1–4 Tools and Procedures

Section 1–4

1 FOCUS

Objectives

1.4.1 ***Describe*** the measurement system most scientists use.
1.4.2 ***Explain*** how light microscopes and electron microscopes are similar and different.
1.4.3 ***Describe*** two common laboratory techniques.
1.4.4 ***Explain*** why it is important to work safely in biology.

Guide for Reading

Vocabulary Preview

Have students write a preliminary definition of each of the Vocabulary terms. As they read the section, they should revise their definitions.

Reading Strategy

Before students read, have them skim the section to identify the main ideas. As they read the section, have them make a list of the supporting details for each main idea.

2 INSTRUCT

Go Online NSTA SCILINKS

Find a worksheet on microscopes for students and additional teacher support from NSTA SciLinks.

A Common Measurement System

Addressing Misconceptions

To reinforce students' ability to make and use metric measurements, prepare a set of flashcards that students can use to learn equivalent units of metric measure. For example:

- 1 kilometer = *(1000)* meters
- 0.45 liter = *(450)* milliliters
- 5000 milligrams = *(5)* grams
- 130 meters = *(0.13)* kilometer
- 2500 milliliters = *(2.5)* liters
- 0.017 grams = *(17)* milligrams

L1

Guide for Reading

Key Concepts

- What measurement system do most scientists use?
- How are light microscopes and electron microscopes similar? How are they different?

Vocabulary

metric system
microscope
compound light microscope
electron microscope
cell culture
cell fractionation

Reading Strategy: Using Graphic Organizers As you read, create a table that lists the equipment and techniques discussed in this section. List one example of what biologists can accomplish using each piece of equipment or procedure.

Go Online NSTA SCILINKS

For: Links on microscopes
Visit: www.SciLinks.org
Web Code: cbn-1014

Imagine being one of the first people to see living things through a magnifying glass. How surprised you would have been to discover a whole new realm of life! Could there still be other types of life that remain undiscovered today because the right tools are not available?

Scientists select and use equipment, which sometimes includes technology such as computers, for their investigations. Electronic balances measure the mass of objects with great precision. Microscopes and telescopes make it possible to observe objects that are very small or very far away. With powerful computers, scientists can store and analyze vast collections of data. Biologists have even devised procedures that help them unlock the information stored in the DNA of different organisms.

A Common Measurement System

Because researchers need to replicate one another's experiments and most experiments involve measurements, scientists need a common system of measurement. **Most scientists use the metric system when collecting data and performing experiments.** The **metric system** is a decimal system of measurement whose units are based on certain physical standards and are scaled on multiples of 10. A revised version of the original metric system is called the International System of Units, or SI. The abbreviation SI comes from the French *Le Système International d'Unités.*

Because the metric system is based on multiples of 10, it is easy to use. Notice in **Figure 1–21** how the basic unit of length, the meter, can be multiplied or divided to measure objects and distances much larger or smaller than a meter. The same process can be used when measuring volume and mass. You can learn more about the metric system in Appendix C.

Common Metric Units

Length	Mass
1 meter (m) = 100 centimeters (cm) 1 meter = 1000 millimeters (mm) 1000 meters = 1 kilometer (km)	1 kilogram (kg) = 1000 grams (g) 1 gram = 1000 milligrams (mg) 1000 kilograms = 1 metric ton (t)
Volume	**Temperature**
1 liter (L) = 1000 milliliters (mL) 1 liter = 1000 cubic centimeters (cm^3)	0°C = freezing point of water 100°C = boiling point of water

Figure 1–21 **Scientists usually use the metric system in their work.** This system is easy to use because it is based on multiples of 10.

SECTION RESOURCES

Print:

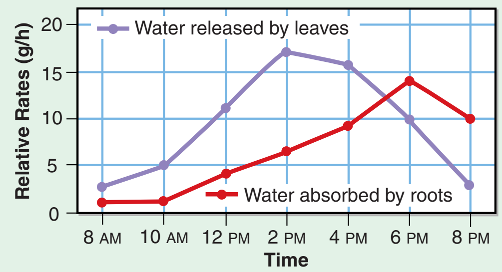
- ***Laboratory Manual A,*** Chapter 1 Lab
- ***Laboratory Manual B,*** Chapter 1 Lab
- ***Teaching Resources,*** Lesson Plan 1–4, Adapted Section Summary 1–4, Section Summary 1–4, Worksheets 1–4, Section Review 1–4
- ***Reading and Study Workbook A,*** Section 1–4
- ***Adapted Reading and Study Workbook B,*** Section 1–4
- ***Investigations in Forensics,*** Investigation 1
- ***Lab Worksheets,*** Chapter 1 Exploration

Technology:

- ***iText,*** Section 1–4
- ***Transparencies Plus,*** Section 1–4

Water Released and Absorbed by Tree

Time	Absorbed by Roots (g/h)	Released by Leaves (g/h)
8 AM	1	2
10 AM	1	5
12 PM	4	12
2 PM	6	17
4 PM	9	16
6 PM	14	10
8 PM	10	3



▲ **Figure 1–22** One way to record data from an experiment is by using a data table. Then, the data may be plotted on a graph to make it easier to interpret. **Using Tables and Graphs** *At what time of day is the rate of water released by leaves equal to the rate of water absorbed by roots?*

Analyzing Biological Data

When scientists collect data, they are often trying to find out whether certain factors changed or remained the same. Often, the simplest way to do that is to record the data in a table and then make a graph. Although you may be able to detect a pattern of change from a data table like the one in **Figure 1–22,** a graph of the data can make a pattern much easier to recognize and understand.

The amount of data produced by biologists today is so huge that no individual can look at more than a tiny fraction of it. To make sense of the data, biologists often turn to computers. For example, computers help determine the structure of molecules. They also allow biologists to search through a DNA molecule, find significant regions of the molecule, and discover how organisms are affected by those regions. At the opposite end of the scale, computers are essential to gathering data by satellite, analyzing the data, and presenting the results. Analyses of satellite data are used to make predictions about complex phenomena such as global climate changes.

CHECKPOINT *How can a graph help biologists analyze data?*

Microscopes

When people think of scientific equipment, one of the first tools that comes to mind is the microscope. **Microscopes,** such as the light microscope in **Figure 1–23,** are devices that produce magnified images of structures that are too small to see with the unaided eye. **Light microscopes produce magnified images by focusing visible light rays. Electron microscopes produce magnified images by focusing beams of electrons.** Since the first microscope was invented, microscope manufacturers have had to deal with two problems: What is the instrument's magnification—that is, how much larger can it make an object appear compared to the object's real size? And how sharp an image can the instrument produce?

▲ **Figure 1–23** **Light microscopes produce magnified images by focusing visible light rays.**

Analyzing Biological Data

Use Visuals

Figure 1–22 Direct students' attention to the graph. Then, ask: **On which axis is time recorded?** *(On the horizontal axis, or x-axis)* **On which axis are the relative rates recorded?** *(On the vertical axis, or y-axis)* **What pattern does the graph show at a glance about water given off and taken in by a tree?** *(The water released by leaves peaks at 2 PM; the water absorbed by roots peaks at 6 PM.)* L1 L2

Microscopes

Build Science Skills

Applying Concepts Most students will remember some things about microscopes from previous science courses, but there is likely to be a wide range of proficiencies in the class. This is the time to get out the light microscopes and have a hands-on review of the parts and their functions. Have students work with partners to practice naming parts, describing functions, and demonstrating proper handling and use. L1 L2

UNIVERSAL ACCESS

Inclusion/Special Needs
Make sure all students can make a graph from data. Before students study Figure 1–22, give them graph paper and the data in the figure's table, and ask them to graph the data. Work with students who have difficulty with this task. L1

English Language Learners
Explain that the term *microscope* is derived from the Greek words *micro-*, meaning "small," and *skop-*, meaning "see." Thus, *microscope* means an instrument for seeing small objects. Then, ask students what *microorganism* means. Students should infer that it means a "small living thing." L1 L2

Advanced Learners
Challenge interested students to find out if a local university science department has an electron microscope. If one is available, encourage students to make an appointment to observe the instrument and learn how it works. L3

Answers to . . .

CHECKPOINT *A graph helps make patterns easier to recognize and understand.*

Figure 1–22 *The rate of water released by leaves is equal to the rate of water absorbed by roots at around 5 PM.*

1–4 (continued)

Build Science Skills

Making Judgments Point out that all microscopes have limits of resolution. Explain that as the magnifying power of a light microscope is increased, more and more detail can be seen, at least up to a certain point. Detail is lost and objects get blurry beyond that point, which is called the limit of resolution. Resolution is the capability to distinguish the individual parts of an object. Ask students: **If you are looking at feathers or insect legs under a microscope, how important is excellent resolution?** *(Not very important, because you are looking at overall structure)* **What if you are looking at slides of plant or animal cells?** *(Resolution is now very important, because detail is important.)* **Name some obvious advantages to looking at living rather than dead specimens under the microscope.** *(Advantages include the ability to observe living color, movement, and reactions to stimuli.)* L2

Build Science Skills

Applying Concepts Give students a list of the following topics, and ask them which kind of microscope, if any, would best serve the topic's investigation, with an explanation of why that kind would serve best:

- **The feeding habits of unicellular protozoa** *(A light microscope, because the organisms are small and would need to be studied alive)*
- **The surface of a red blood cell** *(A scanning electron microscope, because it would be best for looking at surfaces)*
- **The feeding habits of a house cat** *(No microscope is necessary to observe the behavior of an animal as large as a cat.)*
- **The interior structures of a cell** *(A transmission electron microscope, because of the need for high resolution to view the fine structure of cell organelles)* L1 L2

▲ **Figure 1–24** This scientist is using an electron microscope to make observations. **Electron microscopes produce images by focusing beams of electrons.**

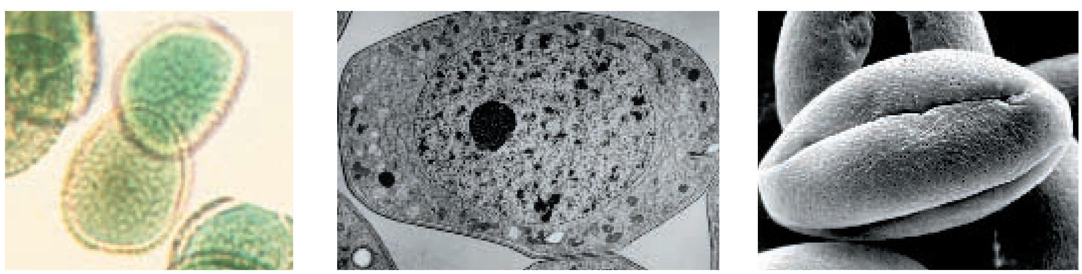
Light Microscopes The most commonly used microscope is the light microscope. Light microscopes can produce clear images of objects at a magnification of about 1000 times. **Compound light microscopes** allow light to pass through the specimen and use two lenses to form an image. Light microscopes make it possible to study dead organisms and their parts, and to observe some tiny organisms and cells while they are still alive. You can refer to Appendix D to learn how to use a compound light microscope.

Biologists have developed techniques and procedures to make light microscopes more useful. Chemical stains, also called dyes, can show specific structures in the cell. Fluorescent dyes have been combined with video cameras and computer processing to produce moving three-dimensional images of processes such as cell movement.

Electron Microscopes All microscopes are limited in what they reveal, and light microscopes cannot produce clear images of objects smaller than 0.2 micrometers, or about one-fiftieth the diameter of a typical cell. To study even smaller objects, scientists use electron microscopes. **Electron microscopes,** such as the one shown in **Figure 1–24,** use beams of electrons, rather than light, to produce images. The best electron microscopes can produce images almost 1000 times more detailed than light microscopes can.

Biologists use two main types of electron microscopes. Transmission electron microscopes (TEMs) shine a beam of electrons through a thin specimen. Scanning electron microscopes (SEMs) scan a narrow beam of electrons back and forth across the surface of a specimen. TEMs can reveal a wealth of detail inside the cell. SEMs produce realistic, and often dramatic, three-dimensional images of the surfaces of objects. Because electron microscopes require a vacuum to operate, samples for both TEM and SEM work must be preserved and dehydrated before they are placed inside the microscope. This means that living cells cannot be observed with electron microscopes, only with the light microscope. **Figure 1–25** shows images taken with a light microscope, a transmission electron microscope, and a scanning electron microscope.

▼ **Figure 1–25** Observe the images of pollen grains as seen with a light microscope (left), transmission electron microscope (center), and scanning electron microscope (right). **Interpreting Graphics** ***In which image can you see the most detail on the pollen grain's surface?***



(magnification: about 400×) (magnification: about 2200×) (magnification: about 1000×)

BIO INSIGHTS — FACTS AND FIGURES

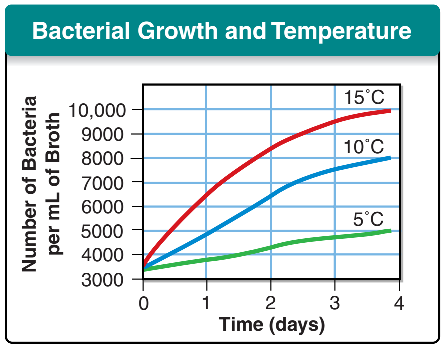
Electron microscopes

In both transmission electron microscopes and scanning electron microscopes, the lenses are made of electromagnets, which gather and focus the beam of electrons. The beam of electrons is produced by heating a filament. For an image to be produced, the path of the electrons must be unobstructed. Therefore, the samples are placed in a vacuum instead of in air. Objects must be extremely thin—less than 0.1 micron—to be examined by a TEM, because the TEM produces an image by passing a beam of electrons through an object. The electrons then either produce an image on a fluorescent screen or produce a permanent image on photographic film. Objects examined by an SEM need not be thin, because the electrons are picked up by detectors after bouncing off the specimen, and the detectors provide the data necessary to form an image on a monitor.

Analyzing Data

Bacterial Reproduction

Bacteria are microorganisms that can reproduce by dividing into two. The graph shows the results of an experiment on the effect of temperature on bacterial reproduction. At the beginning, three populations of bacteria, all of the same type, were of equal size. Each population was kept at a different temperature for 4 days.



1. **Classifying** What variable did the researcher change during this experiment?
2. **Inferring** What do the shapes of the curves tell you about the changes in population size?
3. **Calculating** For the bacteria kept at 15°C, how did population size change during the experiment?
4. **Drawing Conclusions** What effect did the different temperatures have on the growth of the bacterial populations?
5. **Predicting** Suppose some bacteria used in this experiment were kept at a temperature of 100°C (the temperature of boiling water). Would you expect the population sizes to increase even faster than at 15°C? Explain your reasoning.

Laboratory Techniques

Biologists use a variety of techniques to study cells. Two common laboratory techniques are cell culturing and cell fractionation.

Cell Cultures To obtain enough material to study, biologists like the one in **Figure 1–26** sometimes place a single cell into a dish containing a nutrient solution. The cell is able to reproduce so that a group of cells, called a **cell culture,** develops from the single original cell. Cell cultures can be used to test cell responses under controlled conditions, to study interactions between cells, and to select specific cells for further study.

Cell Fractionation Suppose you want to study just one part of a cell. How could you separate that one part from the rest of the cell? Biologists often use a technique known as **cell fractionation** to separate the different cell parts. First, the cells are broken into pieces in a special blender. Then, the broken cell bits are added to a liquid and placed in a tube. The tube is inserted into a centrifuge, which is an instrument that can spin the tube. Spinning causes the cell parts to separate, with the most dense parts settling near the bottom of the tube. A biologist can then remove the specific part of the cell to be studied by selecting the appropriate layer.

CHECKPOINT *What is a cell culture?*

▼ **Figure 1–26** This researcher is transferring bacteria to a solid that contains nutrients, which will enable the bacteria to reproduce. **Comparing and Contrasting** *How do the results of a cell culture differ from the products of cell fractionation?*

BIO INSIGHTS

HISTORY OF SCIENCE

From the kitchen to the lab

The ability to study bacteria in a laboratory is crucial for understanding their structure and function. Robert Koch (1843–1910), a German bacteriologist, was one of the first scientists to perfect a method of doing so. The growth medium he first used was beef broth. The addition of the protein gelatin to the broth solidified the medium, but a problem remained. Many bacteria could digest the gelatin, and the result was the formation of little puddles in the medium, making it difficult to study the bacteria. The answer came in 1881 when the wife of one of Koch's coworkers told Koch about the agar-agar she used in cooking as a solidifying agent. Koch discovered that this substance, produced by the red alga *Gelidium,* could not be digested by bacteria. Agar—the current term for agar-agar—has been used in laboratories as a culture medium ever since.

Laboratory Techniques

Analyzing Data

The experiment is typical of how cell cultures of bacteria and other microorganisms are studied to test responses under controlled conditions. The specific range of temperatures in which bacteria can grow varies among species. Some species, called psychrophiles, can grow at temperatures below 0°C. Other species, called thermophiles, grow at temperatures approaching the boiling point of water and are incapable of growth below 45°C. Most bacteria, called mesophiles, have an optimal growth temperature between 10°C and 50°C. L2

Answers

1. Temperature

2. The population of bacteria at 5°C grew slowly and steadily. At 10°C, the population grew rapidly at first; the rate of growth decreased after about two days. The population at 15°C grew most rapidly at first; the rate of growth slowed steadily after a day, and the population appears to have leveled off at about four days.

3. The population size grew from about 3500/mL of broth at the start to 10,000/mL at the end.

4. The bacterial population grew most at the highest temperature and grew least at the lowest temperature.

5. Students might suggest that population size would increase even faster than at 15°C, because the graph shows that the higher the temperature, the more the bacterial growth. Because 100°C is the boiling point of water, students may say that the bacteria would not survive at 100°C.

Answers to . . .

CHECKPOINT *A group of cells that develops from a single cell placed into a dish containing nutrient solution*

Figure 1–25 *In the image from the scanning electron microscope*

Figure 1–26 *A cell culture is a group of cells that develops from a single original cell. Cell fractionation separates cell parts.*

1–4 (continued)

Working Safely in Biology

Demonstration

To acquaint students with the laboratory in which they will be working, point out the location of the water, the nearest fire extinguisher, and the first-aid equipment. Explain the procedures to follow in case of fire, accident, or injury. You may wish to make instructions for display in the lab. Show how to use safety goggles and heat-resistant gloves. Show some of the equipment students will use in the lab, including glassware, microscopes, heating devices, chemicals, knives, and scalpels. For each piece of equipment, ask: **What is the safety symbol associated with this item?** *(Some students may be familiar with common safety symbols.)* Point out and discuss the safety symbols used in their textbook and laboratory manuals. L1 L2

3 ASSESS

Evaluate Understanding

Call on students at random to explain the differences in structure and image obtained from a compound light microscope, a TEM, and an SEM.

Reteach

Have students look at the image on page 2. Ask them to tell how they know, without reading the caption, that the image was made by an SEM and not a light microscope or a TEM.

You & Your Community

Students' products should include any five of the science safety rules detailed in Appendix B. A typical poster might include one rule from five different categories. Most students will organize their posters as suggested in the directions, though some may develop more imaginative designs.

Interactive Textbook

If your class subscribes to the iText, use it to review the Key Concepts in Section 1–4.

Answer to . . .

Figure 1–27 *To protect themselves from exposure to nuclear wastes*

Figure 1–27 These workers are cleaning up Rocky Flats, a Colorado site once used for producing nuclear weapons. **Applying Concepts** *Why must they wear heavy protective gear?*

Working Safely in Biology

Scientists working in a laboratory or in the field like those in **Figure 1–27** are trained to use safe procedures when carrying out investigations. Laboratory work may involve flames or heating elements, electricity, chemicals, hot liquids, sharp instruments, and breakable glassware. Laboratory or field work may involve contact with living or dead organisms—not just the plants, animals, and other living things you can see but other organisms you cannot see without a microscope.

Whenever you work in your biology laboratory, it's important for you to follow safe practices as well. Before performing any activity in this course, study the safety rules in Appendix B. Before you start any activity, read all the steps, and make sure that you understand the entire procedure, including any safety precautions that must be followed.

The single most important rule for your safety is simple: Always follow your teacher's instructions and the textbook directions exactly. If you are in doubt about any part of an activity, always ask your teacher for an explanation. And, because you may be in contact with organisms you cannot see, it is essential that you wash your hands thoroughly after every scientific activity. Remember, you are responsible for your own safety and that of your teacher and classmates. If you are handling live animals, you are responsible for their safety as well.

1–4 Section Assessment

1. **Key Concept** Why do scientists use a common system of measurement?
2. **Key Concept** What is the difference in the way light microscopes and electron microscopes produce images?
3. What types of objects can be studied with a light microscope? What types can be studied with an electron microscope?
4. Describe the technique and purpose of cell fractionation.
5. **Critical Thinking Applying Concepts** It has been said that many great discoveries lie in wait for the tools needed to make them. What does this statement mean to you? If possible, include an example in your answer.

You & Your Community

Safety Poster
After reading the safety guidelines in Appendix B, prepare a poster on lab safety to display in your school in which you describe at least five safety rules. You might organize your poster or brochure in two columns labeled *Dangerous Way* and *Safe Way,* and contrast unsafe behaviors with their safe alternatives.

1–4 Section Assessment

1. They need to replicate one another's experiments, which often involve measurements.
2. Light microscopes produce images by focusing visible light rays, whereas electron microscopes produce images by focusing beams of electrons.
3. Light microscopes and electron microscopes can be used to study dead and preserved specimens. Only light microscopes can be used to study living organisms or cells.
4. In cell fractionation, cells are broken into pieces, added to a liquid, and placed in a tube. The tube is spun in a centrifuge, where the cell parts are separated into layers according to density. This technique is done to study specific parts of a cell.
5. Sample answer: More advanced tools might reveal parts of living things never observed before. Students may list discoveries that required the development of microscopes.