SECTION 2

Scientific Methods

Key Concept Scientific methods are used to investigate questions and to solve problems.

What You Will Learn

- Scientists ask questions, make observations, form hypotheses, test hypotheses, analyze results, and draw conclusions.
- Scientists communicate their steps and results from investigations in written reports and oral presentations.

Why It Matters

You can use scientific methods to investigate your questions about the natural world.

Vocabulary

- scientific methods
- hypothesis
- controlled experiment
- variable

READING STRATEGY

Outlining In your **Science Journal,** create an outline of the section. Use the headings from the section in your outline.

Investigation and Experimentation

7.7.c Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.

7.7.e Communicate the steps and results from an investigation in written reports and oral presentations.

Imagine that your class is on a field trip to a wildlife refuge. You discover several deformed frogs. You wonder what is causing the deformities.

A group of students from Le Sueur, Minnesota, actually made this discovery! By making observations and asking questions about the observations, the students used scientific methods.

What Are Scientific Methods?

When scientists observe the natural world, they often think of questions or problems. But scientists don't guess the answers. They use scientific methods. **Scientific methods** are the ways in which scientists follow steps to answer questions and solve problems. The steps used for all investigations are the same. But the order in which the steps are followed may vary, as **Figure 1** shows. Scientists may use all of the steps or just some of the steps during an investigation. They may even repeat some of the steps. The order depends on what will work best to answer their questions. No matter where they work or what questions they try to answer, all life scientists have two things in common. They are curious about the natural world, and they use similar methods to investigate it.

Standards Check What are scientific methods? 7.7.c

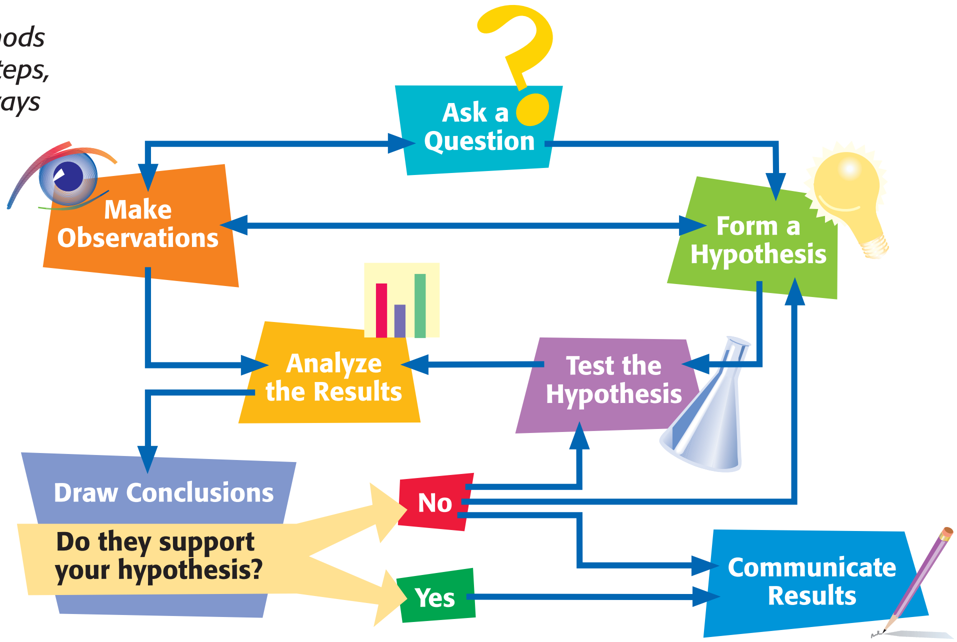


Figure 1 *Scientific methods often include the same steps, but the steps are not always used in the same order.*

Ask a Question

Have you ever observed something that was out of the ordinary or difficult to explain? Such an observation usually raises questions. For example, you might ask, "Could something in the water be causing the frogs' deformities?" Looking for answers may include making more observations.

Make Observations

After the students from Minnesota realized something was wrong with the frogs, they decided to make additional, careful observations. They counted the number of deformed frogs and the number of normal frogs that they caught. The students also photographed the frogs, took measurements, and wrote a detailed description of each frog.

In addition, the students collected data on other organisms living in the pond. They also conducted many tests on the pond water, measuring things such as the level of acidity. The students carefully recorded their data and observations. Observations are only useful if they are accurately made and recorded.

Types of Observations

Any information gathered through the senses is an observation. Observations can take many forms. They may be measurements of length, volume, time, speed, or loudness. They may describe the color or shape of an organism. Or they may describe the behavior of organisms. Scientists use many standard tools and methods to make and record observations. Examples of these tools are shown in **Figure 2.**

INTERNET ACTIVITY

Careers in Life Science

Would you like to be a life scientist? Write an essay on your investigation of an interesting career. Go to **go.hrw.com** and type in the keyword HY7LIVW.

scientific methods
(SIE uhn TIF ik METH uhds) a series of steps followed to solve problems

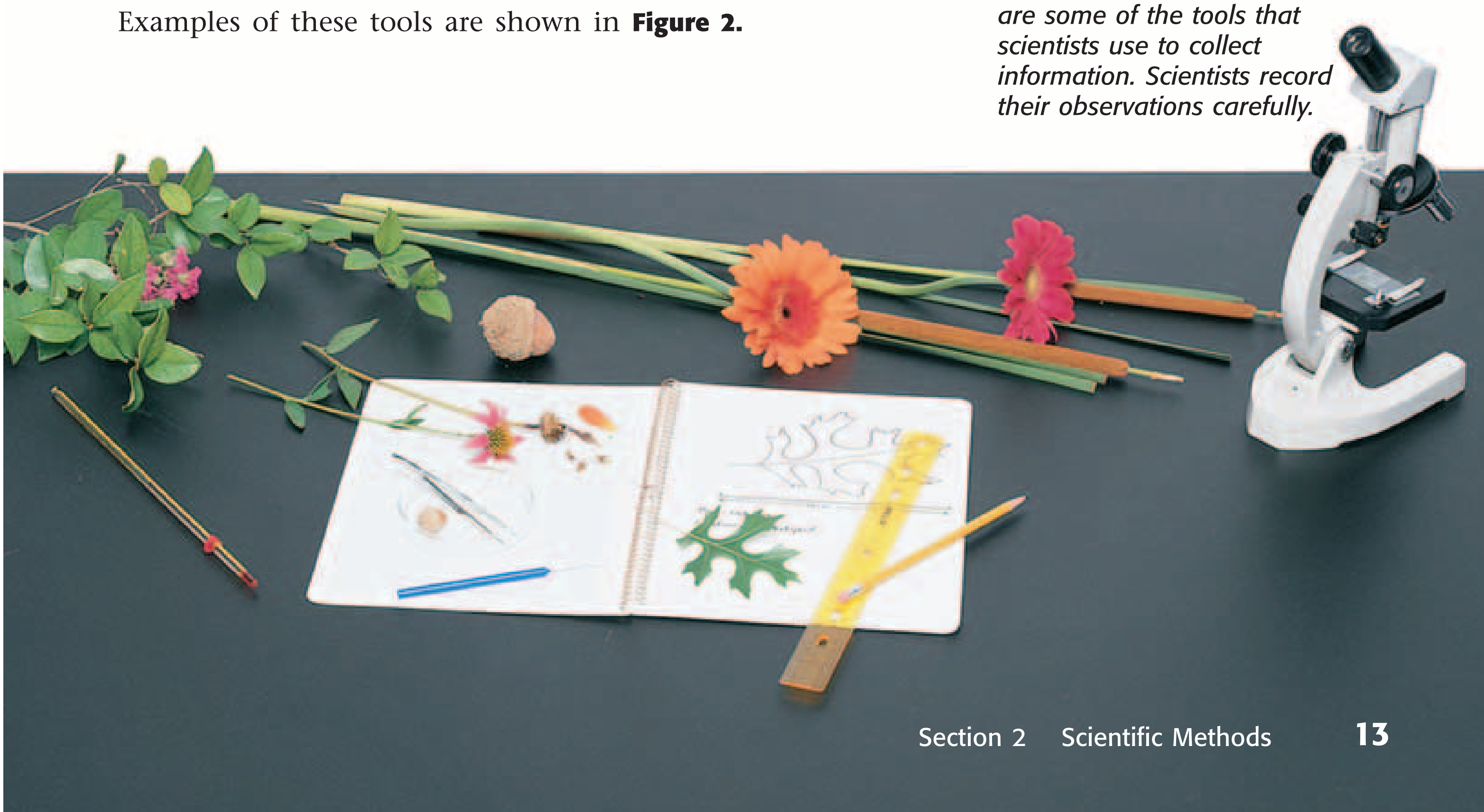


Figure 2 *Microscopes, rulers, and thermometers are some of the tools that scientists use to collect information. Scientists record their observations carefully.*

Form a Hypothesis

hypothesis (hi poth es is) a testable idea or explanation that leads to scientific investigation

Wordwise The prefix *hypo-* means "under." The root *thesis* means "proposition." Other examples are *hypodermic* and *hypoallergenic.*

After asking questions and making observations, scientists may form a hypothesis. A **hypothesis** (hie PAHTH uh sis) is a possible explanation or answer to a question. A good hypothesis is based on observations and can be tested. When scientists form hypotheses, they think logically and creatively and consider what they already know.

Scientists thought about the different things that could be affecting the frogs. Some chemicals can be dangerous to living things. Maybe chemicals used in agriculture and industry had been washed into ponds. Some parasites can cause diseases that produce deformities. Maybe small parasites in the water were attacking the frogs. Large amounts of ultraviolet (UV) light can cause damage in living things. Maybe human activity had damaged the ozone layer, which was letting in more UV light from the sun. Chemical pollutants, parasites, or UV light were possible explanations for the deformities seen in frogs.

Scientists used their observations and reasoning to form the hypotheses in **Figure 3.** Were any of these explanations correct? To find out, scientists had to test each hypothesis.

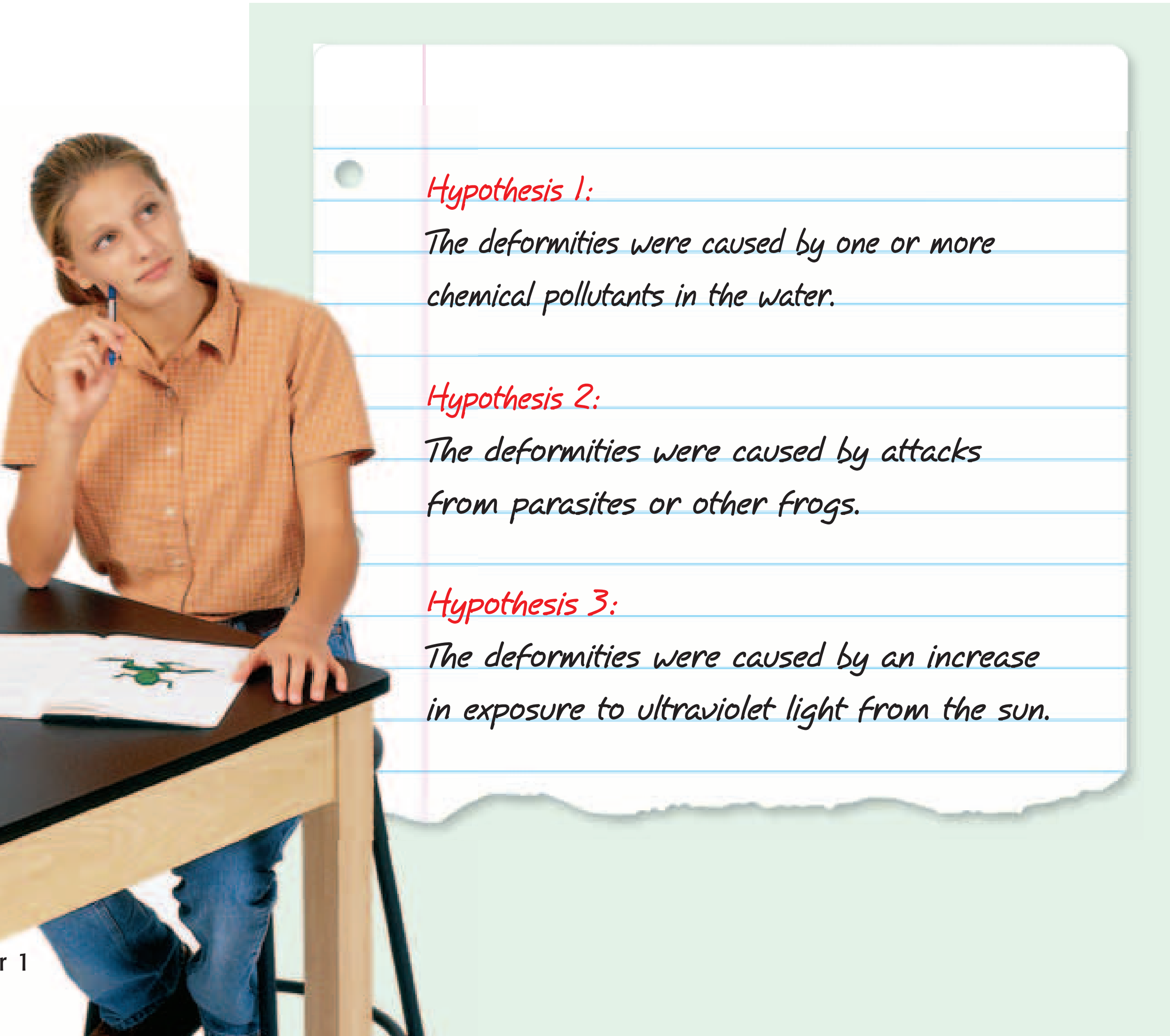


Figure 3 *A single question may lead to more than one hypothesis.*

Predictions

Before scientists can test a hypothesis, they must first make predictions. A prediction is a statement of cause and effect that can be used to set up a test for a hypothesis. Predictions are usually stated in an if-then format, as shown in **Figure 4.**

More than one prediction may be made for each hypothesis. For the hypotheses on the previous page, the predictions in **Figure 4** were made. A prediction for hypothesis 3 is as follows: If an increase in exposure to UV light is causing the deformities, then frog eggs exposed to more ultraviolet light in a laboratory will be more likely to develop into deformed frogs than frog eggs that are exposed to less UV light will.

Scientists can conduct experiments to see whether the results match the predictions of the hypothesis. Sometimes, the results clearly match the predictions of one hypothesis. At other times, the results may not have been predicted by any of the hypotheses. In these cases, new hypotheses and new tests are needed.

Standards Check **What is the connection between hypotheses and the tests that are conducted in an investigation?** 7.7.c

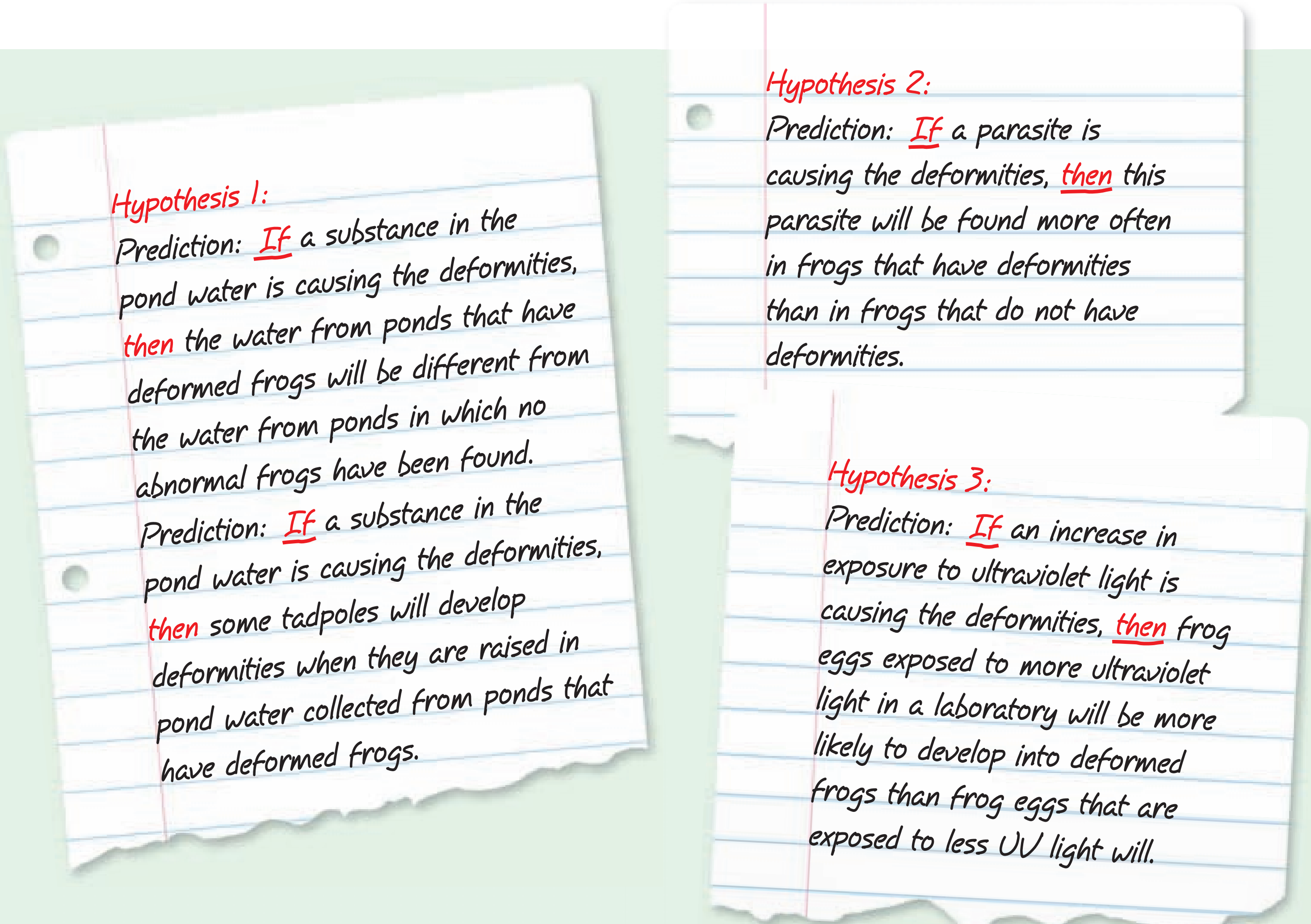


Figure 4 *A single hypothesis may lead to more than one prediction.*

Test the Hypothesis

Scientists try to design experiments that will show whether a particular factor caused an observed outcome. A *factor* is anything in an experiment that can influence the experiment's outcome. Factors can be anything from temperature to the type of organism being studied. Many factors affect the development of frogs in the wild, as **Figure 5** shows.

To study the effect of each factor, scientists perform controlled experiments. A **controlled experiment** tests only one factor at a time and consists of a control group and one or more experimental groups. All of the factors for the control group and the experimental groups are the same except for one. The one factor that differs is called the **variable.** Because the only difference between the control group and the experimental groups is the variable, any differences observed in the outcome of the experiment are probably caused by the variable.

Figure 5 *Many factors affect this tadpole in the wild. These factors include chemicals, light, temperature, and parasites.*

controlled experiment (kuhn TROLD ek SPER uh muhnt) an experiment that tests only one factor at a time by using a comparison of a control group with an experimental group

variable (VER ee uh buhl) a factor that changes in an experiment in order to test a hypothesis

Designing an Experiment

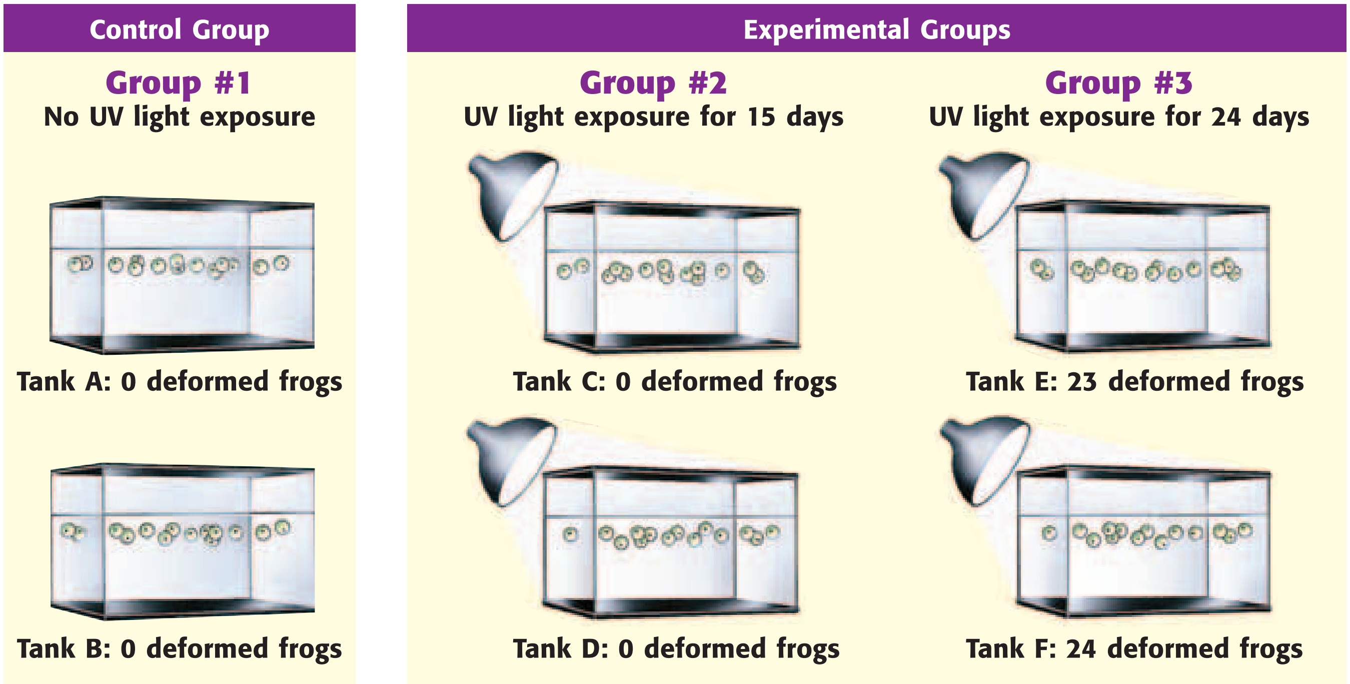
Every factor must be considered when designing an experiment. Scientists must also use ethics guidelines when designing and conducting an experiment. Examine the prediction for Hypothesis 3: *If an increase in exposure to ultraviolet light is causing the deformities, then frog eggs exposed to more ultraviolet light in a laboratory will be more likely to develop into deformed frogs than frog eggs that are exposed to less UV will.* An experiment to test this hypothesis is summarized in **Table 1.**

In the experiment shown in **Table 1,** the variable is the length of time that the eggs are exposed to UV light. All other factors, such as the temperature of the water, are the same in the control group and in the experimental groups. Because the experiment requires the use of animals, scientists use compassion when they care for the frogs in the experiment.

Table 1 Experiment to Test Effect of UV Light on Frogs

Group	Control Factors				Variable
	Tank	Kind of frog	Number of eggs	Temperature of water (°C)	UV light exposure (days)
#1 (control)	A	leopard frog	50	25	0
	B	leopard frog	50	25	0
#2 (experimental)	C	leopard frog	50	25	15
	D	leopard frog	50	25	15
#3 (experimental)	E	leopard frog	50	25	24
	F	leopard frog	50	25	24

Figure 6 **UV Light Experiment**



Collecting Data

As **Table 1** shows, each group in the experiment contains 100 eggs. Scientists always try to test many individuals. The greater the number of organisms that they test, the more certain they can be of the data. They want to be certain that differences between control and experimental groups are caused by differences in the variable, not by differences between individuals. To support their conclusions, scientists repeat their experiments. If an experiment produces the same results again and again, they can be more certain about the effect of the variable on the outcome of the experiment. The experimental setup to test Hypothesis 3 and the results are shown in **Figure 6.**

Analyze the Results

A scientist's work does not end when an experiment is finished. After scientists finish their tests, they must analyze the results. They organize the data so that the data can be analyzed. For example, scientists may organize the data in a table or a graph. The data collected from the UV light experiment are shown in the bar graph in **Figure 7.** Analyzing results helps scientists explain and focus on the effect of the variable. For example, the bar graph shows that the length of UV exposure has an effect on the development of deformities in frogs.

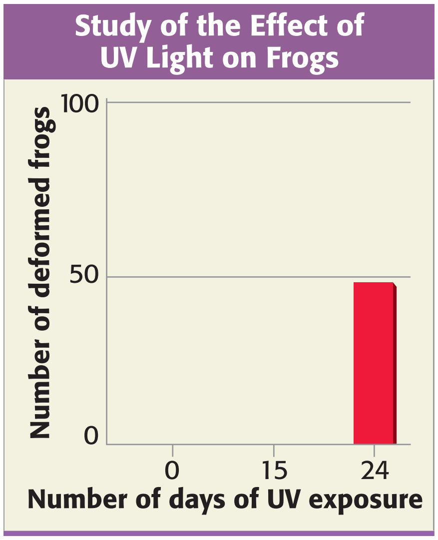


Figure 7 *This graph shows that 24 days of UV exposure had an effect on deformities in frogs. Shorter exposure had no effect.*

Quick Lab

Investigating and Experimenting with Yeast

7.7.c

1. Mix **1/2 tsp of yeast** with **warm water** and **sugar.**
2. Make observations. Compose a list of questions about the factors that influence yeast to activate.
3. Use scientific methods to investigate yeast activation. For this investigation, you will need to form a hypothesis, design and conduct an experiment to test the hypothesis, analyze and collect data, and state the conclusions.
4. Did your results support your hypothesis?

30 min

Draw Conclusions

After scientists have analyzed the data from several experiments, they can draw conclusions. They decide whether the results of the experiments support a hypothesis. When scientists find that a hypothesis is not supported by the tests, they must try to find another explanation for what they have observed. Proving that a hypothesis is wrong is just as helpful as supporting it. Why? The scientist have learned something, which is the purpose of using scientific methods.

What Is the Answer?

The UV light experiment supports the hypothesis that the deformities in frog can be caused by exposure to UV light. Does the experiment prove that UV light caused the frogs living in the Minnesota wetland to be deformed? No, the only thing this experiment shows is that UV light may cause deformities in frog. Results of tests performed in a laboratory may differ from results of tests performed in the wild. In addition, the experiment did not investigate the effects of parasites or other substances on the frogs. In fact, more than one factor could be causing the deformities.

Puzzles as complex as the deformed-frog mystery are rarely solved with a single experiment. The quest for a solution may continue for years. Finding an answer doesn't always end an investigation. Often, that answer begins another investigation. In this way, scientists continue to build knowledge.

Figure 8 *This student scientist is communicating the results of his investigation at a science fair.*

Communicate Results

After they complete an investigation, scientists communicate their steps and results. Written reports and oral presentations are two ways in which scientists share information. **Figure 8** shows a student explaining a science project.

There are several reasons that scientists regularly share their results. First, other scientists may repeat the experiments to see if they get the same results. Second, the information can be considered by other scientists with similar interests. The scientists can then compare hypotheses and form consistent explanations. New data may strengthen existing hypotheses or show that the hypotheses need to be altered. After learning about an experiment, a scientist might have questions and decide to perform his or her own investigation.

Standards Check **Why do scientists communicate the results of their investigations?** 7.7.e