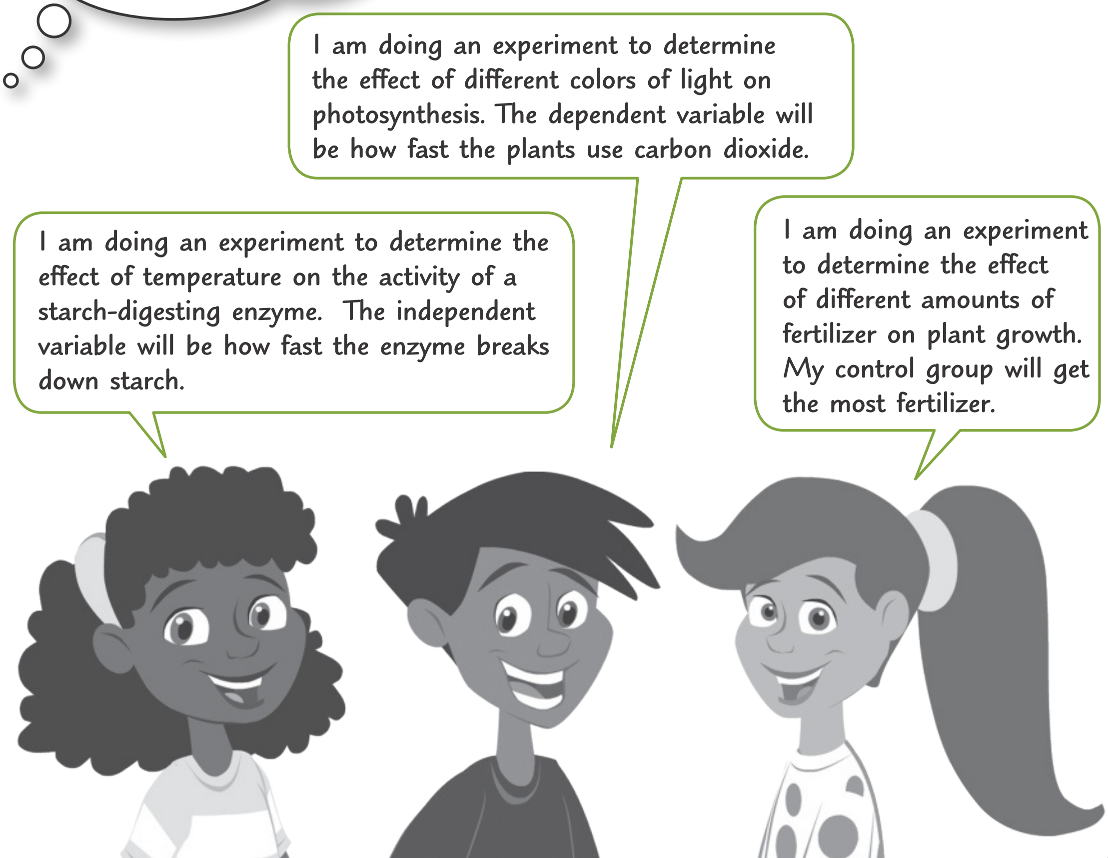
Scientific Inquiry and Skills

TOPIC 8

What do You Think?

Experimental Design



TOPIC

8 Scientific Inquiry and Skills

Vocabulary

assumption	dependent variable	model
bias	evidence	observation
conclusion	experiment	opinion
control	hypothesis	peer review
controlled experiment	independent variable	research plan
data	inference	scientific literacy

Topic Overview

Science is both a body of knowledge and a way of knowing things. Through intellectual and social activities, human thinking is applied to discovering and explaining how the world works. Science originates when people ask questions. Scientists use scientific inquiry and skills to seek answers to questions about the world. This involves formulating hypotheses, designing and conducting experiments, collecting data, and analyzing the data to form conclusions. Scientists also rely on peer review by other scientists to confirm the validity of their results.

What Is Science?

At one time, "scientific" knowledge was just a collection of opinions and unrelated ideas attempting to explain observations. For example, many people gazing out over the ocean were certain that Earth was flat as shown in Figure 8-1. A few individuals were equally sure that Earth was round. The topic was hotly debated. Those believing that Earth was flat offered for **evidence** (support for the idea that something is true) the fact that some ships never returned home. They believed that these ships had been destroyed when they sailed over Earth's edge. Those who believed that Earth was round also had evidence. They had observed boats approaching land and noticed that the tops of the sails were visible before the hull of the boat.

Another common idea once was that living organisms could come from nonliving things. Some people believed that when conditions were just right, frogs formed from the mud, water, and gases in the bottom of a pond. People also thought that if you left some grain and a dirty shirt in a wooden box, mice would develop after a period of time. Many people were certain that reproduction was not necessary for life to form. This idea, too, was discussed and debated.

Today, scientists do more than debate whether or not a new opinion or idea seems to make sense. They develop explanations using observations as evidence. New information is combined with what people already

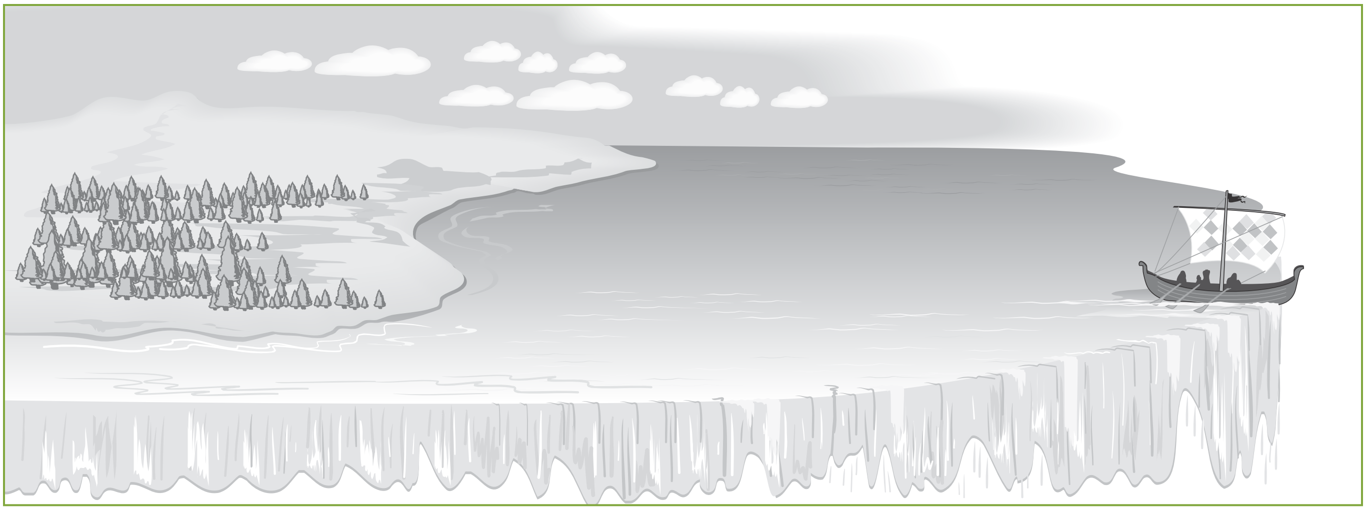


Figure 8-1. Ships at sea: At one time a flat Earth seemed to make sense.

know. Learning about the historical development of scientific concepts and about the individuals who have contributed to scientific knowledge helps people understand the thinking that has taken place. At first, it might seem silly to believe that Earth is flat, but based on observations made at the time and the tools available at the time, it's not surprising that many people believed in a flat Earth. The emergence of life from pond mud seemed equally reasonable.

Scientific Inquiry

Scientific investigation involves the following:

- questioning
- observing and inferring
- experimenting
- collecting and organizing data
- finding evidence and drawing conclusions
- repeating the experiment several times
- peer review

Questioning is at the heart of science. Progress in science depends on people who not only wonder how the world works but who also take the time to develop questions that can be tested and answered.

Observations and Inferences

Observations are things or events that are made using any of the senses or tools, such as thermometers, graduated cylinders, balances, or rulers. As more and better tools are developed, the ability of scientists to observe the natural world increases. For example, the invention of both the microscope (Figure 8-2) and, later, the electron microscope increased our ability to observe the structure of living organisms. This led to the realization that all living things are composed of cells.

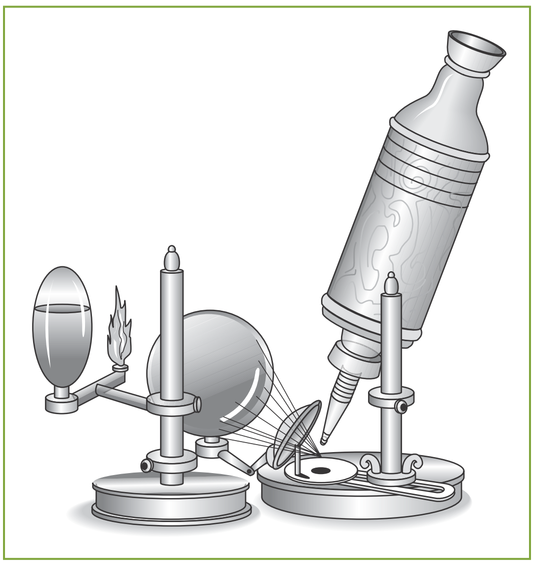


Figure 8-2. The microscope: With the invention of the microscope, scientists could finally observe microorganisms.

Inferences Conclusions or deductions based on observations are **inferences.** Inferences may be very subtle. An inference can also be thought of as an idea or conclusion based on the results of an experiment or observation. For example, you may infer that a slug that remains motionless for several hours is dead.

Assumptions A good experiment keeps assumptions to a minimum. An **assumption** is the belief that something is true. Assumptions also may be very subtle, and at first you may be unaware you are making them. For example, when doing a seed germination experiment, you might assume that all 100 seeds planted will germinate when watered and kept under favorable conditions. The idea that 100% of the seeds will grow is an assumption. An assumption that could be made during a slug feeding experiment is that slugs will eat every day if provided with desirable food.

Opinions Ideas people have that may or may not have any basis in fact are **opinions.** Opinions are often **biased,** or influenced by an assumption that may or may not be correct. Although everyone has opinions, which should be respected, a good way to avoid bias is to leave opinions out of data collection and analysis.

The Scientific View Understanding the scientific view of the world is essential to personal, societal, and ethical decision making. To think scientifically, you must critically analyze events, explanations, and ideas. You should use these skills—as well as ideas from other disciplines—to develop personal explanations of natural events. You should also create visual models and mathematical formulations to represent your thinking.

Keep in mind that asking questions to develop an explanation is a continuing and creative process. Sometimes conflicting explanations arise from the same body of evidence. For example, plants seem to grow better when talked to daily. Some explain this by crediting the voice or words. Others point out that simply breathing carbon dioxide on the plant helps it grow. Science is a search for the truth. Scientific thinking can keep you from being misled and making poor judgments.

Review Questions — Set 8.1

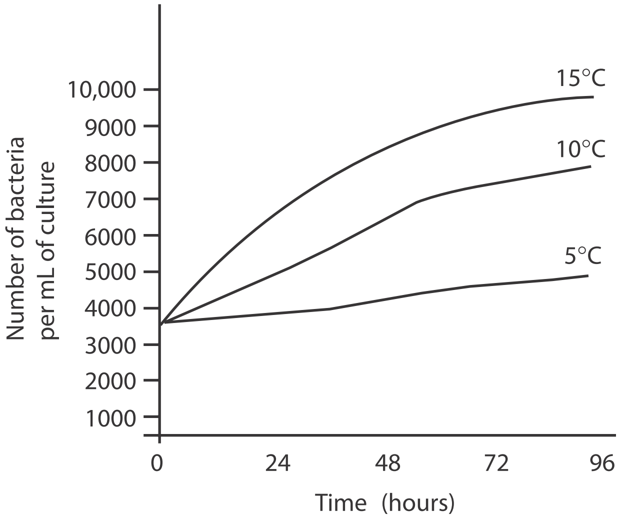
1. A student performed an experiment involving two strains of microorganisms, strain A and strain B, cultured in various temperatures for 24 hours. The results of this experiment are shown in the data table below.

Microorganism Growth and Temperature		
Temperature (°C)	Microorganism Growth (Number of Colonies)	
	Strain A	Strain B
25	10	11
28	10	7
31	11	3
34	12	0

Based on the results of the experiment, the student inferred that strain A was more resistant to higher temperatures than strain B was. What, if anything, must the student do for this inference to be considered a reasonable conclusion?

(1) nothing, because this inference is a valid scientific fact
(2) repeat this experiment several times and obtain similar results
(3) repeat this experiment several times using different variables
(4) develop a new hypothesis and test it

2. The graph below represents the results of an investigation of the growth of three identical bacterial cultures incubated at different temperatures.



Which inference can be made from the graph?

(1) Temperature is unrelated to the reproductive rate of bacteria.
(2) Bacteria cannot grow at a temperature of 5°C.
(3) Life activities in bacteria slow down at high temperatures.
(4) Refrigeration will most likely slow the growth of these bacteria.

3. A student prepared the following list of steps for performing a laboratory investigation. She omitted one important step for completing the investigation.

Steps to Follow in an Experiment
Define a problem.
Develop a hypothesis.
Select suitable lab materials and perform a controlled experiment to test the hypothesis.
Collect, organize, and graph the experimental data.
?

State the procedure that is missing in the chart. [1]

4. When heavy rains occur while apple orchards are in bloom, the apple crop the following fall is much smaller than normal. This information can best be described as

(1) an inference
(2) a hypothesis
(3) a prediction
(4) an observation

5. Which of the steps listed below would be first in a scientific investigation?

(1) Perform the experiment.
(2) Analyze the experimental data.
(3) Formulate a hypothesis.
(4) Define the problem to be investigated.

Inquiry Skills and Understandings

Everyone needs to understand certain concepts about science and inquiry. **Scientific literacy** involves applying critical thinking skills to everyday life, particularly to claims related to health, technology, and advertising. For example, imagine you are watching a television commercial with your family. The advertiser claims its company has developed a cream that makes hair grow when applied to the scalp. According to the commercial, people with thin hair or no hair have both used the cream with success.

Before rushing out to buy this product, you should think about the claims and begin to question some of what you heard. Next, think about how you can get answers to your questions. Then you should evaluate whether or not the information is to be believed. Here is a way to approach the problem:

1. *Inquiry involves asking questions, and locating, interpreting, and processing information from a variety of sources.*

You may begin by thinking about the following questions:

- How many people were tested?
- What is in the product?
- How long do you have to use it to get results?
- Does it have any side effects?

Next, you ask your friends, and no one knows anything about the product. You also find that your state's consumer product information agency has no information about the company or the hair growth product. Then, you may go to the Internet and find that the company has a Web page that claims 50% of the people using the product grew a full head of hair after ten applications.

Now ask yourself: Are you ready to use the product based on the information you have found? Do you know enough about the product to make an informed decision? You might want to find answers to more questions.

- How many people actually took part in the study? In other words, 50% of how many people grew hair?
- What caused the participants to have thinning hair or to be bald? Did they have a medical condition that needed attention?
- How long has the company been in business?
- Why hasn't the consumer information agency heard of them and their product?
- Was the cream tested scientifically with careful experimental techniques and design?

Keep in mind that careful scientific inquiry involves doing research to find answers to questions and explanations of natural phenomena. Much of the research in the hair product example was done by finding information without actually doing a laboratory investigation.

2. *Inquiry involves making judgments about the reliability of the source and relevance of information: Scientific explanations are accepted when they are consistent with experimental and observational evidence.*

When evaluating evidence and making decisions about how useful your information is, keep the following in mind.

- All scientific explanations are tentative. They can be changed or updated as new evidence emerges. What seems to be true today may be disproved tomorrow.
- Each new bit of evidence can create more questions than it answers. This leads to an increasingly better understanding of how things work.
- Good scientific explanations can be used to make accurate predictions about natural phenomena.
- Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations using conventional techniques and procedures. In other words, logic is not enough. Questions should be answered using a good experimental design and thoughtful interpretation.

For example, suppose you read in a magazine about a newly developed HIV vaccine that is said to be effective on monkeys. You should ask:

- Are these results preliminary and tentative, or are they the final results of extensive studies?
- How was the testing done? How many animals were used? For how long have they remained healthy?

- Is HIV in monkeys the same as HIV in humans? Is this the solution to the HIV epidemic in humans or just an early step?

3. *Answers can be found through a research plan and hypothesis testing.*

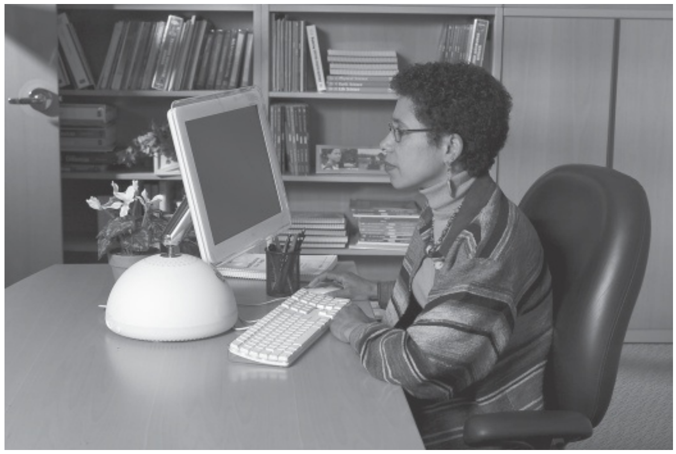


Figure 8-3. Research: A review of the literature must be done before the investigation can be designed. Useful resources include primary science journals, professional Web sites, and library databases.

Developing a Research Plan A **research plan** involves finding background information, developing a hypothesis, and devising an experimental process for testing a hypothesis. Before investing time and resources on research, it is important to find out what others have already learned. (See Figure 8-3.) Most research plans begin with a thorough library search. This search may include the use of electronic information retrieval (the Internet and library databases), a review of the literature (scientific journals), and feedback from the investigator's peers. This background work is done so that the researcher has a thorough understanding of the major concepts being investigated and any similar investigations.

Making Hypotheses Inquiry involves developing and presenting proposals, including formal hypotheses, to test explanations. A good **hypothesis** attempts to explain what has been observed in a way that can be tested. It is a tentative answer to a question. Experiments cannot prove a hypothesis; they can only either support the hypothesis or fail to support it.

Most hypotheses would make sense if the words "I think that" were added to the beginning of the statement. Try adding "I think that" to the beginning of each hypothesis in the following chart.

Examples of Hypothesis Statements
This hormone will make plants grow faster.
The presence of this chemical in our drinking water does not harm us.
If this hormone is applied to plant leaves, then the plant will grow faster.
If this chemical is safe, then it will not harm us when it is added to our drinking water.

A good hypothesis can also help determine the organization of an experiment as well as what data to collect and how to interpret those data. Testing a hypothesis is valuable even when the hypothesis is not supported by experimental results, since new information is gained in the process of testing any hypothesis.

Designing an Experiment

Once the background work has been done and the hypothesis developed, the actual experiment must be designed. An **experiment** is a series of trials or tests that are done to support or refute (disprove) a hypothesis.

Let's say that you suspect that applying the chemical IAA (a growth hormone) to plant leaves will increase the growth rate of the plant. Your hypothesis might read as follows: *If IAA is applied to the leaves of plants, then the plants will grow more rapidly than those that do not have IAA applied to their leaves.* Once you have written your hypothesis, you must make decisions about variables and experimental techniques.

The Dependent Variable What is it that you will measure? In this experiment, you will measure the effect of IAA on plants. What you will measure is called the **dependent variable,** since it depends on what you do to the plants. Since you asked about how the plants will grow, you will need to measure how large the plants are at the beginning as well as at regular intervals until the conclusion of the experiment. You will also have to decide how to make the measurements. Will you measure only the height of the stem, or will you also measure the size of the leaves? What units will you use?

Independent Variables Factors that might influence the dependent variable are **independent variables.** This is the variable the investigation manipulates. If you are investigating the effect of IAA being applied to the leaves, you must decide on the concentration of IAA. How often will it be applied to the leaves, and how will you apply it? You may even decide to test several concentrations of IAA. In this example, the frequency of applications and the concentration of IAA are independent variables.

Controlling Variables How will you control the independent variables that might affect your interpretation of the results? A **control** is an established reference point used as a standard of comparison. It allows you to make comparisons that generate valid information. For example, you should start with plants that are of the same kind and are about the same age and size as in Figure 8-4. All of the plants should be healthy, grown in the same kind of soil, and provided with the same amount of water and light. If you neglect to control all independent variables, one or more of them may affect plant growth, and you may reach a false conclusion concerning IAA.

A **controlled experiment** is one in which the possible variables have been carefully considered and regulated so the results are due only to the independent variable you are testing.

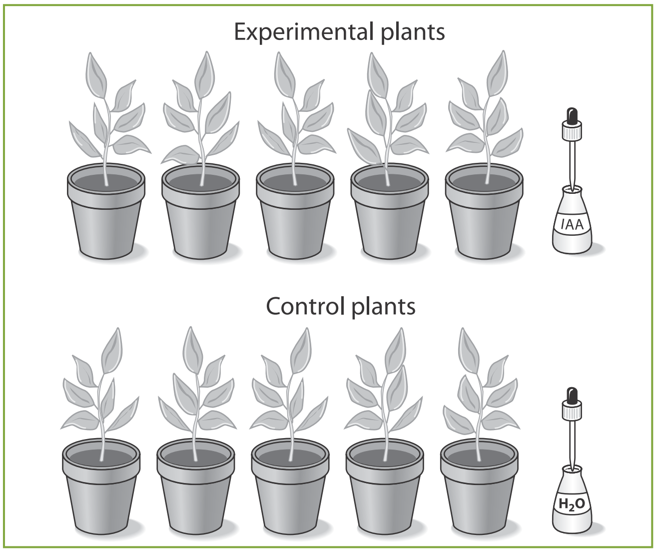


Figure 8-4. **Experimental controls: The control group will have distilled water applied to their leaves in place of IAA. It is important to apply something to the leaves of the control group or they would be treated differently in two ways from the experimental group. The plants will be the same type, size, and age as those in the experimental group. They will be grown in the same soil, with the same amount of light and water.**

Keep in mind that there should only be one variable being tested at one time. You can test different concentrations of IAA, or you can test the frequency of applying IAA, but you cannot test both on the same plants at the same time. You also cannot test both the impact of fertilizer AND the impact of IAA on the same plants at the same time.

Developing Experimental Techniques Selecting, acquiring, and building apparatus, as well as considering safety precautions and planning how to avoid bias, are important parts of this stage in the development of the research plan. For example, in the IAA study, you need to decide how many plants to use. Would one plant for each concentration of IAA be enough? Should you use 100 plants for each concentration? Think about these possibilities. With only one plant, genetic differences could cause variations in growth. Could one of the plants have been infected with a fungus while still an embryo? Would using multiple plants help to cancel out this type of problem? How many trials will you need?

Is one trial enough, or would five or six trials be better? Large sample sizes with repeated trials provide much more accurate information, and there is less probability of error due to chance. Large sample sizes and multiple trials are more likely to produce valid results.

When designing an experiment, think of the steps in the following Experimental Design Guide as a way to assist you in your planning. Remember that you should first formulate the question you want to answer or the problem you want to solve. Then review the literature to learn about the topic you are investigating.

Experimental Design Guide	
What is your hypothesis?	The hypothesis is a testable statement. It should suggest a possible answer to the question you are investigating.
What is your dependent variable?	What should change and/or be measured as a result of the experiment? Make a data table to record the data as they are collected.
What is your independent variable?	What is the treatment? Are you only changing one factor at a time to see its effect? Will there be several groups, with each testing one treatment—such as several pH values, colors of light, or temperatures?
Describe how you will control the experiment.	What other possible factors may vary that could also affect the results and make your experiment inconclusive?
What steps will you take to conduct this experiment?	Make a list of procedures and materials needed to conduct the experiment. Be sure to address safety issues.

Review Questions Set 8.2

6. A drug company tested a new medication before putting it on the commercial market. Pills without medication were given to 500 test subjects in group A, and pills with medication were given to 500 subjects in group B. In this experiment, the individuals in group A served as the

(1) host group (3) control
(2) dependent variable (4) hypothesis

7. In order to find the percentage of organic matter in soil from several different locations, a student collected the samples, weighed them immediately, roasted them for several minutes in a flame to burn off organic matter, and weighed them again. The student concluded that the difference between the first and second weights represented the weight of the organic matter in the soil. The most serious mistake that the student made in this experiment was in

(1) taking large samples
(2) weighing the samples before roasting them
(3) failing to dry the samples before first weighing them
(4) assuming that roasting could remove the organic matter

8. In an investigation to determine the effects of environmental pH on the germination of dandelion seeds, 25 dandelion seeds were added to each of five petri dishes. Each dish contained a solution that differed from the others only in its pH, as shown below. All other environmental conditions were the same. The dishes were covered and observed for 10 days. The data table the student designed is shown below.

The Effect of pH on Seed Germination

Petri Dish	pH of Solution	Number of Seeds Germinated
1	9	
2	8	
3	7	
4	6	
5	5	

State the independent variable in this investigation. [1]

Base your answers to questions 9 through 11 on the information below and on your knowledge of biology.

A student placed five geranium plants of equal size in five environmental chambers. Growing conditions were the same for each plant except that each chamber was illuminated by a different color of light of the same intensity. At the end of 20 days, plant growth was measured.

9. State a possible hypothesis for this experiment. [1]

10. What control should be used in this experiment? [1]

11. Describe one modification you would make in the design of this experiment to make the results more reliable. [1]

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12. A new drug for the treatment of asthma is tested on 100 people. The people are evenly divided into two groups. One group is given the drug, and the other group is given a glucose pill. The group that is given the glucose pill serves as the

(1) experimental group (3) control
(2) limiting factor (4) indicator

13. As part of a laboratory experiment, a thin slice of peeled raw potato weighing 10 grams is placed in an oven at 80°C. After 5 hours, the potato sample is removed from the oven and weighed again. The purpose of this experiment might be to

(1) test for the presence of starch in living tissues
(2) isolate cells in various stages of cell division
(3) determine the water content of potato tissue
(4) study the rate of photosynthesis in potatoes

14. Describe the function of a control group in an experiment. [1]

15. A student wants to shorten the ripening time for tomatoes. He predicts that the more water the seedlings receive, the faster the tomatoes will ripen. To test this prediction, he grows 20 tomato plants in a garden in full sunlight that has dry soil and 20 in a garden in a shadier location where there is greater moisture content in the soil. He then records the time it takes for fruit to develop and ripen on the plants in each garden location.

State a serious error the student made with the design of this experiment. [1]

16. In attempting to demonstrate the effectiveness of a new vaccine, a scientist performed these experimental procedures:

- One hundred genetically similar rats were divided into two groups of 50 rats each (group A and group B).
- Each rat in group A was given an injection of the vaccine in a glucose-and-water solution.
- Each rat in group B was given an injection of the glucose-and-water solution containing no vaccine.
- After several weeks, all rats in both groups were exposed to the disease for which the vaccine was developed.

Identify the dependent variable that was studied in this experiment. [1]

17. Scientists breed mice to be as genetically alike as possible to use in experiments. Explain why scientists would want mice that are genetically alike.

In your answer be sure to explain:

- The advantage of using genetically alike mice [1]
- Why cloned mice would be even better [1]

Collecting and Organizing Data

In science, **data** generally refers to the results of trials, or tests, completed during experiments such as that in Figure 8-5. Scientific inquiry involves the ability to use various methods of recording, representing, and organizing data. Data can be organized into diagrams, tables, charts, graphs, equations, and matrices. Scientists must then be able to interpret the organized data and make inferences, predictions, and conclusions based on those data.

A data table is an important initial stage in making sense of the information you will collect while doing an experiment. When constructing a table to record your data, keep the checklist in mind.

Data Table Checklist

- ✓ Title the table in a way that relates the independent variable to the dependent variable. For example: The Effect of Fertilizer Concentration (the independent variable) on Plant Growth (the dependent variable).
- ✓ Column headings include the dependent and independent variables. They may also include trial or setup numbers or other information.
- ✓ Column headings need to indicate units of measurement.
- ✓ The independent variable is typically recorded in increasing order.
- ✓ The dependent variable is recorded to correspond with the independent variable.

Figure 8-5. Data collection: Making measurements and carefully recording data are important parts of doing an experiment.

The next step is to construct a graph like the one in Figure 8-6 that allows you to see trends or patterns in your mathematical data. Almost every day you interpret graphs. Television, newspapers, and other media often use graphs to illustrate ideas. Advertisers use graphs to convince us to use their pain reliever or allergy medication. They know that a carefully constructed graph can provide us with a large amount of information quickly. Examining columns of numbers in a data table is time consuming and sometimes difficult. Looking at a graph allows us to make comparisons quickly and to draw conclusions.

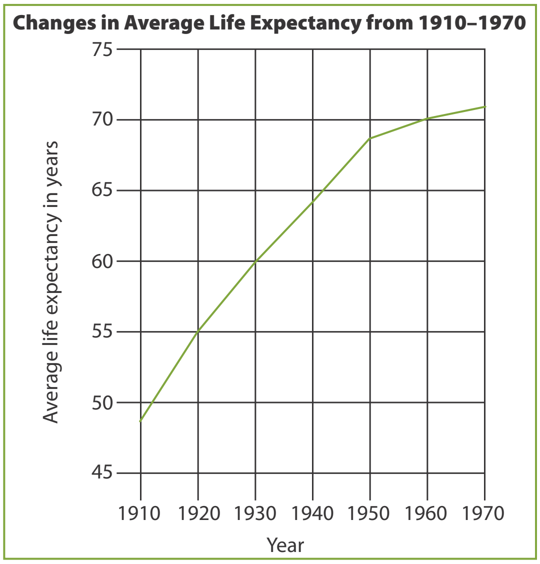


Figure 8-6. Everyday use of graphs: Interpreting graphs like this one is part of everyday life.

Graph Construction Checklist

Title
- ✓ Title your graph so that the reader knows what it is illustrating. You can often use the same title you used on the data table.

Vertical axis
- ✓ Dependent variable is on the vertical axis.
- ✓ Vertical axis is labeled, including units of measure.
- ✓ Scale on the vertical axis is appropriate, without any breaks, and spaced at even intervals.

Horizontal axis
- ✓ Independent variable is on the horizontal axis.
- ✓ Horizontal axis is labeled, including units of measure.
- ✓ Scale on the horizontal axis is appropriate, without any breaks, and spaced at even intervals.

Points
- ✓ Points are plotted accurately.

Data
- ✓ Data points are connected, and the line does not go beyond. (You only know what you measured; beyond that is speculation.)

Legend
- ✓ Legend indicates the meaning of each line if there is more than one. Often you are expected to surround data points with small circles or triangles.

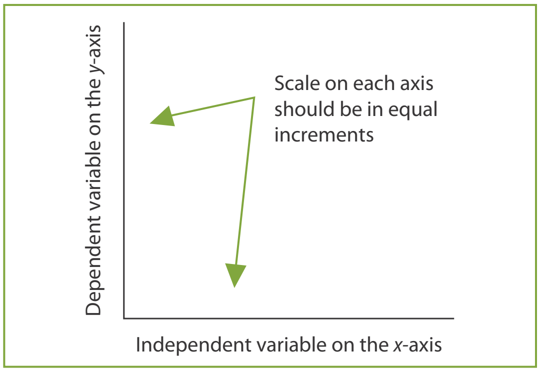


Figure 8-7. Rules for a line graph

There are four basic types of graphs:

- pie or circle graph
- bar graph
- histogram
- line graph

A scientist must decide which type of graph will be the most effective for presenting data so that the conclusion will be clear. Different rules are used in drawing each type of graph. However, there are a few rules common to all line and bar graphs.

Rule 1: The dependent variable is plotted on the vertical, or y-axis. Remember that the dependent variable is what you find out as a result of doing the experiment. It is what you measure during the experiment.

Rule 2: The independent variable is plotted on the horizontal, or x-axis. This is the factor you varied to find its effect on the test organisms or situation.

Rule 3: The spacing between the numbers on both axes must be in equal increments, without any breaks. Figure 8-7 shows how to apply the three rules to a line graph. Use the Graph Construction Checklist when constructing a graph.

The Results

A careful examination of the experimental results involves the ability to look at relationships between the predicted result contained in the hypothesis and the actual result.

Drawing Valid Conclusions After carefully considering how well the predicted result and the actual result of the experiment correspond, a decision about the outcome—a **conclusion**—can be made. A scientist needs to determine whether the hypothesis has been supported.

Scientists often use statistical analysis techniques to find the likelihood that their results were produced by chance. If the results differ only slightly, errors in measurement, genetic differences among the test organisms, or chance may be the reason. Once a significant pattern or relationship has been discovered as a result of data analysis, a scientist next tries to explain why these results were obtained.

Figure 8-8. **A model of DNA**

A **model** can often be used to explain the results of an experiment. A model is a way of explaining or demonstrating what might be happening and to predict what will occur in new situations. A model explains how DNA carries the genetic code and how traits are passed from one generation to the next. As more is learned about the structure and function of DNA, parts of the model are confirmed or changed. See Figure 8-8.

Reporting Results One assumption of science is that other individuals could arrive at the same explanation if they had access to similar evidence. Experiments that cannot be repeated exactly with the same results have little worth.

Research must be shared in such a clear manner that other scientists can repeat the investigation and try to get the same results. When reporting the results of an experiment, a scientist must pay close attention to details. The experimental results may be used by hundreds of other scientists to repeat the experiment. Thus, each step of the experiment must be described accurately and in exact detail.

If you wanted to repeat an experiment done by a friend, would you be able to do it if your friend told you to heat the mixture "for a little while"? Or if you had to add some soap powder to the mixture, would it be acceptable for your friend to tell you to "add two pinches"? If you expect to obtain the same results, your friend must provide precise instructions, such as to heat the mixture at a temperature of 75°C for 5 minutes, and then add 2 grams of a certain kind of soap powder.

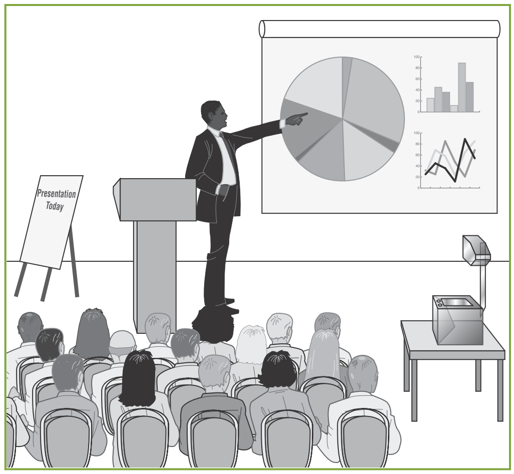


Figure 8-9. **Peer review:** Scientists examine one another's work to ensure that the results are correct.

Scientific inquiry also requires the ability to develop a written report for public scrutiny. Scientists report their findings in scientific journals or during presentations at professional meetings. The report describes the hypothesis, including a literature review of previous studies, the experiment performed, its data and the scientist's conclusion, and suggestions for further study. Based on the results of the experiment and public discussion and review, inquiry may also require the scientist to revise the explanation and think about additional research. A **peer review,** in which several scientists examine the details of an experiment, is an important part of the scientific process. Scientists are expected to question explanations proposed by other scientists. Peers analyze the experimental procedures, examine the evidence, identify faulty reasoning, point out statements that go beyond the evidence, and suggest alternative explanations for the same observations. Peer review is one of the systems of checks and balances in science.

Keep in mind that all scientific explanations are subject to change as more is learned. Scientists know and accept this as a part of the way they work. With new information, they must be willing to change their thinking and, therefore, their explanations.

Evidence is a collection of facts offered to support the idea that something is true. Scientists accept evidence when it is supported by many facts. Until they have a large collection of evidence to support their thinking, scientists must remain neutral.

Sometimes claims are made that are not supported by actual evidence. Scientific claims should be questioned if

- the data are based on samples that are very small, biased, or inadequately controlled
- the conclusions are based on the faulty, incomplete, or misleading use of numbers

For example, enough organisms must be used in an experiment and the difference in data between the control and experimental group must be significant enough so that genetic differences, random chance, and inaccuracies in measurement cannot be responsible for the results. Wherever appropriate, a statistical analysis of the results should be done. This could be something as simple as finding the average, calculating the percentage of difference, or determining the frequency. Claims should also be questioned if

- fact and opinion are intermingled
- adequate evidence is not cited
- conclusions do not follow logically from the evidence given

Further Science Understandings

Well-accepted scientific theories are supported by many different scientific investigations, often involving the contributions of individuals from different disciplines. In developing a theory, scientists carry out many investigations. They may vary in degree of complexity, scale, and focus. Research by different scientific disciplines can bring to light multiple views of the natural world. The resulting theory can encompass many different aspects of natural events. For instance, the theory of evolution began with the observations of one naturalist. But over the years scientists—including botanists, biologists, geologists, oceanographers, and others—researched numerous aspects of the theory to reach one general scientific idea.

Review Questions

Set 8.3

18. A student conducted an original, well-designed experiment, carefully following proper scientific procedure. In order for the conclusions to become generally accepted, the experiment must

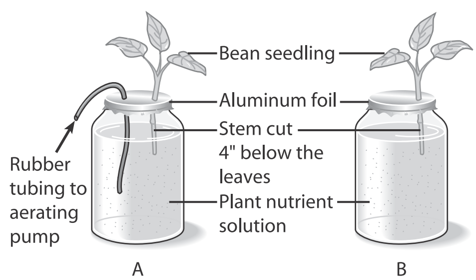
(1) contain several experimental variables
(2) support the original hypothesis
(3) be repeated to verify the reliability of the data
(4) be conducted by a scientist

19. A student tossed a coin five times and observed results of four tails and one head. He concluded that when a coin is tossed, there is an 80% chance of getting a tail and a 20% chance of getting a head. The conclusion would be more valid if

(1) only two tosses of the coin had been used
(2) the weight of the coin had been taken into consideration
(3) a greater number of tosses had been used
(4) the surface the coin landed on had been taken into consideration

Base your answers to questions 20 through 22 on the experiment described below and on your knowledge of biology.

After watching the behavior of earthworms in soil, a biology student suggested that the penetration of air into the soil promotes the root development of plants. The student then set up the following experiment.



20. The important data to be recorded in this experiment will come from the observation of the increase in

(1) leaf size
(2) stem size
(3) number of leaves
(4) number of roots

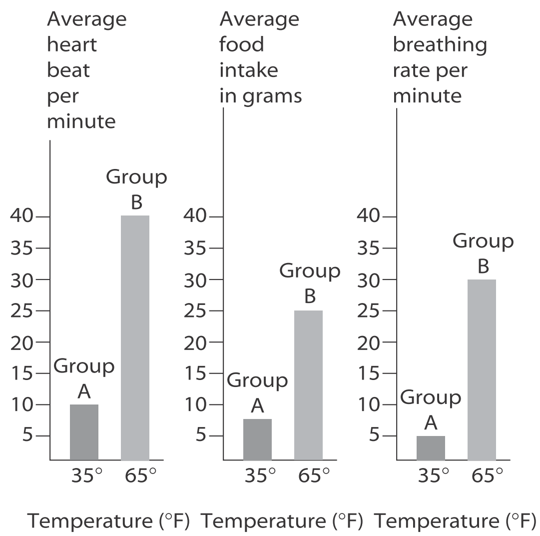
21. State the hypothesis being tested in this experiment. [1]

22. State one way this experiment could be improved to make the results more reliable. [1]

Base your answers to questions 23 through 25 on the experiment described below and on your knowledge of biology.

A group of 24 frogs was separated into two equal groups. Group A was placed in an environment in which the temperature was a constant 35°F. Group B was placed in a similar environment, except the temperature was a constant 65°F.

Equal amounts of food were given to each group at the start of the experiment and again every 24 hours. Immediately before each daily feeding, the excess food from the prior feeding was removed and measured. This allowed the scientist to determine the daily amount of food each group of frogs consumed. Each day, the heart rate and breathing rate of the frogs were checked. At the end of the experiment, the following bar graphs were prepared:



23. Using one or more complete sentences, state the hypothesis the scientist was most likely investigating in this experiment.

24. After examining the graphs, the scientist could reasonably assume that at a low temperature the frogs would

(1) become more active
(2) produce less carbon dioxide
(3) eat more food
(4) use more oxygen

25. The independent variable in this experiment was

(1) heart rate
(2) breathing rate
(3) amount of food consumed
(4) temperature of the environment

Base your answers to questions 26 through 29 on the information below and on your knowledge of biology.

A student was working on an investigation to measure the relative activity of an enzyme at various pH values. He collected the following data: pH 2, enzyme activity 10; pH 8, enzyme activity 50; pH 12, enzyme activity 10; pH 4, enzyme activity 20; pH 6, enzyme activity 40; pH 10, enzyme activity 40

26. Identify the independent variable in this experiment. [1]

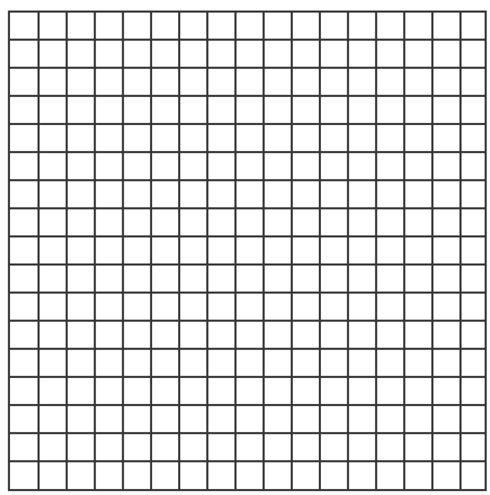
27. Organize the data by filling in the data table provided. Follow these directions when completing your data table.

- Provide an appropriate title for the data table. [1]
- Fill in the first box in each column with an appropriate heading. [1]
- Arrange the data so that pH values are in increasing order. [1]

Title:	

28. Using the information in the data table, construct a line graph on the grid provided, following the directions below:

- Provide an appropriate title for the graph. [1]
- Make and label an appropriate scale, without any breaks, on each axis. [1]
- Plot the data on the grid. Surround each data point with a small circle and connect the points. [1]



29. According to the data, this enzyme would probably work best at what pH values?

(1) 7 and 8
(2) 2 and 12
(3) 6 and 7
(4) 4 and 10

Practice Questions
for the New York Regents Exam

Directions
Review the Test-Taking Strategies section of this book. Then answer the following questions. Read each question carefully and answer with a correct choice or response.

Part A

1 One ounce each of protein, carbohydrate, and fat are burned separately in a calorimeter to determine Caloric content. The results are shown in the data table.

Caloric Content of Substances	
Organic Compound	Number of Calories Produced
Protein	147
Fat	271
Carbohydrate	152

Which statement represents a valid conclusion based on the data?
(1) An ounce of fat contains about twice as many Calories as an ounce of protein.
(2) Protein is a better energy food than carbohydrate.
(3) Carbohydrates, fats, and proteins all yield approximately the same number of Calories per unit of weight.
(4) Proteins and carbohydrates provide the most Calories per ounce.

2 Which laboratory procedure would be best for demonstrating the effect of light intensity on the production of chlorophyll in pea plants?
(1) using 10 plants of different species, each grown in the same intensity of light
(2) using 10 plants of different species, each grown in a different intensity of light
(3) using 10 plants of the same species, each grown in the same intensity of light
(4) using 10 plants of the same species, each grown in a different intensity of light

3 In an early trial of the Salk vaccine for polio, 1,830,000 school children participated. This original trial was an attempt to determine whether the Salk vaccine was effective in preventing polio. Of the 1,830,000 children involved, only 440,000 received the vaccine. The remainder were not given the vaccine because they
(1) had a natural immunity
(2) already had polio
(3) served as a control
(4) were allergic to the vaccine

4 A scientific study showed that the depth at which some microscopic plants were found in a lake varied from day to day. On clear days, the plants were found as far as 6 meters below the surface of the water but were only 1 meter below the surface on cloudy days. Which hypothesis would these observations support?
(1) Light intensity affects the growth of microscopic plants.
(2) Wind currents affect the growth of microscopic plants.
(3) Nitrogen concentration affects the growth of microscopic plants.
(4) Precipitation affects the growth of microscopic plants.

5 A scientist tested a hypothesis that white-tailed deer would prefer apples over corn as a primary food source. The findings of the test, in which the scientist claimed that the deer preferred apples, were published. Which research technique, if used by the scientist, might result in this claim being questioned?
(1) The scientist observed four deer in different locations at various times of the day.
(2) The scientist observed a total of 500 deer in 20 different locations at various times of the day.
(3) The scientist observed 200 deer in various natural settings, but none in captivity.
(4) The scientist observed 300 deer in various locations in captivity, but none in natural settings.

6 Conclusions based on an experiment are most likely to be accepted when
(1) they are consistent with experimental data and observations
(2) they are derived from investigations having many experimental variables
(3) scientists agree that only one hypothesis has been tested
(4) hypotheses are based on one experimental design

Part B

Base your answers to questions 7 through 10 on the information below, and on your knowledge of biology.

The list represents different procedures involved with a scientific experiment and are in no special order. For statements 7 through 10, identify the procedure being described by the appropriate letter.

Experimental Procedures

A. *Test the hypothesis with an experiment.*
B. *State the results.*
C. *Draw a conclusion from the results.*
D. *Form a hypothesis.*

7 Beans will grow faster if you fertilize them at regular intervals than if you only fertilize the ground once before you plant them. [1]

8 If I add more catalyst to the reaction, the reaction will speed up. [1]

9 A scientist took saliva from his dog's mouth and mixed it with a solution of starch and warm water. He took the same amount of saliva from his own mouth and mixed it with the contents of a second tube of starch and warm water. One hour later, the contents of both tubes were checked for sugar. [1]

10 In an experiment, caterpillars consumed 8 grams of lettuce leaves and 0.4 grams of tomato leaves. [1]

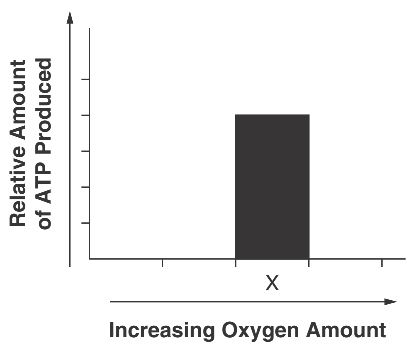
11 The data table below shows an effect of secondhand smoke on the birth weight of babies born to husbands and wives living together during the pregnancy.

Effect of Secondhand Smoke on Birth Weight

	Wife: Nonsmoker Husband: Nonsmoker	Wife: Nonsmoker Husband: Smoker
Number of Couples	837	529
Average Weight of Baby at Birth (Kg)	3.2	2.9

Based on these data, a reasonable conclusion that can be drawn about secondhand smoke during pregnancy is that secondhand smoke
(1) is unable to pass from the mother to the fetus
(2) slows the growth of the fetus
(3) causes mutations in cells of the ovaries
(4) blocks the receptors on antibody cells

12 A student studied how the amount of oxygen affects ATP production in muscle cells. The data for amount X are shown in the graph below.



If the student supplies the muscle cells with less oxygen in a second trial of the investigation, a bar placed on the graph to represent the results of this trial would most likely be
(1) shorter than bar X and placed to the left of bar X
(2) shorter than bar X and placed to the right of bar X
(3) taller than bar X and placed to the left of bar X
(4) taller than bar X and placed to the right of bar X

13 A student studied the location of single-celled photosynthetic organisms in a lake for a period of several weeks. The depth at which these organisms were found at different times of the day varied greatly. Some of the data collected are shown in the table below.

Data Table

Light Conditions at Different Times of the Day	Average Depth of Photosynthetic Organisms (cm)
Full light	150
Moderate light	15
No light	10

A valid inference based on these data is that
(1) most photosynthetic organisms live below a depth of 150 centimeters
(2) oxygen production increases as photosynthetic organisms move deeper in the lake
(3) photosynthetic organisms respond to changing light levels
(4) photosynthetic organisms move up and down to increase their rate of carbon dioxide production

Part C

Base your answer to question 14–17 on the information below and on your knowledge of biology.

Help for Aging Memories

As aging occurs, the ability to form memories begins to decrease. Research has shown that an increase in the production of a certain molecule, BDNF, seems to restore the processes involved in storing memories. BDNF is found in the central nervous system and seems to be important in maintaining nerve cell health. Researchers are testing a new drug that seems to increase the production of BDNF.

14–17 Design an experiment to test the effectiveness of the new drug to increase the production of BDNF in the brains of rats. In your answer, be sure to:

- state the hypothesis your experiment will test [1]
- describe how the control group will be treated differently from the experimental group [1]
- identify two factors that must be kept the same in both the experimental and control groups [1]
- identify the dependent variable in your experiment [1]

Base your answer to question 18–21 on the information below and on your knowledge of biology.

An Experimental SARS Vaccine Works in Animals

Scientists reported that they had protected animals from the effects of the SARS virus by using an experimental vaccine. The SARS virus causes an acute respiratory illness in humans and other animals.

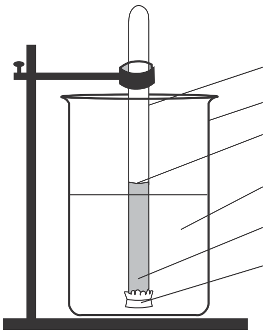
This vaccine was sprayed once into the nostrils of each of four African green monkeys. Four weeks later, these monkeys were exposed to the virus that causes SARS. The monkeys showed no sign of the disease in their respiratory tracts. Blood tests confirmed the presence of proteins known as neutralizing antibodies that indicate protection against disease. The scientists also sprayed a placebo (a substance that did not contain the vaccine) into the nostrils of each of four other African green monkeys. After exposure to the virus that causes SARS, all of these monkeys developed symptoms of this condition.

18–21 Briefly explain the nature of a vaccine and some steps that should be taken before a vaccine is available for public use. In your answer, be sure to include:

- a description of what a vaccine is [1]
- an explanation of why one group had a placebo sprayed into their nostrils before exposure to the virus [1]
- an explanation of why scientists used monkeys to test the SARS vaccine [1]
- a statement of what could be done to verify the results [1]

Base your answer to questions 22 and 23 on the information and diagram below, and on your knowledge of biology.

A laboratory setup for a demonstration is represented in the diagram below.



22–23 Describe how an indicator can be used to determine if starch diffuses through the membrane into the beaker. In your answer, be sure to include:

- the procedure used [1]
- how to interpret the results [1]

Base your answers to questions 24 through 26 on the information below and on your knowledge of biology.

In an investigation, plants of the same species and the same initial height were exposed to a constant number of hours of light each day. The number of hours per day was different for each plant, but all other environmental factors were the same. At the conclusion of the investigation, the final height of each plant was measured.

The following data were recorded:

8 hours, 25 cm; 4 hours, 12 cm; 2 hours, 5 cm; 14 hours, 35 cm; 12 hours, 35 cm; 10 hours, 34 cm; 6 hours, 18 cm

24 Organize the data by completing both columns in the data table provided, so that the hours of daily light exposure increase from the top to the bottom of the table. [1]

Data Table

Dally Light Exposure (hours)	Final Height (cm)

25 State one possible reason that the plant exposed to 2 hours of light per day was the shortest. [1]

26 If another plant of the same species had been used in the investigation and exposed to 16 hours of light per day, what would the final height of the plant probably have been? Support your answer. [1]

Base your answers to questions 27 and 28 on the information and data table below and on your knowledge of biology.

Trout and black bass are freshwater fish that normally require at least 8 parts per million (ppm) of dissolved oxygen (O_2) in the water for survival. Other freshwater fish, such as carp, may be able to live in water that has an O_2 level of 5 ppm. No freshwater fish are able to survive when the O_2 level in water is 2 ppm or less.

Some factories or power plants are built along rivers so that they can use the water to cool their equipment. They then release the water (sometimes as much as 8°C warmer) back into the same river.

The Rocky River presently has an average summer temperature of about 25°C and contains populations of trout, bass, and carp. A proposal has been made to build a new power plant on the banks of the Rocky River. Some people are concerned that this will affect the river ecosystem in a negative way.

The data table below shows the amount of oxygen that will dissolve in fresh water at different temperatures. The amount of oxygen is expressed in parts per million (ppm).

Data Table	
Temperature (°C)	Fresh Water Oxygen Content (ppm)
1	14.24
10	11.29
15	10.10
20	9.11
25	8.27
30	7.56

27 State one effect of temperature change on the oxygen content of fresh water. Support your answer using specific information from the data table. [1]

28 Explain how a new power plant built on the banks of the Rocky River could have an environmental impact on the Rocky River ecosystem downstream from the plant.

Your explanation must include the effects of the power plant on:

- water temperature [1]
- dissolved oxygen [1]
- fish species [1]

Base your answers to questions 29 and 30 on the information in the newspaper article below and on your knowledge of biology.

Patients to test tumor fighter

Boston—Endostatin, the highly publicized experimental cancer drug that wiped out tumors in mice and raised the hopes of cancer patients, will be tested on patients this year.

"I think it's exciting, but … you always have the risk that something will fail in testing," said Dr. Judah Folkman, the Harvard University researcher whose assistant, Michael O'Reilly, discovered endostatin.

Endostatin and a sister protein, angiostatin, destroy the tumors' ability to sprout new blood vessels. This makes cancer fall dormant in lab animals, but no one knows if that will happen in humans.

The Associated Press

29 Explain why it is necessary to test these experimental drugs on human volunteers as well as on test animals. [1]

30 State one reason that mice are often used by scientists for testing experimental drugs that may be used by humans. [1]

Base your answer to questions 31–34 on the information below and on your knowledge of biology.

Many people who are in favor of alternative medicine claim that large doses of vitamin C introduced into a vein speed up the healing of surgical wounds.

31–34 Describe an experiment to test this hypothesis. Your answer must include at least:

- the difference between the experimental group of subjects and the control group [1]
- two conditions that must be kept constant in both groups [1]
- data that should be collected [1]
- an example of experimental results that would support the hypothesis [1]