry device used to track the movement of falcons in the wild.	*A thermocycler used for molecular biological and genetic studies.*	*A sterile laboratory chamber. This laboratory inoculation hood allows researchers to conduct experiments in sterile environments.*

Tools such as a radio telemetry devices, thermocyclers, and inoculation (sterile) hoods shown above are all biological equipment.

Using Maps and Other Models

People use models for many purposes. We use street maps to help us find our way around. A model of the solar system may show the relationship between the planets in space. Life scientists often use maps to show where different organisms live, or to learn about the climate of an area. Scientists use maps and models to explain observations and to make predictions. For example, if a scientist wants to study the effect of temperature on coral reefs, he or she would first consult a map of coral reef locations and then measure the temperature in those specific areas (Figure 1.18).

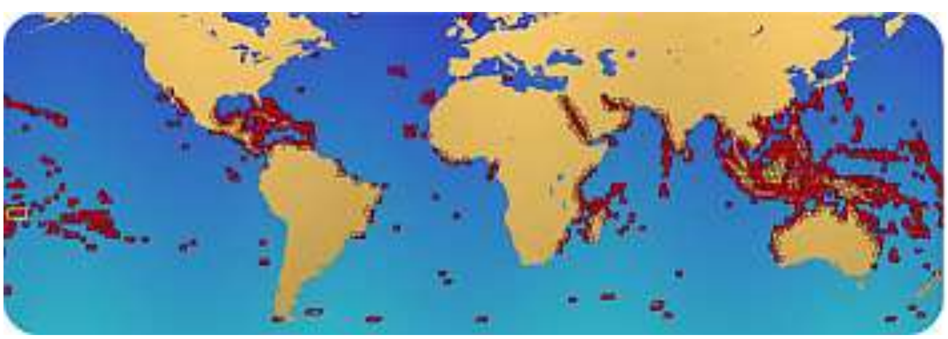


FIGURE 1.18
The above map shows where you can find coral reefs around the world. Coral reefs are shown in red.

Some models are used to show the relationship between different parts of an experiment, or variables.

For example, the graph in Figure 1.19 shows a model of a relationship between a population of coyotes (the predators) and a population of rabbits, which the coyotes eat (the prey).

It shows that when there are few coyotes, there are many rabbits (left side of the graph) and when there are only a few rabbits, there are many coyotes (right side of the graph).

You could make a prediction, based on this model, that removing all the coyotes from the ecosystem would result in an increase in rabbits. This is a good scientific prediction because it can be tested.

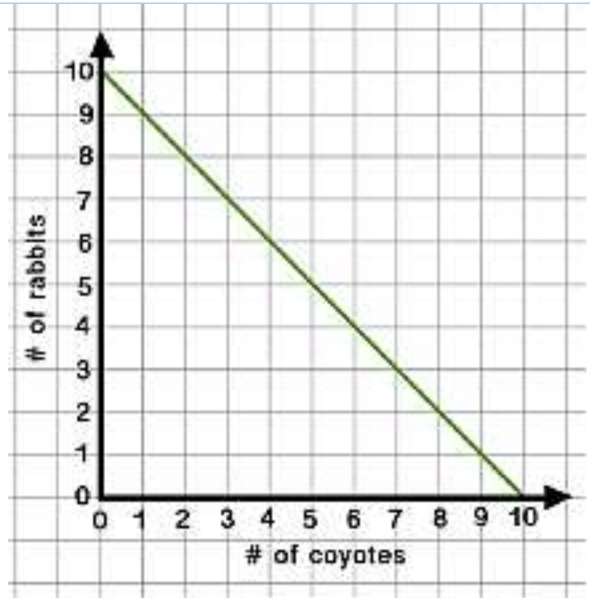


Figure 1.19

Lesson Summary

- From the time that the first microscope was built, over four hundred years ago, microscopes have been used to make major discoveries.
- Life science is a vast field; different kinds of research usually require very different tools.
- Scientists use maps and models to understand how features of real events or processes work.

Review Questions

Recall

1. What did van Leeuwenhoek discover when he looked at scum from his own teeth under the microscope?
2. What does the symbol 10X on the side of a microscope mean?
3. What is a scientific model?

Apply Concepts

4. Look at the predator/prey (coyote/rabbit) model in Figure 1.19. What does the model predict would happen to the rabbit population if you took away all of the coyotes?

Think Critically

5. If you want to describe all of the places on the planet where ants can survive, how would you display this information?
6. What tool might you use to keep track of where a wolf travels?

1.5 Safety in Scientific Research

Points to Consider

- What hazards may biologists face in the laboratory?
- What could be risks may biologists face who complete research outside?
- What do you think biologists do to protect themselves?

Lesson Objectives

- Recognize how the kind of hazards that a scientist faces depends on the kind of research they do.
- Identify some potential risks associated with scientific research.
- Identify how safety regulations protect scientists and the environment.

Vocabulary

- biohazard
- carcinogen
- field scientist
- teratogen

Types of Safety Hazards

There are some very serious safety risks in scientific research. When studying a science like chemistry, scientists need to make sure that they do not mix two explosive chemicals together. Since the life sciences deal with living organisms, some research may have risks not found in other fields. Safety practices must be followed when working with the following hazardous things:

- Disease-causing viruses, bacteria or fungi
- Parasites
- Wild animals
- Radioactive materials
- Pollutants in air, water, or soil
- Toxins
- Teratogens
- Carcinogens
- Radiation

The kinds of risks that scientists face depend on the kind of research they perform. For example, a bacteriologist working with bacteria in a laboratory faces different risks than a zoologist studying the behavior of lions in Africa. Think back to the deformed frogs discussed earlier. If there is something in the frogs' environment causing these deformities, could there be a risk to a researcher in that environment? A chemical in the pond that could cause such deformities is called a teratogen. If the chemical is causing deformities in frogs, could it cause deformities in humans? A scientist would most likely wear gloves and maybe even a mask when dealing with polluted water.

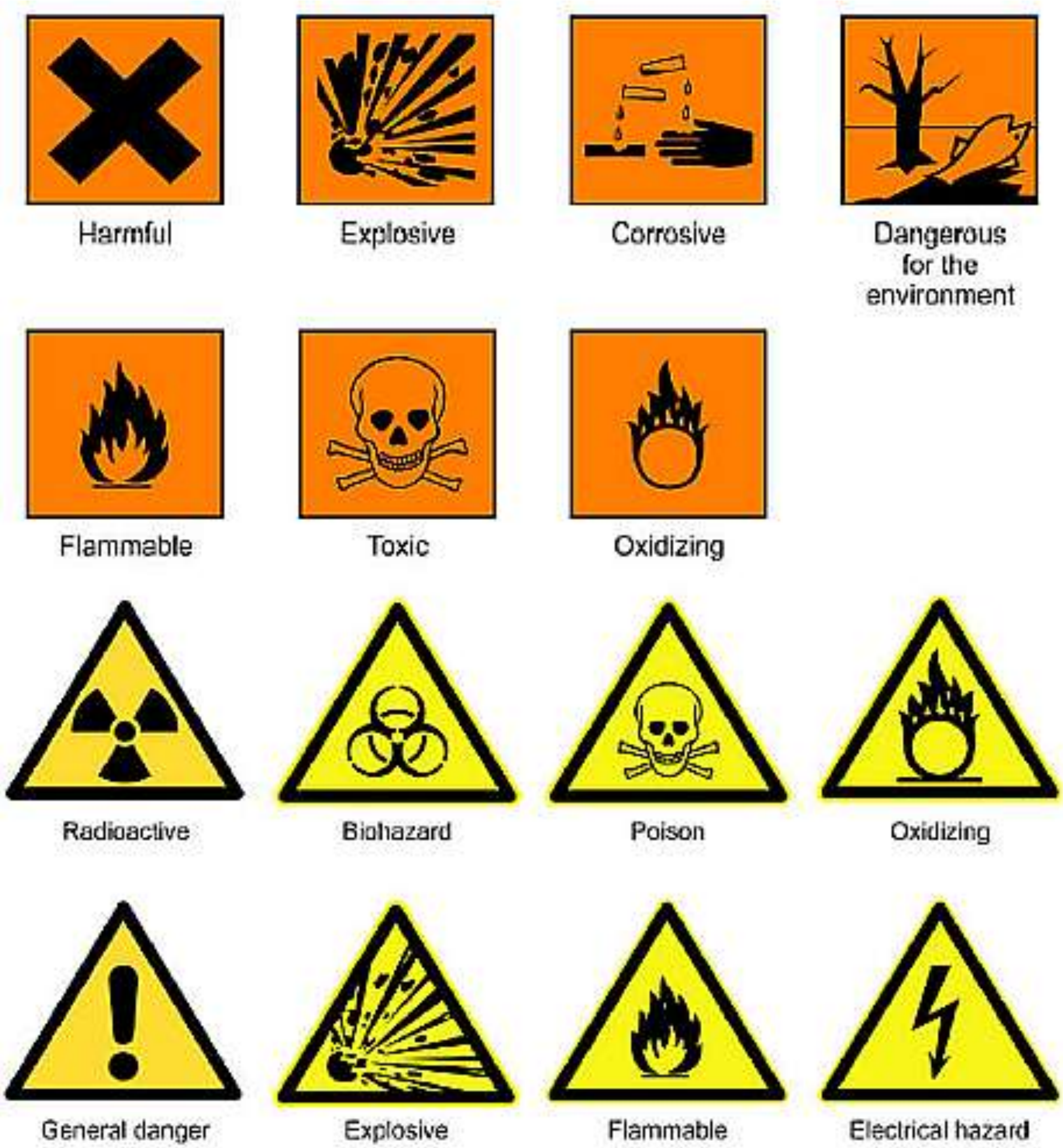


FIGURE 1.20
Science laboratory safety and chemical hazard signs.

Or perhaps a disease is causing the deformities. Viruses and bacteria are called biohazards. Figure 1.20 shows laboratory safety and chemical hazard signs. Biohazards include any biological material that could make someone sick. A used needle or laboratory bacteria are also biohazards.

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.

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 doing labs:

- Be sure to obey all safety guidelines given in lab instructions and your teacher.
- Follow directions carefully.
- Tie back long hair.
- Wear closed 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 and the lab supervisor must know if any materials are damaged or discarded.

Field Research Safety

Scientists who work outdoors, called field scientists, are also required to follow safety regulations designed to prevent harm to themselves, other humans, to animals, and the environment. In fact, 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 1.22) migrations between the United States and Mexico must follow regulations in both countries.

A Monarch butterfly.

Field scientists are also required to follow laws to protect the environment. Before biologists can study protected wildlife or plant species, they must apply for permission to do so, and obtain a research permit. For example, if scientists collect butterflies without a permit, they may unknowingly disturb the balance of the organism's habitat.

Lesson Summary

- Research of any kind may have safety risks. Because life scientists study organisms as diverse as bacteria and bears, they deal with risks that other scientists may never encounter.
- The risks scientists face depend on the kind of research they are doing.
- Scientists are required by federal, state, and local institutions to follow strict regulations designed to protect the safety of themselves, the public, and the environment.

Review Questions

Recall

1. What kinds of hazards might be found in biology laboratories, but not physics laboratories?
2. Who has more freedom to do whatever research they want? Laboratory scientists or field biologists?
3. What is a biohazard?
4. What is a research permit?

Apply Concepts

5. What are some of the precautions you might take if you were collecting frogs in water you think might be
1. polluted?
6. Name some possible hazards to field biologists.

Think Critically

7. You want to complete field research on the border between the United States and Mexico. Before you begin, what precautions should you take?