ORIENTATION

OBJECTIVES

After completing the laboratory session, you should be able to:
1. Describe how to prepare for a laboratory session.
2. Describe laboratory safety procedures.
3. State the meaning of common prefixes and suffixes.
4. Convert from one metric unit to another and convert between metric and English units.
5. Make precise and detailed observations.
6. List the steps of the scientific method.
7. Define all terms in bold print.

Laboratory study is an important part of a course in biology. It provides opportunities for you to observe and study biological organisms and processes and to correlate your findings with the textbook and lectures. It allows the conduction of experiments, the collection of data, and the analysis of data to form conclusions. In this way, you experience the process of science, and it is this process that distinguishes science from other disciplines.

PROCEDURES TO FOLLOW

Your success in the laboratory depends on how you prepare for and carry out the laboratory activities. The procedures that follow are expected to be used by all students.

Preparation

Before coming to the laboratory, complete the following activities to prepare yourself for the laboratory session:

1. Read the assigned exercise to understand (a) the objectives, (b) the meaning and spelling of new terms, (c) the introductory background information, and (d) the procedures to be followed.
2. Label and color-code illustrations as directed in the manual, and complete the items on the laboratory report related to the background information.
3. Bring your textbook to the laboratory for use as a reference.

Working in the Laboratory

The following guidelines will save time and increase your chances of success in the laboratory:

1. Remove the laboratory report from the manual so you can complete it without flipping pages. Laboratory reports are three-hole-punched so you can keep completed reports in a binder.
2. Follow the directions explicitly and in sequence unless directed otherwise.
3. Work carefully and thoughtfully. You will not have to rush if you are well prepared.
4. Discuss your procedures and observations with other students. If you become confused, ask your instructor for help.
5. Answer the questions on the laboratory report thoughtfully and completely. They are provided to guide the learning process.

Laboratory Safety and Housekeeping

Exercises in this manual may involve unfamiliar procedures using hazardous chemicals and a variety of laboratory equipment. Therefore, you should follow a few simple safety procedures.

1. Come to class well prepared for the laboratory session. Understanding the background material and the procedures to be used is the first step toward a safe and successful experience.
2. At all times, follow the directions of your instructor.
3. Keep your work station clean and uncluttered. Unnecessary materials should be kept somewhere other than on your desktop.
4. Keep clothes and hair away from the open flame of a Bunsen burner.
5. Always use a mechanical pipetting device when pipetting fluid; never use your mouth.
6. Keep water away from electrical cords and electronic equipment. Electricity and water are not compatible.
7. Wear disposable protective gloves when working with hazardous chemicals or biologicals, such as blood products, DNA, or urine, to avoid contact with skin or clothes.
8. Inform your instructor immediately of any breakage, spills, or injuries, even minor ones.
9. Do not eat, drink, or apply makeup in the laboratory, and keep other materials away from your mouth. The laboratory is not germ free.
10. Be certain that you understand how to use a piece of equipment before trying to use it. When in doubt, ask your instructor.
11. At the end of the period:
   a. Return all equipment to the designated location.
   b. Wash all glassware and return it and other materials to their designated locations.
   c. Wash your desktop and your hands.

**BIOLOGICAL TERMS**

One of the major difficulties encountered by beginning students is learning biological terminology. Each exercise has new terms emphasized in bold print so that you do not overlook them. Be sure to know their meanings prior to the laboratory session.

Most biological terms are composed of a root word and either a prefix or a suffix, or both. The **root word** provides the main meaning of the term. It may occur at the beginning or end of the term, or it may be sandwiched between a **prefix** and a **suffix**. Both prefix and suffix modify the meaning of the root word. The parts of a term are often joined by adding **combining vowels** that make the term easier to pronounce. The following examples illustrate the structure of biological terms:

1. The term **endocranial** becomes **endo/cranial** when separated into its components. **Endo**- is a prefix meaning “within”; **cra-** is the root word meaning “skull”; **-nal** is a suffix meaning “pertaining to.” Therefore, the literal meaning of endocranial is “pertaining to within the skull.”
2. The term **arthropod** becomes **arthr/o/pod** when separated into its components. **Arthr-** is a prefix meaning “joint”; **o-** is a combining vowel; **pod** is the root word meaning “foot.” Therefore, the literal meaning of arthropod is “jointed foot.”

Once you understand the structure of biological terms, learning the terminology becomes much easier. **Appendix A contains the meaning of common prefixes, suffixes, and root words.** Use it frequently to help master new terms.

**Assignment 1**

Using Appendix A, complete item 1 on **Laboratory Report 1 that begins on page 11.**

**UNITS OF MEASUREMENT**

In making measurements, scientists use the **International System of Units** (SI), which is commonly called the **metric system.** The metric system is the only system of measurement used in many countries of the world. It is an easy and convenient system, once it is learned. Some of the common units are shown in Table 1.1. Study the table to become familiar with the names and values of the units. Note that within each category the units vary by powers of 10, which allows easy conversion from one unit to another. The English equivalents are given for some units for comparison and so you can convert values from one system to the other. If you study the table, you will be able to recognize the relative value of the prefixes in the names of the units, which are summarized here.

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>mega-</td>
<td>M</td>
<td>$10^6 = 1,000,000$</td>
</tr>
<tr>
<td>kilo-</td>
<td>k</td>
<td>$10^3 = 1,000$</td>
</tr>
<tr>
<td>hecto-</td>
<td>h</td>
<td>$10^2 = 100$</td>
</tr>
<tr>
<td>deka-</td>
<td>da</td>
<td>$10^1 = 10$</td>
</tr>
<tr>
<td>deci-</td>
<td>d</td>
<td>$10^{-1} = 0.1$</td>
</tr>
<tr>
<td>centi-</td>
<td>c</td>
<td>$10^{-2} = 0.01$</td>
</tr>
<tr>
<td>milli-</td>
<td>m</td>
<td>$10^{-3} = 0.001$</td>
</tr>
<tr>
<td>micro-</td>
<td>μ</td>
<td>$10^{-6} = 0.000001$</td>
</tr>
</tbody>
</table>

**Length**

Length is the measurement of a line, either real or imaginary, extending between two points. Your height, the distance between cities, and the size of a football field involve length. The basic unit of length is the **meter**.
### COMMON METRIC SYSTEM UNITS

<table>
<thead>
<tr>
<th>Category</th>
<th>Symbol</th>
<th>Unit</th>
<th>Value</th>
<th>English Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>km</td>
<td>kilometer</td>
<td>1,000 m</td>
<td>0.62 mi</td>
</tr>
<tr>
<td></td>
<td>m</td>
<td>meter*</td>
<td>1 m</td>
<td>39.37 in.</td>
</tr>
<tr>
<td></td>
<td>dm</td>
<td>decimeter</td>
<td>0.1 m</td>
<td>3.94 in.</td>
</tr>
<tr>
<td></td>
<td>cm</td>
<td>centimeter</td>
<td>0.01 m</td>
<td>0.39 in.</td>
</tr>
<tr>
<td></td>
<td>mm</td>
<td>millimeter</td>
<td>0.001 m</td>
<td>0.04 in.</td>
</tr>
<tr>
<td></td>
<td>µm</td>
<td>micrometer</td>
<td>0.000001 m</td>
<td>0.00004 in.</td>
</tr>
<tr>
<td>Mass</td>
<td>kg</td>
<td>kilogram</td>
<td>1,000 g</td>
<td>2.2 lb</td>
</tr>
<tr>
<td></td>
<td>g</td>
<td>gram*</td>
<td>1 g</td>
<td>0.04 oz</td>
</tr>
<tr>
<td></td>
<td>dg</td>
<td>decigram</td>
<td>0.1 g</td>
<td>0.004 oz</td>
</tr>
<tr>
<td></td>
<td>cg</td>
<td>centigram</td>
<td>0.01 g</td>
<td>0.0004 oz</td>
</tr>
<tr>
<td></td>
<td>mg</td>
<td>milligram</td>
<td>0.001 g</td>
<td></td>
</tr>
<tr>
<td></td>
<td>µg</td>
<td>microgram</td>
<td>0.000001 g</td>
<td></td>
</tr>
<tr>
<td>Volume</td>
<td>l</td>
<td>liter*</td>
<td>1 l</td>
<td>1.06 qt</td>
</tr>
<tr>
<td></td>
<td>ml</td>
<td>milliliter</td>
<td>0.001 l</td>
<td>0.03 fl. oz</td>
</tr>
<tr>
<td></td>
<td>µl</td>
<td>microliter</td>
<td>0.000001 l</td>
<td></td>
</tr>
</tbody>
</table>

*Denotes the base unit.

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**Mass**

**Mass** is the characteristic that gives an object inertia, the resistance to a change in motion. It is the quantity of matter in an object. Mass is not the same as weight because weight is dependent on the force of gravity acting on the object. The mass of a given object is the same on Earth as on the moon, but its weight is much less on the moon because the moon's force of gravity is less than Earth's. As a nonscientist, you probably can get by using mass and weight interchangeably, although this is technically incorrect.

In this section, you will use a triple-beam balance to measure the mass of objects. Obtain a balance and locate the pans labeled in Figure 1.1. Note that each beam is marked with graduations. The beam closest to you has 0.1-g and 1.0-g graduations, the middle beam has 100-g graduations, and the farthest beam has 10-g graduations. There is a movable mass attached to each beam. When the pan is empty and clean and the movable masses are moved to zero—as far to the left as possible—the balance mark on the right end of the beam should align with the balance mark on the upright post. If not, rotate the adjustment knob under the pan at the left until it does align. Now the balance is ready to use.

**Procedure for Measuring Mass**

All three beams are used if you are measuring an object with a mass over 100 g; the first and third beams are used when measuring an object with a mass between 10 and 100 g; and the first beam only is used when measuring an object with a mass of 10 g or less. Here is how to do it.

Place the object to be measured in the center of the pan. Move the movable mass on the middle (100 g) beam to the right, one notch at a time, until the right end of the beam drops below the balance mark. Then, move the mass back to the left one notch. Now, slide the movable mass on the third (10 g) beam to the right, one notch at a time, until the right end of the beam drops below the balance mark. Next, move the mass back to the left one notch. Finally, slide the movable mass on the first (1 g) beam slowly to the right until the right end of the beam aligns with the balance mark. The mass of the object is then determined as the sum of the masses indicated on the three beams.

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**Volume**

**Volume** is the space occupied by an object or a fluid. The liter is the basic unit of volume, but milliliters are the common units used for small volumes. Graduated cylinders and pipettes are used to measure fluids. Length may also be involved in volume determinations because 1 cubic centimeter (cm³ or cc) equals 1 ml.

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Figure 1.1 A triple-beam balance. **A.** Adjustment knob. **B.** Pan. **C.** Movable mass.
Conversion of Metric Units

A major advantage of the metric system is that units within a category may be converted from one to another by multiplying or dividing by the correct power of 10. The following examples show how this is done.

1. To convert 5.75 meters into millimeters, the first step is to determine how many millimeters are in a meter. Table 1.1 shows that 1 mm = 0.001 m, or 1/1,000 of a meter. Thus, there are 1,000 mm in 1 m. Because you are converting meters to millimeters, you multiply 5.75 m by a fraction expressing that there are 1,000 mm in 1 m and cancel like units. You use the unit that you want to convert to as the numerator of the fraction.

\[
\frac{5.75 \text{ m}}{1} \times \frac{1000 \text{ mm}}{1 \text{ m}} = 5750 \text{ mm}
\]

Note that this equation multiplies 5.75 by 1,000, which moves the decimal three places to the right and changes the units from meters to millimeters. Moving the decimal and changing the unit is a quick way to do such problems.

2. To convert 125 centimeters into meters, the first step is to determine how many centimeters are in a meter. Table 1.1 shows that 1 cm = 0.01 m, or 1/100 of a meter. Thus, there are 100 cm in 1 m. Because you are converting centimeters into meters, you multiply 125 cm by a fraction expressing that 1 m contains 100 cm and cancel like units. Do you know why 1 m is the numerator of the fraction?

\[
\frac{125 \text{ cm}}{1} \times \frac{1 \text{ m}}{100 \text{ cm}} = 1.25 \text{ m}
\]

Note that this equation divides 125 cm by 100, which moves the decimal two places to the left and changes the units from centimeters to meters.

Temperature

Scientists use the degree Celsius (°C) as the base unit for temperature measurements; most nonscientists in the United States use the degree Fahrenheit (°F). A simple comparison of the two systems is shown here.

<table>
<thead>
<tr>
<th>°C</th>
<th>°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>212</td>
</tr>
<tr>
<td>0</td>
<td>32</td>
</tr>
</tbody>
</table>

You can convert from one system to the other by using these formulas.

\[
\text{Celsius to Fahrenheit:} \quad ^\circ\text{F} = \frac{9}{5} ^\circ\text{C} + 32
\]

Fahrenheit to Celsius:

\[
^\circ\text{C} = \frac{5}{9} (^\circ\text{F} - 32)
\]

Assignment 2

Materials

Balance, triple beam
Beaker, 250 ml
Graduated cylinder, 25 ml
Millimeter ruler, clear plastic

1. Complete item 2a on the laboratory report.
2. Perform the procedures that follow and record your calculations and data in item 2 on the laboratory report.
   a. Determine the diameter of a penny in millimeters. Then convert your answer to centimeters, meters, and inches.
   b. Using a balance, determine the mass of a 250-ml beaker in grams. Then convert your answer to milligrams and ounces. If you need help in using the balance, see your instructor.
   c. Fill the beaker about half full with tap water. Pour a little water into the graduated cylinder. Look at the top of the water column from the side and note that it is curved rather than flat. This curvature is known as the meniscus, and it results because water molecules tend to "creep up" and stick to the side of the cylinder. When measuring the volume of fluid in a cylinder or pipette, you must read the volume at the bottom of the meniscus, as shown in Figure 1.2.
   d. While observing the meniscus from the side, add water to the graduated cylinder and fill it to the 15-ml mark. Repeat until you can do this with ease.
   e. Using a graduated cylinder, beaker, and balance, determine the weight (mass) of 20 ml of water.

3. Complete item 2 on the laboratory report.

Observations

In the laboratory, you will be asked to make many observations, and these observations require both seeing and thinking. The process of biology involves making careful observations to collect data, analyzing the data, and forming conclusions.

For example, careful observations are necessary to identify biological organisms. Each species (kind of organism) has certain characteristics that are similar to related organisms and characteristics that are different from related organisms. The greater the similarity
between organisms, the closer is their relationship. Biologists use this principle of similarity to determine the closeness of relationship between organisms. You have subconsciously used this same principle in recognizing the various breeds of dogs as dogs and in distinguishing between dogs and cats.

When classifying organisms, biologists develop a **dichotomous key**, based on the characteristics of the organisms, to separate a variety of organisms according to species. A dichotomous key is constructed so a single characteristic is considered at each step, an either/or decision, to separate the organisms into two groups. A series of these either/or decisions ultimately separates each type of organism from other types. For example, if we were to develop a dichotomous key to distinguish rats, dogs, cats, monkeys, gorillas, and humans (while ignoring all other organisms), it might look like Figure 1.3. This dichotomous key is purely artificial, but it illustrates how one is constructed. *Note that only one distinguishing characteristic is considered at each step (branch).*

Figure 1.3 An example of a dichotomous key.
Assignment 3

Materials

Leaves of various types

1. Several sets of eight to ten different types of leaves are provided in the laboratory for your examination. Each leaf is numbered. Your objective is to develop a dichotomous key to categorize the leaves of one set according to their observable characteristics. To develop such a key, you must first observe the leaves carefully to determine their similarities and distinguishing characteristics. You are not trying to identify the names of the plants from which the leaves were obtained. Instead, you are to record the number of the leaf that fills the position at the end of each final branch of your key. At each branch of your key, record the distinguishing feature of leaves in that branch, as shown in the example in Figure 1.3.

In making your key, consider leaf characteristics such as presence or absence of a petiole (leaf stalk), the arrangement of leaf veins (parallel or netlike), general shape (needlelike, scalelike, or flat, thin leaves), simple or compound leaves, shape of the leaf margin (e.g., smooth, toothed, indented), and so forth. Figure 1.4 illustrates certain characteristics of leaves to help you get started.

There is no one correct way to make this dichotomous key. It can be made in several ways, but it will challenge your ability to recognize the distinguishing characteristics of the leaves.

2. Construct your dichotomous key in item 3 of the laboratory report.

SCIENTIFIC INQUIRY

Biologists use a particular method to find answers to questions about life and living organisms. This method is called the scientific method, an orderly process that provides scientific evidence for explanations of natural phenomena. Unlike anecdotal evidence, scientific evidence consists of measurements or observations that are widely shared with other scientists and that are repeatable by anyone with the proper tools. Therefore, biologists can repeat the measurements or observations to either verify or reject the conclusions of other biologists. In this way, the scientific method makes biology, like other branches of science, an ongoing, self-correcting process of inquiry.

Figure 1.4 Examples of leaf types.
Make Observations

State Key Question

State Hypothesis

State Prediction

Conduct Controlled Experiment or Make Numerous Observations

Analyze Results

Form Conclusion

Figure 1.5 Steps of the scientific method.

You will participate in the scientific method as you perform the activities in this laboratory manual. The key steps in the scientific method are shown in Figure 1.5 and described below. Hypothetical examples are provided for each step.

1. The scientific method begins with careful, thoughtful observations of nature directly or indirectly.

Example: General observations suggest that regular exercise may reduce the risk of heart attacks.

2. Observations raise questions in the biologist's mind that lead to a statement of the key question to be answered. This key question is sometimes called "the problem." This question is usually a "how," "what," or "why" question.

Example: Does regular exercise reduce the risk of heart attacks and coronary artery disease?

3. A testable hypothesis is stated. This is a statement of the anticipated answer to the key question.

Example: Regular exercise reduces the risk of heart attacks and coronary artery disease.

4. A prediction is made based on the hypothesis. It is usually phrased in an "if . . . then" manner. This tells the biologist what to expect if the results support the hypothesis.

Example: If regular exercise reduces the risk of heart attacks and coronary artery disease, then mice on an exercise regimen will develop fewer heart attacks or less coronary artery disease than mice that do not exercise.

5. Either a controlled experiment is designed and conducted or multiple observations are made to test the hypothesis. A controlled experiment provides the most convincing evidence about a hypothesis, but some hypotheses cannot be tested this way. For example, hypotheses about the relationships of fossils in rock strata or the grouping of organisms into taxonomic categories cannot be experimentally tested and require numerous observations. In our example, a controlled experiment can be done and is preferred.

In a controlled experiment, there are three kinds of variables (conditions). The independent variable (in our example, regular exercise) is the condition that is being evaluated for its effect on the dependent variable (in our example, heart attacks or coronary artery disease). Controlled variables are all other conditions that could affect the results but do not because they are kept constant. A controlled experiment consists of two groups of subjects. The experimental group is exposed to the independent variable, but the control group is not. All other variables are controlled (kept constant) in both groups.

Example: A population of laboratory mice have been bred to have identical hereditary compositions that make them susceptible to coronary artery disease and heart attacks. Mice of similar age are selected from this population for the experiment. Fifty randomly selected mice are placed in the experimental group and 50 randomly selected mice are placed in the control group. Mice in the experimental group are placed on a regular exercise regimen (an exercise wheel is in each cage), but mice in the control group are placed in cages without exercise wheels. Data from the exercise wheels are tabulated to be certain that mice in the experimental group are exercising. All other variables are kept identical for each group (i.e., diet, temperature, humidity, light–dark cycles, water availability, etc.). The experiment runs for 120 days.
6. **Results** of the controlled experiment or multiple observations are collected and analyzed.

   *Example:* Among the experimental group, 18 mice had heart attacks or coronary artery disease. Among the control group, 25 mice had heart attacks or coronary artery disease. In addition, mice in the experimental group weighed 10% less, on average, than mice in the control group.

7. A **conclusion** regarding whether the hypothesis is accepted or rejected is made based on the results. A conclusion often leads to the formation of a new key question and hypothesis, which lead to additional experiments or observations.

   *Example:* The hypothesis is accepted because the experimental group had fewer heart attacks or less coronary artery disease than the control group. Biologists use statistics to determine the significance of differences between results of experimental and control groups—but we won’t be concerned about that here.

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**Assignment 4**

*Complete item 4 on the laboratory report.*
1. LABORATORY PROCEDURES AND BIOLOGICAL TERMS
   a. Describe how you are to prepare for each laboratory session.

   b. Using Appendix A, indicate the literal meaning of the following terms:
      Biology
      Morphology
      Unicellular
      Leukocyte
      Organelle
      Gastric
      Pathology
      Dermatitis
      Osteocyte
      Hypodermic
      Pseudoscience
      Intercellular
      Extracellular
   c. Using Appendix A, construct terms with the following literal meanings:
      Study of tissues
      Within a cell
      Large molecule

2. MEASUREMENTS
   a. Indicate the name and value of these metric symbols.
      | Symbol | Name of Unit | Value of Unit |
      |--------|-------------|---------------|
      | km     |             |               |
      | ml     |             |               |
      | mg     |             |               |
b. Indicate the diameter of a penny in the following units:

_______ mm _______ cm _______ m _______ in.

c. Indicate the weight of a 250-ml beaker in the following units:

_______ g _______ mg _______ oz

d. List the steps that you used to determine the weight of 20 ml of water.

1. 

2. 

3. 

4. 

e. Indicate the weight of 20 ml of water.

_______ g

f. A physician directs a patient to take 1 g of vitamin C each day. How many 250-mg tablets must be taken each day?


g. Normal body temperature is 37°C (98.6°F). If a patient’s temperature is 38.5°C, what is the temperature in
degrees Fahrenheit?

__________ °F
h. The U.S. National Research Council recommends that adults eat 0.8 g of protein daily per kilogram of body weight. What is the minimum number of grams of protein that should be eaten by a man weighing 185 pounds?

\[ \text{grams of protein} = \frac{0.8 \text{ g}}{\text{kg}} \times 185 \text{ lb} \]

What is your weight? \[ \text{________} \text{ lb; } \text{________} \text{ kg} \]
What should be your minimum protein intake? \[ \text{________} \text{ g} \]

i. If the ground beef in a \( \frac{1}{4} \)-lb hamburger contains 20% protein and 25% fat, indicate the grams of fat and protein.

\[ \text{fat} = \frac{0.25 \times \frac{1}{4} \text{ lb}}{8} \times 100 = \text{________} \text{ g} \]
\[ \text{protein} = \frac{0.20 \times \frac{1}{4} \text{ lb}}{8} \times 100 = \text{________} \text{ g} \]

3. OBSERVATIONS

a. Examine the leaves provided in the laboratory and construct a dichotomous key based on their characteristics. To help you get started, first separate the leaves into two groups: (1) needle- or scalelike leaves and (2) flat, thin leaves, as shown on the next page. Use the next page for the development of your key.

b. After you have completed your key, describe how you approached the problem and the steps or process that you used to construct your key.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
4. SCIENTIFIC INQUIRY

a. Do you think the generalization that all organisms are composed of cells was established using controlled experiments or multiple observations?

b. Why is a control group important in an experiment?

c. What would you conclude if 23 mice in the experimental group had heart attacks or coronary artery disease?

d. State a new key question that the result of the experiment triggers in your mind.

e. State a testable hypothesis and prediction based on your new key question.

Hypothesis:

Prediction:

f. Describe how you would test this hypothesis in a controlled experiment.